Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669
Research Article
DOI: 10.22067/JSTINP.2022.79551.1025
JSTINP 2022; Vol. 1, No. 3

Investigating the Challenges of Public Transportation and Users Behavior during and Post-COVID-19 Era

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How to cite this article

Roozkhosh, F., Salaripour, A., 2022. Investigating the Challenges of Public Transportation and Users Behavior during and Post-COVID-19 era. *Journal of Systems Thinking in Practice, 1*(3), pp.1-21. doi: 10.22067/JSTINP.2022.79551.1025. https:/jstinp.um.ac.ir/article_42798.html.

ABSTRACT

The coronavirus (COVID-19) spread has significantly affected the city and its citizens from various aspects. Public transport systems are considered one of the essential parts affected by this virus to change citizens' travel behavior. The main aims of this study are, firstly, investigating the travel behavior of citizens in the period before, during, and after the coronavirus epidemic in the three metropolises in Iran (Tehran, Mashhad, and Isfahan) from four different perspectives. These four aspects include 1) the main reasons for the use of public transport in the pre-coronavirus era, 2) changes in the use of public transport during this epidemic disease, 3) the effect of the public transport system on the prevalence of COVID-19, and 4) behavioral changes in the use of public transport after the end of the epidemic. Secondly, assessing the impacts of these aspects on citizens' confidence in using public transportation after the coronavirus outbreak is based on the system dynamics model. The data collection tool is the Likert scale questionnaire, and the results were analyzed descriptively based on the evidence found.

Keywords

Public transportation, COVID-19, Challenges, Pandemic, System dynamics.

Article history

Received: 2022-11-11
Accepted: 2022-12-24
Published (Online): 2022-12-24

Number of Figures: 7 **Number of Tables: 7** **Number of Pages: 21** **Number of References: 22**

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1. Introduction

With the spread of COVID-19 disease, concerns about how to use public transportation during and in the post-COVID period have increased. On the other hand, one of the most critical concerns is the impact of public transportation on the prevalence of infectious diseases at the time of and after the spread of the disease. The COVID-19 pandemic has recently forced half of humanity to experience an unprecedentedly expansive lockdown. Naturally, this has brought urban transport systems to a near standstill, resulting in a sharp drop in carbon emissions and levels of air pollution in affected areas (Koehl, 2020).

The use of public transport holds many advantages over the use of a private automobile for the individual, the community, and the cities from the standpoint of such factors as energy conservation, environmental impact, social equity, and economy (Ojo, 2017). Promoting the use of public transport for urban mobility is not the only key to decarburization and mitigating climate change but also offers direct benefits for public health: improving air quality in densely populated areas, promoting active modes of transport, and encouraging activities that are less stressful than driving (Gutiérrez et al., 2020). While the huge negative effects of living through the COVID-19 pandemic are obvious – psychological stress, fear, severe global economic losses, overwhelmed healthcare systems, and general disruption of societies – the ongoing pandemic may also have some indirect positive impacts (El Zowalaty et al., 2020). By creating a smart structure, this paper explores the relationship between the answers provided by individuals to the questionnaire to identify and categorize the importance of criteria; As the importance of one criterion for the individual increases, what other criteria will be prioritized for this person.

This study uses the presented smart method to examine the internal relationship between the causes of using public transport in the period before the spread of coronavirus, how to change the behavior of citizens in using public transport during the spread of coronavirus, the impact of public transportation on the spread of COVID-19 disease, and how people change their behavior in using public transportation in the post-COVID-19 era from the perspective of citizens. As the largest metropolis in Iran and the Middle East, Tehran has been considered the case study in this study. More than 12 million population and gateway trips increase the floating population to more than 16 million people a day (Shirazian and Eskandari, 2021). Additionally, Iran, with 1,542,076 and 59,184 cases of confirmed infections and deaths persons, respectively, on February 17, 2021, is one of the high-risk areas from the spread of coronavirus perspective.

Therefore, the importance of studying the COVID-19 impacts on the public transportation system in the Tehran metropolitan is undeniable.

2. Literature review

The outbreak of the novel coronavirus disease of 2019/2020 (COVID-19) has resulted in still-increasing numbers of infections and deaths worldwide (Zhang, 2020). As of February 17, the total number of confirmed infections and deaths reached 72,385,935 and 1,615,052 persons, respectively, with the former still showing an upward trend. As a critical infrastructure component of cities, urban public transit offers a significant overall benefit to society (Fei, 2016), which is under threat by the growing COVID-19 disease. Many researchers and organizations have widely investigated the impacts of COVID-19 on the transport sector and corresponding measures (e.g., aviation (IATA, 2020; ICAO, 2020), maritime transport (McCauley et al., 2020; Teoh, 2020), railway (Citroen, 2020), and urban transport (EIT, 2020 a,b)).

In the context of urban transportation, Shen et al. (2020) tried to introduce the prevention and control measures for public transportation in China to promote the global response to COVID-19 and gathered important precautionary and control strategies relating to decreasing the COVID-19 spread in public transportation. Mogaji (2020) also analysed the present and long-term impact of COVID-19 on transportation in Lagos State, Nigeri, and noted a positive correlation between transportation affected by the pandemic and its effect on the people's economic, social, and religious activities. Gutiérrez et al., (2020) demonstrated the effects, challenges and research agenda associated with COVID-19 and urban public transport. Koehl (2020) also examined the possible consequences of COVID-19 on public health and used system thinking to evaluate how stimulus plans could maximize social, health and climate co-benefits. Abu-Rayash and Dincer (2020) proposed a model for smart transportation by considering COVID-19 impacts on the transportation sector and four indicators, including transport efficiency, technology integration, traffic congestion rate, and accessibility ratio. Their historical analyses of past health crises have indicated that the transportation sector will take a long time before full recovery and have shown substantial energy savings and GHG reductions associated with the pandemic. Zhang (2020) proposed a PASS (P: Prepare–Protect–Provide; A: Avoid–Adjust; S: Shift–Share; S: Substitute– Stop) approach for policymaking that accounts for COVID-19 and future public health threats in his study. This new approach has been designed to fill the gaps in transport policymaking amid pandemics by covering the

significant aspects that should be addressed by governments, transport operators, transport users, and the public (Roozkhosh et al. 2022; Roozkhosh and Motahari Farimani, 2022).

