

Identifying Factors Affecting the Resilience of the Country Dealing with Pandemics Using System Dynamics Case Study: COVID-19 Disease

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Abstract- The COVID-19 pandemic spread with a high outbreak speed in early 2020 and left many countries in crisis. This disease had many effects on different aspects of the country causing many challenges for the health system, economy, community, and education of societies, and only resilient communities could overcome this problem. Iranian community also experienced such challenges. Accordingly, this study was conducted to examine and identify factors affecting the government's resilience when dealing with the COVID-19 pandemic as a natural crisis. The data were collected through a fuzzy Delphi questionnaire distributed among 15 experts in the fields related to the research subject who were selected based on purposive sampling. Moreover, library documents and studies were used and finally, 23 important factors affecting resilience in social, economic, healthcare, education, logistics, infrastructural, media, and cyberspace scopes were gathered. Society resilience was presented based on the effective scopes of design and its corresponding scenarios using system dynamics analysis. The results of the analysis indicated that the most substantial components are economic ones, which have lower resilience rather than other scopes. Healthcare scope is in second rank, while education and social scopes are at last rank playing a significant role in resilience.

Keywords- Resilience, COVID-19, Resilience Scopes, Pandemic

Introduction

COVID-19 virus created considerable changes in the lifestyle of people around the world, including Iranians several months after the disease outbreak in China and other countries.

Resilience level can affect the ability of individuals and governments under the occurred conditions (Maguire & Hagen, 2007). The concept of resilience is a powerful base for analyzing the effects of conflict on statuses, while conflict destroys resilience by weakening institutes, the natural environment, and markets. Resilient communities can better cope with conflict effects. Resilience is defined as the ability of individuals, families, communities, and systems to alleviate and relieve, adapt with, and recover from shocks and stressful factors in a way that reduces chronic vulnerability and improves the inclusive growth of a system. A system is defined as a set of interconnected details that follow a certain goal. The more the number of interconnected components of a system, the more sophisticated the system is. Components cannot be solved separately to solve complicated systems; hence, the identification process from whole to detail and consideration of the system's details in dynamic mode must be done based on the connection between details and the system's interaction with the surrounding environment. Many problems we deal with result from unpredicted side

effects of previous performance. Effective decision-making in a world full of dynamic complexities makes us systematic thinkers who can extend the boundaries of a model and use instruments and equipment to grasp the sophisticated structure and behaviors that appeared in it within dynamic mode (Sterman, 2009). On the other hand, each subsystem that indeed is an independent system included certain inputs and outputs. One can plot the graph of subsystems to display the general model ruling the problem and various variables and their impact scopes in a schematic. In this way, the complexity of interaction between different sectors and scopes can be simply shown. The topic of this research is related to the themes of policies. System dynamics models would result in identifying the overall space of the problem and interactions between different variables and their effects on each other.

According to mentioned points, it is highly essential to examine factors affecting resilience level in the design of models for interaction between sectors and scopes. Therefore, governmental decision-makers and politicians must know which components affect resilience in which scopes and with which interactions to make plans, find solutions, and solve the hazards that occurred during the pandemic in different sectors. In this case, they also can examine the complexity of relationships between indicators in

making better decisions and spending budget more reasonably. The present study aims to identify factors affecting Iran's resilience when dealing with the COVID-19 pandemic based on the system dynamics analysis to answer some questions: what are resilient scopes in Iran and how are the behavior dynamics of these resilient factors when coping with pandemics, case study of COVID-19 in this study?

Background
Resilience concept

Various definitions have been proposed for resilience based on the available literature and background. The Latin root of resilience is *resilier*, which means return to the early mode after a shock occurs. This term was used in 1807 for the first time (Walklate & Mythen, 2014). Resilience literature has been shaped based on two different perspectives: static and dynamic. Static school points to an individual's ability to survive after

facing critical conditions while dynamic school includes facing threats but also points to the ability to recover the primary form and renovate and change aftershocks. Now, the latter is at the center of research. According to the dynamic perspective, resilience is the capacity that permanently overcomes threats and identifies new opportunities (Fiksel, 2006). Within a system, resilience means continuing functions despite barriers and environmental fluctuations. Therefore, resilience is a concept that can be used by humans, organizations, enterprises, nations, countries, social movements, etc., so one can examine and evaluate their resilience. Resilience is a dynamic ability that helps an organization to keep implementing its activities even if a hazardous incident occurs (Brandon-Jones, Squire, Autry, & Petersen, 2014). Resilience has been widely used in many fields over recent years, and some of them have been reported in Figure 1.

Author	Definition
Holing (1973)	A criterion of the system's ability to attract alternatives while having previous persistence.
Pimm (1984)	The success of a system in returning to the former state.
Elaveng et al. (2001)	A characteristic that allows a system to bear, use, and even benefit from change.
Kardona (2004)	The capacity of a damaged society or ecosystem to attract negative consequences and compensate for (recover) these consequences.

Figure 1. Definitions of resilience (Ardan et al., 2011)

Three individual, social, and national levels have been highlighted in resilience literature and each of them has addressed various components. The national level of resilience comprises the following subbranches: economic, environmental, governance, infrastructure, and social. Individual resilience refers to psychological and behavioral resilience when facing insecurity, which means a person's ability to continue suitable operations before and after the crisis, ability to overcome it and adapt to the environment. The individual aspect of resilience is associated with the understandability, manageability, and meaningfulness of a person (Kimhi & Eshel, 2005).

The concept of national resilience means attracting permanent or temporary shocks of the governments based on the current conditions. Moreover, resilience can be defined as a concept indicating the ability of countries, communities, and households to manage change against stresses and threats, such as natural disasters, human violence, and or diseases while keeping previous standards (Weichselgartner, 2015). A social system is resilient if can rapidly adapt itself to circumstances without losing stability against

temporary or permanent shocks. At this level, resilience is related to the creativity of society people and how they illustrate or create the future (Anderson, 2014).

Resilient scopes during the COVID-19 pandemic

After the COVID-19 outbreak, scientists and researchers pursued their academic studies and paid more attention to epidemic diseases. At least 170 countries dealt with a virus called Corona over time, so one can address the factors leading to the resilience of governments. Sociological and psychological components are the most effective factors (WHO, 2021). Sociological factors point to institutes, organizations, and the impacts of conditions on the resilience of individuals in a society. In social resilience level, each person is born with a certain resilience level, which can be increased in different conditions, educational situations, and environments. Characteristics of resilient communities must be considered first to identify the resilience scopes of governments. It means that changes in different parts of communities during crises must be addressed.

