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Managing Agility and Efficiency under Uncertainty in Supply Chains: A Dynamic Capabilities Framework Based on Fuzzy Cognitive Maps

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ABSTRACT

Objective: Information and Communication Technology (ICT) companies operate in highly dynamic environments characterized by rapid technological change and substantial uncertainty. Although organizational agility is widely recognized as an effective response to uncertainty, achieving agility often requires sacrificing efficiency, creating an enduring agility–efficiency tradeoff. This study aims to develop a quantitative framework for analyzing this tradeoff from a dynamic capabilities perspective.

Methodology: A fuzzy cognitive map (FCM) approach was employed to model the causal relationships among dynamic capabilities, organizational agility, and efficiency. Research variables were identified through a comprehensive literature review and refined through expert panels. The FCM was developed based on the judgments of 30 experts from 12 leading Iranian ICT companies, including chief executive officers, marketing managers, technical managers, and senior strategy specialists.

Results: The findings indicate that dynamic capabilities play unequal roles in managing the agility–efficiency tradeoff. Sensing, seizing, and transformation capabilities exert different levels of influence on organizational agility and efficiency. The simulation results further show that alternative capability development strategies lead to different organizational outcomes under conditions of uncertainty.

Conclusion: The proposed FCM-based framework provides a quantitative decision-support tool for understanding and managing the agility–efficiency tradeoff in uncertainty-driven industries. The study contributes to the dynamic capabilities literature by integrating uncertainty management, organizational agility, and efficiency within a unified analytical framework.

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Introduction

The future of some industries is vague and unknown. Even though we are more aware of industries, economics, and social systems, a high degree of uncertainty remains in front of managers. Moreover, globalization and the interconnection between various systems make doing business more complex (Walker et al., 2003). Especially with information technology growing and its impact on industries, the rate of technological change has increased, and uncertainty and risk are more intense. With this in mind, organizations should behave differently in this situation (Schwartz & Zozaya-Gorostiza, 2003). Recent studies suggest that uncertainty should not be viewed solely as an external threat but also as a catalyst for organizational adaptation and strategic renewal. Firms that successfully interpret and respond to perceived environmental uncertainty are more likely to develop adaptive capabilities and sustain innovation outcomes in turbulent environments (Han et al., 2023).

One way to manage companies under deep uncertainty is organizational agility (D. Teece & Leih, 2016). The term organizational agility is almost a synonym for “flexibility” (D. Teece & Leih, 2016). In the 1930s, Nobel Laureate economist George Stigler defined flexibility regarding the firm’s ability to manage demand uncertainties (D. Teece & Leih, 2016). Organizational agility refers to a firm’s ability to sense environmental changes and respond rapidly and effectively through appropriate strategic and operational actions. It is widely regarded as a key organizational capability for coping with uncertainty and sustaining competitiveness in turbulent environments (Sharifi & Zhang, 1999; D. Teece & Leih, 2016). Responsiveness refers to the ability to identify changes and respond fast to them, reactively or proactively. This includes sensing and predicting changes, fast reaction to them, and recovering from them. Competency, which is the extensive set of abilities that provide productivity, efficiency, and effectiveness of activities towards the aims and goals of the company. Flexibility is the ability to process different products and achieve different objectives with the same facilities. The last element is quickness, which is the ability to carry out tasks and operations in the shortest possible time (Sharifi & Zhang, 1999). Although Sharifi and Zhang’s framework remains one of the most influential conceptualizations of organizational agility, recent systematic reviews emphasize that agility should be understood as a multidimensional bundle of dynamic capabilities rather than a single organizational attribute. Contemporary studies highlight the interaction between strategic, operational, innovation, workforce, and partnership-related forms of agility in enabling organizational adaptation under rapidly changing conditions (Asghar et al., 2025).

Most studies in management literature would seem to suggest that business firms should doggedly seek to become agile no matter the cost, keeping options open all the time, maintaining redundancy at all times, and staying in a constant state of radical transformation (Fine et al., 2002;

Hamel, 2001; Hamel & Valikangas, 2003; Sull, 2005). However, change is costly and achieving agility involves sacrificing efficiency. Recent research similarly argues that organizational agility should not be treated as a universal remedy. While agility enables organizations to reconfigure resources and respond to environmental changes, excessive investments in agility may impose substantial costs and may not necessarily improve organizational effectiveness when pursued without strategic alignment (Hiller & Ozgen, 2023).

Organizational efficiency generally refers to the ability of a firm to achieve desired outputs while minimizing resource consumption and operational costs. In dynamic business environments, maintaining efficiency remains essential because excessive resource commitments may undermine long-term competitiveness and organizational sustainability (Coelli et al., 2005; Porter, 1996). Concerning the business environment and type of industry, being agile is not an appropriate solution for all situations. Heading towards agility without considering efficiency and the agility/efficiency tradeoff could incur huge costs for firms and lead to failure. Therefore, the ability to determine when and how much we need to invest in agility while remaining efficient is a vital capability for firms (D. Teece & Leih, 2016). Furthermore, recent organizational agility literature indicates that agility outcomes are contingent upon a set of organizational antecedents, including digital technologies, leadership practices, strategic integration, knowledge management, and organizational structures. These antecedents determine the extent to which agility investments can generate sustainable organizational benefits (Asghar et al., 2025; Jaafar et al., 2026). In addition, systematic evidence suggests that organizational innovation is facilitated by flexible organizational structures, technological infrastructures, organizational capabilities, and supportive leadership practices, all of which contribute to organizational adaptability and long-term performance (Jafarzadeh-Ghoushchi et al., 2023).

Teece et al. (2016) conducted a study regarding how firms can survive in deep uncertainty and obtain agility while navigating the agility/efficiency tradeoff using the dynamic capabilities framework. Dynamic capabilities have been proposed as an important mechanism through which organizations adapt to uncertainty and maintain competitiveness in rapidly changing environments (D. Teece et al., 2016). These capabilities are particularly important in industries characterized by technological turbulence and high levels of uncertainty, where conventional operational capabilities may be insufficient to sustain long-term performance. Recent studies further suggest that capability orchestration plays a critical role in enabling organizations to coordinate, integrate, and reconfigure resources during periods of technological transformation and ecosystem change (Yadollahi et al., 2025). Moreover, empirical evidence demonstrates that dynamic capabilities become increasingly important under conditions of technological and economic uncertainty, where they enhance innovation and organizational performance (Leelhaphunt, 2026; Zehir & Vural, 2025). Teece et al. have used qualitative and theoretical studies to model dynamic capabilities to achieve agility and make an agility/efficiency tradeoff. Due to being theoretical, understanding the model and implementing it in organizations is difficult. Thus, this study aims to make a quantitative model of dynamic capabilities for organizational agility and the agility/efficiency tradeoff.