As seen from the literature, there is a wide range of studies regarding urban transportation's current and future challenges during and after COVID-19. However, since this is a novel subject, it should be explored more accurately and from different aspects. This study examines the current behavior of the transportation system and the behavior of the system in the long run, and some key variables are examined by considering policies to improve the behavior of the transportation system in the long term.

3. Methodology

This study relied on a questionnaire to assess the current and leading challenges of public transportation during the spread of COVID-19 and in the post-COVID-19 era, which was distributed among the residents of three cities of Mashhad, Tehran and Isfahan via email, social media, and the professional network between 5 and 10 February 2021. For calculating the ideal sample size, the Cochrane formula was used. Based on the Cochrane formula, 384 questionnaires should be filled out regarding the case studies population.

384 questionnaires were collected with a response rate of 80%; Table 1 shows the demographic information related to the questionnaire. The analysis method of this study has been descriptive.

Table 1. Demographic information

	N=384	%
Gender		
Female	190	49.47
Male	194	50.52
City		
Tehran	209	54.42
Isfahan	71	18.48
Mashhad	104	27.08
Age Group		
15-25	175	45.57
26-35	172	44.79
36-45	21	5.46
46 above	16	4.16
Education Level		
Diploma	48	12.5
Bachelor	155	40.36
Master	158	41.14
PhD	23	5.98

The present study has investigated four different aspects, including the main reasons for using public transport in the pre- COVID-19 era, changes in the use of public transport during the

epidemic, the effect of public transport fleet on the prevalence of the COVID-19, and behavioral changes in the use of public transportation in the post-COVID-19 era. All economic, social, environmental and health aspects were considered while developing the questionnaire questions. The effect of COVID-19 on public transport during the epidemic and in the post-COVID-19 era was investigated according to the data obtained from the questionnaire.

$$n = \frac{\frac{z^2 pq}{d^2}}{1 + \frac{1}{N}\left(\frac{z^2 pq}{d^2} - 1\right)} \quad (1)$$

Where n is the ideal sample number, N is the case studies population, d is the desired level of precision, p is the (estimated) proportion of the population that has the attribute in question, q is 1 – p. Z is the value of the normal variable with confidence level α-1.

System dynamics (SD) is a discipline and a methodology for the modeling, simulation, and control of complex, dynamic systems (Modares et al., 2021). The particular approach of SD lies in representing the issues or systems-in-focus as meshes of dosed feedback loops made up of stocks and flows in continuous time and subject to delays.

The dynamic system also tries to predict their long-term behavior in the future by examining the reference modes and past behavior of critical variables. On the other hand, by examining the challenges ahead with the help of questionnaire results, the rate of some exogenous variables used in the model can be found. In addition, after observing the system behavior, it is possible to change the value of some rates of exogenous variables based on policies and introduce their best rates in the long run. So that planners can rely on these rates to obtain the right policies and introduce the key system variables (Rajabi et al., 2022).

In this article, using the SD approach, the system behavior is considered for the 1000-day time horizon from February 17, 2021. Because the purpose is to review the system's behaviour and provide policy for the future. However, to check the model's validity, a 60-day interval is provided. And the citizens' confidence in using public transportation in the period before, during, and after the coronavirus outbreak is analyzed.

3.1. Case study

This study has examined the three metropolises of Iran, including Tehran, Mashhad and Isfahan. These three cities are among the largest cities in Iran, and public transportation is considered one of the most widely used commuting modes in all three cities. With a population

of around 8.6 million (Statistics Center of Iran in 2016), Tehran is the most populous city of Iran and the capital of this country. With a population of 3 million, Mashhad is the second-largest Iranian city and the religious capital of Iran. The latest statistical information reported by the Statistical Centre of Iran (SCI) in 2016 shows that the third most populous city of Iran is Isfahan, with a population of 2 million (as of 2016), which is one of the most industrial cities in Iran. Bus rapid transit (BRT) and subway lines are considered the most widely used commuting modes (public transport) in all three cities and one of the most important citizens' travel behaviors for daily trips. Public transportation in Iran has introduced new laws during the coronavirus epidemic, as in other countries, including personal hygiene, such as wearing a mask and observing social distancing[1]. However, the significant effects of this epidemic on reducing the daily use of public transport by citizens can't be ignored. The behavior of citizens in relation to public transportation before, during and after COVID-19 in three metropolises of Iran is discussed in the following.

4. The investigating of COVID-19 impacts on the public transportation

4.1. *Why were daily trips carried out by public transport before the COVID-19 pandemic?*

The results of the relevant studies and Table 2 show that 61.71.% (237 people) of the respondents agree that public transportation can be a money saver, and its low cost plays a significant role in prioritizing their commuting mode choice. Furthermore, 46.09% (177 people) of respondents believe that lack of access by personal vehicle, which directly affects the household economy, is considered the second most effective factor in choosing public transport as the commuting mode. As a result, the economic perspective has played the most important role from the interviewees' point of view in choosing a mode of transport to commute (use of public transportation) despite the concerns of urban planners in relation to the use of personal vehicles and relevant environmental problems, such as air pollution, noise pollution, greenhouse gas emissions, increase in respiratory diseases, only 35.67% and 40.62% of respondents (questions 8 and 9 are related to environmental issues and urban air pollution), believe that environmental issues play an important role in choosing public transport as commuting mode. It means that citizens do not pay enough attention to environmental concerns

[1] Social distancing, also called “physical distancing,” means keeping a safe space between yourself and other people who are not from your household. To practice social or physical distancing, stay at least 6 feet (about 2 arms' length) from other people who are not from your household in both indoor and outdoor spaces.

when choosing a mode of transport to commute. Finally, from the interviewees' point of view, the two issues of the possibilities of walking to a public transport station (proper access) and the convenience of public transport had the least effect on the choice of public transport before COVID-19. When using public transport, people face insufficient public transport stations in metropolitan cities of Iran and poor quality (high congestion, poor seats, noise, etc.). On the other hand, although reducing travel time for passengers is considered one of the most important goals of public transport design, 42.44% (163 people) of the interviewees did not consider travel time reduction as an essential factor in public transport mode choice, which can indicate improper timing and efficiency of the public transportation system in metropolitan areas of Iran.

