Modeling the Effect of Information Feedback on the SARS Epidemic in Beijing

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Abstract

Compared with many preventable epidemics, how did a relatively insignificant disease like SARS develop into an international scare? This article describes the application of system dynamics to understand the SARS epidemic in Beijing. The powersim model simulates the structure of transmission dynamics and factors that impact the epidemic. Here, the probable impacts of changes in the system delays, including delays to quarantine, delays of disease diagnose, and the authorities' epidemic information transmitting delays, are discussed. The model aims to present detailed understanding of delayed feedback mechanisms inherent to eliminate the misperceptions of basic dynamics, and then to design high leverage policies for preventing SARS. The article concludes that an open and transparent public information system is the most powerful weapon to curb SARS panics. The government's prompt epidemic information feedback system and relatively instant strong quarantine policies have substantial impacts on containing SARS epidemic.

Keywords: Information Feedback, SARS, Delays, Quarantine, System Dynamics

1 Introduction

1.1 Background Information

SARS (Severe Acute Respiratory Syndrome), an atypical pneumonia of unknown etiology, broke out in China at the end of February 2003. With symptoms similar to that of pneumonia, it is easy to get infected through secretion from respiratory organs and intimate contact. SARS infected 8,439 people in 30 countries on five continents with a death rate of 10 percent (812 people). China was the country worst affected by the epidemic, infecting 5,327 people nationally and killing 349. Especially Beijing city experienced the largest outbreak of SARS, with >2,500 cases reported between March and June 2003. Moreover, the extreme instances of SARS so-called superspreading events (SSEs), where single individuals have apparently infected as many as 300 others, appeared in Beijing.

1.2 Problem Description

Every time there is a scare like SARS, scientists worry that it might be the next big outbreak. Diseases can be both unpredictable and difficult to contain. Moreover, certain environments, such as Southeast Asia, with its high interaction between humans and animals, are optimal breeding grounds for the next super bug. And the increasing regularity of international travel makes it easy for a regional outbreak to quickly become a global one. In this regard, SARS is very much a sign of things to come.

The transmission routes of SARS

The virus is predominantly spread by droplets or by direct and indirect contact. The airborne spread of SARS does not seem to be a major route of transmission. However, the apparent ease of transmission in some instances is of concern.

Incubation period

SARS patients with chronic illnesses occurring concurrently with fever and/or pneumonia and who have a plausible diagnosis are the most challenging to the public health and healthcare systems. Early symptoms of SARS are non-specific and are associated with other more common illnesses. Unrecognized cases of SARS have been implicated in recent outbreaks in Beijing. WHO (World Health Organization) stated that the maximum observed incubation period was 10 days.

Strategies for preventing SARS epidemic

For the unclear virus source, so far, no exclusive medicine, vaccine or treatment for the SARS disease has been found, but most patients can recover by taking supportive and appropriate medical treatments in time. The strategies Beijing authority, medical institutes, and the masses take during the SARS time are three major policies.

1. “Quarantine policies”:

Force to isolate healthy persons who may contact the virus, isolate the infected persons who still no symptoms during incubation period, and isolate and cure the symptomatic patients.

- ***Who should be in Quarantine?***

Individuals who have come into close contact with a person with SARS and did not wear a protective mask. They should remain in quarantine for a 10-day period, even if they are not experiencing symptoms.

2. “Government investment on protection policies”:

A large-scale public SARS protection requires a wide range of services and medical treatment equipment such as masks, sanitizer, ambulance, anti bacteria medicine to be provided to individuals and hospitals. In Beijing, these huge investments were invested by government and some other private social service agencies.

3. “Public protection policies”:

When the public get the information about the density of suspected and in hospital SARS population, comparing with the safety reference density, they gradually reduce the opportunity to contact others to avoid being infected, and purchase and use protection equipment like face masks, sanitizer, and anti bacteria medicine.

2 Conceptual Model

2.1 Problem Hypothesis

The death and infection rate of SARS is similar to the influenza. However, in 2003, Beijing was hard hit. As of early May, the largest source of the epidemic is in China. Beijing has quarantined over 18,000 people, with 2,177 confirmed cases and over 114 fatalities. The size of the international response is overwhelming. So the level of fear and concern of SARS has triggered. When SARS appeared early, people in Beijing started panic buying food and medicine. Some were holed up at home, others fled to the countryside. At the beginning of SARS epidemic, the authorities’ inefficient epidemic information transmitting systems and downplaying the seriousness of the outbreak play a significant role in the uncontrolled spread of the SARS disease.

Every year, the world has influenza outbreaks that cause over a hundred thousand deaths with little comment. These 500+ SARS casualties, however, have triggered a worldwide epidemic of fear and suspicion.

- *How did a relatively insignificant disease like SARS develop into an international scare, causing alarm even in countries that have had no cases, or very few?*

Based on the case of Beijing, the 10-day incubation period of SARS induced our misperception of feedback. At the early stage of SARS crisis, the public did not realize that the SARS virus already spread like wildfire. After the delay of 10-day incubation period, the public just found that the amount of infected persons dramatically rose up. So they immediately took actions to prevent SARS, however, the speed of prevention could not catch that of virus transmission. Thus, authorities took strong actions to enforce quarantine. The major spread was under control. But the public did not know the dynamical trend that the amount of infected persons would fall after about one week; they only saw that the amount was continuously going up. Subsequently, the SARS global panic was sparked.

2.2 Causal Loop Diagrams

2.2.1 Public SARS Infection Sector

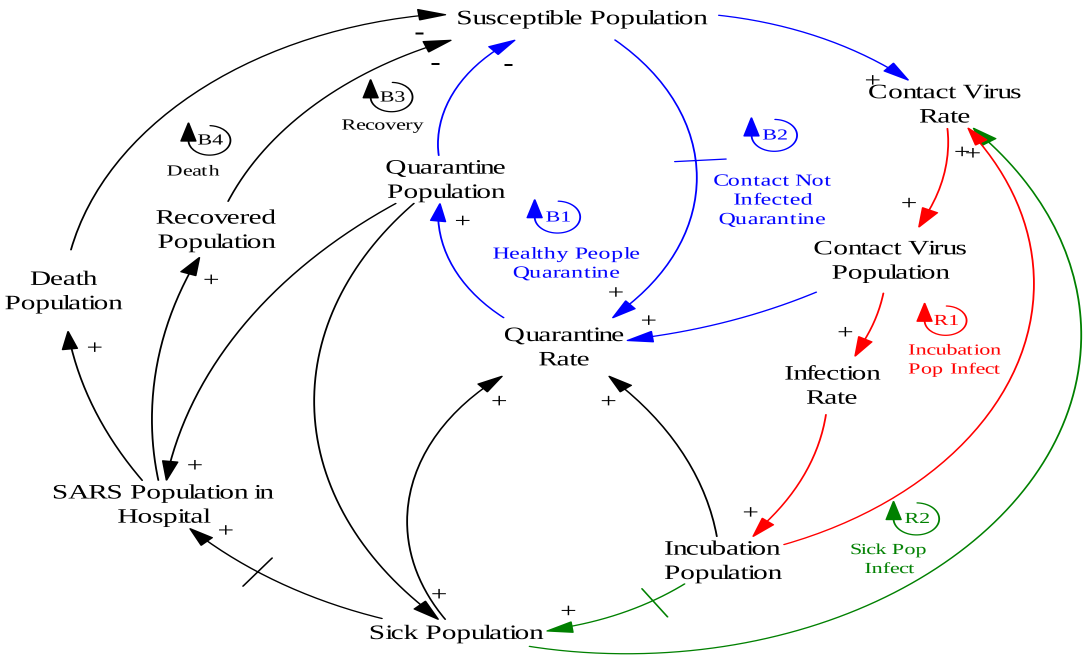


Figure 1: Causal Loop Diagram depicting the feedback structure of public SARS infection

Explanation of the major feedback structure:

R1: Incubation Population Infect Others

The incubation population, who are in the latent period, not in quarantine, can infect any other healthy people in the ordinary contact. So the larger the number of incubated not quarantine population, the higher the contact virus rate will be, the stronger contagion it has, vice versa.

