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Lessons learned from urban crisis management system in COVID-19 pandemic using social network analysis

M. Samadi Foroushani[1], S.S. Miresmaeeli[2], A. Nasiri[3,*], Z. Molamohamadi[4]

[1] Department of Industrial Management, Faculty of Management, Tehran University, Iran. Researcher in Tehran Disaster Mitigation and Management Organization, Iran

[2] Department of Health in Emergency and Disasters. Faculty of Health Management and Information. Iran University Medical of Science. Iran

[3] Department of Health in Emergency and Disasters. Faculty of Health. Baghiyatallah University of Medical Sciences, Iran. President of Tehran Disaster Mitigation and Management Organization, Iran

[4] Tehran Disaster Mitigation and Management Organization, Iran

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ABSTRACT

BACKGROUND AND OBJECTIVES: Crises of high uncertainty and complexity provoke discussion about new requirements of crisis management systems, which is of utmost importance in developing a cooperative environment and providing effective responses. This study aims to analyze the cooperative system of Tehran Municipality departments involved in crisis management of the COVID-19 pandemic, who are called actors afterward and thereby present the lessons learned through this pandemic.

METHODS: Social network analysis has been applied in this research to analyze the collaboration system. Accordingly, the crisis management actions taken by Tehran Municipality are first explored and, 38 actors and 11 areas of knowledge are identified. The two-dimensional matrix of actors-actions and the cooperative system of the actors are then analyzed based on the degree and betweenness centrality indicators in UCINET and NetDraw software to investigate the position of the actors' tacit knowledge power in the cooperative network.

FINDINGS: The actors' cooperative system generally has high density and coherence; however, it seems that the position of some actors must be strengthened within the structure of the crisis management in Tehran Municipality. The results of the degree centrality index identified 7 actors with higher degree centrality (20% of total actors) and 7 actors with lower degree centrality (20% of total actors). Moreover, the betweenness centrality of the network of actors is analyzed to find the highest and lowest betweenness power in the cooperative network. Afterward, a series of recommendations are proposed based on a designed systematic intervention. Moreover, a cooperative system of pandemic crisis management would be developed based on the key actors' experiences and the lessons learned from failures.

CONCLUSION: Existing knowledge presents a valuable prospect for policy-makers in urban crisis management to establish an organizational cooperative system, capitalize on the insights gained, and contemplate pragmatic collective measures to enhance urban resilience in the face of pandemic crises.

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*Corresponding Author:
Email: *alinasiri@bmsu.ac.ir*
Phone: +982144244040
ORCID: 0000-0003-4974-2964

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INTRODUCTION

The COVID-19 pandemic has exposed the vulnerability of urban life and urban performance to such an extent that most of the world's cities have long been in catastrophic chaos (Hassankhani *et al.*, 2021; Isaifan, 2020). Cities are often the focal point of the COVID-19 outbreak due to the high concentration of population and economic activity (Saedi *et al.*, 2022; Motaharian *et al.*, 2022). Accordingly, several researchers are striving to discover the dynamics of the pandemic in urban areas to perceive the impact of COVID-19 on city governance (Sharifi and Khavarian-Garmsir, 2020). The COVID-19 crisis has changed the face of many cities, raising questions about how one must manage urban life during a pandemic and the importance of learning from this in terms of city governance and urban crisis preparedness (Acuto, 2020). Municipalities around the world are considered a complex social system of city management as they provide a wide range of essential and basic services to citizens during a crisis such as the COVID-19 pandemic. Complex societies are better able to tackle complicated problems, provided that society's knowledge and information help to gradually reduce unfavorable systemic changes (Tabara, 2011). Crises with high degree of uncertainty and complexity place new demands on crisis management systems, and the development of a cooperative system between crisis management actors is crucial for an effective response (Chen *et al.*, 2019). In this respect, systems thinking is beneficial in dealing with complex situations and provides opportunities for collective action and learning from the crisis (Masys, 2015). Meanwhile, Social Network Analysis (SNA) is discussed as a social systems approach that aims to facilitate self-assessment of resilience in communities by bringing together actors to identify critical functions and vulnerabilities and to develop situational improvement activities. SNA provides important information about society's vulnerabilities to disasters and enables rapid identification of society's post-crisis sources of knowledge, which are useful for Crisis Information Systems (CIS) (Franco *et* al., 2013). Accordingly, this study uses social network analysis to explore the cooperative system of the COVID-19 crisis management in Tehran Municipality and presents the lessons learned from the development of the COVID-19 pandemic crisis management system as the first urban management experience in pandemic crises. The COVID-19 crisis identifies valuable lessons for sustainable urban planning and development. Moreover, the available knowledge provides an opportunity for decision-makers to take revolutionary actions in forming more just, more flexible, and more sustainable cities (Mejia-Dugand *et al.*, 2020). In this context, extensive research has evaluated the actions taken by municipalities in crisis management and salutary lessons have been learned by crisis managers. Clement *et al.* (2023) investigated the resilience strategies of the municipality in response to COVID-19 in Belgian cities. This study suggested that digital technology solutions can contribute to supporting the resilience of municipalities. Hassankhani *et al.* (2021) discussed a few lessons learned regarding smart cities and managing the COVID-19 pandemic. They analyzed the role of technology in crisis management and proposed policy recommendations appropriate for responding to the COVID-19 pandemic. Regarding the changes in social lifestyle and the ongoing shift from public transportation to private transportation, Corazza *et al.* (2021) evaluated urban management during the coronavirus pandemic and referred to the emergence of transportation policies and opportunities. Tori *et al.* (2023) studied the reactions of the public transportation sector to the COVID-19 pandemic in Belgium and recommended the structural use of foresight methodologies, such as scenario planning, to increase the preparedness of transport operators in the case of future disruptions. Ruszczyk *et al.* (2022) explored the lessons learned from urban health challenges during the coronavirus pandemic and discussed the considerations arising from the changing patterns of urbanization and the role of municipalities in maintaining urban health. Chen *et al.* (2021) examined changes in medical waste disposal technology as effective waste management measures in Wuhan, China during the COVID-19 pandemic. Peng *et al.* (2023) investigated the impact of measures to prevent and control the COVID-19 epidemic on citizens' satisfaction and suggested the timely release of epidemic information and the provision of basic health and medical services to citizens. Sharifi and Khavarian-Garmsir (2020) addressed the effects of the COVID-19 pandemic on cities and the lessons learned from urban planning, urban design, and urban management. They concluded that the improved quality of air and water