Because resilience includes all parts of each government, all available dimensions affecting communities, including social, economic, infrastructural dimensions, planning, and healthcare affairs must be taken into account (Ibn-Mohammed et al., 2021). Boorman, Fajgenbaum, Ferhani, Bhaskaran, Arnold, & Kohli (2013) introduced economic, social, physical-environmental (infrastructural), and institutional scopes as resilience fields of the governments, and expressed that some measures could be taken in economic scope to make governments economically resistant: concentration on exchange flow, supervision over market, optimizing money unit, and focusing on an accurate investment system. They also expressed that individual and group communications and collective morality play a vital role in social scope. They assume that the physical-environmental scope is substantial for identifying those sectors that require investment and asset management. Chakraborty and Maity (2020) consider resilience as a variable that comprises economic, education, health, and social scopes. They believe that society's resilience in the economic field means relying on the social force participation and society equilibrium by keeping interactions. In terms of education, the quality of all educational grades, attention to education and training techniques, and increased literacy level of society due to the increased number of educated people are important factors for the educational resilience of society. However, they believe that the economic level plays the most significant role in enhancing the economic index of governments. Angeon and Bates (2015) believe that a society is economically vulnerable if cannot create a balance between its costs and capital accumulation. Lack of control over the banking system and surveillance of financial decisions may lead to inflation and inaccurate fiscal flow. Fiksel (2006) considered resilience a set of infrastructural, social, psychological, economic, and health scopes. Fiksel considered the economy the most important factor for the resilience of governments expressing that export rate and

domestic product volume without high dependence on oil byproducts in financial policies play a vital role in enhancing the resilience index. Fiksel mentioned health scope after financial policies as the most substantial factor for dealing with natural crises, such as epidemics, floods, and natural disasters. the most important factors identified in health scope include paying attention to medical and therapeutic equipment, such as conditions of hospitals and medicine preparation, teaching personal care, concentrating on environmental health, and selecting an experienced and sufficient workforce. Sookaromdee and Wiwanitkit (2020) considered the role of economic scope, knowledge and technology, communications, infrastructures, logistics (procurement and equipment), and health as the most important factor in the resilience level of all societies. In their study on the effect of the current pandemic on the conditions of governments, they expressed that infrastructures of different textures of a government must be at the center of attention. Insufficient investment in the infrastructure of different scopes cause a lack of flexibility in communities, so it can be achieved only by spending sufficient cost, attracting investor, using serious information systems, and finally applying accurate management method. Smith, Ramos, Yang, Gary, Schultheis, and Walker (2020) pay attention to social factors but also consider shifting to novel and new techniques, economic wealth, fair distribution system, information and communications, the role of society members in crisis, social capital, and infrastructural distribution as the most important resilient indicators of governments. Every resilient scope comprises numerous infrastructural factors that all together are effective as a resilient factor. According to the research background of components affecting resilience in each scope, various factors exist that are different regarding the definition of each scope. This study has tried to gather frequent scopes and sub-scopes in previous studies to list the most important ones. Hence, Table 1 reports the scopes and sub-scopes extracted from previous studies and references.

Table 1. Classification of resilient scopes and sub-scopes based on the research background

Row	Identified sub-scopes	Main scope	Reference
1	Inflation, economic stability, government costs, supporting academic centers, exchange reserve, gold reserve, export, surveillance over financial corruption, capital market control, oil and oil products	Economic	Gilli M. (1992), Briguglio & Cordina (2009) Ernstson, et al (2010); Eraydin & Tasan-Kok, (2012), Briguglio, L. (2003), Spartt, Stephen and Bernini, Wagner & Neshat N. (2010), Michele (2010), Guillaumont P. (2010), Briguglio, L., G. Cordina, N. Farrugia, S. Vella (2006), Hallegatte, Stephane. (2014), Abounoori, E., & Lajevardi, H. (2016), Bates, S., Angeon, V., & Ainouche, A.

Row	Identified sub-scopes	Main scope	Reference
			(2014), Farrugia, N. (2004), Manyena, S. B. (2006), Rose, A., & Krausmann, E. (2013), Anonymous. (2017), Eichenbaum et al. (2020), Nicola et al. (2020), La Torre et al. (2020), Ghiasvand et al. (2013), Ghiasvand and Abdoshah (2015). Rezaie (2013)
2	Social interactions, social solidarity, collective activities, citizenship rights, social trust, literacy level, preventing social harms, group plans, religious and cultural communications	Social	Briguglio, L., G. Cordina, N. Farrugia, S. Vella (2006), Jackbjose.f.herve (2013) Hassler & kohler (2014); Santos Cruz et al.2012; Godschalk (2003); Suárez, Gómez Baggethun, Benayas, & Tilbury(2016); Eftekhari and Abdoreza (2001), Ayoob (2002), Eftekhari (2009), Haghdoost (2010), Rezaie (2010), Siavashi (2011), Rafiee (2019), Gooya (2011), Ardalan et al. (2011), Hasnavi and Fathollahi (2014)
3	Providing equipment, reducing fuel consumption, improving distribution system, public transportation infrastructures, modern technology uses, distributive justice	Logistic	Ernstson, et al (2010); Castleden & McKee (2011), Barthel, et al. (2013); Suárez et al (2016); Zhang et al. (2021), Sadeghi Moghadam, Barani and Safari (2017); Dang koob (2019), Ghasemi, Alidoosti, Hasanvari and Noroozian (2019); Anjomshae and Wang (2019); Daie (2019); Zehung, Wang and Ran (2019); Motamedi et al. (2021)
4	Heath education, psychological health, self-care, nutrition, exercise and fitness, environmental health,	Heath	Waever, Ole (1995), Ghasemi, et al. (2018), Mavi (2017), uncel, G., & Alpan, G. (2010), Mousavi (2015), Ibn-Mohammed et al (2021), Keršulienė et al. (2010), Ian M. Trotter & Luis A. C (2020), Motamedi et al. (2021), Khodabakhsh (2017), Dang Koob (2019), Sadeghi et al. (2020), Fatahi Ardakani et al. (2018)
5	Quantity and quality of educational systems, number, and type of educational centers, public education, educating people, educational techniques (educational implementation methods), educated people of society, professors and teachers who are active now	Education	Alker & Salt (2006), Canetti, & Waismel-Manor Aldrich (2014), (2015), Kimhi. S (2016), McAslan, A.R. (2010), La Torre, D., Malik, T (2020), Fifth Economic, Social, and Cultural Development Plan of Islamic Republic of Iran (2004) Bozan (1999), Bozan (2007), Siyavashi (2019), Haghdoost (2019), Motamedi et al. (2021)
6	Medical centers, physicians and nurses, medical equipment such as equipped beds and rooms for intensive care, pharmaceutical facilities, medical infrastructural distribution, public treatment., medicine production system support	Treatment	Colding; (2007), Cox R, Perry K (2011), Abidi, H., de Leeuw (2013), Hallegatte, Stephane. (2014), Kimhi. S (2016), Abounoori, E., & Lajevardi, H. (2016) Research Center of Islamic Parliament (https://rc.majlis.ir/fa/report/show/1490085) IRNA Press (Islamic Republic) (https://b2n.ir/152022) Cyberspace and faith solidarity research center for Dealing with Corona (https://b2n.ir/568838)

