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Analyzing the Elderly Healthcare Ecosystem: A Hybrid Stakeholder Salience and Fuzzy Cognitive Mapping Approach

Narjes Ghasemnia Arabi [1], Mohammad Reza Sadeghi Moghadam✉ [2], Mohammad Valipour Khatir [3], and Mahsa Soltani Neshan [4]

1. PhD Candidate in Industrial Management, Production and Operation Management, Faculty of Industrial and Technology Management, College of Management, University of Tehran, Tehran, Iran. E-mail: n.ghasemnia313@ut.ac.ir
2. Corresponding author, Associate Prof., Faculty of Industrial and Technology Management, College of Management, University of Tehran, Tehran, Iran. E-mail: rezasadeghi@ut.ac.ir
3. Associate Prof., Faculty of Economics and Administrative Sciences, Department of Industrial Management, University of Mazandaran, Babolsar, Iran. E-mail: valipourkhatir@umz.ac.ir
4. Ph.D., Faculty of Industrial and Technology Management, College of Management, University of Tehran, Tehran, Iran. E-mail: M.soltani20@ut.ac.ir

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ABSTRACT

Objective: The global increase in the elderly population has heightened the need for coordinated, tailored healthcare services that address the complex needs of older adults. This study aims to conceptualize the elderly healthcare ecosystem by identifying its key actors, classifying their roles, and examining the nature of their interactions.

Methodology: A multi-stage methodological approach was employed. First, an extensive literature review—focusing on healthcare ecosystems and ageing studies—was conducted to develop an initial analytical framework. Based on this, ecosystem actors were identified and categorized using Mitchell et al.'s Stakeholder Salience Model. An expert panel was then consulted to validate actor attributes and refine classifications. To analyze interdependencies and determine influential actors, a Fuzzy Cognitive Map was constructed, enabling the assessment of causal relationships and the dynamic positioning of stakeholders within the ecosystem.

Results: The analysis identified seven groups of actors within the healthcare ecosystem. FCM findings reveal that the elderly, families, and medical centers are the most influential actors. At the same time, the Ministry of Health and Medical Education, insurance and pension funds, and the Ministry of Cooperatives, Labor, and Social Welfare emerge as the most influential and central stakeholders in advancing ecosystem objectives.

Conclusion: The study demonstrates that the elderly healthcare ecosystem is inherently dynamic, and stakeholder classifications should not be viewed as static. Attributes such as power, legitimacy, and urgency are fluid and context-dependent. The FCM results further highlight this dynamism by illustrating how shifts in causal relationships can reposition actors across stakeholder categories, underscoring the need for adaptive policymaking.

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Introduction

According to the World Health Organization, the global elderly population is increasing at an astonishing rate: the proportion of people aged 60 and above is projected to rise from 12% to 22% between 2015 and 2050 (WHO, 2015). While developed countries will host the oldest populations, the fastest pace of ageing will occur in developing and less-developed nations (Suzman & Beard, 2017). This demographic shift represents one of the most significant changes in human history and, alongside other macro social trends, profoundly affects individuals and governments. Technological advances, urbanization, and economic globalization have also transformed family structures. As family support declines, societies will need better information and tools to ensure the welfare of an increasing number of elderly citizens worldwide (Suzman & Beard, 2017).

Iran is no exception and is currently undergoing an age-structure transition. Census data reveal that the elderly population has been rising in recent decades. After a decline between 1966 and 1986, the elderly population began to increase from 1996 onward. According to the Statistical Center of Iran, the population aged 60 and above grew from 1,173,679 individuals in 1956 to 7,414,091 individuals in 2016. In other words, the elderly population aged 60+ increased 6.3 times over half a century, while the population aged 65+ grew 6.4 times, compared to a 4.2-fold increase in the total population during the same period (Fathi, 2020).

Although Iran's ageing process began later than in developed countries, the demographic boom of the 1980s and a sharp fertility decline in subsequent decades mean that Iran will experience one of the fastest rates of global ageing. Countries with slower ageing have sufficient time to build infrastructure and resources to adapt, whereas, according to projections, Iran has only two decades to prepare for demographic changes similar to those faced by aged societies. Current and future demographic trends highlight complex challenges for Iran's health system (Azizi Zeinalhajlou et al., 2015). Elderly populations typically face higher burdens of chronic diseases, physical disabilities, mental health issues, and frailty, all of which significantly affect their quality of life (Shrivastava et al., 2013).

Addressing ageing-related challenges cannot be managed by a single organization; it requires the combined capabilities and involvement of governmental and non-governmental sectors. Coordination among relevant organizations for planning and promoting elderly health is crucial. Establishing coordinated structures for planning and guiding elderly-related activities can strategically improve supportive services. Planning within a health network framework to provide primary health and preventive services for older adults is essential (Alizadeh et al., 2014). Delivering care to individuals with special needs, such as the elderly, is complex and involves multiple actors—health organizations, care personnel, regulators, governmental bodies, and IT solution providers. The World Health Organization notes that many existing health systems still manage health issues in a fragmented manner and lack coordination among care providers, stakeholders, organizations, and settings at the time of care delivery (Khodabakhshi Parizi et al., 2025; Marcos-Pablos & García-Peñalvo, 2019).

In recent years, healthcare systems worldwide have been undergoing structural changes, shifting from hospital-centered service delivery toward shared healthcare infrastructures that bring diverse members under a common umbrella to provide community-wide care. The healthcare system is better understood as an ecosystem of interconnected stakeholders, each with a mission to improve the quality of care while simultaneously reducing its costs (Basri et al., 2021; Khodabakhshi Parizi et al., 2025).

Within this ecosystem, some actors play primary decision-making roles, while others influence its direction through their actions. By analyzing actor types and stakeholders, the roles and behaviors of each actor in interaction with others can be clarified; their influence and susceptibility to influence can be assessed, enabling the design of management and development strategies for the ecosystem (Wallin, 2012). Following Xiaoren's (2014) principles for ecosystem design, the process begins with identifying the set of actors and stakeholders, then characterizing their roles and importance using selected criteria (e.g., power, influence, interests), and finally grouping actors according to their ecosystem roles. The last step is to organize inter-actor relations to enhance synergy and reduce conflicts. Accordingly, this study pursues the following objectives:

1.Identify the types of actors involved in forming the elderly healthcare ecosystem.

2.Determine the nature and role of each actor and classify them.

3.Identify influential and influenced relationships among actors.

The remainder of the paper is structured as follows: Section 2 reviews the related literature on the Elderly Healthcare Ecosystem and Fuzzy Cognitive Map. Section 3 explains the methodology for identifying and classifying ecosystem actors and the stages of the Fuzzy Cognitive Map. Section 4 applies the proposed method to the classification of ecosystem actors, maps the relationships of influence among them, and finally, Section 5 concludes with findings and suggestions for future research.