in cities over the periods of quarantine highlights the considerable environmental effects of human activities. Ahsan (2020) presented lessons learned from COVID-19 about the urban built environment and recommended that adequate provision of place, safety, and health-related issues in an integrated manner are needed to form a healthy urban built environment. Regarding an in-depth systematic review, Coccia (2023) demonstrated the importance of environmental factors in the spread of Coronavirus Disease 2019 (COVID-19), and demonstrated the associated aspects with public health, to provide lessons learned of health policy that can decrease the risks of emergence and diffusion of new pandemics with negative societal effect. Cardoso et al. (2023) examined the unsuccessful case of the Brazilian fiscal decentralization policy to help municipalities in fighting COVID-19. Gagliano et al. (2023) conducted a bibliometric analysis to find the research trends in the field of wastewater-based epidemiology (WBE) and provide a snapshot of the Lessons learned from the COVID-19 pandemic. Among the studies and lessons learned in urban management of the COVID-19 pandemic, an emphasis on community-oriented crisis management and the involvement of all stakeholders in crisis management can be found. In this context, Mejia-Dugand *et al.* (2020) explored many lessons learned from responses to the COVID-19 crisis in the cities of Bengaluru (India), Medellín (Colombia), and Cape Town (South Africa) to implement the sustainable development goals and indicated that strengthening multi-level governance and involvement of citizens and community in sustainable decision-making processes will play a critical role in managing cities around the world after the outbreak of Covid-19 (Mehia-Dugand *et al.,* 2020). He and Zhang (2022) investigated urban epidemic governance based on event system analysis on the COVID-19 outbreak and control in Wuhan, China and analyzed the system of Wuhan's COVID-19 response mechanism in four dimensions, including graded response systems, interactive relationship between multilevel entities of epidemic governance, quarantine regulations and the governance of public sentiment. Van den Oord *et al.* (2020) presented the lessons learned in Antwerp, Belgium about crisis management during the COVID-19 pandemic and found the significance of collective focus and integrity in creation and recreation of an effective crisis management system. They concluded that governance of organizational networks and involving the experts and planners are of utmost importance for revisiting the current design. Garavaglia *et al.* (2021) explored the challenges facing mayors in Milan, Italy during the COVID-19 pandemic and proposed some solutions on governance frameworks and institutions focused on involvement of volunteer groups and application of technology in sharing information on crisis management. Mirvis (2020) addressed the repercussions of the COVID-19 crisis management in the United States as learning from failures, analyzed the inadequacies regarding early warning, preparation, virus testing, coordination, communications and systematic challenges of the crisis and proposed recommendations on preparing for and responding to resembling crises in the future. Thielsch *et al*. (2021) discussed management of demands, sources and effective actions in multidisciplinary Crisis Management Teams (CMTs) and described the structuring of work processes, accurate, disciplined, predictive and purposeful communications and quick issue solution as especially effective actions taken by CMTs and presented it in an integrative model. Yan *et al.* (2023) designed consensus-reaching model in the social network environment for large-group emergency decision-making to managing non-cooperative behaviors. In a review of the studies conducted regarding disasters, Franco *et al.* (2013) examined the use of social network analysis in evaluating the possibility of cooperation and sustainability in response to social disasters and indicated how academic-social involvement can offer solutions for gaining more information on current relationships. Goswami *et al.* (2018) applied social network analysis in a disaster-struck society in the West Bengal state in India and analyzed the cooperative network of key actors through the various stages of the disaster. Based on social network analysis in the crisis management during the earthquake in China, Chen *et al.* (2019) examined the involvement mechanism of social organizations in emergency relief after natural threats and proposed policies for improving cooperation between social organizations and the government and enhancing the efficiency of emergency relief. On the assumption that knowledge exchange through stakeholder networks could effectively enhance absorption of innovation, Bojovic and Giupponi