Row	Identified sub-scopes	Main scope	Reference
			Sevin and Raveshti (2016), Ghasemian Sahebi, Iman, Amoozad Mahdiraji (2017), Ketabchi et al. (2018), Eskandari et al. (2019)
7	Social networks, radio and TV networks, press, annual publications, cinema and theatre, the content created by media, media literacy education, broadcasting	Media and cyberspace	Gaillard, J, Christophe (2007), Castleden M, McKee M, Murray V, Leonardi G (2011), McAslan, A.R. (2010), Madhuri &, Tewari, H (2014) Hanna (2010), Brusset, X., & Teller, C. (2017) Hamid et al. (2012), "Evaluation of the trajectory and musts in the path ahead" Report (2020), Motamedi et al. (2021)
8	e-education, e-commerce, information security, e-government, information management, intellectual property, telecommunication networks, internet, and bandwidth, society smartening	Information technology (IT)	McAslan, A.R. (2010), Cutter, Susan et al., (2008), Stadler, J. (2005), Martínez-Noya & García-Canal,(2011), -World Bank (2012) , Kimhi, S. (2016), Karlsson, et al(2021), Keyvanara, M., et al., Bozan (2007), Haghdoost (2010), Rafian et al. (2011), Amiri (2018), Hamid et al. (2012), Motamedi et al. (2021)
9	Infrastructural financial management, identifying available infrastructures, investors, providing infrastructures, creating a database of implementing (operating) infrastructures, using technology to develop infrastructures	Infrastructural	Godschalk (2003); Marzluff(2004), Walker & Salt (2006); Alberti Chelliri & Colding(2007), Eraydin & TasanKok(2012), The Rockefeller Foundation, (2014); Feliciotti et al, (2016); Sharifi& Yamagata (2016); Chen, D., et al (2020), Shah, K., et al., (2020) Sadeghi Moghada, et al. (2017), Namjooyan et al. (2017), Media Considerations to Deal with coronavirus in the Country (2019), Motamedi et al. (2021)

Table 2 reports a summary of some studies conducted on resilience.

Table 2. Summarized studies on resilience

Row	Researcher(s)	Year	Subject	Method	Results
1	Behtash et al.	2011	Evaluation and analysis of dimensions and components of Tabriz metropolis resiliency	<ul style="list-style-type: none"> Using experts' opinions based on a five-point Likert scale Analysis of the questionnaire and statistical computations 	<ul style="list-style-type: none"> The resiliency rate in Tabriz equals 2 and 23 indicating the undesired rate of resiliency.
2	Ouyang et al.	2012	Urban infrastructure strategies in resilience scope	<ul style="list-style-type: none"> Comparing the main model of the electricity network with several assumed models augmented with flexibility 	<ul style="list-style-type: none"> Recovery sequences, available sufficient resources, extension deployment, hardening vital components, and ensuring rapid recovery increase the annual expected

Row	Researcher(s)	Year	Subject	Method	Results
					flexibility of the power network (0.034%) rather than the main network.
3	Borman et al.	2013	Resilience assessment in five groups of developed countries against hazards	<ul style="list-style-type: none"> Measuring resilience index 	<ul style="list-style-type: none"> Financial policy, bank soundness, export diversity, stability of exports and reserves, the effectiveness of government, and low private foreign debt are components of resilience in the countries.
4	Rose and Krausmann	2013	An economic framework for the Development of a business resilience index	<ul style="list-style-type: none"> Measuring economic resilience index based on the economic frameworks and research background 	<ul style="list-style-type: none"> Most indexes used for this purpose have not been necessarily related to measuring resilience at micro, middle, and macroeconomic levels after a disaster. Recommending a framework for selecting suitable short-term indexes to develop an effective economic resilience index
5	Francis and Bekera	2014	resilience analysis of engineered and infrastructure systems	<ul style="list-style-type: none"> Qualitative 	<ul style="list-style-type: none"> Defining resilience based on adaptivity, absorptivity, and recoverability
6	Bates et al.	2014	Vulnerability and Resilience in the development economy	<ul style="list-style-type: none"> An algorithm for identifying an efficient set of variables Creating a net vulnerability-resilience index 	<ul style="list-style-type: none"> Introducing four major indexes strengthening economic resilience: macroeconomy stability, the efficiency of the microeconomic market, good governance, and social development
7	Angeon and Bates	2015	Composite vulnerability and resilience indexes	<ul style="list-style-type: none"> Creating a hierarchical multimetric composite index (NVRT) based on the mathematical algorithm and graph theory (net vulnerability-resilience index) 	<ul style="list-style-type: none"> Developed countries have high resilience, while less-developed countries have lower resilience.

Row	Researcher(s)	Year	Subject	Method	Results
8	Dadashpoor and Adeli	2015	Evaluation of resilience capacities of Tabriz City	<ul style="list-style-type: none"> Definition of criteria and indexes in various economic, social, institutional, and physical-spatial dimensions, resilience rate in the urban complex of Qazvin was compared with optimal levels. 	<ul style="list-style-type: none"> The urban complex of Qazvin has improper resilience status in terms of institutional (by 48% distance from optimal level) and physical-spatial (by 45% distance from optimal level) dimensions.
9	Rezaei et al.	2015	Examining resilience dimensions and Approaches in urban communities	<ul style="list-style-type: none"> Review study based on databases 	<ul style="list-style-type: none"> Definition of urban resilience, social resilience, economic resilience, resilience approaches, natural disasters, accident and crisis management
10	Karimi and Karimzadeh	2016	Study of the factors affecting the resilience of the worn-out fabric of Shiraz City (social)	<ul style="list-style-type: none"> Questionnaire Library and field study 	<ul style="list-style-type: none"> Presenting a new strategy to reduce vulnerability and increase the ability to cope with accidents and incidents, especially in urban worn-out fabrics
11	Yuncaï et al.	2018	Identifying Characteristics of resilient urban communities	<ul style="list-style-type: none"> Review of library and field studies on urban communities regarding the assessment of resilience in critical conditions 	<ul style="list-style-type: none"> A resilient community is a community that is flexible, public-oriented, smart, forecaster, and participative. These factors are interacting with each other
12	Liu and Song	2020	Review of studies on the resilience of urban critical infrastructure networks (CINs)	<ul style="list-style-type: none"> Review of resilience literature on six critical infrastructure networks, including water, drainage, gas, transportation, electric, and communication networks. Analysis of resilience definitions, hazard categories, methodology, and enhance measures for each CIN 	<ul style="list-style-type: none"> Resilience reflects the efficiency of a system dynamically before and after dealing with a crisis, and adaptive, absorptive, and recoverability capacities are the most important characteristics of it.
13	Peidaei et al.	2020	Identification of the resiliency of human resource dimensions during	<ul style="list-style-type: none"> Four resiliency dimensions were identified using Fuzzy Delphi techniques and a 	<ul style="list-style-type: none"> Identifying resiliency dimensions: financial-economic resiliency, physical-biological