B1: Healthy People Quarantine

According to the SARS epidemic situation when the government force a part of susceptible healthy population to go to quarantine to halt the contagion with the SARS disease, the number of susceptible healthy population will decrease, and then after 10-day quarantine period the susceptible individuals will be released from quarantine.

B2: Contact Not Infected Quarantine

The government force the contact virus not infected susceptible population to go to quarantine to prevent the potential infection and contagion with the SARS disease.

2.2.2 The SARS Prevention Policy

Without the vaccine and effective treatment to tackle SARS, therefore, nowadays the common method of quell SARS is to prevent the spread of SARS epidemic. The decline of SARS cases in the city to two kinds of factors, social one and natural one. Social factors, especially measures taken by the government, are decisive in reducing SARS cases. The measures taken by the city government, an important part of the social factors, proved correct, effective and timely. Those measures include the establishment of SARS-only hospitals and fever clinics, protection of medical workers, mobilization of the public and strengthening of surveillance work.

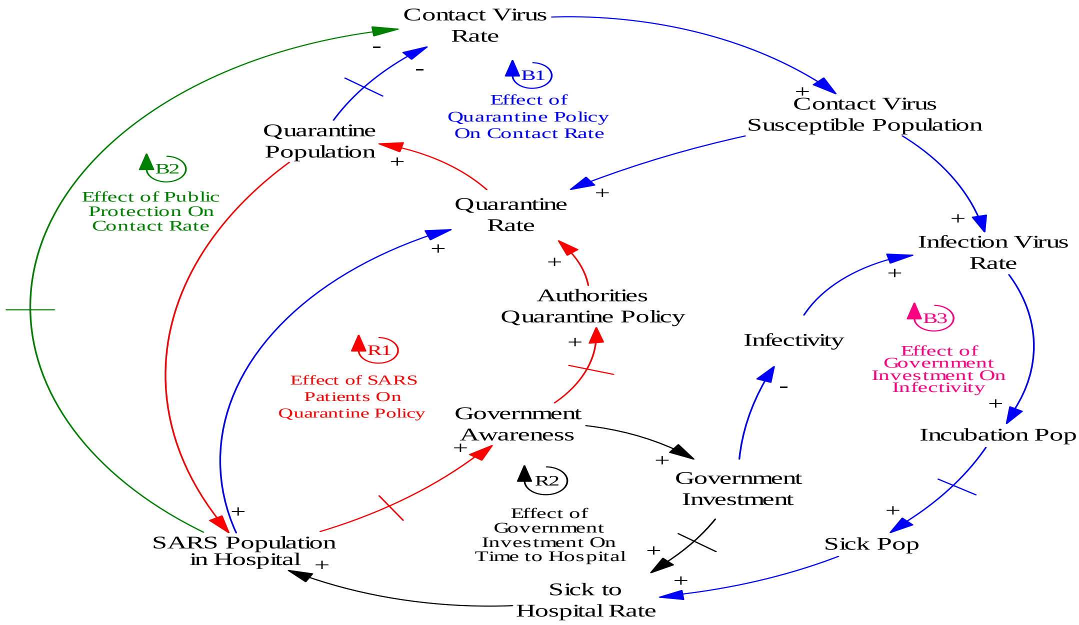


Figure 2: Causal Loop Diagram depicting the feedback structure of the prevention policy

R1: Effect of SARS Patients on Quarantine Policy

When the authorities get the information about the density of SARS population, they will change the quarantine rate. When the density is high, the government will dramatically increase the quarantine rate, vice versa. Thus, more sick people will be in quarantine and then go to hospital to halt the SARS epidemic.

R2: Effect of Government Investment on Time to Hospital

When the government gathers the real information about the number of in hospital SARS population, they will invest plenty of money in prevention materials, services and facilities to help the sick people go to hospital as soon as possible.

B1: Effect of Quarantine Policy on Contact Rate

According to the density of suspected and in hospital SARS population, when the government implement a strong quarantine policy, the contact rate with SARS infectious people will dramatically diminish.

B2: Effect of Public Protection on Contact Rate

When the public get the information about the density of suspected and in hospital SARS population, comparing with the safety reference density, they can spontaneously change their contact rate with others.

B3: Effect of Government Investment on Infectivity

A large-scale public SARS protection requires a wide range of services and medical treatment equipment to be provided for individuals and hospitals. When the government gathers the real information about the number of SARS situation, they will invest plenty of money in order to reduce the probability of infectivity.

2.3 Sectors

This SARS epidemic model is mainly divided into five sectors as follows:

- The basic module of public SARS infection
- The contact rate
- Probability of infectivity
- Quarantine rate
- Actual time to hospital

3 Formal Model

3.1 Basic Module of Public SARS Infection

Facing the new SARS disease, until now we have not found the vaccine and effective treatment, therefore nowadays every healthy population, except the SARS recovered people, has not immunity from SARS virus. Thus, all healthy people excluding SARS recovered people are the susceptible people.

When the susceptible people contact with the not isolated sick or incubation individuals, some of them will be very lucky not infected, however, the others will be infected with virus, and then become the incubation people. The lucky ones will be forced to go to 10-day quarantine period to halt the contagion and will be released from quarantine after 10 days.

According to the power of government quarantine policy, parts of the incubation people will be soon quarantined and then go to hospital. But the uncontrolled incubation people are still in the city to contact others. After the delayed incubation period, the incubation people will have the symptoms and become sick. The sick persons not isolated will be sent to the hospital at different response time.