(2020) revealed the potential of social network analysis in spreading and acceptance of innovations for managing disasters in Nepal and Kenya by applying social network analysis and discussed improving the role of network actors. Using the SNA approach, Jayasekara *et al.* (2021) analyzed the effectiveness of the actors' performance in planning to prepare for epidemics in Sri Lanka and referred to the dire need for an integrative legal framework and an efficient governance system for managing the risks involved in biological hazards in the country. Furthermore, they emphasized the expansion of the range of stakeholders involved in planning for preparedness and response to biological hazards, including the private sector, international development agencies, and non-governmental organizations. Adiyoso (2022) assessed governments' emergency responses to the COVID-19 outbreak using a social network analysis in Indonesia. Using the SNA approach and based on set time frames, Cho *et al.* (2022) analyzed Korea's response to COVID-19, with a focus on the network between the government and responding agencies. Es'haghi *et al.* (2022) evaluated the coordination of emergency response teams through social network analysis. Kannangara *et al.* (2022) explored the network of risk and crisis communication of government agencies in Sri Lanka during the early stages of COVID-19 through a social network analysis-based approach. Ilbeigipour and Teimourpour (2023) evaluated the relationship between the mobility network metrics and the COVID-19 outbreak through a social network analysis approach. Yao *et al.* (2023) evaluated urban resilience in the United States during the COVID-19 pandemic via social network analysis. Reviewing the literature reveals that the social systems approach has rarely received research attention in the COVID-19 pandemic management., Moreover, the network analysis of the pandemic crisis management is majorly limited to describing the whole network and its actors, and the cooperative system of the COVID-19 pandemic crisis management actors has been neglected. This study aims to analyze the cooperative network of the actors involved in the COVID-19 crisis management of Tehran Municipality as a complex social system through a process of systematic intervention using the SNA approach. After recording the urban managers' experience, the solutions are proposed for developing an epidemic crisis management system. The current study has been carried out in Tehran in 2022.

MATERIALS AND METHODS

In disaster research, social network analysis is applied where a system boundary can be defined, actors can be identified, and their relationships can be recognized (Goswami *et al.,* 2018). In SNA, the relationship network of social actors is calculated using the UCINET software based on the graph theory and network centrality concepts, and the network is drawn and analyzed by utilizing the Net Draw software (Hanneman *et al.,* 2012). This study analyzes the cooperative network of the COVID-19 crisis management in Tehran Municipality. For this purpose, the actions are classified into 11 crisis management knowledge areas according to the reported actions of the organizational units involved in the COVID-19 crisis management. Fig. 1 illustrates the actions declared in the reports of the COVID-19 crisis management headquarters by distinct knowledge areas. It depicts that the majority of actions can be classified in the knowledge area of medical and preventive services, public urban services, cultural services and social support, and transportation and traffic services.

To identify the relationships of the actors in the cooperative network, based on the actions taken in knowledge areas, the actors-actions matrix of the COVID-19 crisis management headquarters of Tehran Municipality is then considered as a two-dimensional network. The entries of this matrix are the number of declared actions of actors in each knowledge area. Table 1 presents the symbols of the knowledge areas and Table 2 presents the symbols of the responsible and partner organizational units of the COVID-19 crisis management headquarters. The analysis of the network matrix data is done using the UCINET software and the graphs are drawn using the NetDraw software. The cooperative network includes 38 actors and 11 knowledge areas and the relationships between two nodes in this network is to indicate that an action is taken by the actor in that area. Fig. 2 illustrates the actors-actions network of the COVID-19 crisis management in Tehran Municipality.

RESULTS AND DISCUSSION

To analyze the cooperation network of the COVID-19 crisis management system, a one-dimensional data set of actor-to-actor relationships

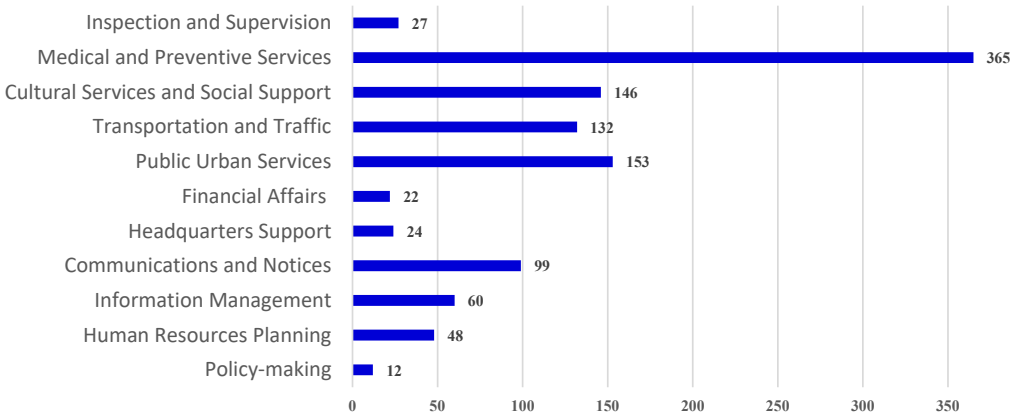

Fig.1: Classification of the COVID-19 crisis management actions

Table 1: Symbols of Actions in the Actors-Actions Network Matrix

Symbol	Knowledge Area	Symbol	Knowledge Area
ACTG 01	Policy-making	ACTG 07	Public Urban Services
ACTG 02	Human Resources Planning	ACTG 08	Transportation and Traffic
ACTG 03	Information Management	ACTG 09	Cultural Services and Social Support
ACTG 04	Communications and Notices	ACTG 10	Medical and Preventive Services
ACTG 05	Headquarters Support	ACTG 11	Inspection and Supervision
ACTG 06	Financial Affairs		