Row	Researcher(s)	Year	Subject	Method	Results
			covid-19 pandemic condition from the Islamic point of view	suitable framework was proposed to improve resiliency.	resiliency, cultural-social resiliency, and psychological-spiritual resiliency <ul style="list-style-type: none"> Designing plans for improving human resource resiliency to deal with Corona pandemic in today's organizations

Method

This is a survey study with a qualitative method. Data and information study were collected through library and documentary studies, and questionnaires were filled out by society experts. Data analysis is done through fuzzy Delphi techniques and the system dynamics method. The output of the first step was identifying indexes and criteria affecting resilience in research, while the second step addressed relationships between the most important criteria. In this research, statistical society comprised 15 experts in different fields who completed interviews to find effective factors. The selected experts included faculty members of the university, medical experts of the University of medical sciences, Management and Planning Organization, General Department of Industry, Mining, Trade, and Governance who had 10 years of experience in the studied subject and could participate in the study.

Results

After components affecting resilience were reviewed in the available literature, 23 factors were selected for to first turn of a survey of the Fuzzy Delphi questionnaire. In the first step, the subject and objectives of the study were introduced then experts were asked to express their ideas about factors

affecting Iran's resilience during the COVID-19 pandemic to examine the importance of each factor at a five-point Likert scale. The Fuzzy average of experts' opinions about each criterion was measured based on the simple mean formula. Moreover, the de-fuzzified mean has been measured based on the Minkowski formula (Mirsepasi et al., 2010).

$$\text{Minkowski formula: } \aleph = m_3 + \frac{m_1 - m_2}{4}$$

The options of the first-turn questionnaire and each expert's opinion were kept but also mean value of participants' opinions was added to the questionnaire as a de-fuzzified mean value to express the concept of that value. The experts were then asked to express their ideas about factors affecting resilience in the country during the COVID-19 pandemic.

According to experts' opinions in the first step and comparing them with the results of opinions in the second step, the de-fuzzified mean difference between the two criteria was examined and compared with the very-low threshold. If the mean difference is highly less than the very-low threshold limit (0.1), the survey process is terminated (Mirsepasi et al., 2010). Table 3 reports the de-fuzzified mean value of participants' opinions and their difference rates to assess the survey termination condition.

Table 3. Difference rate between experts' opinions in the first and second surveys

Criteria	Step 1	Step 2	Difference
1 Educational quality	0.92	0.92	0
2 Government Cost	0.90	0.90	0
3 Social networks	0.81	0.92	0.11
4 Public health education	0.90	0.90	0
5 Media	0.83	0.88	0.05
6 Investment stock	0.83	0.88	0.05
7 Citizenship rights	0.92	0.92	0
8 Number of educated people	0.80	0.81	0.01
9 Exports	0.70	0.78	0.08
10 Collective activities	0.81	0.84	0.03

Criteria	Step 1	Step 2	Difference
11 News agencies and the press	0.69	0.71	0.02
12 Quantity and quality of content created by media streams	0.48	0.48	0
13 Medical equipment and medicine	0.92	0.92	0.009
14 Teaching people media literacy	0.58	0.063	0.05
15 Media streams	0.87	0.88	0.01
16 Total number of publications in one year	0.94	0.95	0.01
17 Literacy level	0.94	0.94	0
18 Government revenue	0.86	0.87	0.01
19 Cinema and theater	0.73	0.75	0.02
20 Economic stability and market control	0.64	0.66	0.02
21 Social interactions	0.71	0.75	0.04
22 Investment	0.87	0.90	0.03
23 Social solidarity	0.92	0.92	0.002

As seen in Table 3, the participant has reached a consensus in all criteria, and the opinion difference in the first and second steps of all components is less than the very-low threshold limit (0.1); hence, the survey process is terminated in the second turn. After the survey steps were finished, resilience factors were screened. If the threshold value (d) of each criterion equals or is smaller than 0.2, the factor is confirmed. The mean difference between a fuzzy number and a respondent's fuzzy number is calculated based on the

formula below to measure the threshold value of each factor. The formula for measuring the threshold limit of each component:

$$d(m, n) = \sqrt{\frac{1}{3}\{(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\}}$$

After the threshold limit was measured for each component, it was decided on confirming or rejecting that component. Table 4 reports the results.

Table 4. Confirmation/rejection of components based on the average threshold limit

Row	Criterion	Average d	Criterion status
1	Educational system quality	0.03	•
2	Government costs	0.04	•
3	Social networks	0.11	•
4	Public health education	0.16	•
5	Media	0.07	•
6	Investment stock	0.09	•
7	Citizenship rights	0.22	×
8	Number of educated people	0.06	•
9	Exports	0.10	•
10	Collective activities	0.38	×
11	News agencies and the press	0.43	×
12	Quantity and quality of content created by media streams	0.58	×
13	Medical equipment and medicine	0.04	•
14	Teaching people media literacy	0.39	×
15	Media streams	0.51	×
16	Total number of publications in one year	0.41	×
17	Literacy level	0.33	×
18	Government revenue	0.05	•
19	Cinema and theater	0.52	×

Row	Criterion	Average d	Criterion status
20	Economic stability and market control	0.02	•
21	Social interactions	0.29	×
22	Investment	0.01	•
23	Social solidarity	0.51	×

According to Table 4, therefore, factors affecting resilience in Iran during the pandemic are as follows:

1. Educational system quality
2. Government revenue
3. Social networks
4. Public health education
5. Media
6. Investment stock
7. Number of educated people
8. Exports rate and diversity
9. Investment
10. Economic stability and market control
11. Medical equipment and medicine
12. Government revenue

Model structure

The first step in system dynamics is to examine and identify the considered problem. It should be mentioned that different components affecting resilience are effective with different coefficients. Each factor is influenced by other components within the feedback and causal loops.

Model boundary: model boundary graph depicts flow, stock, and auxiliary variables that have been used in the model. A flow variable is defined as a variable within a certain interval. A stock variable is definable at a certain moment. The auxiliary variable is used to link different parts of a system.

Table 5. Variables of the model

Number of educated people (members)
Liquidity (billion Rls)
Investment stock (billion Rls)
Investment (billion Rls)
Exports (billion Rls)
Government Cost (billion Rls)
Capacity of educational centers (number)
Media literacy
Producing the appropriate content
Health infrastructure
The number of treatment staff
Infrastructure
Educational infrastructure
Government revenue
workforce
Economic stability
Number of medical centers
Medical Equipment
Health education
Management of public opinion
Entrepreneurship rate
Public Education
Educational Quality

Cause-effect and state-flow graph

The cause-effect graph is a diagram that indicates the relationship between different variables to illustrate

the whole system. Cause-effect graph of the considered problem has been illustrated in Figure 2.