Literature Background

Elderly Healthcare Ecosystem

The term "ecosystem" was introduced into the social sciences by sociologist Amos Hawley, who defined it as "a pattern of interdependencies within a population through which the whole functions as a unit, thereby maintaining a sustainable environmental relationship" (Kapoor, 2018). Natural ecosystems provide a powerful metaphor for understanding business ecosystems, as both consist of diverse inhabitants with distinct characteristics and interests, interconnected through multiple reciprocal relationships. Similar to the concept of supply chains, business ecosystems emphasize interconnections and mutual relationships among firms, since organizations do not exist in isolation but depend on the capabilities and resources of their ecosystem (Weber & Hine, 2015). In the field of business strategy, the concept was first introduced by Moore (1993), who argued that companies should not be viewed merely as members of a single industry but rather as participants in a broader business ecosystem composed of firms from multiple industries (Kapoor, 2018). Moore described a business ecosystem as a wide-ranging system of mutually supportive organizations, including customer communities, suppliers, core producers, other stakeholders, financial providers, trade associations, standard-setting bodies, labor unions, governmental and semi-governmental institutions, and other interested parties (Peltoniemi & Vuori, 2004; Wieringa et al., 2019).

The Elderly Care Ecosystem (ECE) represents a specific case of a collaborative business ecosystem. It encompasses both general elements of a collaborative environment (such as management, intermediaries, virtual organizations, planners, and coordinators) and specific elements that characterize it as a network dedicated to elderly care. These include the elderly themselves (as clients), their requests and requirements, care needs, care services, and service-providing institutions (Baldissera & Camarinha-Matos, 2016). Such an ecosystem requires mechanisms to integrate and coordinate its functions and stakeholders. Uncoordinated care can be harmful to patients, leading to repeated diagnostic tests and inappropriate care plans, while also wasting resources (Tinetti et al., 2004).

Different studies have identified and categorized the actors involved in the elderly healthcare ecosystem using diverse approaches. A synthesis of domestic and international research on ecosystem actors is presented in Table 1.

Table 1. Actors in the Elderly/Patient Healthcare Ecosystem (Source: Author)

	(Kong et al., 2024)	(Sun et al., 2023)	(He & Zhu, 2022)	(Viswanadham, 2021)	(Marinescu et al., 2021)	(Li & Carayon, 2021)	(Liu & Tian, 2021)	(Secundo et al., 2021)	(Zhao & Chu, 2019)	(Zhao, 2022) (Zhao, 2020)	(Shao et al., 2020)	(Pereno & Eriksson, 2020)	(Marcos-Pablos & García-Peñalvo, 2019)	(Lee, 2019)	(Bereczky, 2019)	(Wu et al., 2018)	(Damani et al., 2018)	(Baldissera et al., 2017)	(León et al., 2016)	(Ma et al., 2016)	(Baldissera & Camarinha-Matos, 2016)	(Yuehong et al., 2016)	(Mohrman & Shani, 2014)	(Christos et al., 2014)	(Serbanati et al., 2011)	(Khorshidzadeh et al., 2021)	(Shaarbafchi Zadeh et al., 2020)	(Shirali & Shahhazi, 2020)	(Daraffshaniam)	(Alizadeh et al., 2014)
Elderly / Patients		✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	✓		✓	✓	✓		✓		✓		✓	✓			✓	
Government	✓			✓				✓	✓	✓		✓		✓	✓		✓	✓	✓		✓		✓		✓					
Families / Caregivers / Supporters	✓	✓			✓		✓	✓				✓	✓		✓		✓		✓				✓		✓					
Ministry of Social Welfare / Civil Affairs	✓																										✓	✓		✓
Ministry of Finance (MOF)	✓																													
Ministry of Health	✓							✓																			✓	✓		✓
Elderly Commission / Council	✓																										✓			✓
Medical and clinical Centers	✓			✓	✓	✓			✓		✓			✓	✓	✓	✓	✓						✓	✓	✓	✓		✓	
Elderly Care Centers	✓		✓	✓		✓			✓	✓					✓		✓	✓									✓			
Charitable Associations for the Elderly	✓			✓						✓	✓			✓													✓	✓		
Producers of Health and Pharmaceutical Products	✓			✓			✓	✓			✓	✓		✓	✓	✓	✓	✓			✓			✓						
Service Providers (Doctors, Nurses, etc.)		✓	✓		✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓			✓	
Insurance Companies / Pension Funds	✓						✓	✓						✓	✓	✓	✓	✓					✓	✓				✓		✓
Universities / Research Centers				✓				✓			✓	✓		✓		✓		✓												✓
Financial Institutions / Investors												✓	✓	✓	✓		✓									✓				

Stakeholder Classification Approaches in Ecosystems

Stakeholder management within an ecosystem refers to the effort of enabling stakeholders to achieve their expected goals and meet their needs through appropriate governance. This involves collecting information and identifying stakeholders, using stakeholder data to predict their behavior, determining how to respond to their actions, and managing them effectively to achieve ecosystem objectives (Morsing & Schultz, 2006). Therefore, describing, understanding, and recognizing stakeholders, as well as conducting stakeholder analysis, are among the most critical tasks in stakeholder management. A review of prior studies on stakeholders indicates that the most essential prerequisite for stakeholder management is stakeholder analysis and classification (Bahadorestani et al., 2018). Over time, various methods and models have been proposed for this purpose.

For this purpose, after identifying the various actors within an ecosystem, appropriate criteria must be selected to classify them, enabling a deeper understanding and the adoption of suitable approaches to manage relationships and interactions among actors toward achieving ecosystem objectives. Different authors have employed diverse—sometimes overlapping—criteria as the basis for stakeholder classification. A comprehensive and concise summary of these approaches is presented in Table 2.

Table 2. Criteria and Types of Ecosystem Actor Classification in Previous Studies (Source: Author)

Researcher	Criteria / Type of Classification
Peifer and Newman (2020)	Level 1 Benefits: Product and Revenue; Level 2 Benefits: Law and Policy; Level 3 Benefits: Organizational Reputation and Credibility
Kastalli and (2013) Neely	Liaison: Responsible for establishing and coordinating communication among ecosystem actors. Gatekeeper: Acquires resources from outside the ecosystem and distributes them among its members. Itinerant broker: Facilitates the exchange of information between two or more actors. Representative: Engages in information exchange or negotiation with actors outside the ecosystem.
Friedman and Miles (2006)	Compatibility: The degree of alignment or misalignment of ideas and interests among stakeholders. Necessity: The extent to which the presence or absence of stakeholders is essential, including the conditional nature of relationships with them.
Bryson (2004)	Power, Legitimacy, Interests
Iansiti and (2002) Levien	Key Actor, Niche Actor, Dominant Actor, Hub Actor
Scholes et al.(2002)	Benefits, Power
Eden and (1998) Ackermann	Interests, Power
Mitchell et al. (1997)	Power, Legitimacy, Urgency
Freeman and Evan (1990)	Relative Stakeholder Power, Cooperation Potential
Kousari et al. (2021)	Key Actor, Niche Actor, Dominant Actor, Hub Actor Power/Urgency/ Interests
Saghafi et al. (2019)	Cognitive, Relational, Structural
Moshabaki (2021)	Manager, Broker, Integrator, Coordinator
Saghafi et al. (2014)	Threat, Cooperation, Urgency, Power / Influence Intensity, Interests / Value Creation, System Creation to Operationalization

A synthesis of the aforementioned models indicates that, although numerous frameworks have been proposed over time—each approaching the subject from a different perspective—most share a strong conceptual affinity with Mitchell et al.'s stakeholder salience model. For example, the widely used basic stakeholder analysis technique focuses on two of Mitchell's three attributes, namely *power* and *legitimacy*. Similarly, in other studies such as Bryson (2004), Scholes et al. (2002), Eden and Ackermann (1998), Freeman and Evan (1990), Kousari et al. (2021), and Saghafi et al. (2019), at least one of the three attributes—power, legitimacy, or urgency—is explicitly emphasized. Mitchell et al. (1997) propose that stakeholder salience is determined by three attributes: power, legitimacy, and urgency. The combination of these attributes forms a typology that enables managers to assess the relative importance of stakeholders and prioritize their claims.