Table 2: Symbols of Municipal Departments in the Actors-Actions Network Matrix

Symbol	Municipal Department	Symbol	Municipal Department
ORG 01	Tehran Disaster Mitigation and Management Organization (TDMMO)	ORG 02	Deputy of Planning, Human Resources Development and Councils Affairs
ORG 03	Office of Planning Monitoring, Project Control, and Performance Evaluation	ORG 04	Municipality Districts Affairs and Coordination
ORG 05	Administrative Office of Human Resources	ORG 06	Administrative Office of Budget
ORG 07	ICT Organization	ORG 08	Tehran Urban Research & Planning Center
ORG 09	Communications and International Affairs Center	ORG 10	Tehran Municipality Protection Unit
ORG 11	Tehran Municipality HSE System	ORG 12	Urban Financial and Economic Department
ORG 13	Administrative Office of Financial Affairs and Properties	ORG 14	Administrative Office of Support
ORG 15	Administrative Office of Technical and Civil Coordination of Organizations and Districts	ORG 16	Administrative Office of Urban Services
ORG 17	Tehran Fire Department	ORG 18	Waste Management Organization
ORG 19	Tehran Municipality Management of Fruit and Vegetables Organization	ORG 20	Shahrvand Chainstore Co.
ORG 21	Shahrban Company	ORG 22	Tehran Gardens and Green Spaces Organization
ORG 23	Occupations and Industries Organizing Company	ORG 24	Behesht Zahra Organization
ORG 25	Deputy of Transportation and Traffic	ORG 26	Tehran Urban & Suburban Railway Company
ORG 27	Tehran and Suburbs Bus Company	ORG 28	Taxi Management and Supervision Organization
ORG 29	Bus Terminals Organization	ORG 30	Social and Cultural Affairs Department
ORG 31	Retirees Organization	ORG 32	Sport Organization
ORG 33	Tehran Municipality Basij	ORG 34	Administrative Office of Health
ORG 35	Shahre Salem Company	ORG 36	Ministry of Cooperatives Labor and Social Welfare
ORG 37	Administrative Office of Isargaran's Welfare Affairs	ORG 38	Inspection Organization of Tehran Municipality

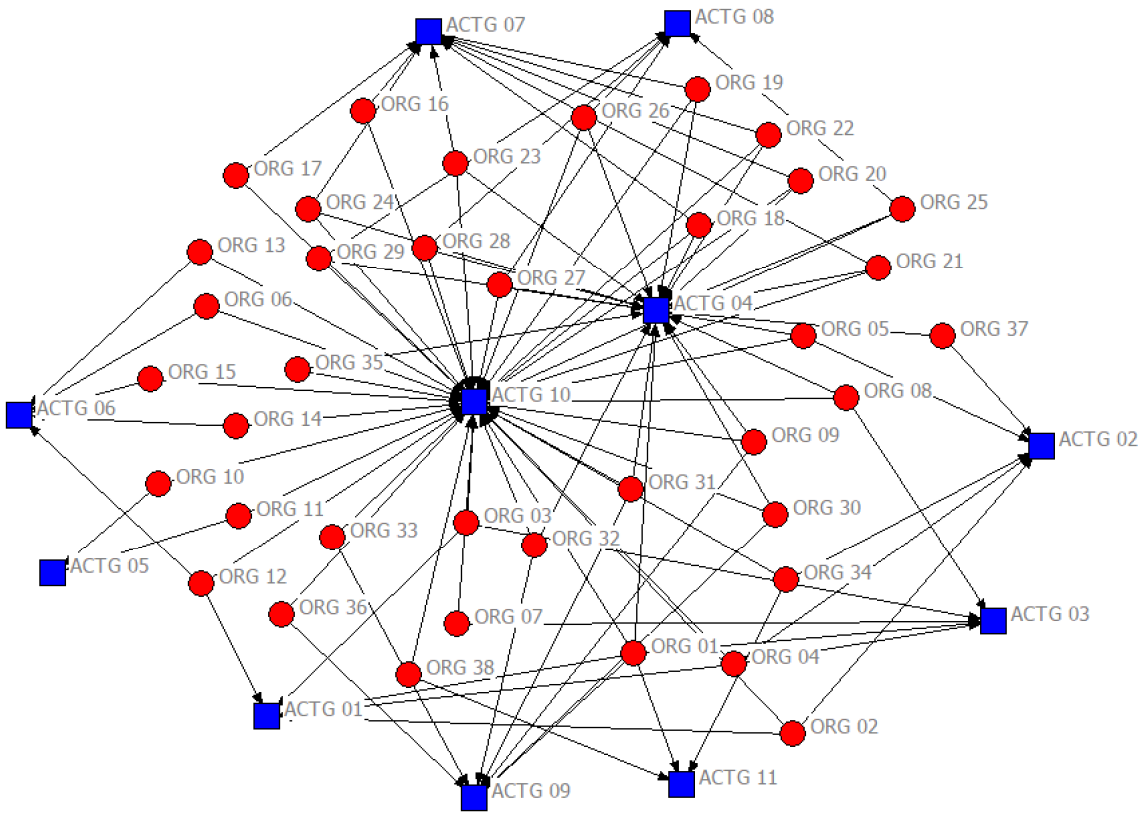

Fig.2: Actors-Actions Network of the COVID-19 Crisis Management in Tehran Municipality

is generated based on the two-dimensional actors-actions data, and the one-dimensional actors-actors network is analyzed based on network analysis indexes. Considering the role of actors in the cooperative system, a combination of actors with high and low degree centralities and high betweenness centrality, including 10 senior managers, is selected and their managers' experiences are recorded through some semi-structured interviews. The managers are asked to describe their experiences of success and failure to record and extract tacit knowledge. The findings of network analysis and the lessons learned from the key actors' experiences during the COVID-19 crisis management in the Municipality of Tehran are as follows. The actor-to-actor relationships dataset is generated based on the two-dimensional actor-action data. This dataset assesses the strength of the relationships between each pair of actors based on the frequency with which the actors take similar actions in each knowledge domain of crisis management. This value is summed for the action groups of 11 knowledge areas of crisis management and was considered as an actor-actor matrix entry. Accordingly, the cooperative network of the actors is analyzed in the UCINET software and drawn in the NetDraw software based on the degree centrality indexes and the betweenness centrality. Table 3 presents the degree of centrality and the betweenness centrality of the actors' cooperative network in the COVID-19 crisis management in Tehran Municipality.