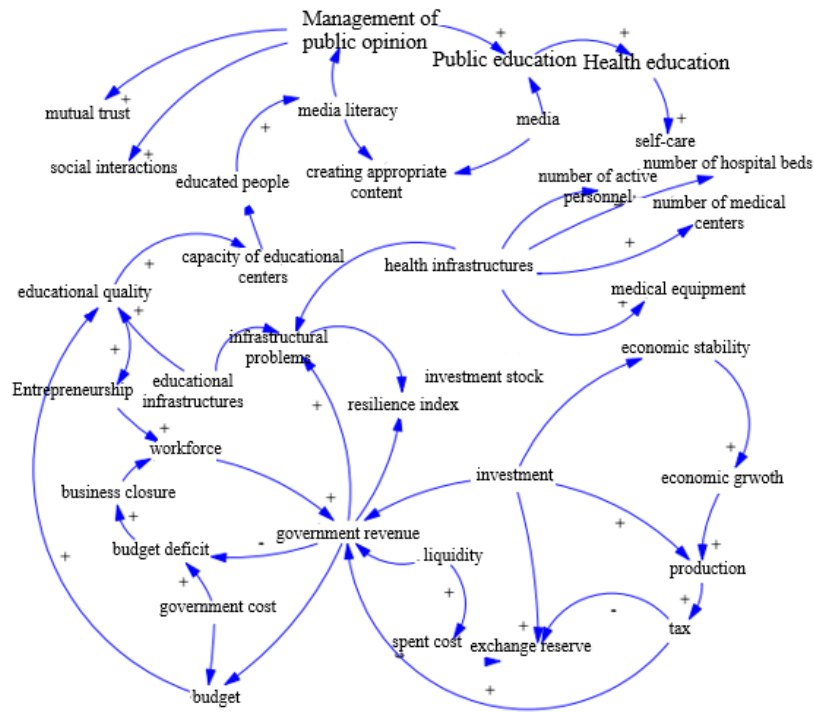


Figure 2. Causal graph of resilience

State-flow graph designed for resilience has been depicted in Figure 3.

The state-flow graph is composed of stock and flow variables that are used in the modeling process.

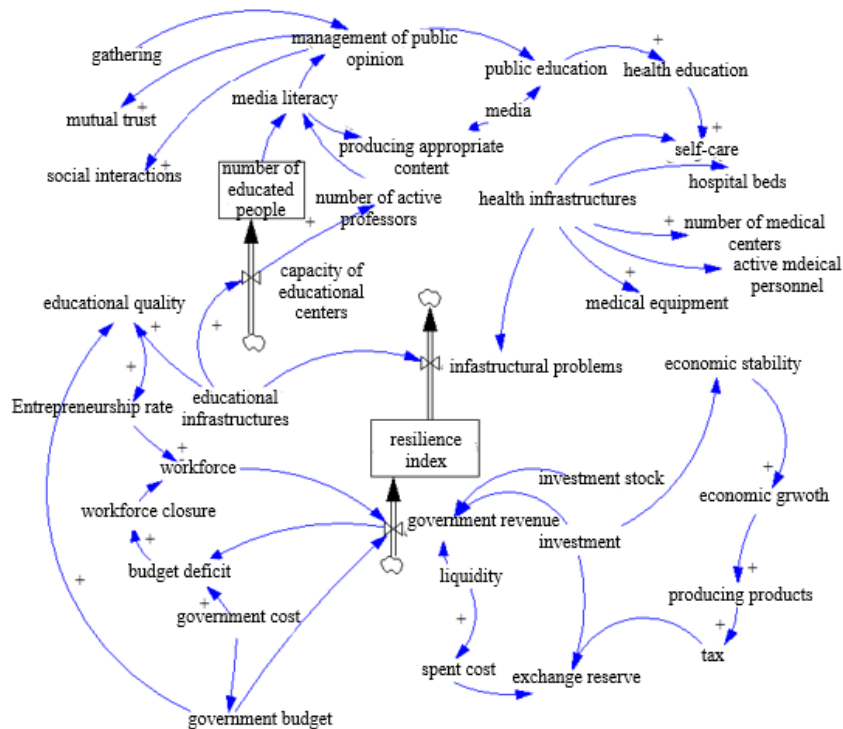


Figure 3. State-flow graph of resilience

A systematic attitude is required to understand different parts of a system due to extensive interactions in it. This understanding can be achieved

only through studying all details and finding the relationship between them. Hence, system dynamics modeling is done to create a platform for

comprehending relations between system details to find possible strategies.

The first part includes economic branches and sub-branches. According to the model, saving, tax, domestic products, and consumption affect the savings and exchange reserves of the country. Moreover, investment is considered as investment stock within a certain interval; hence, investment is

considered a flow variable. On the other hand, domestic products are taxable. Tax-to-domestic products ratio equals a constant rate of 0.5%, which is placed in the model. In another part, the government budget, which is the difference between government cost and revenue must be used to provide required equipment when dealing with possible threats. This value has been also entered into the model.

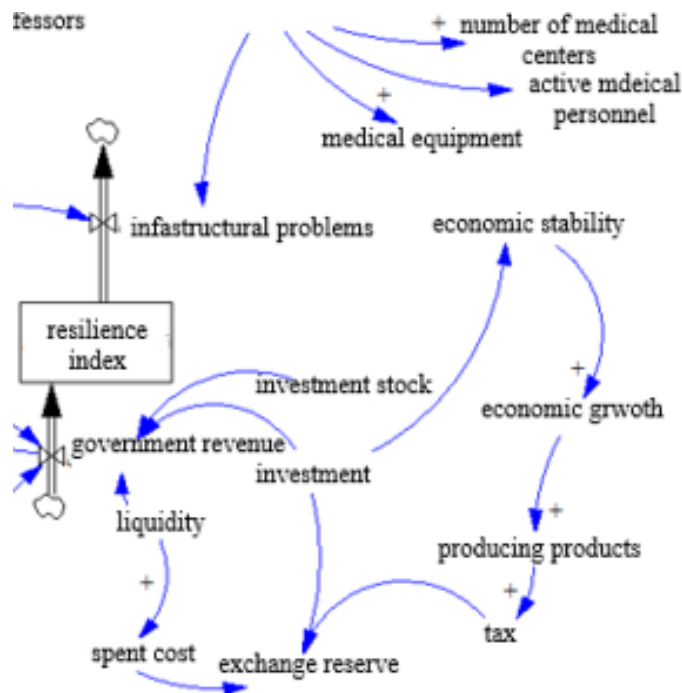


Figure 4. Economic index part

Model simulation

Simulation of the research problem is done by running the Vensim software to design state-flow graphs. In this phase, software design and modeling have been done by entering data and relationships between components.

Validation Methods

Some indicators have been used for model error estimation to validate the model. The coefficient of determination (R^2) expresses approximate results of considered parameters in the future to examine correlation probability and examined its adaptability with reality.