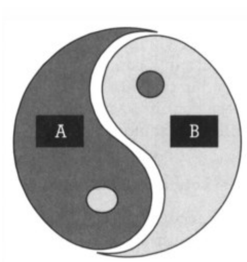
Despite the growing body of literature on organizational agility and dynamic capabilities, several important research gaps remain. First, most studies have examined agility and dynamic capabilities from conceptual or qualitative perspectives, providing limited quantitative insight into the causal relationships among organizational capabilities. Second, although the agility–efficiency tension has been widely recognized, few studies have attempted to model this tradeoff explicitly under conditions of uncertainty. Third, the application of Fuzzy Cognitive Maps to investigate the interactions among dynamic capabilities, organizational agility, and efficiency remains limited, particularly within ICT industries operating in highly uncertain environments. Furthermore, limited research has investigated how different categories of dynamic capabilities contribute unequally to organizational agility and efficiency outcomes, creating a need for more detailed causal analysis. Therefore, this study seeks to address these gaps by developing a quantitative FCM-based model that captures the causal structure of dynamic capabilities and supports agility–efficiency tradeoff analysis under uncertainty. This study contributes to the literature in three ways. First, it extends the dynamic capability perspective by providing a quantitative representation of the relationships among sensing, seizing, and transformation capabilities in the context of organizational agility. Second, it offers a structured approach for analyzing the agility–efficiency tradeoff under uncertainty using Fuzzy Cognitive Maps. Third, by focusing on the Iranian ICT sector, the study provides empirical insights into capability development in innovation-driven industries characterized by rapid technological change and environmental uncertainty. This study also builds upon previous FCM-based research published in the Industrial Management Journal, which demonstrated the usefulness of Fuzzy Cognitive Maps for scenario planning and organizational decision support, while extending their application to the agility–efficiency tradeoff under deep uncertainty (Sadeghi Moghadam et al., 2019). Based on the identified research gaps, this study addresses the following research questions: (RQ1) How can Fuzzy Cognitive Maps (FCMs) be used to quantitatively model the relationships among dynamic capabilities, organizational agility, and organizational efficiency under uncertainty? (RQ2) Which dynamic capability dimensions exert the greatest influence on the agility–efficiency tradeoff? (RQ3) How do different capability development scenarios affect organizational agility and efficiency in uncertain ICT environments? These research questions provide the foundation for the proposed FCM model and guide the subsequent empirical analysis.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature on organizational agility, uncertainty, dynamic capabilities, and Fuzzy Cognitive Maps. Section 3 presents the research methodology and model development process. Section 4 reports and discusses the empirical findings. Finally, Section 5 concludes the study, outlines managerial implications, and suggests directions for future research.

Literature review

Agility/Efficiency Tension

Due to globalization, economic dynamism, and intense competition between firms in today's world, organizational tensions have increased. Stohl and Chenet (2001) define organizational tensions as "clash of ideas, principles, or action and reactions to the discomfort that may arise as a result (Stohl & Cheney, 2001). There are so many tensions in the literature such as control/cooperation (Sundaramurthy & Lewis, 2003), individualism/collectivism (Murnighan & Conlon, 1991), flexibility/efficiency (Adler et al., 1999), exploration/exploitation (Smith & Lewis, 2011), profit/social responsibility (Margolis & Walsh, 2003), and make/buy decision (Murnighan & Conlon, 1991). Organizational tensions are divided into three types: paradox, dilemma, and dialectic. Each of these tensions is naturally distinct and requires a different way of management (Smith and Lewis, 2011). Figure 1 shows the differences and similarities between these three tensions.

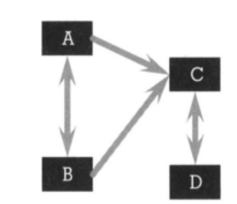


Paradox

Contradictory yet interrelated elements (dualities) that exist simultaneously and persist over time. Such elements seem rational when considered in isolation, but illogical, inconsistent, and absurd when together.

Dilemma

Competing choices, each with pros and cons. Paradoxical when choices are contradictory and interrelated such that any option between them is temporary and tension will resurface.



Dialectic

Contradictory elements resolved through synthesis, which, will confront new opposition.

Fig 1. Different Organizational Tensions (Source: Smith and Lewis (2011))

The paradox is contradictory yet interrelated elements (dualities) that exist simultaneously and persist over time. The dilemma is competing choices, each with advantages and disadvantages. Dialectics are contradictory elements (thesis and antithesis) resolved through integration (synthesis), which, over time, will confront a new position (Smith & Lewis, 2011). Tradeoffs are defined when the tension is paradoxical. Thus, the type of tension between agility and efficiency should be explored. Here we give brief literature regarding agility/efficiency in the literature. Agility (flexibility) and efficiency are concepts that have raised much attention among organizational theorists. Thomson (2020) introduces this tension as "paradox of administration." Managers should choose between organizational structure fit for routines, repetitive tasks and structure fit for none routine activities and innovative tasks (Welch & Nayak, 1992). Intense competition between firms led companies to consider both agility and efficiency dimensions simultaneously (De Meyer et al., 1989; Thompson, 2020). To better manage this tension, we should first determine what the type of agility/efficiency tension is. Recent studies on organizational paradoxes suggest that organizations increasingly face competing demands for adaptability and efficiency in highly dynamic environments. Rather than eliminating one objective in favor of the other, successful organizations develop mechanisms that allow them to balance exploration and exploitation activities simultaneously. This perspective reinforces the view that the agility–efficiency relationship should be understood as a persistent organizational tension requiring continuous management rather than a one-time strategic choice (Hiller & Ozgen, 2023; Smith & Lewis, 2011).

Recent studies continue to support the existence of a persistent tension between agility and efficiency. However, contemporary research suggests that the relationship is more nuanced than a simple tradeoff. Organizational agility contributes to organizational effectiveness when supported by appropriate structures, leadership mechanisms, and strategic alignment, whereas excessive agility investments may generate coordination costs and reduce operational efficiency. Therefore, recent scholars increasingly conceptualize agility and efficiency as competing yet complementary organizational objectives that require dynamic balancing rather than exclusive prioritization (Hiller & Ozgen, 2023). Several studies have been conducted around the agility/efficiency tension in the literature. Adler et al. conducted the first study. In 1999 and the most recent one was done by Teece et al. in 2016. Most studies claim that agility/efficiency tension is more of a paradox problem and firms should make a tradeoff between the two concept (Adler et al., 1999; Ebben & Johnson, 2005; Eisenhardt et al., 2010; Gebauer & Schober, 2006; Jørgensen & Messner, 2009; Magnusson et al., 2009; Su et al., 2012; Swink et al., 2005; Tan & Wang, 2010; D. Teece et al., 2016; Volberda, 1996). Table 1 shows studies regarding agility/efficiency tension in the literature. This table shows the management approach in each study regarding the tension.

Table 1. Agility/Efficiency tension in the literature

Reference	Research Method	Data	Tension
(Leelhaphunt, 2026)	Statistical analysis	Manufacturing firms	Dynamic balancing
(Zehir & Vural, 2025)	Statistical analysis	Firms	Dynamic balancing
(Asghar et al., 2025)	Systematic review	Literature	Dynamic balancing
(Sun et al., 2024)	Conceptual	Literature	Complementary
(Chen et al., 2023)	Systematic review	Literature	Dynamic balancing
(Han et al., 2023)	Statistical analysis	Corporate firms	Dynamic balancing
(Hiller & Ozgen, 2023)	Conceptual	Theoretical	Complementary
(Rehman & Jajja, 2023)	Empirical/statistical analysis	Manufacturing firms	Paradox

As it can be seen, the agility/efficiency tension is seen as a paradoxical problem in the literature. While the majority of prior studies conceptualize the agility–efficiency relationship as a paradoxical tension, recent evidence suggests that organizations may simultaneously pursue both objectives through capability development and strategic alignment. This perspective shifts the focus from choosing between agility and efficiency toward understanding the organizational mechanisms that enable their dynamic balancing under uncertainty.