Table 2. The main reasons why daily trips were carried out by public transport before the COVID-19 pandemic

The main reasons why daily trips were carried out by public transport before the COVID-19 pandemic	Completely agree	Agree	Medium	Disagree	Completely Disagree	Average Likert scale
Lower costs	127	110	96	32	14	3.76
Lack of access to personal vehicle	96	81	108	69	26	3.39
More convenience when using public transport	42	66	113	110	47	2.85
Lack of access to parking at the destination	52	82	107	102	38	3.01
Less travel time	51	83	82	104	59	2.89
High traffic and fatigue from driving a personal car	56	88	105	87	43	3.06
Ability to walk more (from home to the station) when using public transport	37	69	108	122	43	2.83
Protecting the urban environment and reducing fossil fuel consumption	71	66	135	81	29	3.12
Prevent air pollution in the city	53	103	123	81	22	3.21
Existence of compulsion and impossibility of using a personal car due to traffic restriction plans	47	112	102	81	39	3.12

4.2. *What has changed with the outbreak of coronavirus in the way you use public transportation?*

As the results of relevant studies and Table 3 show, people often avoid unnecessary travel to protect their health and the health of those around them in the COVID-19 era and turn to Internet software and online shopping for more weekly and daily shopping than ever before. On the

other hand, according to the view of 65.10% (250 people) of the interviewees, they did not use public transportation such as subway or city taxis at all in the COVID-19 era and preferred to use Internet taxis and agencies; this issue is important from various aspects, which will be discussed in the next sections. Many environmental and economic problems will be created due to less use of public transport and the preference to use Internet taxis or agencies.

For example, some of the most important environmental and economic problems include the increase in emissions of greenhouse gases (GHG) due to a large number of taxis in the city, the increased cost of internet taxis, the effect of costs in the market basket, increased air pollution, increased respiratory diseases and other cases. From the interviewees' point of view, lower cost and air pollution, which were among the main factors in public transportation choice instead of personal transportation in the pre-corona era, have changed significantly during the epidemic, which will be associated with irreparable economic and environmental pressures. According to the investigation results of questions 6 and 7 of Section 2, which were related to the coercion and authority of individuals to use public transport in the COVID-19 era, both coercion and authority have minimal effect on individuals' decisions to use public transportation. People have a minimal inclination to use public transportation during the corona due to the fear of being indoors and not observing social distances. People were very reluctant to use public transportation during the COVID due to fear of being indoors and disregarding social distancing. However, the number of people forced to use public transportation due to economic and time constraints is more than those who want to use it in this era.

On the other hand, according to the results, people are inclined to reach their destinations via cycling and walking. This may be due to the World Health Organization's recommendations that the coronavirus remains "viable in aerosols" — infectious in the air — or due to the incorrect placement of public transport stations in the city. This will be associated with many environmental and health problems that lead to increased greenhouse gas emissions and air pollution, leading to the spread of diseases such as obesity, diabetes, and high blood pressure in people due to reduced mobility.

Table 3. Changes in the way people use public transportation during the COVID-19 pandemic

Changes in the way people use public transportation during the COVID-19 pandemic	Completely agree	Agree	Medium	Disagree	Completely Disagree	Average Likert scale
I completely eliminated unnecessary trips	231	83	49	13	4	4.37
I do not use public transportation (bus and subway) in any way.	193	57	63	39	28	3.90
I do not use public taxis in any way	133	73	98	48	28	3.61
I use the Internet and personal taxis instead of public transportation.	120	100	91	46	23	3.65
I use the Internet more than in the past to buy and receive services	148	112	87	26	10	3.94
I continue to use public transportation as before due to coercion and restrictions.	27	27	64	120	140	2.16
By my own choice, I continue to use public transport as before.	11	22	46	138	162	1.90
I mostly use walking and cycling to reach my destination	41	61	100	87	91	2.26
I use public transportation more than personal vehicles to get to my destination	39	41	41	79	168	2.19

4.3. *What do you think about the effect of public transport on the onset of COVID-19?*

Based on Table 4, the majority of respondents, 74.73% (287 people), believed that the prevalence of COVID-19 in public transport is unavoidable, and 65.10% (250 people) of them considered public transport as one of the most dangerous places for the spread of the virus. Also, in their view, only personal hygiene (wearing a mask, gloves, and frequent use of disinfectants) when using public transportation is not enough to avoid illness, although necessary. It is necessary to create a coordinated campaign among all people involved in public transportation, this coordination does not end with the compulsion to wear masks all people, and there is a need for frequent disinfection of transportation devices and, most importantly, the reduction of congestion, the observance of social distance and appropriate timing in the use of public transport. According to the results of studies, people only decide to use public transportation if they are sure that public transportation is always hygienically disinfected and the whole people involved observe their health and respect the social distancing.