MAPE is another index used to measure model accurate error. Moreover, MAE is an index used to assess the error of model approaches to real values.

Testing model

To test the model, the results of two important components affecting resilience (government revenue and investment rate) were validated then policies and their effects on national resilience were examined. The data entered the model were related to the 2016-2021 years (billion Rls). A comparative graph of real and estimated government revenues by the model is shown as follows. Results of the model and validation process have been presented under each variable.

1) government revenues

Figure 5 depicts a graph of actual and estimated government revenues measured in the model.

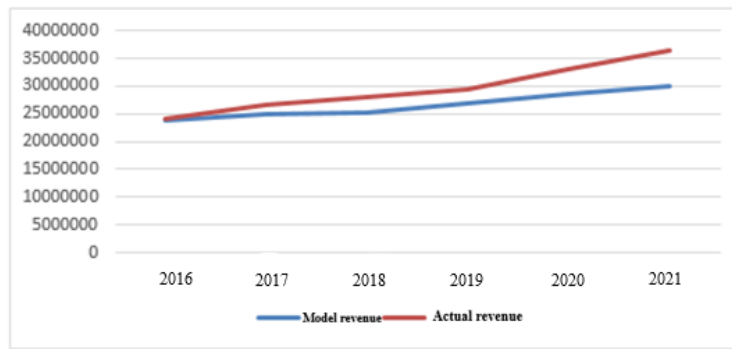


Figure 5. Graph of actual and estimated data of government revenue model

Results of model validation are mentioned here for government revenue based on the three indicators mentioned above. The coefficient of determination equals 0.912, which is around 91% indicating an optional rate of reality. Model error equals 24% which is acceptable. Model error for forecast equals 17%, which shows an optimal rate.

$$R^2 = 0.912$$

$$MAPE = 0.239$$

$$MAE/MEAN = 0.167$$

2) investment stock

The results of investment statistics (billion Rls) used in the public sector during 2016-2021, including the pandemic period (2019-2021) are shown in the figure below.

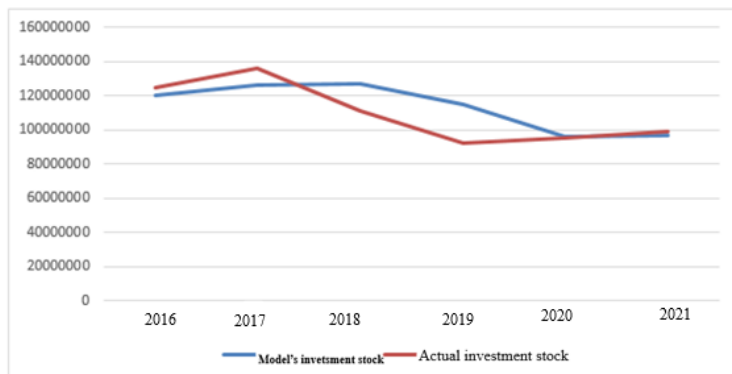


Figure 6. Graph of actual and estimated data of investment stock model

The results of the model simulation could identify and estimate the investment stock to a certain extent. according to validation indicators, R^2 equals 0.902 indicating 90% adaptability with reality, Error index equals 23% which is acceptable, and model error index (9%) which is a confirmable value.

$$R^2 = 0.902$$

$$MAPE = 0.231$$

$$MAE/MEAN = 0.087$$

Analysis of the model's policy

According to available literature, various factors affect resilience, especially at the national level. Ahmadi, Hosseininasab, and Azmoudeh (2021) pointed to economic scope, particularly liquidity and government investments. Sarvari Dardashti et al.

(2020) mentioned the role of cultural and educational factors, including education equality, educational capacity, and number of graduates. Sajadi et al. (2020) mentioned the role of media, social networks, and the educational system.

According to these studies and the importance of components, the model's sensitivity analysis is done to examine resilience changes based on three underlying variables: educational quality, medical equipment, and economic stability.

1) Government revenue

According to the importance of educational issues and creating educational infrastructures of schools and universities, the model's sensitivity analysis has been considered based on the minimum and maximum of

government revenues and the effects of its variations on the number of educational qualities. The result has been shown as a graph.

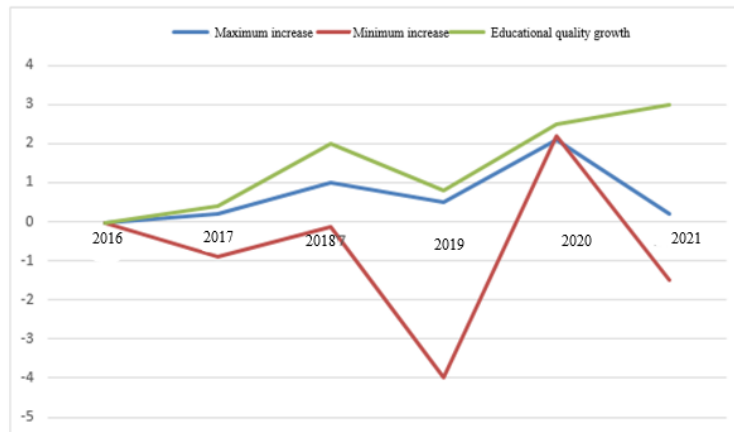


Figure 7. Sensitivity Analysis of educational quality by changing government revenue

According to the variations graph, educational quality in the maximum state does not show very considerable change compared to the model but just many fluctuations exist, which is not useful for developing the quality of educational infrastructures. These fluctuations indicate that variation in government revenue does not affect increasing

educational quality in Iran. According to this graph, in the minimum state, educational quality has considerably decreased compared to base mode and has become negative in some cases. According to the comparison between minimum and base graphs, educational quality improvement highly depends on the government revenue of the country.

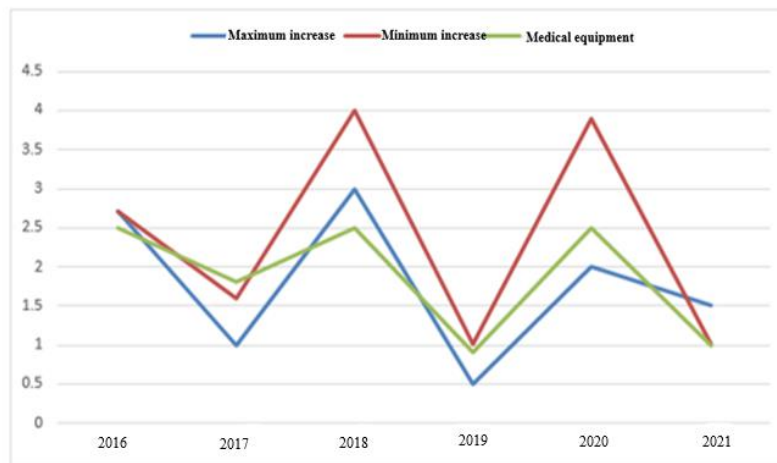


Figure 8. Sensitivity analysis of medical equipment by changing government revenue

According to the sensitivity graph, medical equipment has been developed in both minimum and maximum states compared to the early model. This difference is higher in the minimum state. Hence, it can be expressed that the improvement of medical equipment depends on government revenue, so any change cause variation in a constant annual increase in equipment. Therefore, the model is highly sensitive to this variable.