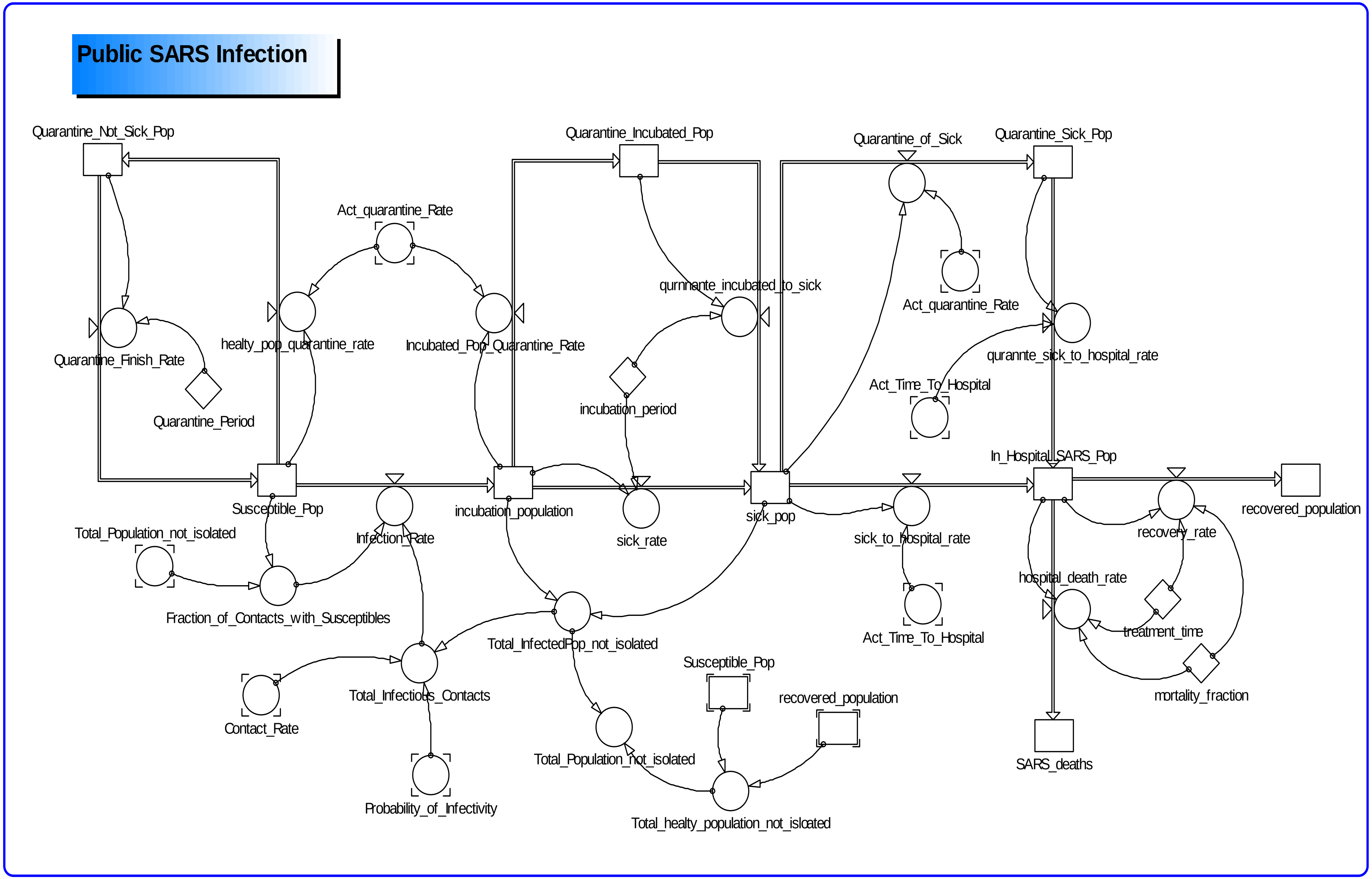


Figure 3: Stock and flow diagram - the basic public SARS infection sector

3.2 The Contact Rate

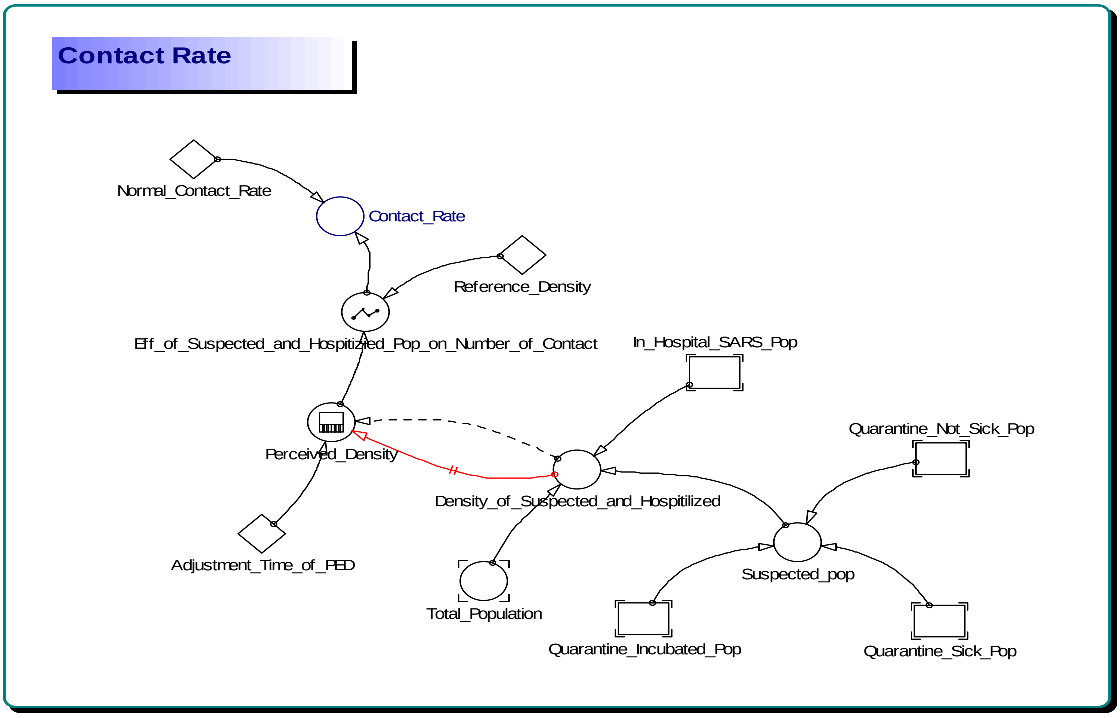


Figure 4: Stock and flow diagram - the contact rate sector

In this sector, we can clearly see the influential factors in the contact rate, the Effect of Suspected and Hospitizied Population on Number of Contact. When the public receive the information from media such as newspaper, television, radio, internet about the density of suspected and in hospital SARS population, they will change the contact rate with others according to the reported degree of SARS epidemic. When the density is high, the public gradually decrease the rate of contacting in the region to protect them from infecting, vice versa. That also names the effect of public protection on contact rate.

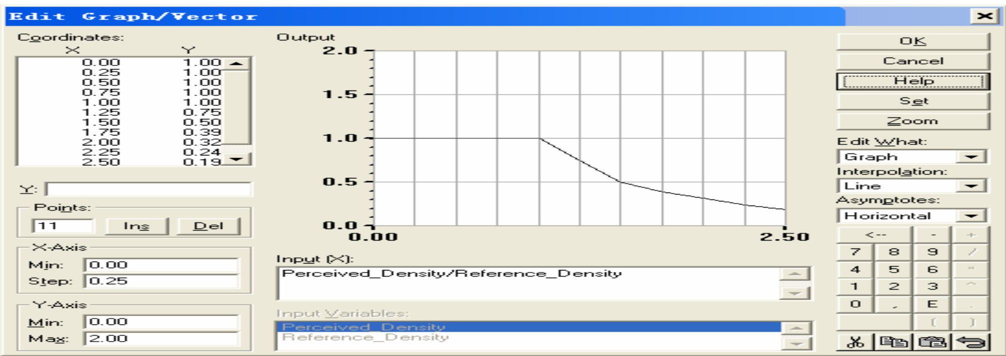


Figure 5: Effect of Suspected and Hospitizied Pop on Number of Contact (dimensionless)

So as the *Figure 5* above, when the perceived density increases over the safety reference density, it is the signal that SARS density is high (Perceived Density/Reference Density>1), so the Effect of Suspected and Hospitizied Pop on Number of Contact will gradually decrease, and people reduce the contact with others.

However, there are always some delays and over exaggerated reporting from the media. That is the information delay to get the real information about the density of suspected and in hospital SARS population. The relative adjustment time of perceived density is how many days we can get the reliable information.