Risk and Uncertainty

Businesses are more complex and fast-changing today. The source of these changes mostly emerges as risk and uncertainty. These two are substantially different and require different management approaches (D. Teece et al., 2016). Risk is quantifiable and measured using probability rules, including limited possibilities. However, uncertainty is not measurable, and unknowns remain unknown. Recent empirical studies further demonstrate that perceived environmental uncertainty significantly influences firms' innovation behavior and strategic adaptation. Under uncertain conditions, organizations increasingly rely on dynamic capabilities such as sensing, coordination, integration, and flexibility to identify emerging opportunities and mitigate environmental threats (Han et al., 2023; Rehman & Jajja, 2023). The risk is managed by a special risk management mechanism, but dealing with uncertainty is different. Different types of risk include economic (exchange rate, inflation rate, tax, financial regulation changes), financial (bankruptcy, profit margin), technical (failure, equipment reliability, bad design), safety (workplace incidents), human (human resource failure), and political (sanctions). Favorite sources of uncertainty are short product cycle, short design cycle, hypercompetition, disruptive technologies, easy entrance to the industry, etc (Kortmann et al., 2014; D. Teece & Leih, 2016). Technology uncertainty and economic uncertainty have recently attracted particular attention in the dynamic capability literature. Evidence suggests that firms possessing stronger dynamic capabilities are better positioned to maintain innovation performance and competitive advantage under technological turbulence and economic crises (Leelhaphunt, 2026; Zehir & Vural, 2025). Recent research further indicates that uncertainty is not merely a condition to be managed but also

Industrial Management Journal, Volume 18, Issue 4, 2026

a source of strategic opportunities. Organizations capable of sensing emerging market shifts and technological disruptions can transform uncertainty into competitive advantage. Consequently, the development of dynamic capabilities becomes increasingly important as environmental uncertainty increases, particularly in innovation-intensive industries such as information and communication technology (ICT).

Dynamic capabilities

A firm's dynamic capabilities govern how it integrates, builds, and reconfigures internal and external competences to address rapidly changing business environments (D. J. Teece et al., 1997). This category of capabilities is underpinned by organizational and managerial competencies for both "reading" and shaping the environment and developing business models that address new threats and opportunities. Therefore, dynamic capabilities are the firm's capacity to innovate, adapt to change, and create changes that are favorable to customers and unfavorable to competitors (D. Teece et al., 2016). Dynamic capabilities can be thought of as falling into three primary clusters: The sensing–seizing–transforming framework proposed by Teece has become the dominant foundation for understanding how organizations respond to environmental turbulence. These three capability clusters collectively enable firms to identify opportunities, mobilize resources, and continuously reconfigure organizational assets to maintain competitiveness under uncertainty (D. J. Teece, 2007). Although the sensing–seizing–transforming framework remains the dominant perspective in dynamic capability research, recent studies have extended the theory by integrating the resource-based view and examining the micro foundations underlying capability development. These studies emphasize that dynamic capabilities emerge from interactions among organizational resources, managerial cognition, routines, learning mechanisms, and strategic decision-making processes (Chen et al., 2023; Sun et al., 2024). Recent evidence from platform-based industries further suggests that firms must continuously reconfigure and orchestrate their capabilities in response to technological paradigm shifts to sustain competitive advantage and support ecosystem evolution (Yadollahi et al., 2025).

- Sensing opportunities and threats

Today, customer needs, technological opportunities, and competitors' behavior are rapidly changing. Opportunities are available for both existing and new competitors, therefore, jeopardizing existing competitors' income opportunities. Sensing opportunities and threats is like scanning, creating, and learning. Investment in research and development activities is a critical factor for strengthening sensing capabilities (D. J. Teece et al., 1997). A set of organizational capabilities in this category includes generative sensing, scenario planning, and purchase of real options (D. J. Teece et al., 1997; D. Teece & Leih, 2016). Recent research indicates that sensing capabilities become particularly valuable in environments characterized by high uncertainty and environmental turbulence. Firms with superior sensing mechanisms are more capable of detecting weak market signals, anticipating technological shifts, and identifying innovation opportunities before competitors (Han et al., 2023).

Generative sensing capabilities involve undertaking actions to proactively create hypotheses about the future implications of observed events and trends, and testing these hypotheses to grease the pathway for new products, services, and business models. Relatedly, the new product development process requires listening deeply to customers and following their problems, bringing together different disciplines and perspectives in the process. Thus, generative sensing is about hypothesis creation and learning (D. Teece & Leih, 2016). Scenario planning can aid generative sensing. It can be an essential tool to manage uncertainty and quick response to changes. Shoemaker defines scenario planning as “a disciplined methodology for imagining a possible future in which organizational decisions may be played out” (D. Teece & Leih, 2016). Real options analysis is related to scenario planning. A real option is “the firm’s decision right to delay, leave, expand, propose or contract an investment project” (D. J. Teece, 2007). Firms with strong dynamic capabilities are likely to “purchase” real options (e.g., through research and development investments) and then “exercise” them at the right time for a lower cost than would otherwise be possible (D. Teece & Leih, 2016).

- Seizing Opportunities

Seizing opportunities involves implementing and doing things. Recent studies suggest that the effectiveness of seizing capabilities depends heavily on organizational flexibility, coordination mechanisms, resource integration processes, and managerial decision-making quality. Organizations capable of rapidly mobilizing and redeploying resources are better able to convert identified opportunities into operational and strategic outcomes under uncertain conditions (Rehman & Jajja, 2023). Different capabilities such as flexible sourcing arrangements, building “slack” into the organization itself, reengineering rule-bound hierarchies, creating commitment and loyalty, and using open innovation processes fall into this category (D. J. Teece et al., 1997; D. Teece & Leih, 2016).

First, consider flexible sourcing. The industrial age was accompanied by a relatively stable environment, and the most highlighted economic criteria were economy of scale. High vertical integration facilitated optimization up and down the value chain. This method was effective while costly and not agile in its time. One way to untether management decisions from the effects of large fixed investments is to preserve maximum flexibility by both outsourcing one’s manufacturing and preserving contractual flexibility (D. Teece & Leih, 2016). The second capability is making a type of agility into the organization’s architecture. This flexibility is created through building “slacks” (maintaining resources and excess capacity in the organization). This is like holding cash in investors' hands as a buffer against operational outages/failures. Also, the establishment of major inventories to buffer the manufacturing process is another use of programmed “slack” (D. Teece & Leih, 2016).

Organizational structure is another aspect of seizing. Rule-bound hierarchies with many vertical levels can be the major prevention of agility. Concepts such as self-organizing, multidivisional structures, matrix structures, and decentralization can speed up responsibility and flexibility in achieving opportunities (D. J. Teece et al., 1997; D. Teece & Leih, 2016). Open innovation methodologies can also assist agility by enriching and speeding up new product development to meet nascent market opportunities. Chesbrough states that open innovation is “the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation respectively” (McGrath, 1999). Firms can use outside-to-inside or inside-to-outside processes (e.g., building a spin-off to develop technology outside the company or selling rejected projects’ licenses to other companies to use ideas) (Chesbrough, 2003). Open innovation is used when the source of innovation and creativity are widely dispersed, organizationally and geographically (D. J. Teece et al., 1997; D. Teece & Leih, 2016).

- Transformation/Pivoting

In recent years, different methods for change and continual improvement in organizations have been proposed. One of the most widely recognized approaches is the Lean Startup methodology, which emphasizes iterative experimentation through the build–measure–learn cycle (Ries, 2011). The idea is that when managing under deep uncertainty (when possible), build a minimum viable product (MVP), launch it, learn quickly, adjust accordingly, and improve (D. Teece & Leih, 2016). Another capability in this category includes knowledge management activities. Recent dynamic capability research highlights that transformation activities are strongly influenced by organizational learning, knowledge recombination, and managerial micro foundations. Successful transformation requires continuous reconfiguration of resources and organizational routines to align with changing environmental conditions and technological developments (Chen et al., 2023; Sun et al., 2024). Recent digital transformation studies also indicate that successful organizational transformation requires technological readiness, human competencies, and the reconfiguration of business models, leading to greater organizational agility and sustainable performance outcomes (Momenzadeh et al., 2026). The main activities in knowledge management from a dynamic capabilities perspective are organizational learning, knowledge transfer between firms, know-how integration, and intellectual property regulations. The last capability is co-specialization, which is the organization's ability to analyze strategic fit for cooperation with other firms and create value using complementary assets (D. J. Teece et al., 1997; D. Teece & Leih, 2016).