- Power refers to the ability of stakeholders to influence organizational outcomes, derived from coercive, utilitarian (financial), or symbolic/normative resources.
- Legitimacy denotes socially accepted and expected structures or behaviors, often reinforcing the credibility of stakeholder claims.
- Urgency reflects the degree to which stakeholder demands require immediate managerial attention, based on time sensitivity and criticality.

By combining these attributes, seven stakeholder types emerge: dormant, discretionary, demanding, dominant, dependent, dangerous, and definitive (Figure 1). Stakeholders possessing all three attributes are classified as *definitive* and require an immediate managerial response, while those with none are not considered stakeholders. Notably, the framework emphasizes that salience increases with the accumulation of attributes, and stakeholders with two or more attributes are prioritized over those with only one. Importantly, these attributes are dynamic and context-specific; actors can gain or lose them over time, leading to shifts in their classification. This framework provides a structured lens for analyzing stakeholder roles and their relative influence in complex ecosystems (Mitchell et al., 1997).

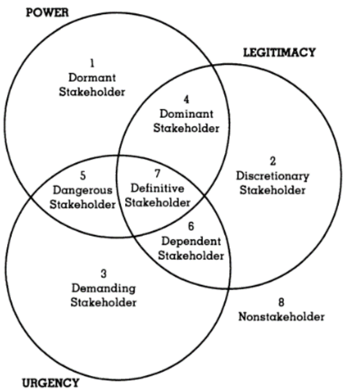

Figure 1. Stakeholder Classification from the Perspective of Mitchell et al. (1997)

Fuzzy Cognitive Map (FCM)

A Fuzzy Cognitive Map (FCM) is a graphical representation composed of nodes that denote interrelated components within a decision-support environment, with links between nodes representing the relationships among those components. FCM is a modeling methodology for complex decision-making systems that emerged from the integration of fuzzy logic and neural networks. It describes system behavior in terms of concepts, where each concept represents an entity, a state, a variable, or a characteristic of the system (Rodriguez-Repiso et al., 2007b). This method was first introduced by Kosko (1986) as a relational model for representing knowledge as a signed, directed graph that infers causal relationships among concepts. Fuzzy Cognitive Maps (FCMs) are recognized as a soft computing technique that supports a deeper understanding of complex systems through logical processes in which uncertainty and ambiguity play a central role. This technique can also evolve from a static and inflexible tool into a dynamic and adaptive method responsive to change (Sarebanzadeh et al., 2024). By incorporating insights from experts and specialists, FCMs can analyze the mutual interactions among factors and identify the indicators that exert the most significant influence in such environments. Moreover, FCMs can rank a set of influencing factors to determine the most appropriate and essential options for final decision-making (Kazemi et al., 2020; Sadeghi Moghadam et al., 2019). Overall, Fuzzy Cognitive Maps are considered supervised learning–based neural systems that, due to their flexibility and strong adaptability to complex problems, are capable of providing practical and effective solutions (Rodriguez-Repiso et al., 2007b).

Materials and Methods

Most existing studies on healthcare ecosystems have primarily focused on identifying actors, while paying limited attention to understanding their nature, classifying them, and examining their relationships to enhance coordination and guide their performance toward achieving ecosystem goals. Therefore, the present study seeks to redesign the framework and model of the elderly healthcare ecosystem by adopting a systematic approach. Based on this objective, the research questions can be formulated as follows:

1. Who are the key actors involved in the elderly healthcare ecosystem?
2. What are the roles and characteristics of these actors within the healthcare ecosystem based on the Mitchell et al. model?

How do the influential and affected relationships and interactions among these actors unfold? The present study is applied in its purpose and employs a mixed qualitative–quantitative approach to data collection. The primary data were obtained through a review of scientific articles, examination of documents, reports, and records, and in-depth interviews with experts to understand the roles and interactions among ecosystem actors. Additional data were collected through questionnaires distributed among experts, including physicians specialized in gerontology, family physicians who work extensively with older adults, university faculty members and researchers with expertise in aging studies, insurance specialists, and managers of organizations directly involved with older adults—such as nursing homes—as well as producers and software companies operating in the healthcare sector. In the initial stages of the research, when limited knowledge exists about the actors and the ecosystem's structure, an exploratory strategy is adopted to identify the actors and gain preliminary insights into their roles and relationships, using qualitative methods such as in-depth interviews. Subsequently, to provide a more precise description of the characteristics, roles, and relationships among the actors and to classify them, a descriptive strategy is employed, utilizing a combination of qualitative and quantitative methods.