2) investment stock

According to previous studies, the effect of investment and allocation expenses on the infrastructures of the country plays a vital role in dealing with crises and national resilience in general. The rapid spread of the coronavirus in the early days of the pandemic left the economic system of Iran in a huge crisis. The most critical challenges caused by the COVID-19 pandemic included lower production in the country, a reduction in workforce, a decline in trade and domestic and

foreign exports, a budget deficit, and capital and exchange markets' fluctuations. Hence, sensitivity analysis of investment stock and its effect on

resilience was done by examining two maximum and minimum states during past years. The following graph indicates the results.

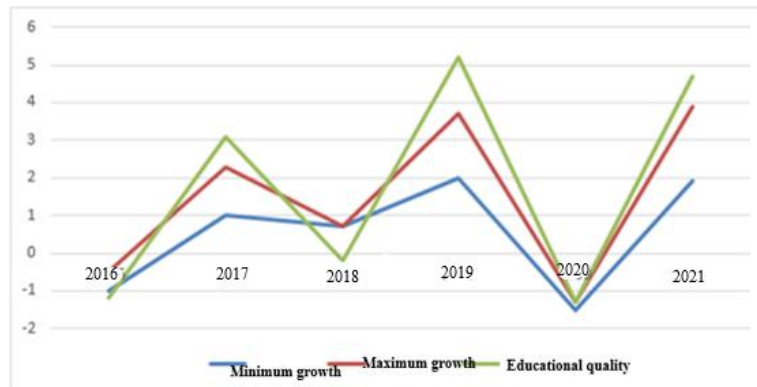


Figure 9. Sensitivity analysis of educational quality by changing investment stock

As seen in the graph, results of educational quality indicate lower oscillation when investment stock reaches its highest rate. Higher fluctuations are seen in base and minimum states. Hence, it can be explained that educational quality becomes problematic when investment stock remains fixed. On

the other hand, some points indicate problem incidence in minimum state. According to the results of some graphs, investment stock shows few changes in minimum and maximum states, while this rate is lower in maximum states. Medical equipment has less sensitivity to investment stock.

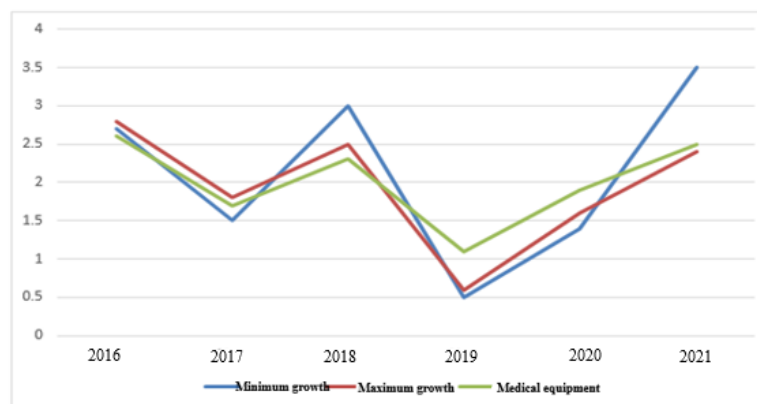


Figure 10. Sensitivity analysis of investment stock effect on medical equipment

This low rate may be explained in this way that stock investment may have two different effects if is achieved by increased investment in healthcare contexts and increased recruitment of expert forces and providing the salary costs.

Design and evaluation policy

In the last phase of modeling, scenarios of the coming ten years of Iran's resilience have been designed. These policies have been addressed in considered effective indicators to enhance the national resilience of Iran. After policies and strategies were designed, sensitivity analysis of several main variables of the model was examined.

Designing scenarios

In the last phase, scenarios of resilience in the coming 10 years of Iran have been designed to enact and evaluate the strategy. Considered policies for enhancing resilient scopes' strength have been proposed, and their application, the future of anticipated models, and policy have been investigated. Then, several main variables of the model have been implemented and model power has been measured under uncertainty conditions. Some scenarios must be designed for the model's variable to increase resilience power and predict the future (2022-2031). According to the importance of revenues of the country and the allocation of budget

for improving and planning different infrastructures, a 5% increase will occur in the budget based on the statistics of previous years. The data indicates that the budget reaches from 682857 billion dollars in 2022 to 1024286 billion dollars by 2031.

Proposed strategies

Some strategies have been proposed for some variables of the model, including the government's investment stock, educational and health infrastructures:

- 7% annual rise in government revenue
- Enhancing health and medical scope infrastructures with an annual 5% rate
- Increasing (5% annually) educational infrastructures

These strategies have been reviewed herein:

1. Seven percent increase in government revenue

Government revenue has a significant effect on economic fluctuations because it depends on exports and affects the liquidity of the country. Because resistive infrastructures are provided based on government liquidity during crises, the government revenues that enter the budget must be increased over the years. The government can increase revenues based on oil activities, tax, and product exports, so can improve educational and health infrastructures. The increased revenues indeed enhance the budget and expenditure allocated to different scopes. Hence, an annual 7% increase in revenue can promote economic resistive policy to a resilient scope.

2. Increasing health infrastructures:

As mentioned before, healthcare scope which is a leading field in Iran's resilience dealt with numerous hazards during the COVID-19 pandemic. Medical facilities and infrastructures directly affect the protective equipment, laboratory equipment, health facilities, employment of medical personnel, health

staff, and experts, providing hospital facilities, and quarantine equipment for patients. An annual 5% increase in medical equipment and infrastructures provides the field for the development of medical equipment. On the other hand, professional medical staff would face more needs when medical facilities and hospitals increase. Hence, this variable indirectly affects the economy and the creation of business scopes.

3. Annual five percent increase in educational infrastructures:

High financial costs must be spent to fill the gap in digital approaches and optimize online education capacities in educational programs and create systematic plans to train teachers and professors. In critical conditions, the maximum use of educational infrastructure capabilities is broadly increased. Because educational conditions were not prepared to use remote education amenities during COVID-19, many problems occurred for teachers, professors, and university and school students. According to the fundamental evolution document, optimum resource management and education system uses are provided from the educational system's credits. Hence, educational infrastructures must receive great attention to provide and allocate resources and use educational mechanisms in preventing education pauses when dealing with possible hazards.

Sensitivity analysis of the model after implementing policy

Sensitivity analysis is done to find to what extent the model is sensitive to changes in parameters' values. In the model of this study, the results of sensitivity analysis of change in educational and health infrastructures and government revenues have been done for predicting the model for the resilience index. The results can be examined in the following figures.