Operational capabilities

Operational or ordinary capabilities allow firms to do a set of defined tasks efficiently. While operational capabilities are essential for efficiency and routine performance, recent literature emphasizes that they are insufficient for long-term adaptation in turbulent environments. Sustainable competitive advantage increasingly depends on the interaction between operational capabilities and higher-order dynamic capabilities that enable organizations to respond proactively to uncertainty and change (Sun et al., 2024). Operational capabilities remain essential because they provide the efficiency, reliability, and consistency required for day-to-day activities. Consequently, organizational performance depends not only on the development of dynamic capabilities but also on the effective alignment between operational and dynamic capabilities. These capabilities do not necessarily lead to the firm's growth or geographical development and cannot necessarily help companies respond to fluctuations (Teece & Leih, 2016).

Materials and Methods

The research steps include identifying research variables from the literature and then selecting final indices by focus group technique. Afterward, FCM experts are selected. Since this model is developed for the ICT sector in Iran, 12 top ICT companies concerning IMI100 (list of 100 top Iranian companies) have been selected, and expert was chosen from them. Finally, the FCM model is created and analyzed.

Fuzzy Cognitive Map (FCM)

Fuzzy Cognitive Map (FCM) is a computing technique for modeling complex systems in a situation exactly as a human does, using a reasoning process that consists of uncertainty and ambiguity (Ries, 2011). Cognitive maps were introduced before by Axelrod for representing social scientific knowledge using signed diagraphs (Papageorgiou et al., 2004). In follow, Kosko proposed fuzzy cognitive maps that represents the model of a system using a graph of nodes (concepts) that illustrates cause and effects relationships among them. FCMs are powered by fuzzy logic and neural networks and the combination of these two concepts (Axelrod, 1976). In FCMs, systems are modeled into a one-layer network, and through this network there are some nodes or concepts (C_i) which represent key characteristics of the system, and weighted arcs (W_{ij}) relating the nodes or concepts, show the casual relationships that exist among that nodes (Dickerson & Kosko, 1994). Any existing knowledge regarding the behavior of the system is stored in the structure of concepts and interconnections of the map. Recent methodological studies have demonstrated that Fuzzy

Cognitive Maps are increasingly applied as decision-support tools in complex and uncertain environments. Their ability to capture causal relationships, integrate expert knowledge, and simulate alternative scenarios makes them particularly suitable for strategic decision-making problems characterized by ambiguity, uncertainty, and interdependent factors (Sarmiento et al., 2024). Furthermore, recent methodological developments have extended conventional FCM into multilayer quantitative frameworks capable of modelling systems with a large number of interacting variables, thereby improving the scalability and analytical capability of FCM for complex decision-making problems (Sangbor et al., 2021). There are three types of relationships between nodes: $(W_{ij} > b)$ and $(W_{ij} < b)$ showing positive and negative relationships, respectively, and $(W_{ij} = b)$ meaning that no relationship exists between the concepts. The values of a sample weight called W_{ij} show the effect strength of concept C_i on C_j (Kosko, 1986). Values of concepts and weights can be both crisp and fuzzy. If the values are fuzzy, they ought to be transformed to real numbers by a defuzzification method. To calculate the new value of nodes at each time iteration, the following equation is used (Dickerson & Kosko, 1994):

$$A_i^t = f\left(\sum_{i=1.j\neq i}^{n} A_j^{t-1}W_{ji} + A_i^{t-1}\right) \tag{1}$$

Where A_i^t is the value of concept C_i at time t, A_i^{t-1} the value of concept C_i at time t-1, A_j^{t-1} the value of concept C_j at time t-1, and W_{ji} is the weight of the connection between concept C_j and C_i. The function f plays role as a threshold function to squash the output in the interval [0.1]. This value shows the node activation level. In fact, this level can be interpreted as relative abundance (Groumpos, 2010). To solve the limitation of sigmoid function, we propose the transformed version of Equation 1 (Hobbs et al., 2002):

$$A_i^t = f\left(\sum_{i=1.j\neq i}^{n} (2A_j^{t-1} - 1)W_{ji} + 2A_i^{t-1} - 1\right) \tag{2}$$

Moreover, the uni-polar sigmoid function is used to activate any node's value.

$$f(x) = \frac{1}{1 + e^{-w(x)}} \tag{3}$$

To build an FCM, experts with knowledge in a certain domain problem construct a mental model manually. Firstly, they recognize key domain issues or concepts (nodes in the map). Then they will determine the casual relationships between these issues of concepts, and finally, the strength of these relationships are estimated (Hobbs et al., 2002). All suggested values proposed by experts are linguistic variables and transformed to numerical weight with the defuzzification method of Center of Gravity (Hobbs et al., 2002). A casual connection from some concept node C_i to concept node C_j, say $C_i - -\sim C_{k1}$, $C_{k1} - -\sim \ldots C_n$, $C_{kn} - -\sim C_j$can be showed by sequence $(i.\ k_1. \ldots\ k_{n.j})$. The indirect effect of C_i on C_j is causality $C\sim I$ imparted by the path $(i.\ k_1. \ldots\ k_{n.j})$. The total effect of C_j on C_i consists of all indirect effect causalities $C\sim$ impart to C_i (Axelrod, 1976).

A fuzzy causal algebra is built by considering the indirect effect operator I as the minimum operator (or t-norm) and the overall effect operator T as the maximum operator (or s-norm) on the partially ordered set P of causal values (Papageorgiou, 2010). Consider $\sim$ as causal concept space, and e: $\sim x \sim P$ as a fuzzy causal edge function, and presume that there are m causal relationship paths from of C_i to C_j: $(i.\ k_1. \ldots\ k_{n.j})$ for $1\sim < r\sim < m$. Then let Ir $(C_i. C_j)$ represent C_j represent the indirect effect of node C_i on node C_j by the rth causal relationship path, and let T $(i. C_j)$ represent total effect of node C_i on node C_j over all m causal paths. Therefore:

$$I\sim\left(C_i. C_j\right) = \min\left(w\ \left(C_p. C_{p+}\right)(p. p+1)\sim(i. k^{\sim} \ldots k^{\sim}. j)\right) \tag{4}$$

$$T\left(C_i. C_j\right) = \max\left(Ir\ \left(C_i. C_j\right)\right). I < \sim r < \sim m \tag{5}$$

Where p and $p+1$ show contiguous left or right path indices in the equation (Axelrod, 1976). Two types of analysis are used in FCM. FCM has previously been applied for maturity assessment and scenario planning in organizational systems, demonstrating its capability to support strategic decision-making and evaluate alternative future states under complex conditions (Sadeghi Moghadam et al., 2019). A static analysis is used to show the effect of each node on the target node. This is done using the above algorithm. A dynamic analysis that allows us to explore "what-if" scenarios using simulations in the model with different initial state vectors. We can gain some insights into the system behavior by studying the results of these simulations, and also use it to support decision-making or predictions regarding future states (Peláez & Bowles, 1996). Moreover, recent developments in FCM-based decision-making approaches emphasize the integration of uncertainty analysis and advanced causal modeling techniques to improve the robustness of strategic evaluations. Such developments further support the suitability of FCM for modeling dynamic capability interactions and organizational agility under uncertain business environments (Sarmiento et al., 2024).