Table 4. The effect of public transport fleet on the prevalence of COVID-19

What is your opinion about the effect of public transport fleets on the prevalence of COVID-19	Completely agree	Agree	Medium	Disagree	Completely Disagree	Average Likert scale
1. The use of public transportation is the main reason for increasing the outbreak of COVID-19 in metropolitan areas	108	142	102	26	4	3.85
2. Transmission of the disease in public transport is inevitable	158	129	59	23	12	3.93
3. The use of public transport does not affect the risk of contracting the disease	7	4	13	132	226	1.52
4. If personal hygiene is observed, people will not get sick while using public transportation possibility.	13	61	132	120	53	2.63
5. By disinfecting the environment of public transport, the transmission of the disease in public transport can be controlled.	33	58	165	79	43	2.89
6. By reducing congestion and proper timing of using public transportation, disease transmission can be controlled.	53	120	157	33	18	3.40
7. Citizens' commitment to using masks and personal hygiene is the most important factor in reducing transmissibility in public vehicles.	99	127	122	21	13	3.72

4.4. *How will you use public transport in the Post-COVID-19 Pandemic era?*

According to Table 5, although 58.85% (226 people) of the interviewees admitted to using it without worries after the COVID-19 outbreak, 64.32% (247) of the interviewees believed that they would use public transportation with more caution than health tips and prefer to use masks and continue to disinfect public vehicles in the Post-COVID-19 Pandemic era. However, one of the most important effects of this virus on citizens' travel behavior is walking and cycling. Most respondents believed they would continue their habit of walking and cycling in the Post-COVID-19 Pandemic era, which plays a vital role in cities and citizens in various economic, social, and environmental aspects. On the other hand, the use of the Internet in daily activities such as shopping, payments, and other things that most citizens have tried to use during the COVID-19 era also plays a significant role in doing citizens' affairs in the post- COVID-19 era. In other words, most respondents (with a rate of 3.14) claimed they would avoid unnecessary

travel and use the Internet as much as possible for daily activities in the post- COVID-19 era. This will reduce the economic benefits (in terms of travel costs, fuel costs, etc.) for individuals and help to reduce greenhouse gas emissions. However, most interviewees claimed that they would use public transport more cautiously (after discovering the COVID-19 vaccine and in the post- COVID-19 era, but 29.42% (113 people) still claim to continue to use their vehicle to reach their destinations in the post- COVID-19 era. It is crucial to pay attention to this issue, given that public transportation is considered one of the essential commuting modes to achieve sustainable development goals. So, city planners and managers must put policies on their agenda to increase safety and regain people's confidence to use public transportation in the post-COVID-19 era.

Table 5. How people use public transportation in the post- COVID-19 era

How will you use public transportation after the epidemic?	Completely agree	Agree	Medium	Disagree	Completely Disagree	Average Likert scale
Despite the end of the pandemic, I will still keep the use of public transportation limited.	34	61	97	144	44	2.72
After the end of the COVID-19 pandemic, I will still use my personal vehicle to get around the city.	34	79	119	110	38	2.89
I will eliminate unnecessary trips and use the Internet more than in the past to buy and receive services	44	96	134	84	22	3.14
I will use public transportation safely in the post-COVID-19 era.	96	130	105	33	16	3.67
I will continue using public transportation more cautiously in observing health tips in the post-COVID-19 era.	100	147	96	24	13	3.77
I will maintain the habit of walking and cycling.	78	114	127	44	16	3.50

5. Results

5.1. *Presenting a dynamic hypothesis and causal loop diagrams*

The causal loop diagram shows the relationships between the variables drawn by the dynamic hypotheses. For example, with the increase in travel, the disease spreads among more people, so the number of patients increases, the fear of disease is expected to increase, and the greater the fear, the less public transportation is used. On the other hand, with the increase in the number

of patients, people increase the use of personal vehicles to maintain their health. With the increase in traffic with private vehicles, traffic and air pollution increase, and as a result, people again want to use public transportation. As the number of people using public transportation decreases (such as subways, buses, etc.), the crowd will decrease, eventually reducing the number of patients. As observed, increasing one factor in the cycle reduced the same factor, so the loop is a balancing type. Figure 1 shows all the loops.

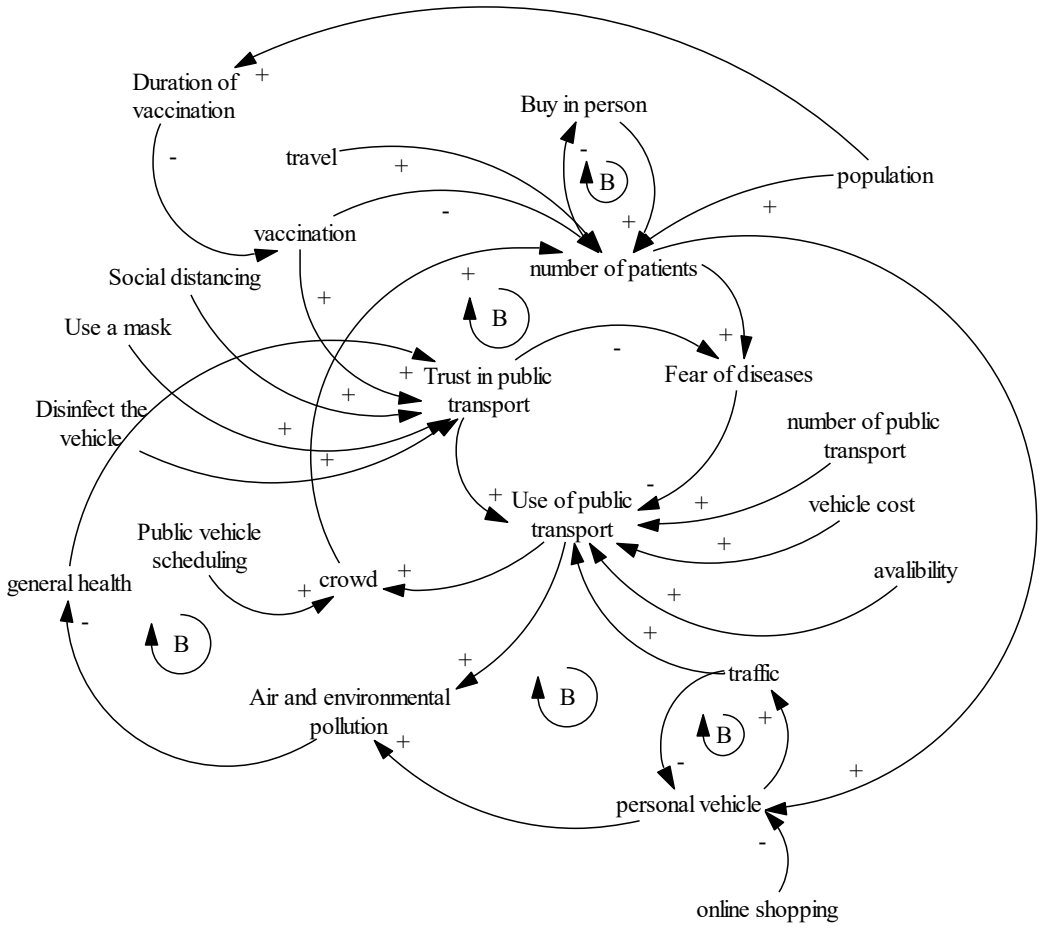

Figure 1. Causal loop diagram of model

5.2. *The stock and flow charts*

Table 6 shows some of the most important formulas of stock and flow variables. These formulas have been formulated for the 1000-day horizon to consider the impact of coronavirus on public transportation in the three cities of Tehran, Mashhad, and Isfahan. The relationship between endogenous, exogenous, auxiliary, accumulation, and flow variables has been investigated.