3.3 Probability of Infectivity

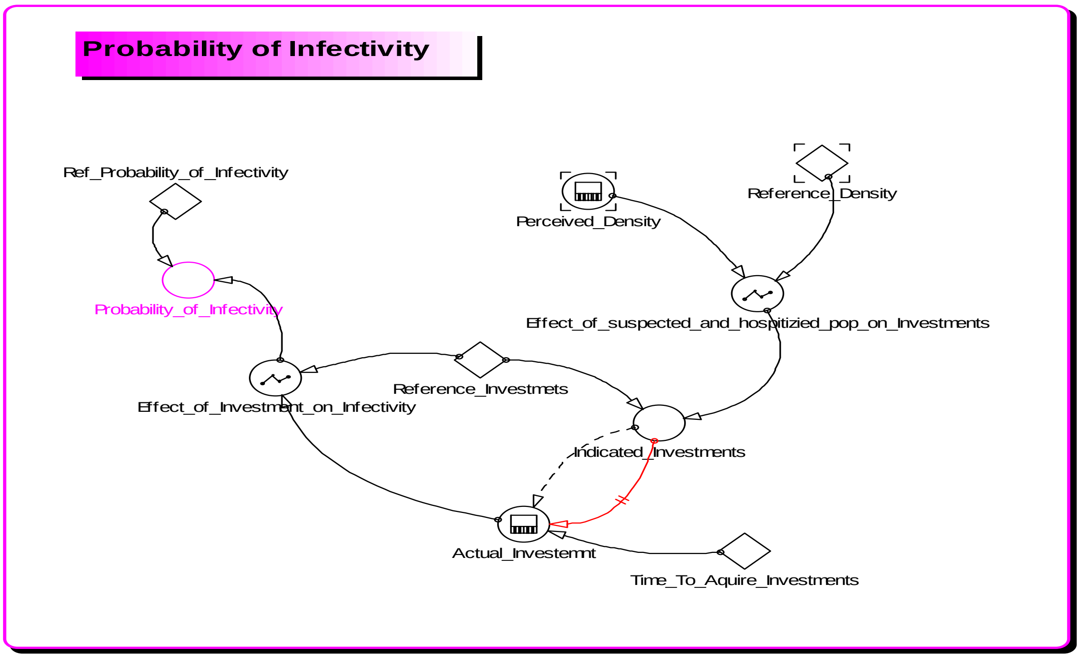


Figure 6: Stock and flow diagram - the probability of infectivity sector

As soon as the government receive the already delayed information about the density of suspected and hospitizied population, they will increase the investment for a large-scale public SARS protection to supply a wide range of health services and medical treatment equipment such as masks, sanitizer, ambulance, anti bacteria medicine, respirators to the individuals and hospitals. On the other hand, when the SARS epidemic is controlled and no more new infection cases appear, the government will gradually decrease the ratio of investment.

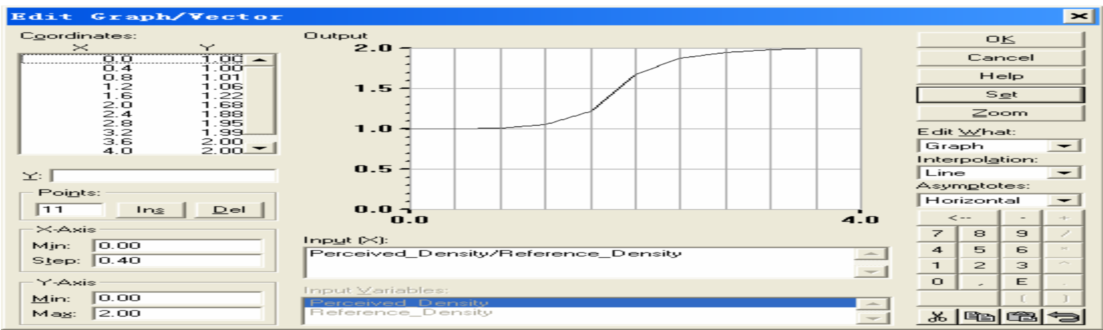


Figure 7: Effect of Suspected and Hospitizied Population on Investment (dimensionless)

It is easy to find that the Effect of Suspected and Hospitizied Population on Investment also shows the S-shape. When the perceived density is less than or equal to the safety reference, the investment will be the same as amount of reference investment. If the perceived density is more than the safety reference density, the investment will soon exponentially increase at first, but then gradually slows toward the equilibrium level, twice as large as the reference investment.

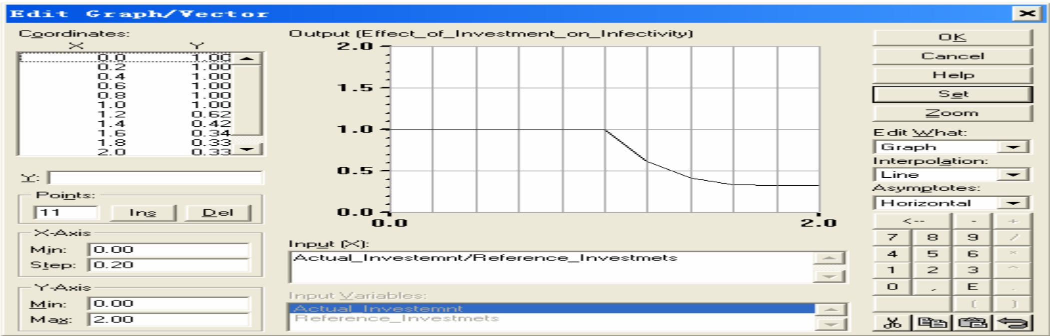


Figure 8: Effect of Investment on Infectivity (dimensionless)

The infectivity of the disease is the probability that a person will become infected after exposure to someone with the disease. When the government pays more attention and investment on public health and medical service, there will be more advanced medical treatment equipment and facilities available to the public in order to reduce the probability of infectivity. Thus, as the *Figure 8* shows, when the Actual_Investemnt/Reference_Investmets>1, the increased investment to crack the SARS will help to lessen the probability of infectivity.

3.4 Quarantine Rate

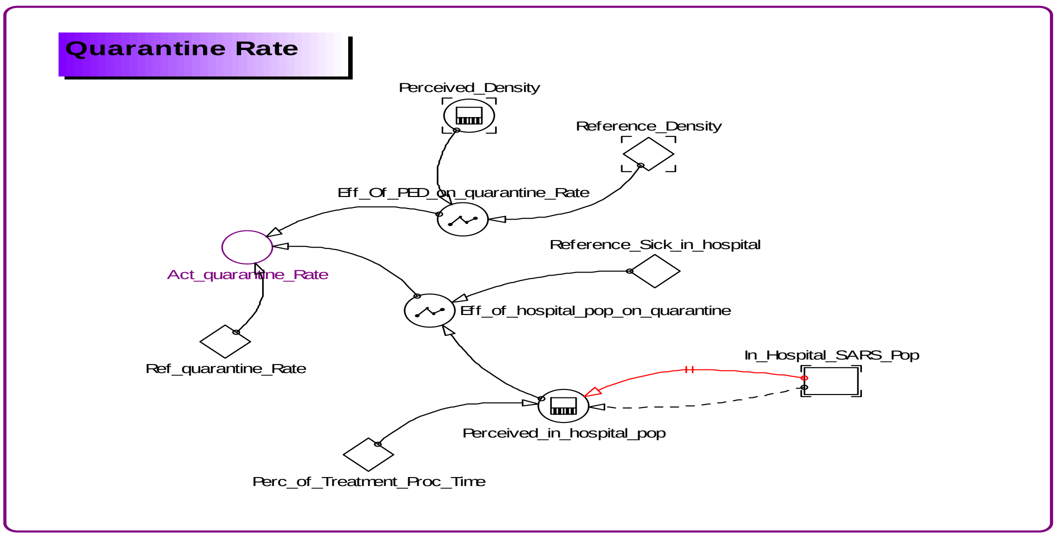


Figure 9: Stock and flow diagram - the Quarantine Rate sector

Figure 9 represents the structure of the quarantine rate, which is determined by the reference quarantine rate and two effects--- Effect of Perceived Density on Quarantine Rate, and Effect of Hospital Population on Quarantine.