Agility/Efficiency tradeoff model

The purpose of this study is to apply the FCM technique for modeling the agility/efficiency tradeoff using the dynamic capabilities framework in Iranian ICT companies. To do so, the literature has been reviewed, and indices of variables have been identified. The final research variables were validated through focus group discussions involving both academic experts and industry practitioners. The focus group consisted of six participants, including three academic experts in strategic management and three senior managers from ICT companies. Two discussion sessions were conducted, each lasting approximately two hours. The participants reviewed the preliminary list of variables extracted from the literature and evaluated their relevance, clarity, and applicability to the ICT sector. Variables that received consensus among participants were retained in the final model. This procedure ensured that the selected variables were theoretically grounded while remaining relevant to the operational realities of ICT firms. The validated variables are presented in Table 2.

Table 2. Research final indices

Model variables	Indices	References
Organizational capabilities	Logistics, Administration, Risk and cost management, Operation management, Quality control, Performance management, Sales and marketing, CRM, Project management, PR management, Resource alignment, Generative sensing, Scenario planning, Real option purchase, flexible sourcing, Building slacks, Organizational structure reengineering, open innovation, Lean-Startup methodology, Loyalty and commitment, Knowledge management, IP, Co-specialization	Teece et al. (1997), Teece (2007), Chen et al. (2023), Ries (2011), Rehman & Jajja (2023), Sun et al. (2024), Zehir & Vural (2025), Leelhaphunt (2026)
Organizational change Source	Risk, Uncertainty	Teece et al. (2016), Han et al. (2023)
Organizational strategy	Organizational agility, Organizational efficiency	Asghar et al. (2025), Hiller & Ozgen (2023)

Using experts' opinions, the conceptual model of the research was developed. This conceptual model is depicted in Figure 2.

Fig 2. Agility/Efficiency tradeoff model

Also, to extract interconnections between concepts for the use of FCM, experts' opinions were used again. To enhance the reliability and consistency of the FCM graphs, using a panel of experts is suggested (Stach et al., 2010). The optimal number of participants depends on the characteristics of the research itself. To be similar to other works (Hakim & Hakim, 2010; Hobbs et al., 2002; Lopez & Salmeron, 2014; Salmeron, 2010; Xirogiannis et al., 2008; Yaman & Polat, 2009), and since we had 12 sample companies, experts were grouped into panels of 2 to 3. So we had panels of 2 to 3 in 12 companies. Each panel consisted of people from different backgrounds and experiences (CEO, marketing manager, and technical manager). In total, 30 experts participated in the FCM development process. The participants included chief executive officers, marketing managers, technical managers, and senior strategy specialists from the selected ICT companies. All participants had substantial managerial experience and were directly involved in strategic decision-making processes. This purposive sampling strategy ensured that the expert panel represented diverse managerial functions and organizational perspectives across the Iranian ICT industry, thereby improving the representativeness of the elicited causal knowledge. After experts were selected, the method was explained to them. They were asked to represent the interactions that exist between research indices. Each expert was separately asked to explain the interactions using linguistic variables. The linguistic evaluations provided by experts were converted into numerical weights using the Center of Gravity (COG) defuzzification method. The resulting weights were then aggregated across all experts to construct the final adjacency matrix used in the FCM simulations. To reach the augmented matrix, the following equation is used:

$$W_{ij}^{Aug} = \frac{\sum W_{ij}}{m} \tag{6}$$

Where m is the number of FCMs added. To reduce potential individual expert bias, the aggregation procedure combined judgments from experts representing different managerial functions and organizations rather than relying on a single source of expertise. In addition, the aggregated FCM was reviewed collectively by the expert panel to verify the plausibility and consistency of the resulting causal structure. Any relationships lacking broad expert agreement were discussed and refined before finalizing the model. This iterative validation process served as a qualitative inter-rater consistency check and enhanced the credibility of the aggregated FCM. To validate the resulting FCM, the aggregated map was reviewed by the participating experts. The experts examined the causal relationships and confirmed that the final model adequately represented the interactions among dynamic capabilities, organizational agility, and efficiency within the ICT industry context. Table 3 shows the relationships between numbers and linguistic variables.

Table 3. Linguistic values and equivalents in fuzzy numbers

Source: Adapted from Kosko (1986) and Papageorgiou et al. (2004)

Linguistic Values	The Mean of Fuzzy Numbers
Very high (VH)	1.00
High (H)	0.70
Medium (M)	0.50
Low (L)	0.30
Very low (VL)	0.10

Therefore, the interdependencies among model concepts are extracted in Table 4.

Table 4. Path effect analysis of the source of change to organizational strategy

Concepts	Organizational Agility	Organizational Efficiency	Average Effect
Risk	0.24	0.89	0.565
Uncertainty	0.94	0.38	0.66

Table 4 also shows the interconnection map between concepts. Following the construction of the FCM, both static and dynamic analyses were performed. Static analysis was used to evaluate the direct and indirect influence of each concept on organizational agility and efficiency. Dynamic analysis was conducted through scenario simulations by assigning different activation levels to selected capability variables and observing the resulting changes in system behavior until equilibrium was reached.

Results

Based on the data in Table 5 and equations 4 and 5, the path effect in the model can be calculated. The first path effect is from the source of changes to organizational strategy (agility and efficiency), and the second path is from organizational capabilities to organizational strategy. The results are summarized in Tables 4 and 5. Concerning Table 4, the average path effect of risk and uncertainty on model output is 0.565 and 0.66, respectively, showing that uncertainty has more impact on the output. Table 5 also shows that the most impact on model output among organizational capabilities belongs to C12 (generative Sensing) with an overall effect of 0.47. C19 (lean startup methodology), C14 (purchase of real options), and C22 (coo specialization) have the most effects after C12 with values of 0.385, 0.355, and 0.34, respectively.

Table 5. Path effect analysis of organizational capabilities to organizational strategy

Concepts	Organizational Agility	Organizational Efficiency	Average Effect of Concept	Average Effect of Capabilities
C1	0.02	0.56	0.29	0.239
C2	0.06	0.34	0.2	
C3	0.04	0.44	0.24	
C4	0.18	0.35	0.265	
C5	0.02	0.4	0.21	
C6	0.08	0.12	0.1	
C7	0.22	0.46	0.34	
C8	0.2	0.2	0.2	
C9	0.22	0.34	0.28	
C10	0.22	0.25	0.235	
C11	0.16	0.38	0.27	
C12	0.8	0.14	0.47	0.251
C13	0.42	0.08	0.25	
C14	0.6	0.11	0.355	
C15	0.1	0.2	0.15	
C16	0.1	0.1	0.1	
C17	0.12	0.11	0.115	
C18	0.1	0.1	0.1	
C19	0.73	0.04	0.385	
C20	0.52	0.04	0.28	
C21	0.34	0.11	0.225	
C22	0.34	0.34	0.34	

The most influential on organizational agility belongs to C19 (lean startup) with the effect of 0.73, and after that are C20 (loyalty and commitment) and C13 (scenario planning) with effects of 0.52 and 0.42, respectively. Also, the most influence on organizational efficiency is for C1 (logistics) with the effect of 0.56, and after that C7 (sales and marketing), C3 (cost and risk management) with effects of 0.46 and 0.44.