Table 6. Model formulation to evaluate the impact of coronavirus on transport

Initial value "per day" (unit)	Variable/ parameter type	Formula	Variable
5000000 (number)	stock variable	Integral (number of people using public transportation + number of using public transportation again-using change rate)	total number of people using public transportation
20000 (number)	stock variable	Integral (using change rate-number of using public transportation again)	total number of personal vehicles, and so on
190000 (number)	stock variable	Integral (number of improved)	total number of improved
262153 (number)	stock variable	Integral (number of patients-number of death-number of improved)	Total number of patients
13000000 (number)	stock variable	Integral (birth-death-number of patients)	Papulation
100000 (number)	stock variable	Integral (number of death)	total number of deaths
(Number)	Flow variable	papulation*rate of birth	birth
(Number)	Flow variable	DELAY1(crowd*number of patients rate*papulation, 10)	number of patients
(Number)	Flow variable	probability of death*Total number of patients	number of deaths
	Auxiliary variable	total number of improved/papulation	The ratio of improvements to patients
	Auxiliary variable	The ratio of improvements to patients*total number of patient rate	the effective number of patient rate
	Flow variable	DELAY1(rate of personal vehicle*Total number of patients, 10)	using change rate
(Number)	Auxiliary variable	(Effective crowd rate "Effective in-person purchase rate "+Effective travel rate +online shopping Public vehicle scheduling) *total number of people using public transportation	crowd
	Auxiliary variable	general health*Social distancing*Use a mask	Trust in public transport
(Number)	Flow variable	DELAY1(Disinfect the vehicle * Fear of diseases * rate of public transport users * traffic rate*total number of personal vehicle and so on, 10)	number of using public transportation again
(Number)	Flow variable	DELAY1(effective number of patient rate*rate of Improved number, 10)	number of improved

The formulation given in Table 6 is related to the accumulation, flow, and endogenous

auxiliary variables, the rate variables are part of the exogenous variables, and their values are extracted from the questionnaire (the Average Likert scale column of Tables 2-3-4-5).

To formulate and use the dynamic conditions between the variables, simulation in the Vensim environment has been done, which first is drawn the accumulation-flow diagram according to Figure 2. Flow variables represent stock variables' input and output values, and auxiliary variables (internal and external) help to complete loops and relationships between variables. The following diagram shows the stock and flow diagram of the model, which examines the model relationships.

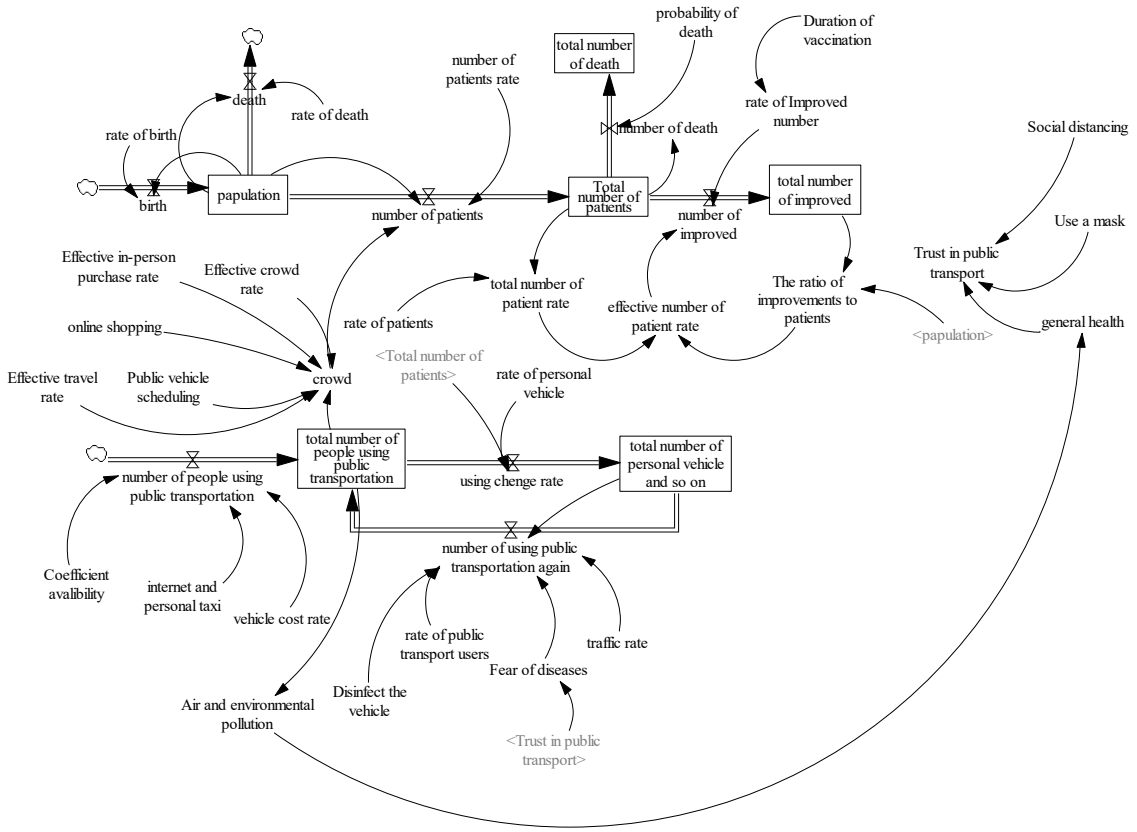

Figure 2. Stock and flow diagrams to evaluate the impact of coronavirus on public transport

5.3. *The numerical simulation results*

The following diagrams show the behavior of model mode variables after numerical simulation. Figure 4 shows the results of all simulation mode variables. The simulation horizon is intended for 1000 days from the beginning of February 2021. The chart below (Figure 3) shows the exact statistics of COVID-19 patients in Iran since February 2021, which can be used to check the model's validity with the total number of patients obtained from the model simulation.