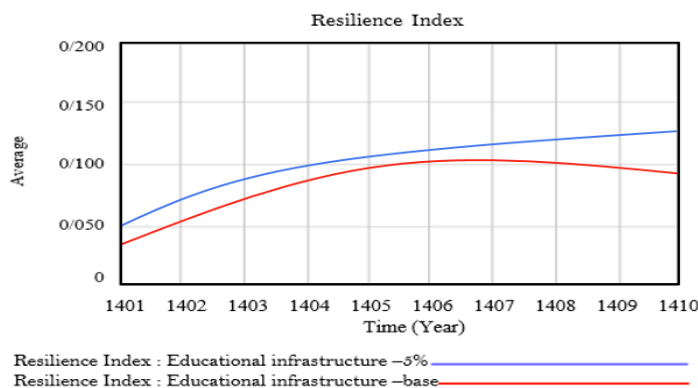


Figure 11. Sensitivity analysis of model by changing educational infrastructures

According to the results, strategies taken for educational infrastructures have affected the mean value of the resilience index. As it is seen, a continuous increase occurs in the mean value of resilience after a relatively constant trend.

The enhanced educational infrastructure indeed is a positive change that creates desired conditions for enhancing academic centers and accepting educators over time.

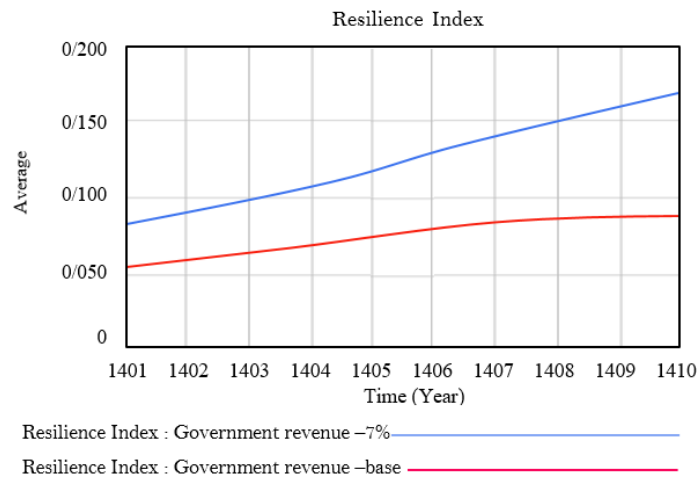


Figure 12. Sensitivity analysis of model by changing government revenue

Government revenue is one of the strategic parameters in the dynamics model of this study. In this model, we expect to reach higher resilience after applying an annual 7% increase in government revenue. Figure 12 depicts the pattern of the resilience index after adopting the strategy of government revenue. The resilience index curve moves upwards with a dramatic slope over time. Hence, higher government revenue and liquidity power lead to more economic resistance during crises. In terms of health infrastructures, an increase in this variable leads to a

considerable ascending slope of the resilience index average reaching the predicted value of the model at the end of 2022. Increase health and medical infrastructures lead to higher health equipment, more employment of professional staff, and higher hospital amenities. According to the results of policies analysis, variation in the resilience index compared to the base state, the model reaches the results of the base model within the long term (10 years) after implementing proposed strategies, so the resilience index will rise.

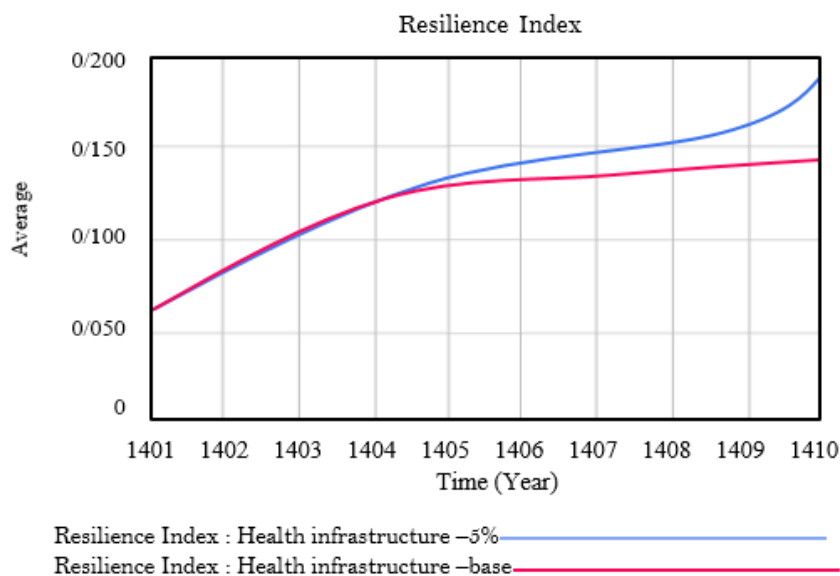


Figure 13. Sensitivity analysis of model by changing health infrastructures

Discussion and Conclusions

According to the resilience definition, social, economic, and health indicators must be defined to return to the origin and resist changes. In the extant study, the resilient components of Iran were discussed and examined during the COVID-19 pandemic. The results of classifying resilient scopes and sub-scopes during the COVID-19 pandemic are consistent with the results obtained by Banerjee and Kallivayalil (2021). They introduced economic scope and some sub-scopes (economic stability, supporting domestic businesses, and exchange market control) as the most important resilient scope. In this research, the resilience of Iranian society in dealing with the COVID-19 pandemic was identified based on the flexibility elements of the community. The most effective factors in the resilience field include exports rate and diversity, economic stability, investment and liquidity system, government cost, government revenue and financial policies, inflation, social, religious, and cultural activities, social solidarity, social plans, enhancing e-government, e-education, information security, society smartening, quality of educational centers (schools and universities), education implementation models, number of medical centers, health and medical personnel, medical equipment, distribution of infrastructures, investments and infrastructures, providing security of infrastructures, providing equipment and pieces, distributive justice, etc.

After resilient components of Iran during the COVID-19 pandemic were identified, relationships between components were found using cause and flow graphs. In different resilient scopes, the communication chain can decrease or increase other components. In economic scope, the cycle of relationships between liquidity, saving, government expenditures, investment, and investment stock was identified. In line with the increased workforce in this cycle, the effect of the financial system and government saving on the increased products was examined. In the dynamics assessment of resilient factors, the applied statistics and information were proposed then Vensim software was used to do simulation based on the effective components then actual and estimated results were compared. According to the results and their validation, the presented model could predict the model to a desired extent. After sensitivity analysis was done on the most significant factors, the results indicated the highest sensitivity of the model to economic stability and health equipment. The model was implemented based on the strategies of an annual 7% increase in government revenue, 5% in educational infrastructures, and 5% in health

infrastructures then the model's future was anticipated for the next 10 years. According to the results of implemented strategies, a considerable increase occurred in the resilience index. According to resilience dynamics, the implementation of proposed strategies could indeed improve national resilience and reduce vulnerability

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