Table 6. Final augmented matrix of FCM

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	R	U	C25	C26
C1	0.00	0.14	0.00	0.56	0.28	0.10	0.50	0.72	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.12	0.88
C2	0.16	0.00	0.12	0.06	0.00	0.34	0.00	0.00	0.02	0.34	0.04	0.00	0.00	0.00	0.06	0.00	0.06	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.58
C3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82
C4	0.60	0.35	0.00	0.00	0.00	0.00	0.26	0.18	0.18	0.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.12	0.94
C5	0.00	0.00	0.00	0.00	0.00	0.40	0.02	0.00	0.34	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	-0.54	0.80
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.08	0.12	0.00	0.10	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.18	0.54
C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.14
C8	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.06	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.22	0.46
C9	0.00	0.06	0.00	0.00	0.20	0.08	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.36	0.76
C10	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
C11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.16	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.72
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.88	0.20	0.02	0.12	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.62	-0.26
C13	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.08	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.80	-0.46
C14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00	0.88	-0.48
C15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.56	0.38
C16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	-0.10
C17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.10	0.06	0.00	0.12	0.00	0.00	0.00	0.78	0.04

C18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.24
C19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.06
C20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.26
C21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.34	0.00	0.00	0.60	0.11
C22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.11
R	0.85	0.46	0.78	0.86	0.56	0.34	0.62	0.72	0.89	0.23	0.72	0.22	0.10	0.24	0.22	0.06	0.00	0.00	0.00	0.16	0.06	0.06	0.00	0.00	0.00	0.00
U	0.06	0.00	0.00	0.12	0.00	0.00	0.02	0.02	0.06	0.00	0.12	0.66	0.94	1.00	0.58	0.64	0.54	0.58	0.34	0.42	0.44	0.58	0.00	0.00	0.00	0.00
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Concerning results, it can be seen that the average effect of all operational capabilities (C1 to C11) with a value of 0.239 is less than the average effect of all dynamic capabilities (C12 to C22) with a value of 0.253.

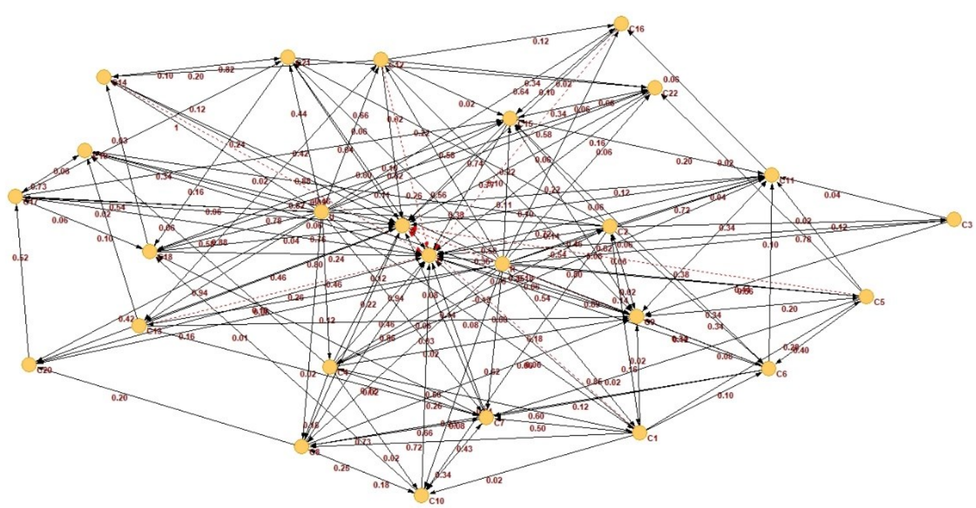


Fig 3. Agility/Efficiency tradeoff FCM map

Using FCM dynamic analysis, different scenarios were simulated. All calculation algorithms were done using MATLAB. Scenarios are initial states of concepts, and when they are the same in two successive iterations (the differences between two iterations are zero), calculations will stop. These scenarios are shown in Table 7.

Table 7. Simulations and related results

Concepts	Scenario 1	Result	Scenario 2	Result	Scenario 3	Result	Scenario 4	Result	Scenario 5	Result	Scenario 6	Result	Scenario 7	Result	Scenario 8	Result	Scenario 9	Result	Scenario 10	Scenario 11	Result	Scenario 12	Result	Scenario 13	Result	Scenario 14	Result
C1	1	0.59	1	0.43	1	0.58	0	0.48	0	0.69	0	0.07	1	0.59	1	0.92	1	0.28	0.5	0.2	0.51	0.8	0.58	0.5	0.44	0.5	0.55
C2	1	0.47	1	0.36	1	0.47	0	0.39	0	0.43	0	0.07	1	0.47	1	0.77	1	0.23	0.5	0.2	0.42	0.8	0.46	0.5	0.07	0.5	0.45
C3	1	0.09	1	0.06	1	0.09	0	0.05	0	0.65	0	0.00	1	0.09	1	0.72	1	0.04	0.5	0.2	0.06	0.8	0.09	0.5	0.48	0.5	0.07
C4	1	0.51	1	0.39	1	0.51	0	0.41	0	0.70	0	0.03	1	0.51	1	0.90	1	0.26	0.5	0.2	0.44	0.8	0.50	0.5	0.41	0.5	0.48
C5	1	0.43	1	0.36	1	0.43	0	0.36	0	0.51	0	0.09	1	0.43	1	0.78	1	0.26	0.5	0.2	0.38	0.8	0.42	0.5	0.56	0.5	0.41
C6	1	0.63	1	0.46	1	0.63	0	0.45	0	0.33	0	0.03	1	0.63	1	0.85	1	0.35	0.5	0.2	0.50	0.8	0.61	0.5	0.93	0.5	0.57
C7	1	0.95	1	0.92	1	0.95	0	0.81	0	0.56	0	0.09	1	0.95	1	0.99	1	0.85	0.5	0.2	0.88	0.8	0.94	0.5	0.93	0.5	0.93
C8	1	0.95	1	0.91	1	0.95	0	0.82	0	0.62	0	0.09	1	0.95	1	0.99	1	0.84	0.5	0.2	0.89	0.8	0.94	0.5	0.89	0.5	0.93
C9	1	0.92	1	0.77	1	0.90	0	0.85	0	0.83	0	0.38	1	0.91	1	0.99	1	0.59	0.5	0.2	0.87	0.8	0.91	0.5	0.62	0.5	0.89
C10	1	0.67	1	0.60	1	0.67	0	0.45	0	0.23	0	0.02	1	0.67	1	0.81	1	0.55	0.5	0.2	0.55	0.8	0.66	0.5	0.59	0.5	0.62
C11	1	0.63	1	0.58	1	0.62	0	0.53	0	0.73	0	0.28	1	0.62	1	0.87	1	0.43	0.5	0.2	0.55	0.8	0.62	0.5	0.34	0.5	0.60
C12	1	0.38	1	0.38	1	0.31	1	0.38	1	0.56	1	0.38	0	0.32	0	0.22	0	0.19	0.5	0.5	0.36	0.5	0.36	0.2	0.58	0.8	0.38
C13	1	0.64	1	0.60	1	0.46	1	0.64	1	0.75	1	0.60	0	0.55	0	0.10	0	0.26	0.5	0.5	0.61	0.5	0.61	0.2	0.22	0.8	0.63
C14	1	0.28	1	0.26	1	0.20	1	0.28	1	0.52	1	0.26	0	0.20	0	0.24	0	0.13	0.5	0.5	0.25	0.5	0.25	0.2	0.66	0.8	0.27
C15	1	0.73	1	0.69	1	0.62	1	0.67	1	0.68	1	0.52	0	0.67	0	0.62	0	0.40	0.5	0.5	0.66	0.5	0.70	0.2	0.14	0.8	0.70
C16	1	0.16	1	0.14	1	0.12	1	0.15	1	0.18	1	0.11	0	0.14	0	0.12	0	0.07	0.5	0.5	0.14	0.5	0.15	0.2	0.58	0.8	0.15
C17	1	0.64	1	0.60	1	0.35	1	0.56	1	0.86	1	0.49	0	0.61	0	0.06	0	0.20	0.5	0.5	0.56	0.5	0.61	0.2	0.23	0.8	0.60