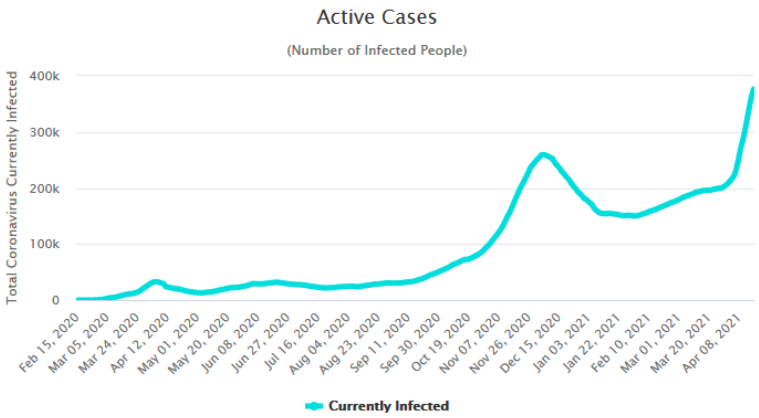

Figure 3. The exact statistics of COVID-19 patients in Iran since February 2021
(Source: www.worldometers.info/coronavirus/country/iran/)

Based on Figure 3 and considering February 2021 as the starting point, the system's behaviour is exponential. The number of patients is increasing, and now comparing it with the pattern obtained from the model shown in Figure 4, It can be understood that the model has a good reputation because the model behavior in the real world has grown exponentially during that period.

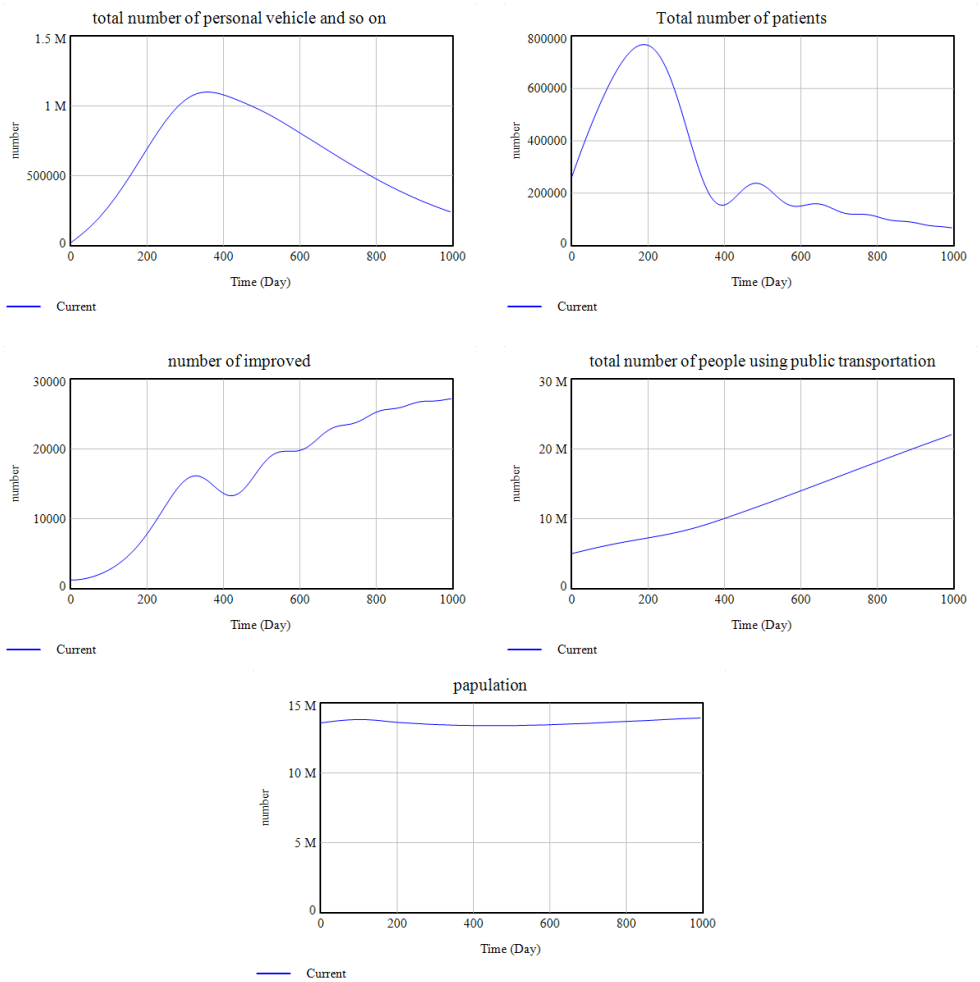

Figure 4. Simulation results of model variables

5.4. *The model validation*

After drawing and formulating the accumulation-flow diagram, to ensure the accuracy and precision of the model, it is necessary to test the model. In this research, three tests have been performed to validate the model. According to the reported coronavirus statistics related to Iran, the real behavior of the variables has been extracted from a valid website.

5.4.1. Test the ability of the model under limited conditions

In this test, other relevant variables are expected to behave correctly by zeroing or multiplying the coefficient of one variable. Therefore, in this model, the disinfection and public transport hygiene rates were considered zero, and the results were reported in Figure 5.