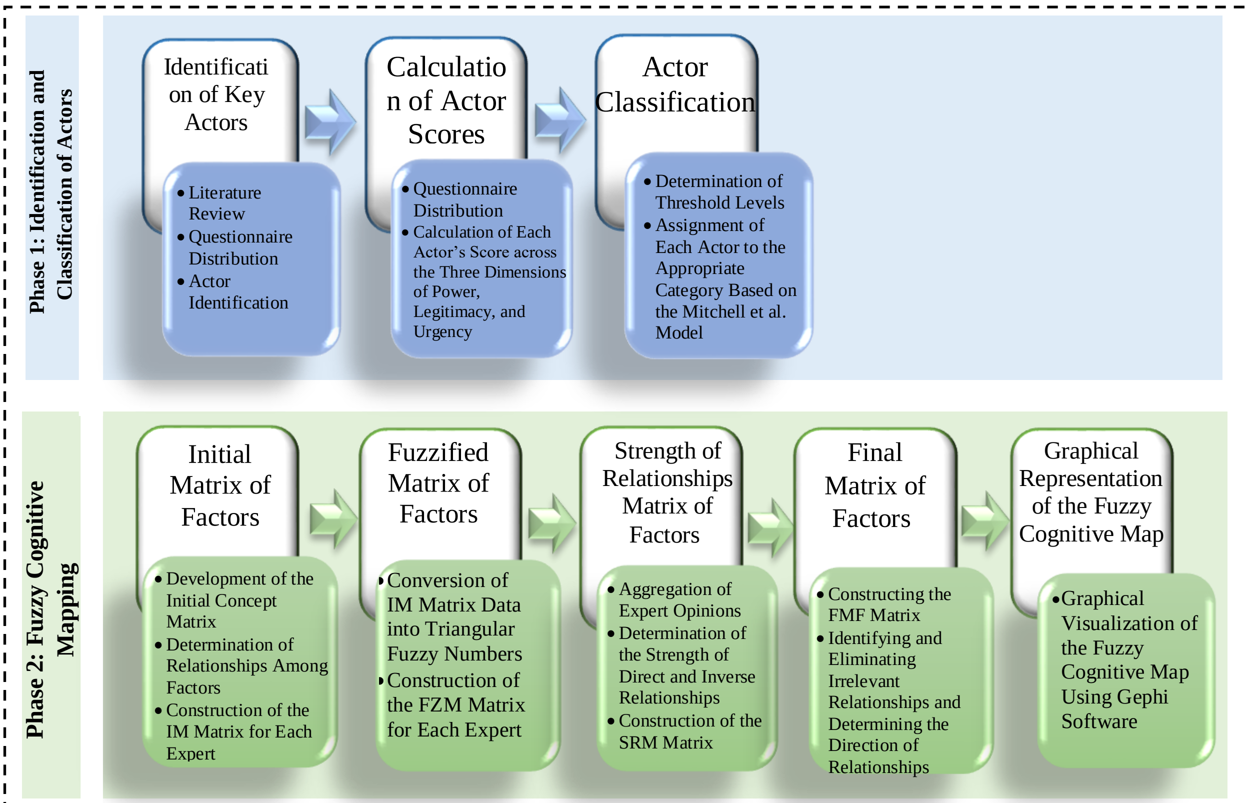

Figure 2. Procedural Steps of the Study

Phase 1. Identification and Classification of Ecosystem Actors

Step 1: Identification of Key Actors in the Healthcare Ecosystem: In this step, to determine the key actors within the healthcare ecosystem, a list of actors identified in the initial stage of the study—through a comprehensive review of the theoretical literature—is provided to experts via a questionnaire. The questionnaire is evaluated using the Delphi–Saaty method, with a scoring scale ranging from 1 (very low importance) to 10 (critically important). Ultimately, all actors with an average importance score exceeding 7 are selected as key actors.

Step 2: Calculating Actor Scores Based on the Dimensions: In the second step, a questionnaire was administered to experts to determine each actor's position along the three dimensions of power, legitimacy, and urgency. To identify the nature and position of each actor, the framework proposed by Mitchell et al. (1997) was adopted as the reference model. This model not only assesses the importance and attributes of stakeholders but also categorizes them into groups based on these dimensions.

In this model, it is assumed that each actor either possesses or does not possess each attribute (power, legitimacy, and urgency). For example, a stakeholder either has power or lacks it. Based on the possible combinations of these attributes, Mitchell et al. (1997) developed a classification that divides stakeholders into seven distinct types, each assigned an appropriate label. Figure 1 illustrates this model. Subsequently, to determine the importance (score) of each actor across the dimensions of power, legitimacy, and urgency, a questionnaire was distributed to experts. They were asked to evaluate each key actor using a scale from "very low" to "very high." After collecting the responses, the linguistic terms were converted into their corresponding triangular fuzzy numbers (Table 2). Finally, by calculating the fuzzy average of expert judgments (Equation 1), the score of each actor in each dimension was obtained.

Table 2. Linguistic Variables and Corresponding Fuzzy Numbers(Chang et al., 2022)

Linguistic Variables	Fuzzy Numbers
Very High (VH)	(10،9،8)
High (H)	(8،7،6)
Medium (M)	(6،5،4)
Low (L)	(4،3،2)
Very Low (VL)	(2،1،0)

$$\text{Score} = \{S_{ij}, where\ i = 1, 2, 3, \ldots, \text{m};\ \text{j}=, 2, 3\} \quad (1)$$

$$\tilde{S}_{ij} = \frac{1}{n} \otimes (S_{ij1} \oplus S_{ij2} \oplus S_{ij3} \oplus \ldots \oplus S_{ijn})$$

Here, m represents the number of actors, and j denotes the three attributes (power, legitimacy, and urgency). The parameter n refers to the number of experts, which in this study is m=14 and n=9. The term $\widetilde{S_{ij}}$ indicates the average score of actor i on attribute j, expressed as a triangular fuzzy number defined as:

$$\widetilde{S_{ij}} = (S_{ij\alpha}, S_{ij\beta}, S_{ij\gamma})$$

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Based on the results of the previous steps, the fuzzy scores for each actor and attribute have been determined. However, since the status of each actor in each dimension must be expressed in binary form (“presence” or “absence” of the attribute), the fuzzy scores obtained in the earlier stage are first defuzzified using the centroid method. Afterward, by applying a threshold value of 6, scores greater than 6 are interpreted as the “presence” of that attribute in the stakeholder, and scores below this threshold indicate its “absence.”

The defuzzification formula using the centroid method is expressed as:

$$s = \frac{\alpha + 4\beta + \gamma}{6} \tag{2}$$

Phase 2: Fuzzy Cognitive Mapping of the Ecosystem

The large number of actors involved in the ecosystem, the diversity of their roles, the presence of mutual interdependencies, and the extensive network of interactions necessitate a method capable of modeling this complexity by leveraging existing knowledge and expert experience. A **Fuzzy Cognitive Map (FCM)** provides a graphical representation of systems characterized by uncertainty and complex processes, visually illustrating the relationships among key concepts within a system and the feedback loops that connect them.

To implement a fuzzy cognitive map, the following five steps are carried out sequentially (Rodriguez-Repiso et al., 2007a):

Step 1: Initial Matrix of Factors (IMF)

The initial matrix of factors consists of n related factors (also referred to as n variables or concepts) and m interviewees, who represent the sample data points. Accordingly, the initial factor matrix is an n×m matrix. The elements of this matrix are denoted by Iij, where expert j assigns a degree of importance to a specific concept i. Each factor in this matrix represents a meaningful value ranging between 0 and 100.

Step 2: Fuzzified Matrix of Factors (FZMF)

The values of the initial matrix are mapped onto the interval [0, 1] to generate a fuzzy set. By transforming the vector Vi, which consists of the elements Ii1, Ii2, Ii3,…,Iim, the fuzzified matrix can be obtained using the following relations:

$$FZ(\max(I_{iq}))=1 \quad \forall_i = 1,\dots,n \ \& \ \forall_q = 1,\dots,m \tag{3}$$

$$FZ(\min(I_{ip}))=0 \quad \forall_i = 1,\dots,n \ \& \ \forall_q = 1,\dots,m \tag{4}$$

$$FZ_{ij}= \frac{I_{ij}-\min(I_{ip})}{\max(I_{iq})-\min(I_{ip})} \tag{5}$$

The maximum value of Vi is determined by assigning the value 1 to FZiq, according to Equation (3). Similarly, the minimum value of Vi is calculated by assigning the value 0 to FZip, as shown in Equation (4). Finally, all elements are mapped to the interval [0,1] using Equation (5), where FZij represents the membership degree of Iij.

In addition, two threshold values are required, referred to as the upper and lower thresholds. Accordingly, the upper threshold (αu) and the lower threshold (αl) can be defined as follows:

$$\text{If} \quad I_{ij} \geq \alpha_u \quad \text{then} \quad FZ_{ij} = 1 \quad \forall_i = 1,\dots,n \ \& \ \forall_j = 1,\dots,m \tag{6}$$

$$\text{If} \quad I_{ij} \leq \alpha_l \quad \text{then} \quad FZ_{ij} = 0 \quad \forall_i = 1,\dots,n \ \& \ \forall_j = 1,\dots,m \tag{7}$$

It should be noted that, given the threshold values of 80 and 20, respectively, if an expert evaluates the importance of a criterion as greater than or equal to 80, the corresponding numerical value in the fuzzified matrix is set to 1. Likewise, if the value is less than or equal to 20, it is converted to 0 in the fuzzified matrix.

Step 3: Strength of Relationships in the Matrix of Factors (SRMF)

The SRMF matrix is constructed by considering the relevant factors as the rows and columns of an n×n matrix. In Equation (8), the value S(final)rt represents the relationship between concepts r and t. This value ranges between [−1, +1] and is interpreted as follows:

If S(final)rt is positive, it indicates a direct relationship between *r* and *t*; in other words, an increase in *r* leads to an increase in *t*.