The Effect of Perceived Density on Quarantine Rate shows the strength of government policy. When the government gathers the delayed information about the density of suspected people and in hospital SARS population, comparing with the safety reference density, the government will change the quarantine rate. When the density is high, the public quarantine rate quickly goes up, vice versa.

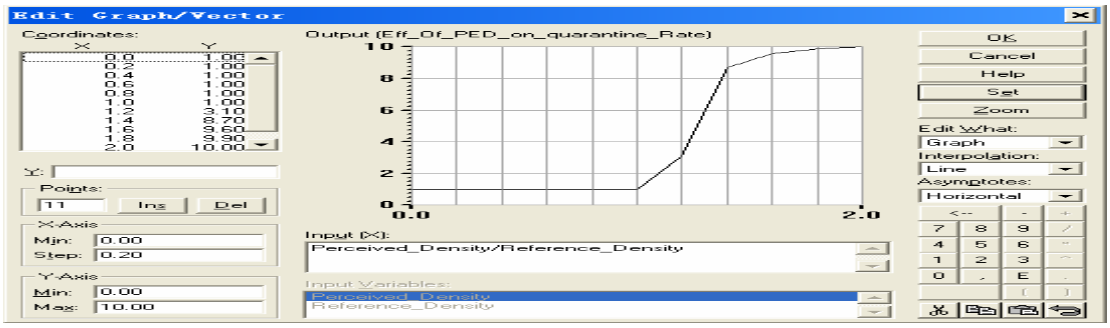


Figure 10: Effect of Perceived Density on Quarantine Rate (dimensionless)

The Effect of Hospital Population on Quarantine rate is another influential factor to quarantine rate. It describes that when the information about the number of in hospital SARS population has been received by government, comparing with the reference number (how many sick persons are in hospital is considered to be safe or acceptable), the government can change the quarantine rate. If the perceived number is less or equal to the safety reference value, the government will gradually diminish the quarantine rate. The isolated healthy people can leave their quarantine period to the normal working and daily life.

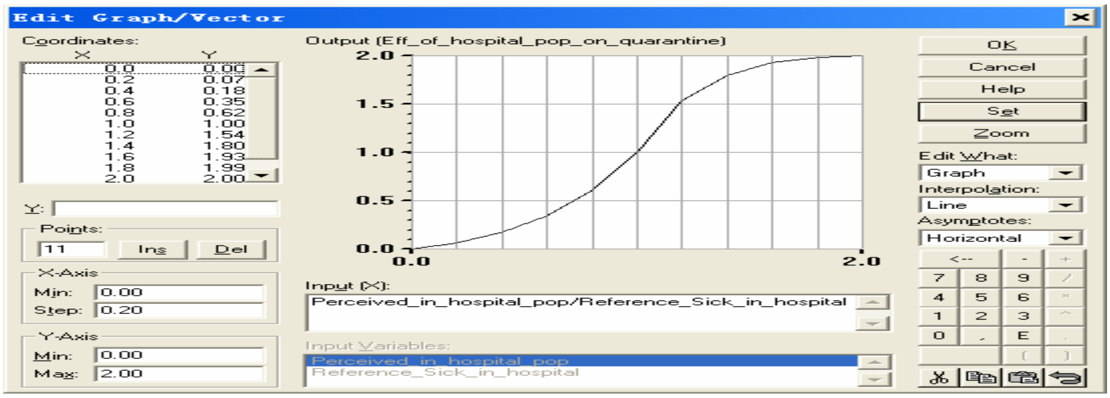


Figure 11: Effect of Hospital Population on Quarantine rate (dimensionless)

As follows, there is also an information delay about the number of perceived patients in hospital. This is an actual portraiture of the government information transmitting system.

3.5 Actual Time to Hospital

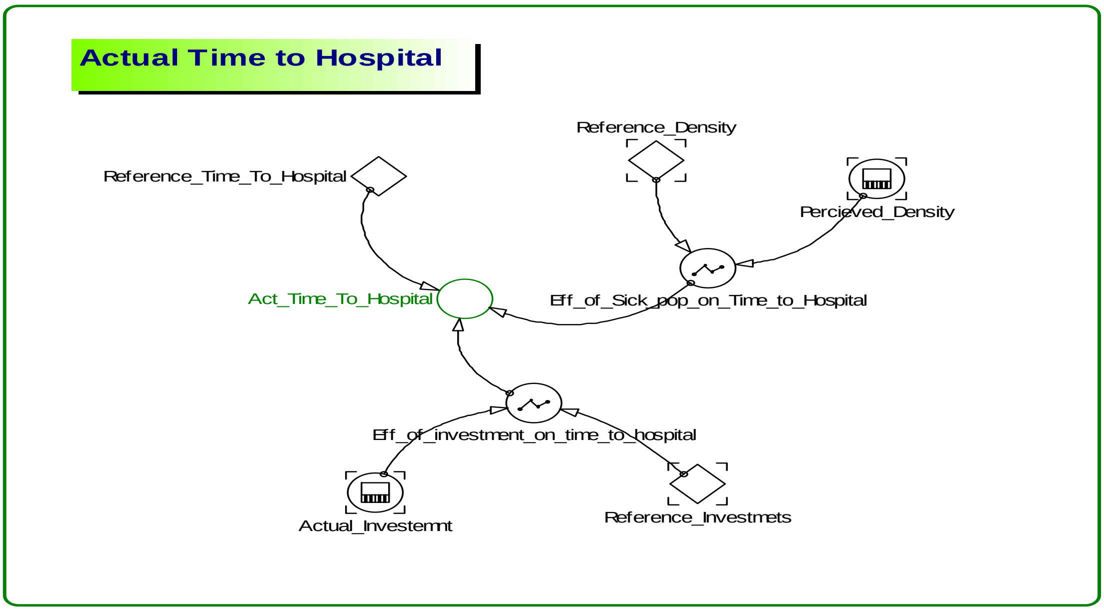


Figure 12: Stock and flow diagram - the Actual Time to Hospital sector

The actual time to hospital reflects how many days sick persons will go to hospital. There are also two effects, effect of sick population on time to hospital and effect of investment on time to hospital, to impact the time to hospital.

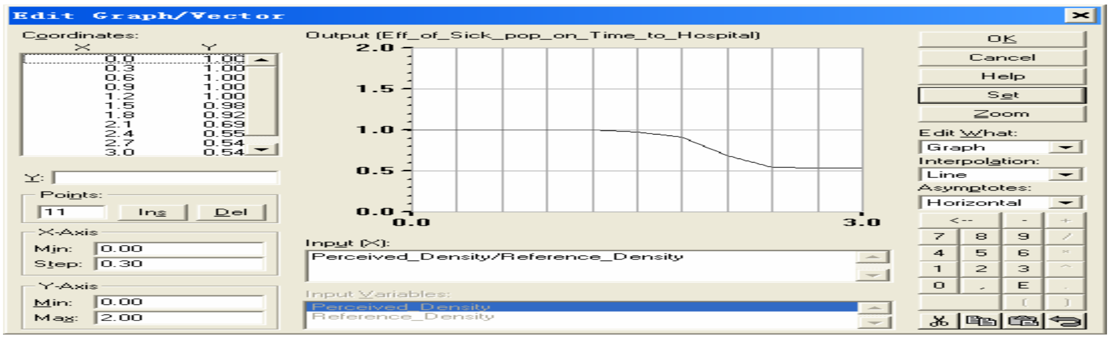


Figure 13: Effect of Sick Population on Time to Hospital (dimensionless)

When the perceived density of suspected and in hospital SARS population increases over the reference density, the sick people will be more attention and go to hospital more quickly, vice versa. Moreover, there is also an information delay to get the real time reports of the epidemic density.