The degree of centrality index results reveal that some actors possess a greater degree of power than others involved in the cooperative network of the Municipality's COVID-19 crisis management. According to the degree centrality index, 7 actors with a high degree centrality (20% of total actors) are identified as high-power actors in the cooperative network, including Shahre Salem Company (ORG 35), Deputy of Transportation and Traffic (ORG 25),

Table 3: Degree centrality and betweenness centrality of the cooperative network of the actors in the COVID-19 crisis management in the Tehran Municipality

Actor	Degree Centrality	Betweenness Centrality	Actor	Degree Centrality	Betweenness Centrality
ORG 01	33.054	1.714	ORG 20	160.324	1.217
ORG 02	23.757	1.217	ORG 21	63.432	1.217
ORG 03	27.811	0	ORG 22	65.486	1.217
ORG 04	91.486	1.217	ORG 23	121.351	1.217
ORG 05	79.405	1.217	ORG 24	153.270	1.217
ORG 06	11.297	0	ORG 25	317.270	1.217
ORG 07	118.919	0	ORG 26	178.297	1.217
ORG 08	40.351	1.217	ORG 27	247.189	1.217
ORG 09	129.243	1.217	ORG 28	215.378	1.217
ORG 10	68.811	0	ORG 29	167.108	1.217
ORG 11	97.027	0.235	ORG 30	243.676	1.312
ORG 12	51.811	0	ORG 31	47.324	1.217
ORG 13	11.297	0	ORG 32	175.946	1.217
ORG 14	20.649	0	ORG 33	174.378	0
ORG 15	22.054	0.602	ORG 34	18.703	1.217
ORG 16	13.946	0	ORG 35	846.892	1.714
ORG 17	81.946	0	ORG 36	69.568	0
ORG 18	191.514	1.217	ORG 37	6.622	0
ORG 19	171.676	1.217	ORG 38	30.270	0

Tehran and Suburbs Bus Company (ORG 27), Social and Cultural Affairs Department (ORG 30), Taxi Management and Supervision Organization (ORG 28), Waste Management Organization (ORG 18) and Tehran Urban & Suburban Railway Company (ORG 26). Furthermore, 7 actors with a low degree centrality (20% of total actors) are identified as actors with a low degree of power in the cooperative network, which include Administrative Office of Isargaran's Welfare Affairs (ORG 37), Administrative Office of Financial Affairs (ORG 13), Administrative Office of Budget (ORG 06), Administrative Office of Urban Services (ORG 16), Administrative Office of Health (ORG 34), Administrative Office of Support (ORG 14), Administrative Office of Technical and Civil Coordination of Organizations and Districts (ORG 15). Fig.3 is an illustration of the cooperative network of the actors involved in the COVID-19 crisis management in Tehran Municipality.

In addition to the degree centrality index, the betweenness centrality of the network of actors is analyzed. Fig.4 depicts the cooperative network of the actors involved in the COVID-19 crisis management in Tehran Municipality based on the betweenness centrality index. The size of each node is indicative of the betweenness centrality for each actor. The actors possessing the highest and lowest degrees of betweenness power with other actors in the cooperative network are identified based on the betweenness centrality index. Those with the highest betweenness power in the cooperative network of the actors involved in the crisis management of the Municipality of Tehran were the Tehran Disaster Mitigation and Management Organization (ORG 01), Shahre Salem Company (ORG 35), Social and Cultural Affairs Department (ORG 30). The actors identified with the lowest betweenness centrality in the cooperative network of the actors involved in the crisis management of the Municipality of Tehran are the Urban Financial and Economic Department (ORG 12), Ministry of Cooperatives Labor and Social Welfare (ORG 36), Administrative Office of Isargaran's Welfare Affairs (ORG 37), Administrative Office of Financial Affairs and Properties (ORG 13), Administrative Office of Budget (ORG 06), Office of Planning Monitoring, Project Control and Performance Evaluation (ORG 03), Inspection Organization of Tehran Municipality (ORG 38), ICT Organization (ORG 07), Administrative Office of Support (ORG 14), Tehran Fire Department (ORG 17) and Administrative Office of Urban Services (ORG 16).