Conversely, if S(final)rt is negative, it reflects an inverse relationship, meaning that an increase in *r* results in a decrease in *t*.

It should also be noted that the value of S(final)rt must incorporate the following three key components:

- Sign: This component indicates whether the relationship between *r* and *t* is direct (positive) or inverse (negative).
- Strength: This component reflects the magnitude of the influence that *r* exerts on *t*.
- Direction of Causality: This indicates whether *r* influences *t*, or conversely, whether *t* influences *r*.

Equation (8) is used to calculate the strength of the direct relationship between the two given concepts, denoted as $S_{(direct)\,rt}$.

$$S_{(direct)rt} = 1 - \frac{\sum_{j=1}^{m} |FZ_{rj} - FZ_{tj}|}{m} \quad \forall_r = 1, \dots, n \;\&\; \forall_t = 1, \dots, n \;\&\; \forall_j = 1, \dots, m \tag{8}$$

When $S_{(direct)rt}=1$, it indicates complete similarity between the two concepts. Conversely, when $S_{(direct)rt}=0$, it reflects the highest level of dissimilarity between them.

To compute the strength of the relationship between two concepts that are inversely related, denoted as $S_{(inverse)rt}$, the previous equation must be modified as follows:

$$S_{(inverse)rt} = 1 - \frac{\sum_{j=1}^{m} |FZ_{rj} - (1 - FZ_{rj})|}{m} \quad \forall_r = 1, \dots, n \;\&\; \forall_t = 1, \dots, n \;\&\; \forall_j = 1, \dots, m \tag{9}$$

When $S_{(inverse)rt} = 1$, it indicates complete inverse similarity between the two concepts. Conversely, when $S_{(inverse)rt} = 0$, it represents the highest degree of inverse dissimilarity.

Finally, to compute $S_{(final)rt}$, all corresponding elements of the two matrices—namely the inverse and direct relationship matrices—must be compared. If

$S_{(direct)rt} < S_{(inverse)rt}$,

then

$S_{(final)rt} = - S_{(inverse)rt}$

Otherwise,

$S_{(final)rt} = + S_{(direct)rt}$

This comparison determines the final value of $S_{(final)rt}$, reflecting the overall influence of both direct and inverse relationships between the two concepts.

Step 4: Final Matrix of Factors (FMF)

Not all related factors are necessarily interdependent, nor do they always exhibit causal relationships. Therefore, some data in the SRMF matrix may be inaccurate or misleading. To identify the FMF matrix—which includes only numerical fuzzy values and reflects the actual causal relationships among the relevant factors—experts must review and analyze the data using the SRMF matrix.

Although the SRMF and FMF matrices may exhibit mathematical dependencies, they do not necessarily share a direct conceptual or logical relationship. In such cases, experts can readily identify irrelevant or non-causal relationships. Accordingly, by incorporating expert judgment, the SRMF matrix is refined and transformed into the FMF matrix, ensuring that only valid and meaningful relationships remain. This process enhances the model's credibility and ensures its reliability and trustworthiness.

Step 5: Graphical Representation of the Fuzzy Cognitive Map (FCM)

The graphical representation of the final matrix of factors as a fuzzy cognitive map provides a structured, purposeful visualization of the key factors. In the final representation, each arrow connecting factors *i* and *j* carries a signed weight. This value indicates the strength of the direct or inverse causal relationship between the two factors. It corresponds to the numerical value presented in the FMF matrix at row *i* and column *j*.

Results

Based on a comprehensive review of the theoretical foundations and prior domestic and international studies, a list of potential stakeholders (actors) involved in the ecosystem was provided to the experts. They were asked to determine whether each actor was relevant to the ecosystem under investigation. The interviewees were selected through purposive, non-random sampling, and a total of nine in-depth, semi-structured interviews were conducted.

Accordingly, the stakeholders identified as relevant to the elderly healthcare ecosystem were selected for further analysis in the subsequent steps. These stakeholders include: older adults; families; insurance and pension funds; healthcare centers (hospitals, clinics, medical centers, primary healthcare networks, and rehabilitation centers); the Ministry of Health and Medical Education; the Ministry of Cooperatives, Labor, and Social Welfare; the National Council for the Elderly; care service providers (physicians, nurses, allied health professionals, and social workers); pharmaceutical and medical equipment manufacturers; State Welfare Organization; elderly care service centers; non-governmental and charitable organizations; the Imam Khomeini Relief Foundation; and universities and research institutions.

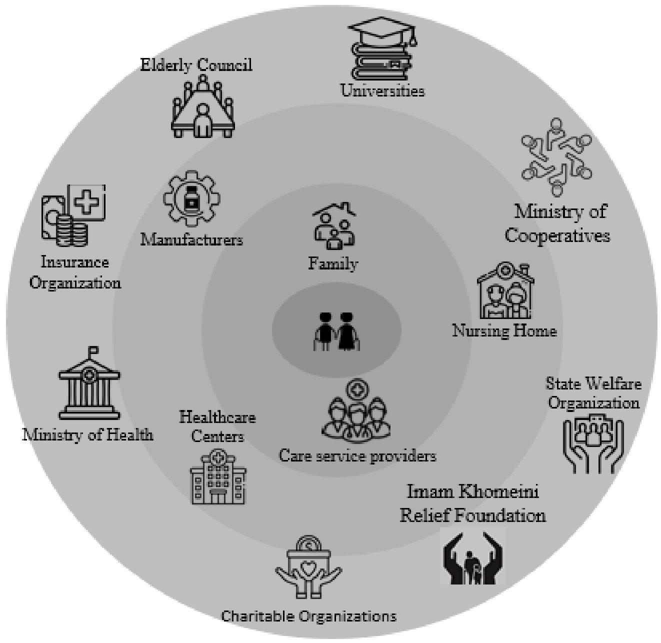

Figure 3. Actors in the Elderly Healthcare Ecosystem

After identifying the key actors in the elderly healthcare ecosystem, the next step was to evaluate each actor's characteristics using the Power, Legitimacy, and Urgency Attributes. This assessment was conducted using a structured questionnaire completed by subject-matter experts, and the consensus of expert opinions is presented in Table 3. Subsequently, the corresponding crisp numerical values were calculated using Equation (2).

Table 3. Aggregated Expert Opinions on the Status of Each Ecosystem Actor Based on Three Salience Attributes

Experts / Actors	Fuzzy			Crisp		
	($\widetilde{S_{i1}}$) Power	Legitimacy ($\widetilde{S_{i2}}$)	($\widetilde{S_{i3}}$) Urgency	Power (S_{i1})	Legitimacy (S_{i2})	Urgency (S_{i3})
Older adults	4.44 ,3.44 ,) (2.44	8.22, 7.22,) (6.22	7.78, 6.78,) (5.78	3.44	7.22	6.78
Families	4.44 ,3.44 ,) (2.44	8.44, 7.44,) (6.44	8.44, 7.44,) (6.44	3.44	7.44	7.44
Insurance	8.89, 7.89,) (6.89	9.33, 8.33,) (7.33	3.78, 2.78,) (1.78	7.89	8.33	2.78
Healthcare centers	8.22, 7.22,) (6.22	8.44, 7.44,) (6.44	3.11, 2.11,) (1.11	7.22	7.44	2.11
The Ministry of Health and Medical Education	9.33, 8.33,) (7.33	8.44, 7.44,) (6.44	8.44, 7.44,) (6.44	8.33	7.44	7.44