C18	1	0.31	1	0.31	1	0.28	1	0.28	1	0.27	1	0.25	0	0.21	0	0.07	0	0.21	0.5	0.5	0.26	0.5	0.28	0.2	0.12	0.8	0.30
C19	1	0.15	1	0.12	1	0.14	1	0.13	1	0.08	1	0.08	0	0.12	0	0.08	0	0.07	0.5	0.5	0.13	0.5	0.14	0.2	0.19	0.8	0.14
C20	1	0.20	1	0.19	1	0.20	1	0.13	1	0.16	1	0.00	0	0.20	0	0.35	0	0.18	0.5	0.5	0.16	0.5	0.19	0.2	0.67	0.8	0.19
C21	1	0.71	1	0.68	1	0.50	1	0.70	1	0.76	1	0.68	0	0.65	0	0.08	0	0.21	0.5	0.5	0.68	0.5	0.69	0.2	0.28	0.8	0.70
C22	1	0.38	1	0.36	1	0.33	1	0.37	1	0.45	1	0.35	0	0.24	0	0.08	0	0.25	0.5	0.5	0.32	0.5	0.33	0.2	0.00	0.8	0.36
R	1	0.00	0	0.00	1	0.00	1	0.00	1	0.00	0	0.00	1	0.00	1	0.00	0	0.00	1	1	0.00	1	0.00	1	0.00	1	0.00
U	1	0.00	1	0.00	0	0.00	1	0.00	0	0.00	1	0.00	1	0.00	0	0.00	1	0.00	1	1	0.00	1	0.00	1	0.00	1	0.00
A	0	1.00	0	1.00	0	0.98	0	1.00	0	1.00	0	1.00	0	0.48	0	0.21	0	0.19	0	0	0.64	0	0.69	0	0.23	0	0.95
E	0	1.00	0	0,99	0	1.00	0	0.48	0	0.00	0	0.88	0	1.00	0	1.00	0	0.98	0	0	0.39	0	0.94	0	0.63	0	0.91

Scenarios are based on different organizational situations. The first nine scenarios consider the extreme state of operational and dynamic capabilities in risky, uncertain, or both risky and uncertain environments. The last five scenarios consider randomized values between the interval of [0,1], conveying the situation when organizations obtain some degree of capabilities. The outcomes of the dynamic simulations for all fourteen scenarios are reported in Table 7. As can be seen in Table 7, when all organizational capabilities are active, in both risky and uncertain situations, we have agility and efficiency of almost 1. In scenario 4, only dynamic capabilities are active, meaning that both risk and uncertainty are active. In this scenario, agility reaches 1, and efficiency obtains the value of 0.48. Scenarios 5 and 6 describe a situation where only dynamic capabilities are active. The result is that in scenario 6, agility is 1 and efficiency is almost 0, and in scenario 6, agility is 1 and efficiency is 0.88. Scenarios 7,8 and 9 are situations where only operational capabilities are active, and risk and uncertainty are first active in scenario 7, and then risk and uncertainty will be deactivated in scenarios 8 and 9. The results in these 3 scenarios for agility and efficiency are 1/0.71, 1/0.21, and 0.98/0.28, respectively.

Discussion

The findings indicate that dynamic capabilities exert a stronger overall influence on organizational agility and strategic adaptation than operational capabilities. This result is consistent with dynamic capability theory, which argues that higher-order capabilities become increasingly important in environments characterized by technological turbulence and uncertainty. While operational capabilities support efficiency and routine execution, dynamic capabilities enable organizations to sense environmental changes, seize emerging opportunities, and transform organizational resources in response to changing conditions. The simulation results further demonstrate that organizational agility and efficiency should not be viewed as mutually exclusive objectives. Instead, the findings suggest that an appropriate combination of operational and dynamic capabilities can support both outcomes simultaneously. In particular, dynamic capabilities appear to play a critical role in helping organizations maintain efficiency while responding to uncertain and rapidly changing environments.

The prominence of generative sensing and scenario planning in the results highlights the importance of anticipatory capabilities in uncertainty management. Recent studies similarly suggest that organizations capable of identifying weak environmental signals and interpreting future trends are better positioned to sustain innovation and strategic flexibility under uncertain conditions (Han et al., 2023). Furthermore, the strong influence of dynamic capabilities observed in this study supports recent empirical evidence showing that sensing, seizing, and transformation capabilities contribute significantly to organizational adaptation and competitive advantage in technology-intensive industries (Sun et al., 2024; Zehir & Vural, 2025). According to Table 5, we understand that the overall effect of uncertainty on organizations' strategic decisions of being agile or efficient is higher than the risk in Iranian ICT companies. Thus, regarding the environment with uncertainty for these companies, uncertainty management mechanisms seem to be more effective than risk management. Also, concerning Table 6, the overall impact of dynamic capabilities on an organization's strategy is higher than operational capabilities. Therefore, achieving dynamic capabilities for companies to obtain agility while having efficiency is essential.

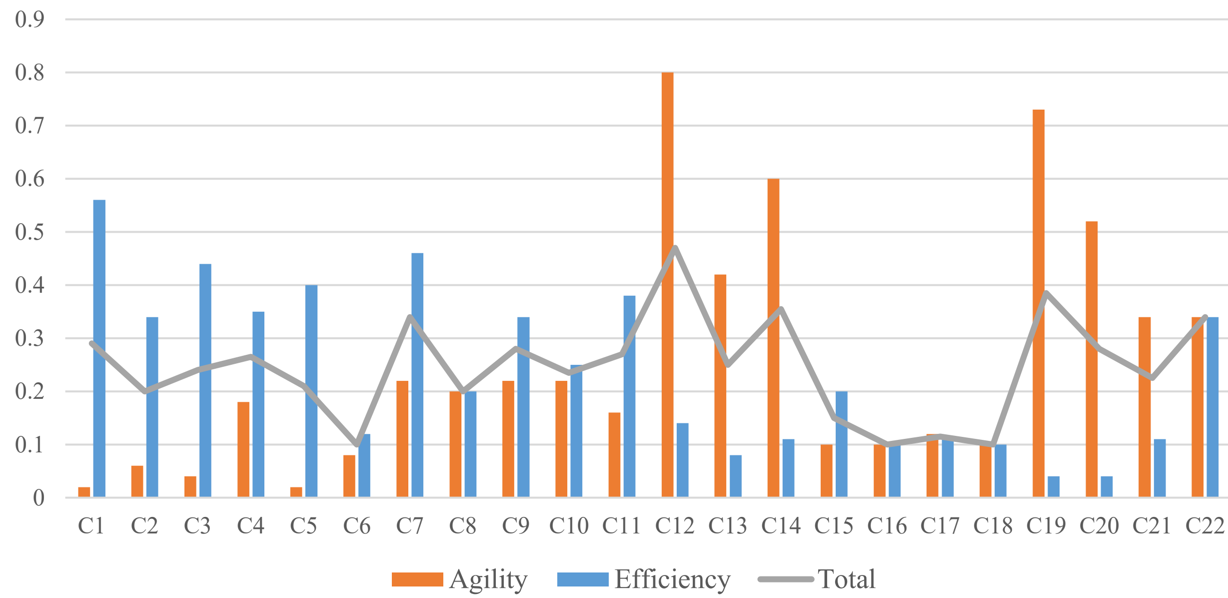


Fig 4. The path effect of organizational capabilities on organizational strategy

Figure 4 visually summarizes the relative path effects obtained from the FCM analysis and further illustrates the stronger contribution of dynamic capabilities compared with operational capabilities in shaping organizational strategy under uncertainty. Scenarios 1 to 9 were binary simulations with two states. Scenarios 10 to 14 show parametric situations. According to these scenarios, at first, all input concepts are considered 0.5. In this scenario, agility and efficiency both obtained the value of 0.66. In scenarios 11 and 12, operational capabilities were decreased and increased, respectively. According to that, when operational capabilities increased, agility almost remained the same, but efficiency dropped to 0.39. On the other hand, when operational capabilities increase up to 0.8, a little increase is seen in agility, and efficiency increases to 0.94. In scenario 13, operational capabilities remain at 0.5, and dynamic capabilities decrease to 0.2. In this scenario, compared to scenario 10, agility extensively decreases to 0.23, and efficiency remains the same. Also, in scenario 14, operational capabilities remain the same, and dynamic capabilities have increased to 0.8, resulting in an increase in both agility and efficiency compared to scenario 10.