It can be generally stated that the cooperative network of the actors involved in the crisis management of Tehran Municipality enjoys great density and coherence so that all the actors cooperated in the group of actions of the COVID-19

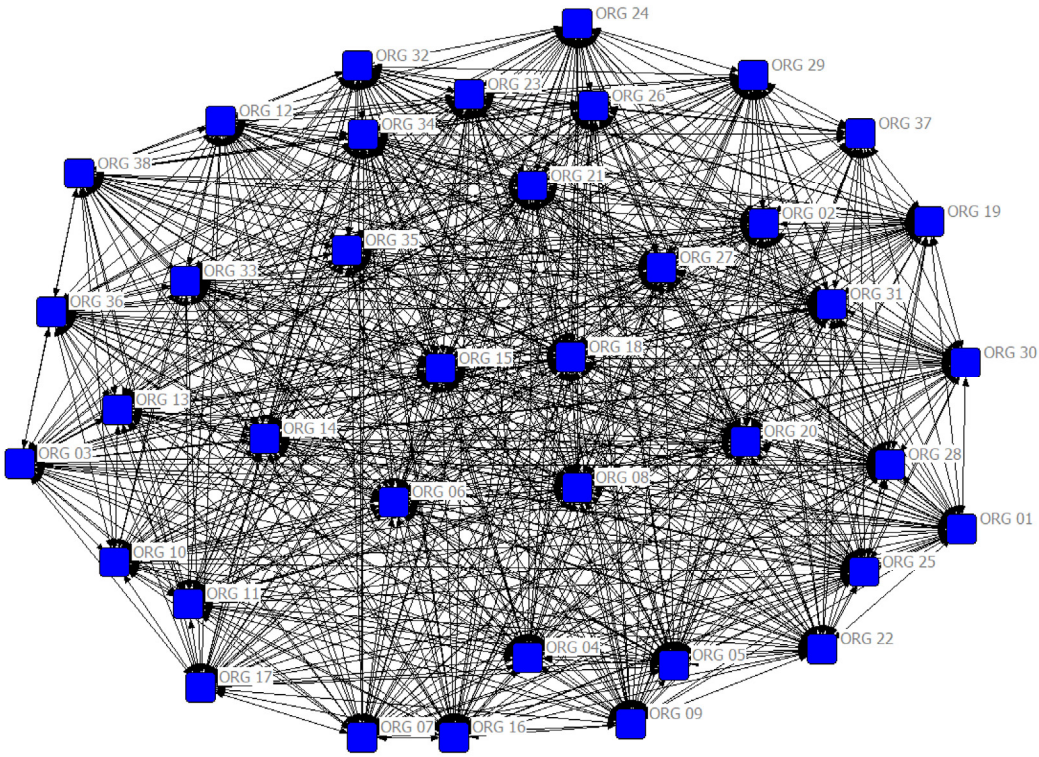

Fig.3: Cooperative network of actors involved in the COVID-19 crisis management in Tehran Municipality based on degree centrality index

crisis management. Nonetheless, considering the key positions of some actors in crisis management, they must be given more power in the structure of the COVID-19 crisis management. As the results of the degree centrality and the betweenness centrality indicate, the actors of the financial and economic provision have low power in the cooperative network. Thus, effective measures must be taken regarding the budget and financial resource management to expand the cooperative network. On the other hand, actors such as Municipality ICT organizations, Office of Planning Monitoring, Project Control and Performance Evaluation, and Inspection Organizations have low betweenness centralities despite their acceptable degree of centrality. Given the role and importance of performance management in greatly uncertain situations, such as the COVID-19 crisis, where the quality of the decisions made by organization senior managers depends on up-to-date and accurate information on the crisis, these actors' power positions within the network must be improved.

Lessons learned

To recognize the instances of success and examples of probable failures, the managers of the key actors, a combination of actors with high and low degree centralities and high betweenness centralities, have been interviewed. Then the most prominent successes of COVID-19 pandemic crisis management in Tehran Municipality are discussed and the lessons learned from failures are addressed afterward. Finally, some suggestions about developing a cooperative system of key actors are made based on the relative agreement of these actors.

Learning from successes

• *Attention to early international warnings and timely response*

Concentrating on the early warnings of the pandemic in the world and following up the international studies led to the proper preparedness of Health Care departments of Tehran Municipality for a timely response to the outbreak of the pandemic in the city. Compilation of specific instructions, provision