The Ministry of Cooperatives	8.44, 7.44,) (6.44	8.67, 7.67,) (6.67	8.44, 7.44,) (6.44	7.44	7.67	7.44
The National Council	4.11, 3.33,) (2.22	8.44, 7.44,) (6.44	3.78, 2.78,) (1.78	3.28	7.44	2.78
Care service providers	8.89, 7.89,) (6.89	(8, 7, 6)	3.78, 2.78,) (1.78	7.89	7.00	2.78
Pharmaceutical manufacturers	3.78, 2.78, 178) (	2.89, 2.78,) (1.33	7.11, 6.11,) (5.11	2.78	2.78	6.11
Elderly care service centers	4.22, 3.22,) (2.22	7.56, 6.56,) (5.56	4.22, 3.22,) (2.22	3.22	6.56	3.22
Charitable organizations	8.67, 7.67,) (6.67	3.67, 2.89,) (1.78	4.44, 3.44,) (2.44	7.67	2.83	3.44
State Welfare Organization	8.89, 7.89,) (6.89	7.78, 6.78,) (5.78	4.22, 3.22,) (2.22	7.89	6.78	3.22
The Imam Khomeini Relief Foundation	8.89, 7.89,) (6.89	(8, 7, 6)	4.67, 3.67,) (2.67	7.89	7.00	3.67
Universities	(4, 3, 2)	8.67, 7.67,) (6.67	4.44, 3.44,) (2.44	3.00	7.67	3.44

Based on the results presented in Table 3, each actor receives a score for each of the Three Salience Attributes. Therefore, in accordance with the logic of Mitchell et al.'s stakeholder salience model, the presence or absence of each attribute for every stakeholder in the ecosystem must be determined. Accordingly, based on the predefined threshold, the status of each actor across the three dimensions is coded so that a value of "1" indicates possession of the attribute. In contrast, a value of "0" indicates its absence (Table 4).

Table 4. Classification of Ecosystem Actors Based on the Attributes of Power, Legitimacy, and Urgency

Actors	Notation	Power	Legitimacy	Urgency	stakeholder categories
Older adults	A1	0	1	1	Dependent
Families	A2	0	1	1	Dependent
Insurance and pension funds	A3	1	1	0	Dominant
Healthcare centers	A4	1	1	0	Dominant
The Ministry of Health and Medical Education	A5	1	1	1	Definitive
The Ministry of Cooperatives, Labor, and Social Welfare	A6	1	1	1	Definitive
The National Council for the Elderly	A7	0	1	0	Discretionary
Care service providers	A8	1	1	0	Dominant
Pharmaceutical and medical equipment manufacturers	A9	0	0	1	Demanding
Elderly care service centers	A10	0	1	0	Discretionary
Non-governmental and charitable organizations	A11	1	0	0	Dormant
State Welfare Organization	A12	1	1	0	Dominant
The Imam Khomeini Relief Foundation	A13	1	1	0	Dominant
Universities and research institutions	A14	0	1	0	Discretionary

In the second phase of the study, in order to construct and analyze the cognitive map, the relationship power matrix shown in Table 5 was also obtained using Equations (3) to (9).

Table 5. Relationship Power Matrix among Ecosystem Actors

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
A1		0.86	0.93	0.88	0.91	0.49	0.34	0.93	0.83	0.36	0.27	0.64	0.61	0.73
A2	0.86		0.89	0.89	0.85	0.53	0.40	0.89	0.75	0.50	0.31	0.70	0.65	0.70
A3	0.93	0.89		0.95	0.95	0.43	0.30	1.00	0.84	0.39	0.21	0.59	0.54	0.68
A4	0.88	0.89	0.95		0.93	0.48	0.35	0.95	0.84	0.44	0.25	0.64	0.59	0.67
A5	0.91	0.85	0.95	0.93		0.47	0.34	0.95	0.86	0.42	0.25	0.64	0.59	0.72
A6	0.49	0.53	0.43	0.48	0.47		0.79	0.42	0.56	0.74	0.70	0.72	0.75	0.66
A7	0.34	0.40	0.30	0.35	0.34	0.79		0.29	0.46	0.77	0.84	0.66	0.65	0.57
A8	0.93	0.89	1.00	0.95	0.95	0.42	0.29		0.84	0.39	0.20	0.59	0.54	0.67
A9	0.83	0.75	0.84	0.84	0.86	0.56	0.46	0.84		0.49	0.37	0.71	0.65	0.75
A10	0.36	0.50	0.39	0.44	0.42	0.74	0.77	0.39	0.49		0.81	0.72	0.71	0.59
A11	0.27	0.31	0.21	0.25	0.25	0.70	0.84	0.20	0.37	0.81		0.61	0.62	0.52
A12	0.56	0.62	0.52	0.57	0.56	0.80	0.74	0.51	0.68	0.78	0.69		0.91	0.78
A13	0.57	0.61	0.51	0.55	0.55	0.79	0.69	0.50	0.65	0.75	0.66	0.89		0.71
A14	0.73	0.70	0.68	0.67	0.72	0.66	0.57	0.67	0.75	0.59	0.52	0.74	0.71	

To construct the final matrix, a focus group of five experts in the healthcare ecosystem was convened. During this stage, meaningless or irrelevant connections among the actors were removed, and the causal direction of the remaining relationships was determined. The results of this process are presented in Table 6.

Table 6. Final Causal Relationship Matrix among Ecosystem Actors

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
A1														
A2	0.86										0.31	0.70		
A3	0.93	0.89		0.95	0.95		0.30	1.00	0.84			0.59		
A4	0.88	0.89	0.95					0.95	0.84					0.67
A5	0.91	0.85	0.95	0.93			0.34	0.95	0.86	0.42				0.72
A6	0.49	0.53	0.43	0.48			0.79	0.42	0.56	0.74	0.70	0.72		
A7	0.34		0.30		0.41	0.76				0.77		0.66	0.65	
A8	0.93			0.95	0.74									
A9	0.83			0.84	0.71			0.84						
A10	0.36	0.50									0.81	0.72		
A11	0.27	0.31		0.25	0.42					0.81		0.61		
A12	0.56	0.62					0.74			0.78				
A13	0.57	0.61					0.69					0.89		
A14				0.67	0.73			0.67	0.75					

In the subsequent step, to analyze the structure of the fuzzy cognitive map, the final matrix was imported into the FCMapper software. This allowed for the calculation of each actor's degree of influence, degree of dependence, and centrality. The software output is presented in Table 7.

- Degree of Influence: The total sum of the fuzzy output (causal) values of a factor, representing the magnitude of its impact on other factors.
- Degree of Dependence: The total sum of the fuzzy input (effect) values of a factor, indicating the extent to which other factors influence it.
- Centrality: The sum of the fuzzy input and output values of a factor, reflecting its overall level of interaction and its position within the system. The centrality index captures both influence capacity and susceptibility to influence. Accordingly, factors with higher combined influence and dependence are considered dominant or pivotal actors.