The simulation results are generally consistent with prior studies emphasizing the critical role of dynamic capabilities in enabling organizational adaptation under uncertainty. In particular, the prominent influence of sensing, seizing, and transformation capabilities observed in the FCM simulations aligns with the dynamic capabilities framework proposed by Teece and subsequent empirical studies reporting positive relationships between these capabilities and organizational agility under uncertain environments. Furthermore, unlike conventional statistical approaches such as structural equation modeling (SEM), which primarily estimate linear relationships among predefined constructs, the FCM approach enables the representation of feedback loops, nonlinear causal interactions, and scenario-based simulations. This capability makes FCM particularly suitable for analyzing complex managerial systems characterized by uncertainty and interdependent organizational capabilities. Therefore, the present findings not only corroborate previous empirical evidence but also demonstrate the additional analytical value of FCM as a decision-support tool for exploring alternative capability development scenarios.

Comparison with previous studies

To further validate the present findings, they were compared with the results of recent empirical studies addressing dynamic capabilities and organizational agility under uncertainty. Although previous studies mainly employed statistical approaches, whereas the present study applies Fuzzy Cognitive Maps (FCM), comparing the relative importance of capability dimensions provides a useful basis for assessing the consistency and external validity of the proposed model. Table 8 summarizes this comparison.

Table 8. Comparison of the present FCM findings with previous studies

Capability	Present study	Previous evidence	Consistency
Generative sensing	Moderate influence on agility (0.47)	Dynamic sensing capabilities positively influence innovation and organizational adaptation (Leelhaphunt, 2026)	Consistent
Lean Startup	Strongest causal influence on organizational agility (0.73)	Dynamic capabilities enhance innovation performance under uncertainty (Zehir & Vural, 2025)	Consistent
Scenario planning	Positive influence	Environmental sensing improves strategic adaptation (Han et al., 2023)	Consistent
Dynamic capabilities	Greater overall impact than operational capabilities	Dynamic capabilities enhance organizational adaptation and competitive advantage (Sun et al., 2024; Zehir & Vural, 2025)	Consistent

Table 8 compares the principal findings of the present study with recent empirical research. Although previous studies mainly employed statistical techniques such as structural equation modeling (SEM), whereas the present research applies FCM, the overall pattern and relative ranking of the findings are broadly consistent. Specifically, generative sensing and Lean Startup emerged as influential capability dimensions supporting organizational agility under uncertainty, which is broadly consistent with the findings reported by Leelhaphunt (2026) and Zehir and Vural (2025). Likewise, the dominant role of dynamic capabilities over operational capabilities is consistent with previous empirical evidence emphasizing sensing, seizing, and transformation capabilities as key drivers of organizational adaptation (Han et al., 2023; Sun et al., 2024). Nevertheless, direct numerical comparison is not methodologically appropriate because FCM influence weights represent causal strengths derived from expert knowledge, whereas SEM coefficients estimate statistical relationships from observational data. Minor differences in capability rankings may therefore be attributed to differences in industrial context (Iranian ICT versus manufacturing industries), environmental uncertainty, expert-based causal modelling in FCM, and methodological differences between FCM and SEM-based analyses.

Managerial implications

The findings provide several practical implications for managers operating in ICT industries under uncertainty. First, the FCM results indicate that generative sensing (C12) exerts a substantial overall influence on organizational agility (overall effect = 0.47), suggesting that managers should strengthen environmental scanning, market intelligence, and scenario-planning capabilities to improve strategic responsiveness. Establishing dedicated scenario-planning teams and systematically monitoring technological and market signals can enhance organizations' ability to anticipate future changes. Second, Lean Startup methodology (C19) demonstrates the strongest direct influence on organizational agility (0.73). Therefore, ICT managers are encouraged to adopt Minimum Viable Product (MVP) experimentation, rapid prototyping, and iterative customer feedback mechanisms to accelerate learning while reducing the risks associated with uncertain innovation projects. In addition, the use of real-options reasoning can support incremental investment decisions under uncertainty by allowing firms to delay, expand, or abandon projects based on evolving market conditions. Finally, the scenario analysis guides resource allocation decisions. Scenario 14, in which the level of dynamic capabilities increases to 0.80, achieves simultaneously high organizational agility (1.00) and organizational efficiency (0.99). This scenario may therefore serve as a practical benchmark for managers seeking to balance agility and efficiency through sustained investment in dynamic capability development.

Conclusion

Results show that generative sensing capability has the most effect on an organization’s strategy. This shows that for making an agility/efficiency tradeoff, companies should continuously predict the future of the industry and make hypotheses about future events. Also, it was shown that logistics management plays a vital role in organizational efficiency. Simulation results show that using dynamic and operational capabilities simultaneously in a situation that source of change is both risk and uncertainty results in a rational agility/efficiency tradeoff for companies. Scenarios 1 to 3 show that when the source of change is only risk, operational capabilities and risk management mechanisms suffice for the management, and investing in dynamic capabilities seems to be unnecessary. Scenarios 4 to 6 show that when facing only risk, dynamic capabilities are not the only solution for reaching an agility/efficiency tradeoff, and agility seems to be expensive. However, when encountering deep uncertainty, investing in dynamic capabilities is justifiable, and it is accompanied by efficiency. Scenarios 8 and 9 also show that merely focusing on operational capabilities would bring low agility and high efficiency for companies. Scenarios 10 to 14 also show that increasing operational capabilities has an impact on organizational efficiency. Also, findings show that companies can gain agility by investing in dynamic capabilities. Finally, scenario 14 explains that an increase in dynamic capabilities will lead to an appropriate level of agility and efficiency and a tradeoff between them.

Limitation and Future Research

This study has several limitations that should be acknowledged. First, the proposed model was developed using expert judgments from Iranian ICT companies; therefore, the findings may not be fully generalizable to other industries or national contexts. Second, the initial FCM weight matrix relies on subjective expert assessments, which may introduce judgmental bias despite the structured elicitation process. Third, the proposed model assumes a static causal structure in which the initial causal weights remain unchanged during simulations, whereas organizational capabilities may evolve in real-world settings.

Future research can address these limitations in several ways. First, the proposed model may be validated in manufacturing, service, or other technology-intensive industries to examine its generalizability across different organizational contexts. Second, future studies may reduce expert dependency by integrating FCM learning algorithms, such as nonlinear Hebbian learning, to update causal weights using objective organizational performance data. Finally, longitudinal studies may investigate how dynamic capabilities evolve and examine additional capability dimensions influencing the agility–efficiency tradeoff under different environmental conditions.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

All authors contributed equally to the conceptualization of the article and writing of the original and subsequent drafts.

Data Availability Statement

Data available on request from the authors.

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Conflict of interest

The authors declare no conflict of interest.

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