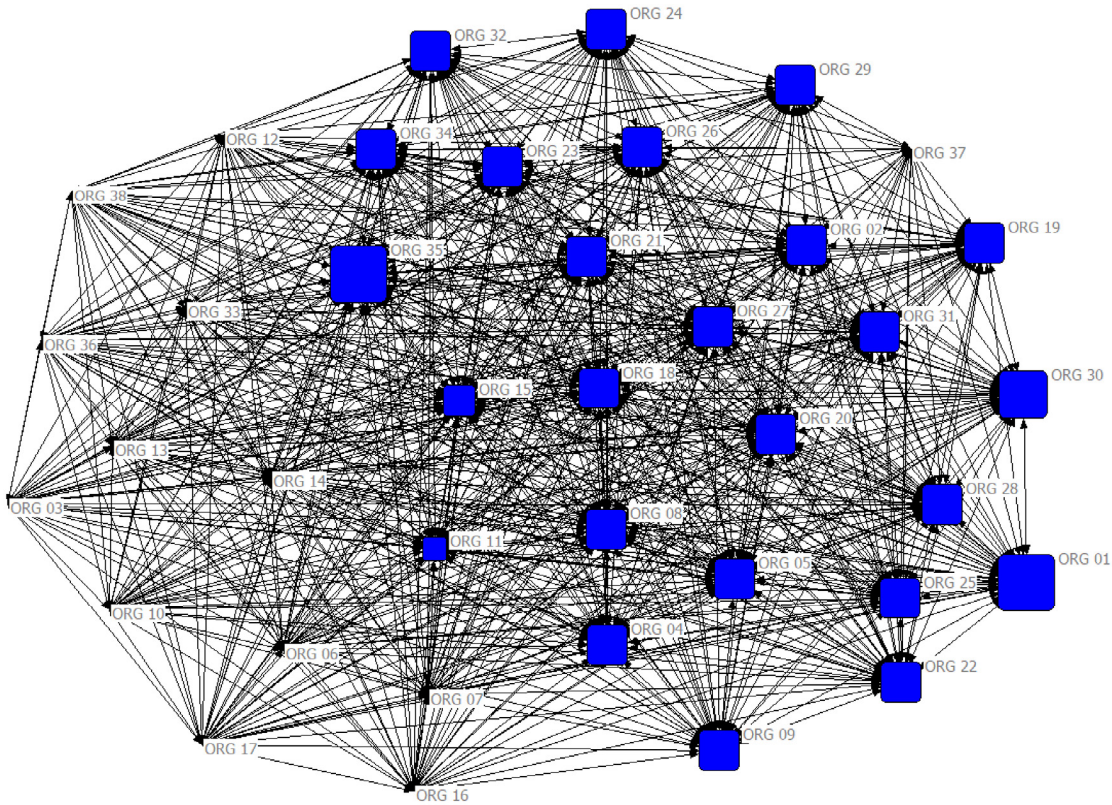

Fig.4: Cooperative network of actors involved in the COVID-19 crisis management in the Municipality of Tehran based on the betweenness centrality index

of administrative and scientific mechanisms, ongoing implementation of COVID-19 screening initiatives on Tehran Municipality staff, allocation of Tehran Municipality clinics in different districts to the COVID-19 patients, and 24/7 activity of some Tehran Municipality medical centers during the COVID-19 crisis peaks are some of the successful experiences of the COVID-19 pandemic crisis management in Tehran Municipality.

• *Volunteer attendance in vaccination*

At the beginning of vaccination, when the vaccination centers of the Ministry of Health were inadequate and long queues were formed, Tehran Municipality began vaccinating a wide range of Tehran citizens by establishing vaccination centers, including mosque vaccination centers, subway station vaccination centers, and vaccination buses known as the "Life Bus".

• *Development of a special vaccination service for vulnerable or disabled citizens*

During the coronavirus pandemic, mobile vaccination centers provided vaccination services to vulnerable groups, such as foreign citizens, working children, addicts, disabled, and elderly people, at their residences. Vaccination of these vulnerable groups is considered one of the most prominent actions taken by the Municipality of Tehran in managing the COVID-19 crisis, with emphasis on respecting human dignity and the citizens' welfare, as well as the acceleration of vaccination.

• *Society-oriented involvement of public volunteer forces*

Society-oriented involvement of public volunteer forces during the COVID-19 crisis is considered by Tehran Municipality as another successful experience of crisis management. Participation in vaccination

initiative conducted by the Municipality of Tehran, cooperation in providing crisis management training at schools, participation in relief maneuvers and local and regional rescue training, cooperation in holding public crisis management training in the neighborhoods, involvement in the neighborhood-oriented screening plan, and provision of social support services are only some instances of the actions taken by public volunteers during the COVID-19 pandemic.

• *Acceleration of smart city development by expanding IT and communications infrastructure*

The COVID-19 outbreak necessitated the provision of electronic services and the infrastructure established for staff telecommuting can also accelerate the smart city development in Tehran. Considering the role of information technology in crisis management, Tehran's smart city plan must be implemented more seriously and its electronic services must be strengthened and expanded for the resilience of the urban management system.

Learning from failures

• *Delay in activating the Incident Command System*

The lack of a comprehensive plan for managing all types of crises is one of the basic deficiencies of the country's crisis management, which led to a lack of prior planning for taking advantage of the existing potentials and capacities; therefore, despite the preparedness of many Tehran municipal organizations and people to provide services in the COVID-19 pandemic crisis management, the capacities and potentials were not utilized efficiently. It is suggested that at both national and Tehran levels, the roles and relationships of every single organization, involved in the incident command system, be determined; the rules and regulations of the country's crisis management be revised; and the scope of responsibility and authority of the key actors be clarified.

• *Delay in providing financial resources*

Due to the considerable reduction in income and imposition of new costs, the COVID-19 crisis affected Tehran Municipality's financial situation considerably. Given inadequate funding, supplying credits and making payments happened with delays, which resulted in demotivating some working units. Although the mechanisms of funding and budget allocation are addressed in the country's disaster management law, the executive guarantee in this regard proves challenging. It is recommended that not only should legal approvals be sought regarding the funding of Tehran's crisis management, but also necessary measures be taken for granting the associated budget to the commander and the crisis managers. In addition, to anticipate and reduce the costs of providing urban services during a crisis, value engineering is recommended.

• *Underutilization of the provided capacity by public volunteer forces*

Reports indicate that only a portion of the volunteers was employed in managing the COVID-19 crisis. Managers attribute this underutilization to the fact that the nature of the epidemic crises is completely different from short-term crises, such as floods and earthquakes. Given the length of the COVID-19 pandemic, it was not feasible to provide long-term volunteer services and the volunteer groups could not be considered as the main human resources for crisis management. It seems that to apply the maximum capacity of the volunteers in the long-term process of epidemic crisis management, a thorough analysis must be conducted in advance. Accordingly, for the sake of organizing and integrating volunteers, it is recommended to make arrangements with the Iranian Red Crescent Society as the main administrator of supplying public volunteer forces and other related institutions and plan for using public volunteer forces in managing different sorts of crises based on the volunteers' database.