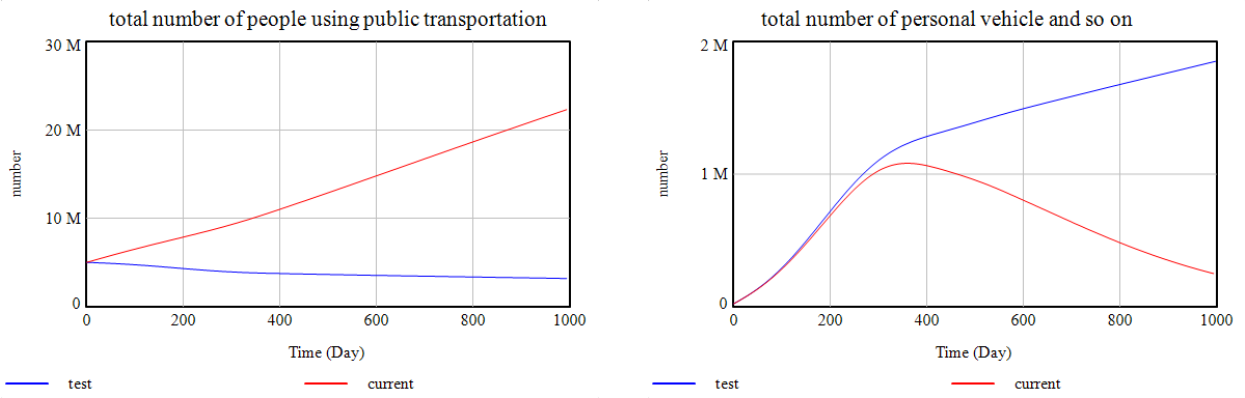

Figure 5. Reset to zero disinfection rate and study its effects

Figure 5 shows that if the rate of disinfection and hygiene of public transport is considered zero, then the use of public transport will decrease, and the use of personal transport will increase sharply; Naturally, in these circumstances, users will prefer to use their personal vehicles for their own safety.

5.4.2. Sensitivity analysis test

This test shows that if the coefficient of one variable changes slightly, the behavior of the other variables should not change sharply. To prove this test, in the model, the travel coefficient changed from 0.0001 to 0.0002, but no significant change was observed in the trend of the graphs. Figure 6.

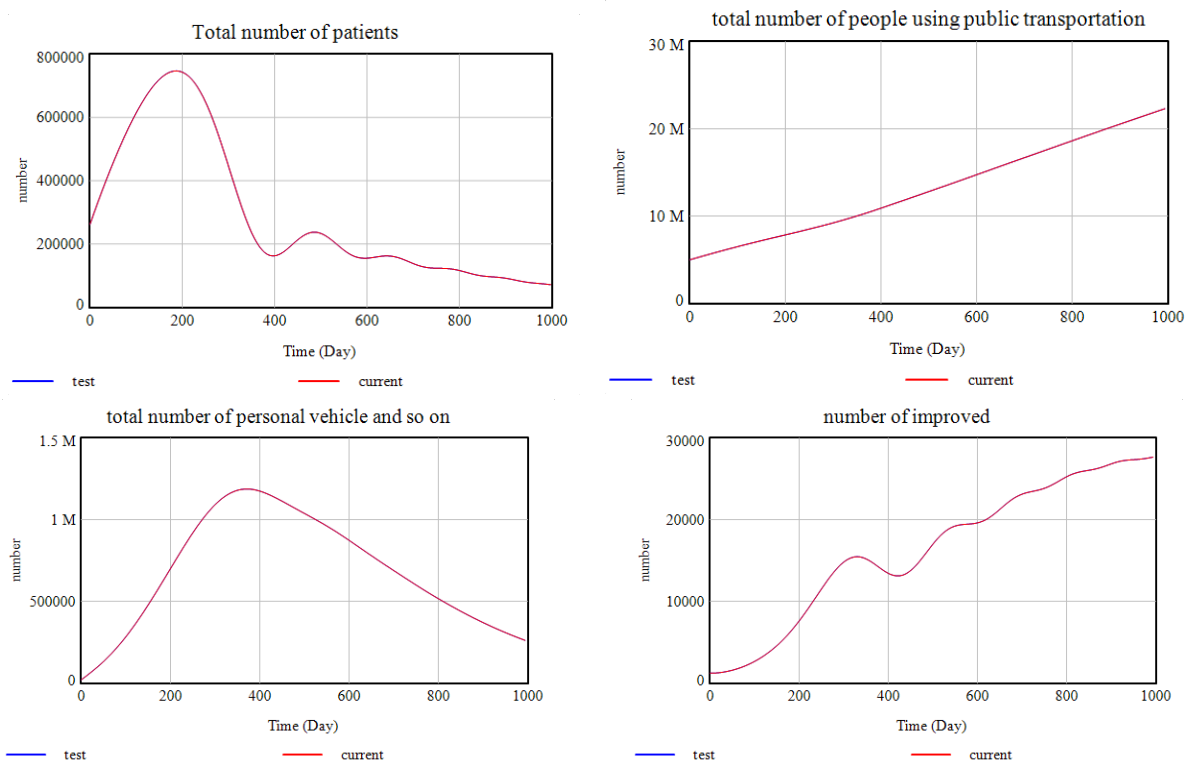

Figure 6. Sensitivity analysis test charts

The conformity of the diagrams in Figure 6 shows the accuracy and validity of the proposed model. Because with small changes, no special change is expected in the model process.

5.4.3. Dimension test

This test involves a Dimension analysis of rate equations. This test was confirmed based on the compliance of all units with the option of unit check-in Vensim software.

5.5. *The policy design and evaluation*

One of the most important capabilities of the systems dynamics approach is to consider different policies and compare the results of these policies. In these policies, according to the nature of the problem, different decisions are made, and according to the results, different policies can be evaluated, and the results can be compared with each other. In this issue, the effect of social distance on the variables of problem stock was investigated.

5.5.1. The policy of social distancing

This section examines the effect of changing social distance on public transport and other variables. One way to reduce the number of patients is to increase social distancing. Table 7 shows the relevant policy. The relevant results are also shown in Figure 7.