Table 7. Degree of Dependence, Degree of Influence, and Centrality of Ecosystem Actors

Actor	Degree of Influence	Degree of Dependence	Centrality	Actor	Degree of Influence	Degree of Dependence	Centrality
A1	0.00	7.91	7.91	A8	4.83	2.61	7.44
A2	1.86	5.20	7.06	A9	3.86	3.22	7.07
A3	6.44	2.63	9.07	A10	3.53	2.38	5.91
A4	5.18	5.07	10.25	A11	1.82	2.68	4.50
A5	6.93	3.96	10.89	A12	4.89	2.70	7.59
A6	5.87	0.76	6.63	A13	0.65	2.75	3.40
A7	3.88	2.85	6.73	A14	1.39	2.83	4.22

Among the fourteen actors involved in delivering healthcare services to the elderly, the Ministry of Health, Treatment, and Medical Education (A5) demonstrates the highest centrality—defined as the combined magnitude of influence and dependence—highlighting its pivotal, system-shaping role within the ecosystem. The Elderly (A1), Family (A2), and Hospitals (A4) emerge as the most dependent actors, indicating their substantial susceptibility to the actions and decisions of other stakeholders. In contrast, the Ministry of Health, Treatment, and Medical Education (A5), Insurance Organizations (A3), and the Ministry of Cooperatives, Labor, and Social Welfare (A6) are the most influential actors, exerting the most significant causal impact on the functioning and performance of the healthcare ecosystem.

To further illustrate the structure of the fuzzy cognitive map, the final matrix was visualized in Gephi. In the resulting network diagram (Figure 4), each circle represents one of the fourteen actors, while the connecting edges depict the causal relationships among them. The diameter of each node corresponds to its centrality score, such that actors with higher combined influence and dependence appear as larger nodes. The direction of the arrows indicates the causal flow between actors, and the thickness of the edges reflects the relative strength of influence and dependence within the network.

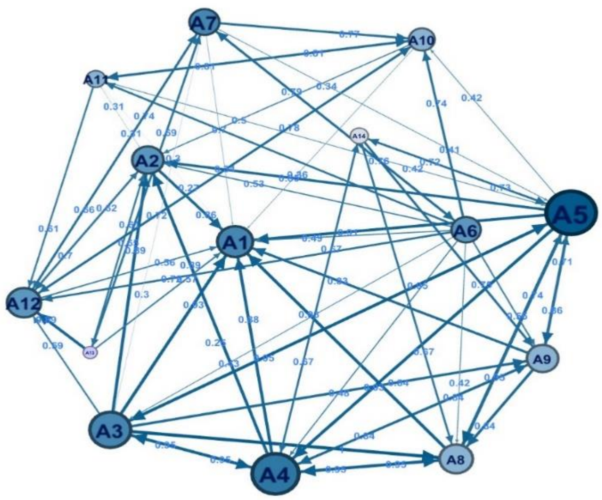

Figure 4. Fuzzy Cognitive Map of the Key Actors in the Elderly Healthcare Ecosystem

Based on the density and configuration of incoming and outgoing connections, the Ministry of Health, Treatment, and Medical Education (A5) and the Elderly (A1) are identified as the most influential and the most dependent actors within the ecosystem, respectively. The Ministry of Health assumes a central, system-shaping role, exerting substantial direct and indirect influence on the behavior and performance of other components. Following this, Insurance and Pension Funds (A3) rank second in terms of influence, serving as a critical structural driver within the healthcare ecosystem.

From the perspective of dependence, the Elderly (A1) emerge as the most highly affected actor, reflecting their extensive and multidimensional interactions with a wide range of ecosystem elements. The Family (A2) and Hospitals (A4) also exhibit significant dependence, indicating strong bidirectional linkages with other components of the system. Such patterns underscore the interconnectedness of these actors within the broader network of healthcare provision and their sensitivity to changes occurring elsewhere in the ecosystem.

Conclusion

The rapid ageing of the population and the increasing demand for healthcare services for older adults introduce a wide range of social and economic challenges that extend far beyond the scope of a simple supply chain or linear service system. A healthcare ecosystem comprises numerous actors, each contributing in different capacities; some hold central and decision-making roles and, through their influence, shape the overall direction and functioning of the ecosystem. Accordingly, the present study sought to develop a structured perspective on the key stakeholders within this ecosystem to enhance support, coordination, and oversight of healthcare activities, thereby improving the quality of life and health outcomes of the elderly population.

Most studies in the field of ecosystems have been conducted using qualitative methods for identifying and classifying the stakeholders, which is based solely on a static approach (Basri et al., 2021; Kousari et al., 2021; Moshabaki, 2021; Pereno & Eriksson, 2020; Saghafi et al., 2019). Only a few studies have examined the multi-criteria decision-making (MCDM) methods for the healthcare ecosystem context (He & Zhu, 2022; Kong et al., 2024; Wan et al., 2016). This is because the types and dynamics of relationships among ecosystem actors, and their changing nature over time, have been ignored, leading to a simplification of the real-world context of the research subject.

Therefore, the present study aims to fill this research gap. Various groups of actors were first identified, and a comprehensive framework was developed to classify stakeholders in the elderly healthcare ecosystem based on their power, urgency, and legitimacy. This framework not only clarifies which entities hold critical roles within the system but also provides a practical foundation for identifying primary stakeholders in elderly healthcare at the national level.

Subsequently, the nature of the relationships among actors, as well as their respective levels of influence and dependence, was examined using a fuzzy cognitive mapping approach. This analysis enabled a deeper understanding of how actors interact, how their actions shape system performance, and how interdependencies can be managed to enhance service delivery. The insights derived from this study offer valuable guidance for policymakers and decision-makers, supporting the identification of capability requirements, strengthening stakeholder roles, and further developing the elderly healthcare ecosystem.

Furthermore, the fuzzy cognitive map, as a robust analytical instrument, enabled a clear and explicit representation of the relationships among the identified factors. The integration of the stakeholder-based framework with the fuzzy cognitive mapping approach—unlike previous studies that predominantly relied on qualitative or single-dimensional methods—allowed the strengths of each method to compensate for the other's limitations. This combined approach thus provided a comprehensive, multidimensional perspective for analyzing the actors and interactions that shape the elderly healthcare ecosystem.

The study's findings initially revealed that 14 key actors play a significant role in this ecosystem. Subsequently, the analysis of inter-actor relationships was conducted, and, as illustrated in Figure 5, a network of influence and dependence among these 14 actors was mapped using the classification of Mitchell et al. (1997) This network representation offers a nuanced understanding of how actors interact, the extent to which they influence or are influenced by others, and the structural configuration that underpins the functioning of the elderly healthcare ecosystem.

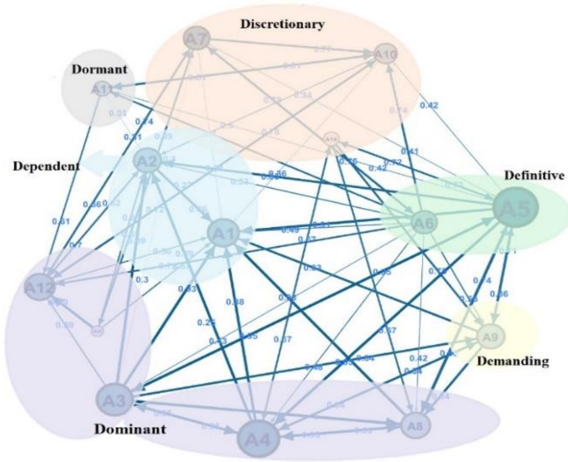

Figure 5. Integrated Model of the Fuzzy Cognitive Map and the Mitchell et al. Stakeholder Classification Framework

The study's findings indicate that the Ministry of Health, Treatment, and Medical Education (A5) and the Ministry of Cooperatives, Labor, and Social Welfare (A6) possess high levels of power, legitimacy, and urgency in advancing their mandates, directives, and programs. Consequently, these actors hold a decisive and authoritative position within the ecosystem. In line with the stakeholder typology proposed by Mitchell et al., such actors are classified as highly salient, underscoring their exceptional importance relative to other stakeholders.