• *Inaccessible data and analysis tools*

In the planning phase of the COVID-19 crisis management, sufficient information and analysis tools were not provided to the decision-makers in proper time and the designed information dashboards could not help operational planning promptly. It is suggested to have a strategic plan for improving the data accessibility and analysis tools to be able to respond more efficiently and effectively in times of crisis.

• *Failure to impose restrictions on public transportation*

Aiming to prevent the spread of COVID-19

by refusing the entry of unvaccinated people to the public transportation system, the crisis management headquarters of Tehran Municipality could not succeed in accessing the citizens' vaccination information system. This was mainly due to a lack of information integrity and a deficit in inter-organizational cooperation. Considering the importance of accessibility of databases to the management system and despite the existence of some databases, it is suggested to identify the required databases for managing all types of urban crises and integrate the information systems of urban crisis management.

• *Lack of efficient scenario-based planning for human resource management*

Since there were no prior rules or regulations related to the employee's attendance during the COVID-19 outbreak and the municipal employees were not culturally ready for telecommuting, some restrictions were imposed. Moreover, some profitable activities/services of the municipality had ceased to prevent the rapid spread of coronavirus and there was no planning for their employees. Therefore, it is worth reviewing and revising the human resource rules and guidelines to determine and adapt the policies and procedures for human resource management in crisis.

• *Failure to document*

Although Tehran Municipality presented some valuable documents and reports on the COVID-19 crisis management, not all of the weaknesses and deficiencies were explicitly addressed. Regarding the fact that the realistic pathology of Tehran Municipality's crisis management system requires the use of scientific methods of crisis documentation and reporting, it is suggested to implement critical analyses by using the key actors' experiences, in addition to documenting and recording. As mentioned in the introduction, the previous research mostly focused on a single aspect of the effects the pandemic had on urban management. For instance, Hassankhani *et al.* (2021) mentioned various technology-driven policies and actions could help manage crises, enhance the well-being of the community, and increase urban resilience. Corazza *et al.* (2021) noted that regarding transport policies, the lesson of the pandemic highlights inequality and leaves opportunities only for the more affluent citizens. Chen *et al.* (2021) discussed the great difficulty that COVID-19 posed for the medical waste disposal system of Wuhan. Ruszczyk *et al.* (2022) stated COVID-19 believed that the pandemic has worsened the current challenges of climate change, urbanization, and the changes in local government. Tori *et al.* (2023) focused on the public transport operators in Belgium, who see COVID-19 as a learning platform to get ready for future crises. Ahsan (2020) mentioned centralized decision-making and active participation and implementation at the local level as a way to deal with the pandemics, such as COVID-19. However, a small number of papers considered the issue generally; for example, Garavaglia *et al.* (2021) discussed the challenges that the mayors of Milan faced during the COVID-19 pandemic and proposed some solutions. The current study considers the effects of the pandemic on urban life from a general point of view and tries to extract the learned lessons by considering the overall perspective.

CONCLUSION

COVID-19 has further highlighted the deficiencies of urban management and has provided a unique opportunity to rethink, replan, and redesign urban management. The lessons learned from the urban management of the COVID-19 crisis cannot be ignored due to the quarantined urban dwellers, the besieged cities, the recession, and most importantly and unfortunately, the loss of citizen lives. Municipalities are considered a social system of city government as they provide a variety of essential and basic services to citizens in crises. Since success in delivering a system's services requires the coordination and coherence of social interactions between subsystems, it is important to create a collaborative system between crisis management actors. This study analyzed the cooperation system of COVID-19 crisis management actors in the city of Tehran by using SNA and presented the lessons learned from the development of the COVID-19 pandemic crisis management system in Tehran Municipality, as an instance of the first urban management experience regarding the pandemic crisis. Accordingly, 38 actors were identified and classified into 11 knowledge areas by examining the reported actions of the COVID-19 crisis management in the Municipality of Tehran. The network of actors was then analyzed, a systematic

intervention was introduced to select high and low-centrality actors and the key actors, and a series of recommendations were proposed. The aim of this study is not only to expand the existing knowledge on pandemic crisis management in municipalities but also to provide a suitable background for future research. Since the topical issue is defined within the framework of Tehran city's COVID-19 crisis management system, future research can expand the scope of social crisis management analysis and analyze the views of citizens and stakeholders outside Tehran city in the cooperative network of COVID-19 crisis management. Furthermore, given the existing challenges at the governance level of crisis management, it is recommended that future research evaluates the governance structure of crisis management based on the country's disaster management laws and analyzes crisis participatory governance balancing solutions based on the distribution of legal power among the actors of the current structure of the country's crisis management and the theory of participatory governance of crisis management.

AUTHOR CONTRIBUTIONS

M. Samadi-Foroushani performed the literature review, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. S.S. Miresmaeeli and Z. Molamohammadi compiled the data and manuscript preparation. A. Nasiri conceived the idea and reviewed the manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication, falsification, double publication, submission, and redundancy, have been entirely witnessed by the authors.

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PUBLISHER'S NOTE

ABBREVIATIONS

ACTG	Action Group
CIS	Crisis Information Systems
CMTs	Crisis Management Teams
ICT	Information and Communications Technology
ORG	Organization
SNA	Social Network Analysis
TDMMO	Tehran Disaster Mitigation and Management Organization

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