The effect of investment on time to hospital has the same tendency as the effect of sick population on time to hospital. When the government pay more attention and investment on medical service, such as the more advanced medical treatment equipment, special SARS ambulance and other facilities available, to the public, the time of sick people to hospital doing the treatment will be shorter. There is also a material delay for the public to get the investment.

4 Model Validation

4.1 Extreme Conditions Test

Through developing the extreme input or policies on the model, we will examine the robustness of the model. Here are two extreme conditions tests in this section. One is the condition where the infection rate suddenly drops to zero, to see how the behavior of the system changes correspondingly.

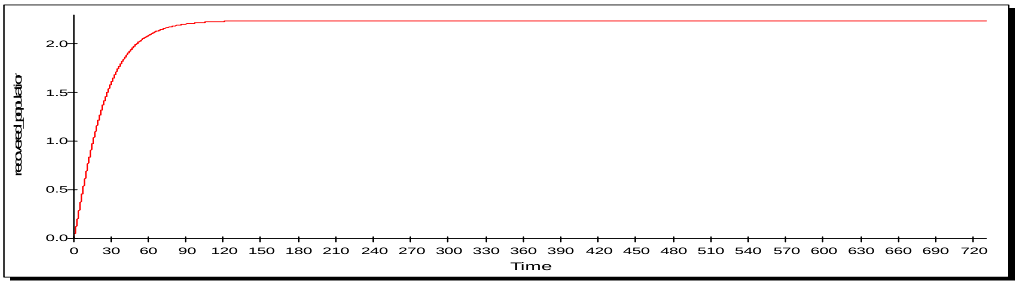
4.1.1 Extreme Condition Test I: A Sudden Drop of the Infection Rate

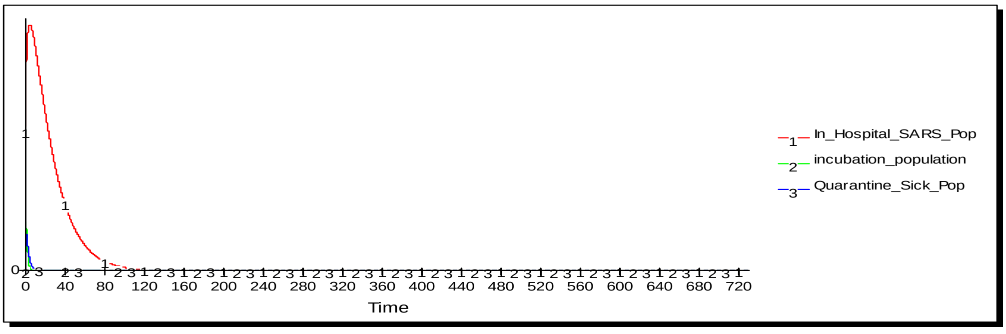
In this scenario, the total simulation time horizon is 730 days (2 years). Suppose that after 20 days, the infection rate suddenly and unexpectedly drops to zero. What would happen to the behavior of the system?

When we run the model under this extreme condition, if there is no infection rate, there will be no more people infected after all the incubation patients go to hospital, consequently there is no need to be afraid of the SARS, and, certainly, there is no need to have health people quarantined in the home. Thus, after somewhat delay, the healthy people will leave from the quarantine period and the SARS infection would disappear. Does the model generate the same behavior fashion as what we hope? Let us check it out in the following graphs below.

*Total_Infectious_Contacts*Fraction_of_Contacts_with_Susceptibles+STEP*

*(-Total_Infectious_Contacts*Fraction_of_Contacts_with_Susceptibles, 20)*





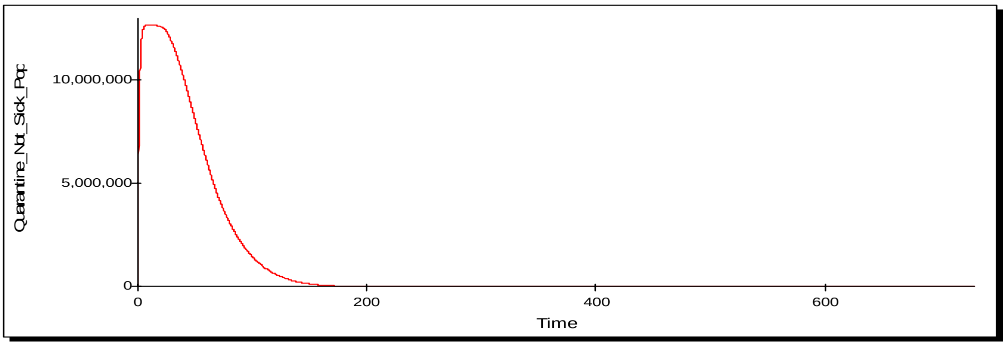
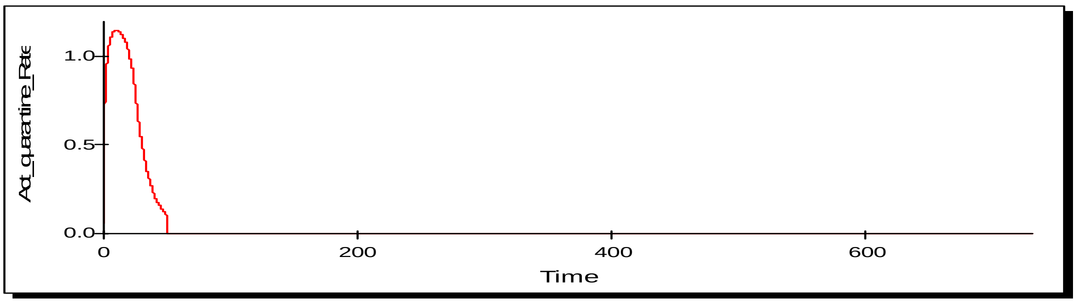


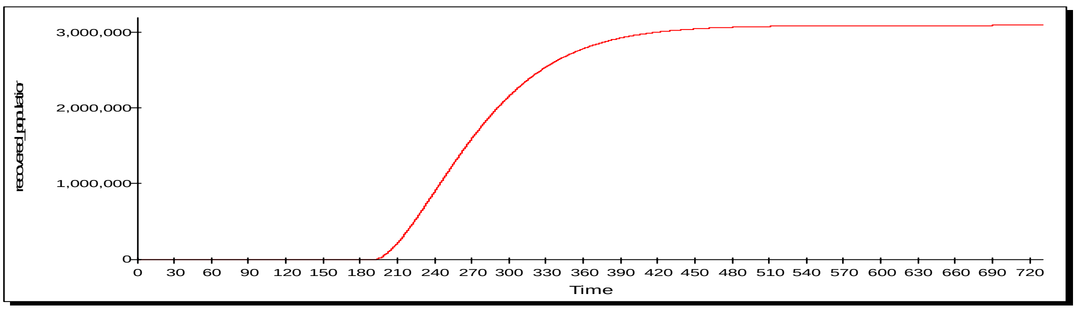
Figure 14: The System Behavior in Extreme Conditions Test I

Represented in the above equation, the infection rate suddenly drops to zero after 20 days. *Figure 14* shows that the quarantine SARS population starts to drop after a certain time of delay. The number of recovered population and the cumulative population will reach the equilibrium state at last. The behaviors resulting from the model match our expectation. So the model passes the extreme condition test I.