Table 7. The policy of social distancing

Policy	Decision Variable	Value
First	social distancing	0.001
Second	social distancing	0.01
Third	social distancing	0.1

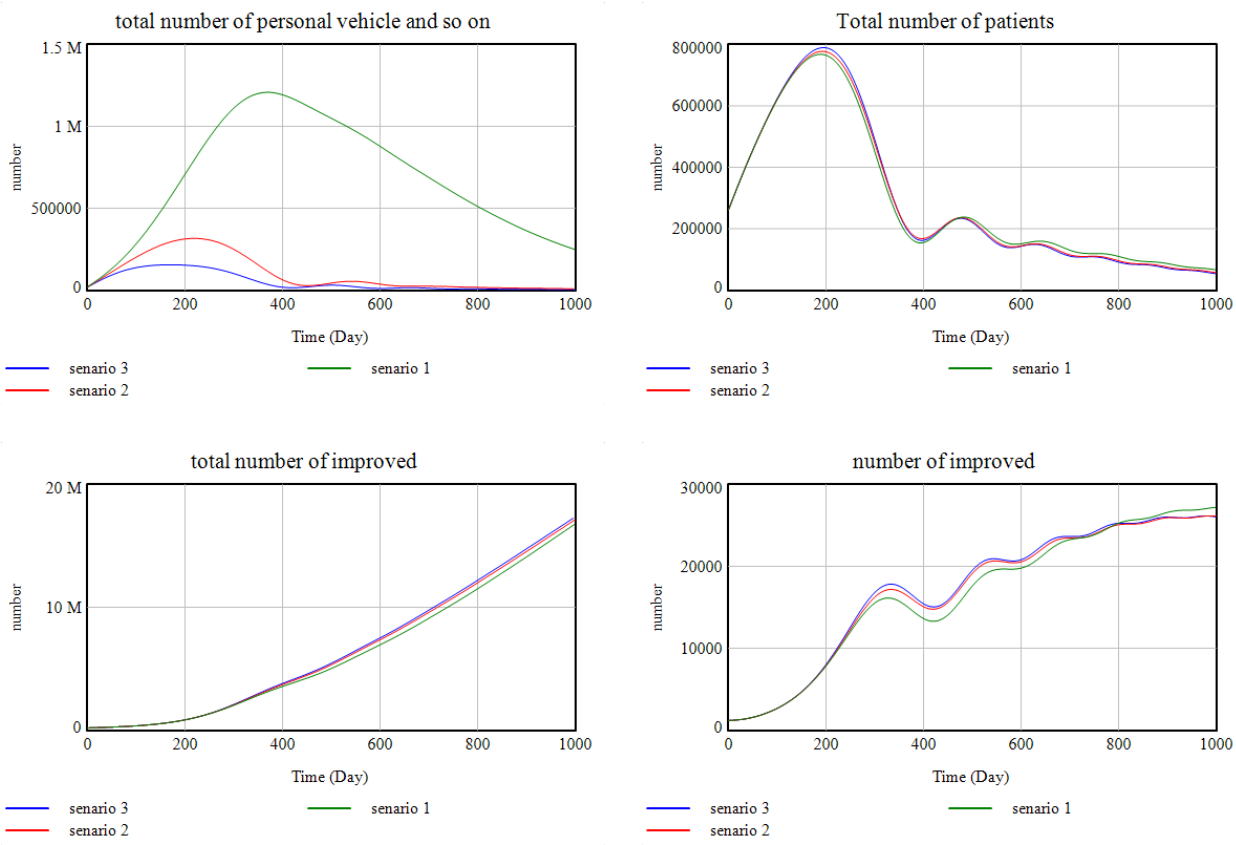

Figure 7. Social distancing policies

As can be seen, the higher rate of social distancing and the lower use of public transportation due to the reduction of congestion, and this decrease have also positively affected the rate of patients. On the other hand, if the social distance rate is more than 0.1, the personal vehicle volume will increase a lot, which will cause environmental pollution, etc., so in this model, the best rate used is 0.01.

6. Conclusion

Despite the many economic, environmental, and social problems created by COVID-19 on public transportation, including the preference to use more personal vehicles, spending more money on internet taxis and agencies, wearing masks, gloves and the constant use of disinfectants, fear of being in closed public spaces such as the subway and buses and other items, more studies probably would prove that COVID-19 has had many benefits. These include

more use of internet services and providing the proper context for moving to the smart city, increasing walking and cycling, reducing air pollution and greenhouse gas emissions, paying more attention to health issues, etc.

According to the results of this study, in the three metropolises of Iran (Tehran, Mashhad, and Isfahan), although the majority of respondents used public transportation for daily commuting before the outbreak of the virus due to economic purposes such as lower costs of public transport (61.71%) and no access to a personal car (46.09%), 65.10% of the interviewees claimed that they did not use public transport at all during the epidemic and preferred to use Internet taxis or agencies (57.29%), to protect their health, that is the economic pressure on households and the environmental problems caused by the release of fossil gases during the COVID-19 epidemic due to the use of single-passenger taxis. On the other hand, 74.73% of the respondents stated that it is impossible to avoid illness on public transport, which can be considered the most important reason people do not use public transport. Respondents believed that they would continue to use public transportation with more caution in the post- COVID-19 era, which requires the maximum attention of policymakers and city managers in the field of public transport in the post- COVID-19 era. Some effective factors in the use of public transport in the post-COVID-19 period include making wearing masks in indoor public spaces mandatory in the post-COVID-19 era, the continuation of disinfection of transport equipment, and proper use schedule from public transportation to social distancing. Additionally, based on the system dynamics approach, the variables affecting transportation according to the existing conditions in the pandemic situation were examined, and the change in the behavior of overcrowding of public transportation in the three cities of Tehran, Mashhad, and Isfahan in Iran was identified. The horizon studied in this research is 1000 days and is considered from February 17 2021. Also, considering a scenario, the effect of social distance on the status of using public transportation in pandemic conditions has been investigated. The results indicate that after a while, with the decrease in the epidemic peaks of COVID-19, public transportation will increase, and personal transportation traffic will decrease. However, in the current situation, people prefer private cars over public transport.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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