The results derived from the fuzzy cognitive map further reinforce these conclusions. The Ministry of Health, Treatment, and Medical Education, with a centrality score of 10.89, exhibits the highest combined level of influence and dependence among all actors. This elevated centrality highlights its substantial impact and its pivotal role in shaping the structure and dynamics of the elderly healthcare ecosystem.

The Elderly (A1) and their Families (A2) are positioned as dependent actors within the ecosystem. The elderly with the highest degree of dependence (7.91) exhibit the most significant reliance on and interaction with other actors. This dependence stems from the nature of their needs—namely, the requirement for timely and high-quality healthcare services—which carries strong legitimacy and, due to the chronic nature of age-related conditions, is characterized by persistent urgency. Nevertheless, the elderly lack formal power to address these needs independently. Consequently, and in accordance with the stakeholder typology proposed by Mitchell et al., they are classified as dependent stakeholders. These findings align fully with the fuzzy cognitive map's results, which similarly highlight their high susceptibility to the actions of other actors within the ecosystem.

Insurance and Pension Funds (A3), Healthcare Providers (physicians and nurses) (A8), Healthcare Facilities (hospitals, clinics, health centers, and rehabilitation institutions) (A4), the Welfare Organization (A12), and the Imam Khomeini Relief Committee (A13) constitute the dominant actors within the ecosystem, possessing both power and legitimacy. Their influence is effectively guaranteed, as these attributes enable them to form the "dominant coalition" within the system. Consequently, these actors operate through formal mechanisms that underscore the strategic importance of their relationships with other stakeholders. Indeed, dominant actors are often those identified by scholars as the primary drivers of ecosystem functioning (Mitchell et al., 1997). Analysis of their interactions with other ecosystem members reveals that healthcare facilities, with the second-highest centrality score (10.25), serve as a pivotal actor within the dominant group, highlighting their critical role in ensuring timely, high-quality healthcare services for the elderly.

Charitable organizations (A11), classified as latent actors, possess considerable financial and symbolic power; however, due to their lack of legitimacy or urgency, their influence remains largely unrealized. Their minimal or nonexistent interaction with other actors is reflected in their low influence (1.82) and dependence (2.68) scores in the fuzzy cognitive map. Nevertheless, given their potential to acquire additional attributes—such as legitimacy or urgency—managers must remain attentive to their presence. The dynamic nature of stakeholder relationships implies that if a latent actor gains legitimacy or urgency, its salience and strategic importance may increase substantially.

Elderly care service centers (A10), the National Council for the Elderly (A7), and universities and research institutions (A14) are categorized as discretionary actors, characterized by high legitimacy but lacking both power and urgency. As such, they exert limited influence on other stakeholders and face no immediate pressure to engage in active relationships. Their low influence and dependence scores in the fuzzy cognitive map further confirm this status. Notably, the National Council for the Elderly demonstrates stronger connections with other ecosystem actors compared to the other members of this group, a pattern attributable to the institutional authority of its constituent members. This suggests that the Council holds the potential to acquire symbolic power and transition into the dominant actor category, thereby increasing the significance of its interactions within the ecosystem.

Producers of pharmaceuticals and medical equipment (A9), despite their critical role in supporting healthcare delivery, are characterized by high urgency but insufficient power and legitimacy. As demanders within the ecosystem, they exhibit moderate-to-low influence (3.86) and dependence (3.22), indicating a relatively limited role in shaping inter-actor dynamics. Nonetheless, given their essential role in meeting the healthcare needs of the ecosystem, greater attention from key actors is warranted to ensure adequate provision of medical products and technologies.

The integrated analysis of the fuzzy cognitive map and the stakeholder identification model proposed by Mitchell et al. (1997) offers a novel perspective for understanding the dynamic nature of actors within the elderly healthcare ecosystem. The findings demonstrate that this ecosystem is inherently dynamic, and the classification of actors should not be interpreted as static. The positions of actors within Mitchell's seven stakeholder categories—such as definitive, dependent, or discretionary—are not fixed labels; instead, the attributes of power, legitimacy, and urgency are fluid and context-dependent, and may be acquired or lost over time. The results of the fuzzy cognitive map further substantiate this dynamism, as the weights of causal relationships and centrality indices reveal the potential of actors to shift across stakeholder categories.

For instance, actors such as elderly care centers, which may currently possess legitimacy alone due to resource constraints and are therefore categorized as discretionary stakeholders, could acquire urgency or power in response to national policy shifts or emerging aging-related crises, thereby transitioning into the definitive stakeholder group. Actors actively seek to enhance their influence by acquiring attributes they currently lack. For example, families possess legitimacy and urgency, yet by forming advocacy associations for the elderly, they may gain collective power and transition from dependent to definitive stakeholders. This movement across categories—referred to by Mitchell as "stakeholder dynamism"—is observable in this study through shifts in influence and dependence vectors within the fuzzy cognitive map. The causal relationships extracted from the map confirm that strengthening a single link between two nodes can alter the balance of power across the entire network. Changes in relationship weights directly affect actors' influence and salience over time, potentially transforming a peripheral actor into a strategic one within the future ecosystem.

In Iran, rapid demographic and technological transitions accelerate this phenomenon of stakeholder dynamism. Emerging care crises may enhance the "power" of actors such as pharmaceutical and medical equipment manufacturers, enabling them to move from the latent (demanding) category to more influential positions. Similarly, the rapid growth of the elderly population increases their political bargaining power, amplifying the attribute of "urgency" and shifting the elderly from dependent stakeholders to central, policy-shaping actors. Conversely, the financial instability of insurance and pension funds may gradually erode their "power" within the healthcare financing chain. This power vacuum, as indicated by the causal pathways in the fuzzy cognitive map, creates opportunities for pharmaceutical and medical technology producers to assume a more prominent role. By leveraging technological advancements and transitioning from mere suppliers to providers of remote monitoring solutions, these actors may acquire power through innovation and evolve into definitive stakeholders.

Moreover, changes in family structures and the decline of traditional support systems transfer the attributes of "legitimacy" and "urgency" from families to elderly care centers and private sector providers. Meanwhile, the Ministry of Health—particularly healthcare facilities—will face significant capacity constraints, potentially shifting their role in the fuzzy cognitive map from direct service providers to regulators of protocols and standards. Consequently, effective ecosystem governance requires policymakers to monitor not only current roles but also the latent potential of actors to redefine their attributes through evolving interactions captured in the cognitive map. The sustainability of the elderly healthcare ecosystem thus depends not on the stability of roles, but on actors' capacity to continuously redefine themselves in response to the changing needs of the aging population. This underscores the necessity of adopting a process-oriented rather than a static approach to stakeholder management.

Given the macro-level societal trends discussed above, future research would benefit from scenario-based dynamic simulations. Potential avenues include modeling the long-term sustainability of insurance and pension funds under aging-related pressures, and system dynamics simulations of the shifting burden of care from families to technology-driven sectors.

Data Availability Statement

Data available on request from the authors.

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Ethical considerations

The authors have witnessed various ethical issues, including plagiarism, failure to obtain informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy.

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Conflict of interest

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