4.1.2 Extreme Condition Test II: A Sudden Drop of the Quarantine Rate

In this scenario, the total simulation time horizon is 730 days (2 years). After 50 days, we assume that, for some reasons, the authorities and public suddenly stop the quarantine policy (the quarantine rate decreases to zero). Under this extreme situation, there are no more people no matter the healthy or infected to be in the quarantine period. Then, what would happen to the society? No doubt, a serious SARS epidemic will break out in the city. The SARS will attack lots of people soon. A huge number of populations will be infected through contagion. The panic and rumor of SARS will spread around the city.





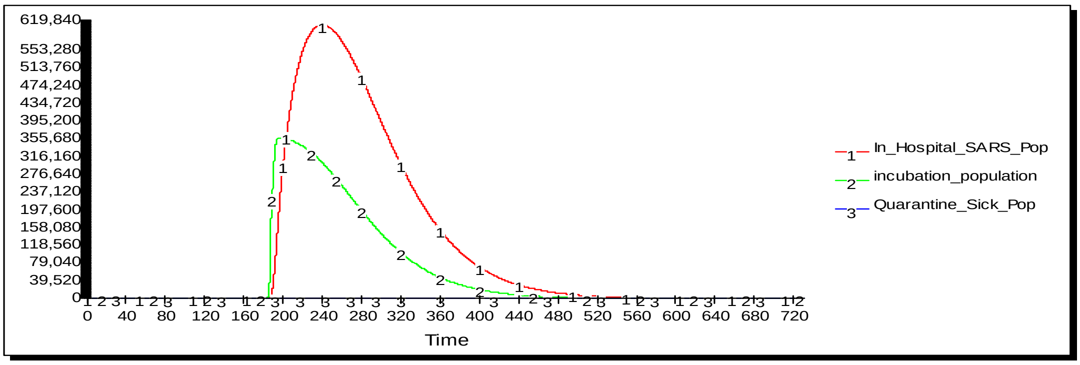


Figure 15: The System Behavior in Extreme Conditions Test II

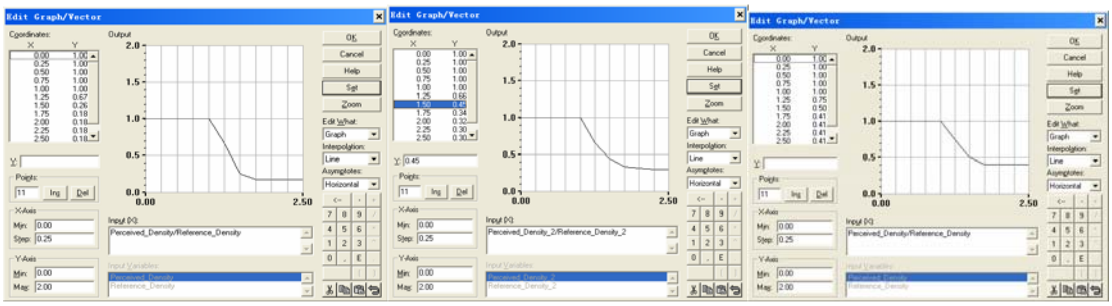
As *Figure 15* depicts that when the quarantine rate decreases to zero after 50 days, the total number of infected population will dramatically increase. Lots of healthy people are infected. A severe SARS epidemic happened. The behaviors resulting from the model successfully meet our expectation under this extreme test, and demonstrate the robustness of the structure.

4.2 Sensitivity Analysis

In this research, what counts here is behavior mode sensitivity and policy sensitivity. Given the limited time and resources, to do a comprehensive sensitivity analysis is impossible since it requires testing all combinations of assumptions over their plausible range of uncertainty. We execute two sensitivity analysis tests to the effect of suspected and hospitizied population on number of contact rate and the time delays in the model.

4.2.1 Sensitivity Analysis Test I: the Effect of Suspected and Hospitizied Population on Number of Contact Rate

When there are no policies of investment and quarantine in the base run, we change the effect of suspected and hospitizied population on the number of contact rate to test the model sensitivity.



Run 1-strong effect Run 2-normal effect Run 3-weak effect

Figure 16: The change of the effect of suspected and hospitizied population on number of contact rate

In the structure of this model, the contact rate is determined by the reference density and the effect of suspected and hospitizied population on number of contact rate. We form the table functions that describe this effect mainly based on our knowledge. We need a numerical description to formulate the equations. However, neither the current literatures nor available data offer the detailed information of the effect. Therefore, in this test, we are going to check whether the model behavior is still robust when we change the effects during the plausible range of uncertainty.

Figure 16 shows the three different formulations of the table function of effects. Run1 is a strong effect on contact rate. When the public receive the information about the high density of suspected and hospitizied population in the city, they will soon decrease the contact rate with others to a very low number. Run2 is a normal effect and Run3 is a week effect on contact rate respectively, by expanding different tendency in the graph.

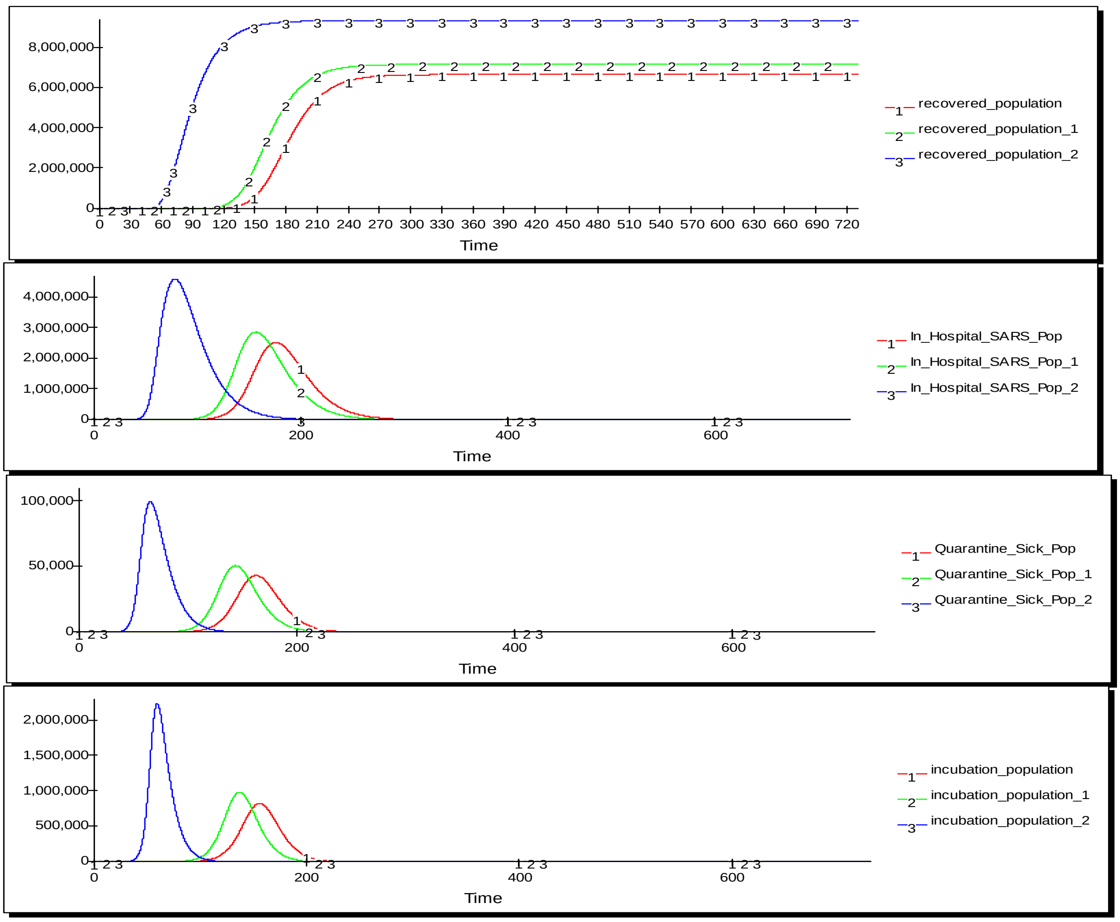


Figure 17: The comparison of the model behavior in sensitivity analysis test I

A set of behaviors resulting from the three runs is exhibited in the *Figure 17*. The pattern of behavior in each run is similar, but the amplitude for the level of the recovery population and the sick population is different. In the case of strong effect on the contact rate, the average level of the recovery population and the sick population climes up to a higher level than the other cases. In addition, the shape in the behavior shows a shorter period of delay.

From the results of the test, we do not identify a significant change in the pattern of behavior when we change the assumption of the effects on the contact rate over the different range of uncertainty. Therefore, we conclude that the model is not qualitatively sensitive to the table functions of the effects chosen in the model.

4.2.2 Sensitivity Analysis Test II: Time Delays in the Model.

In the structure of the model, the major time delays include the adjustment time of perceived density, percentage of treatment process time, and the time to acquire the investment. The time delays have no data available to estimate their values accurately. Therefore, in the sensitivity analysis test, we run the model with the time delays changing over different range of uncertainty to check whether the behavior has been changed.

When there are government policies of investment and quarantine in the run, we change the adjustment time of perceived density, which is how many days we can get the information about the density of suspected and in hospital SARS population, to test the model sensitivity; percentage of treatment process time, which is how many days we can get the information about the number of in hospital SARS population.; and the time to acquire investment, which is how many days we can get the investment.

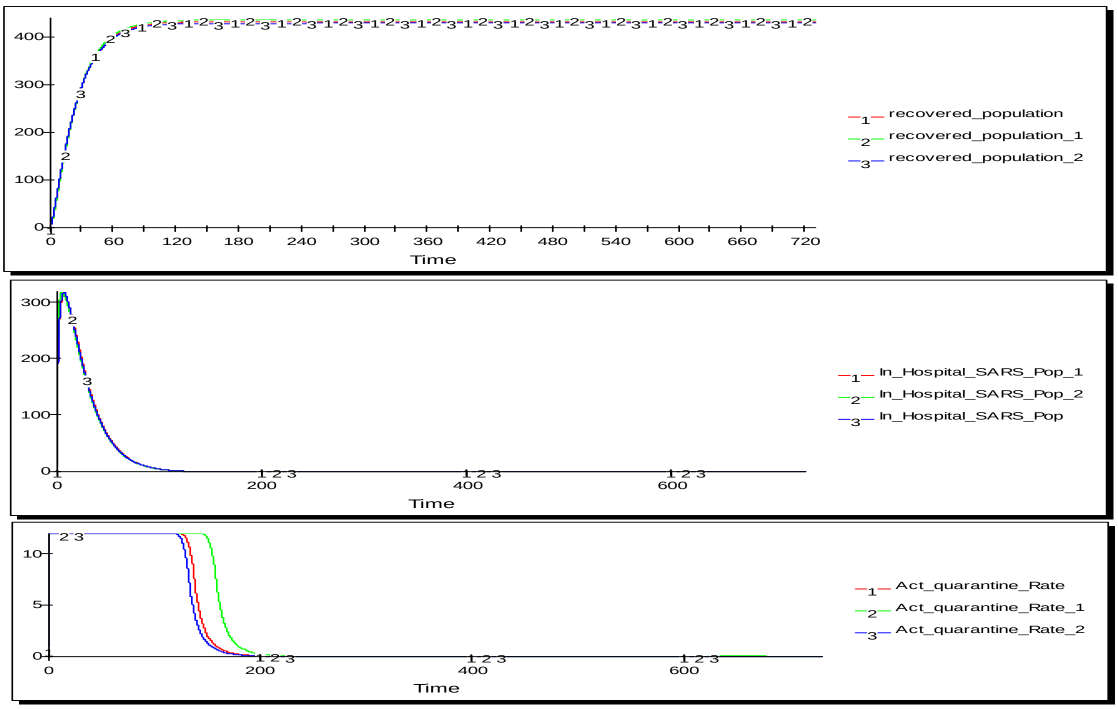


Figure 18: The comparison of the model behavior in sensitivity analysis test II

Normal Run1: Adjustment_Time_of_PED=7, Perc_of_Treatment_Proc_Time=5
Time_To_Acquire_Investments=7

Strong Run 2: Adjustment_Time_of_PED=21, Perc_of_Treatment_Proc_Time=15, Time_To_Acquire_Investments=21

Weak Run 3: Adjustment_Time_of_PED=1, Perc_of_Treatment_Proc_Time=1, Time_To_Acquire_Investments=1

As we can see from the *Figure 18*, the pattern of behavior in three runs keeps the same. The only difference is that with a longer delay involved, the tendency of the quarantine rate shows a correspondingly longer period. With longer delays it takes more time for the system to respond the perceived requirements.

From the above results of the test, we do not find a significant change in the pattern of behavior when we change the assumption of the time delays over the different range of uncertainty. Therefore, we certainly conclude that the model is not qualitatively sensitive to the values of time delays chosen in the model.

5 Simulation and Behavior Analysis

This section represents the result of model simulation under three scenarios: a base run and problem statement, policy design and an ideal situation.

5.1 Scenario1: Base Run & Problem Statement

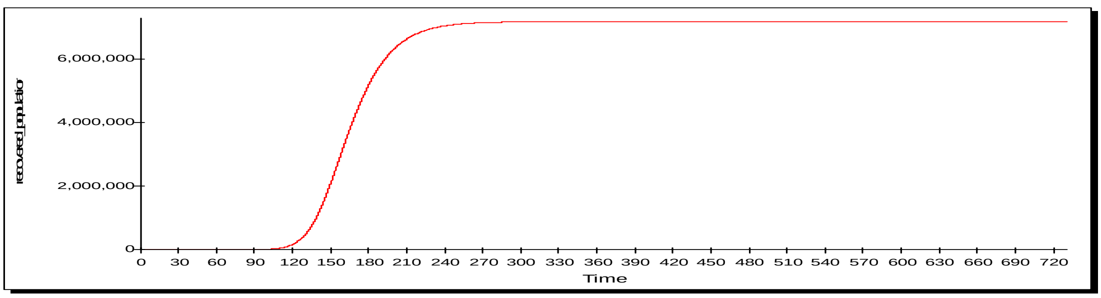
We first run the base run, which has not the government policy and public policy in quarantine and investment. So the government policies are all the constant 1:

Effect_of_Investment_on_Infectivity=1 Eff_of_investment_on_time_to_hospital=1
Eff_Of_PED_on_quarantine_Rate=1

In this scenario we do not consider the government investment and quarantine methods. In addition, the public policies are also the constant 1:

Eff_of_Suspected_and_Hospitizied_Pop_on_Number_of_Contact=1
Eff_of_hospital_pop_on_quarantine=1

Base Run:



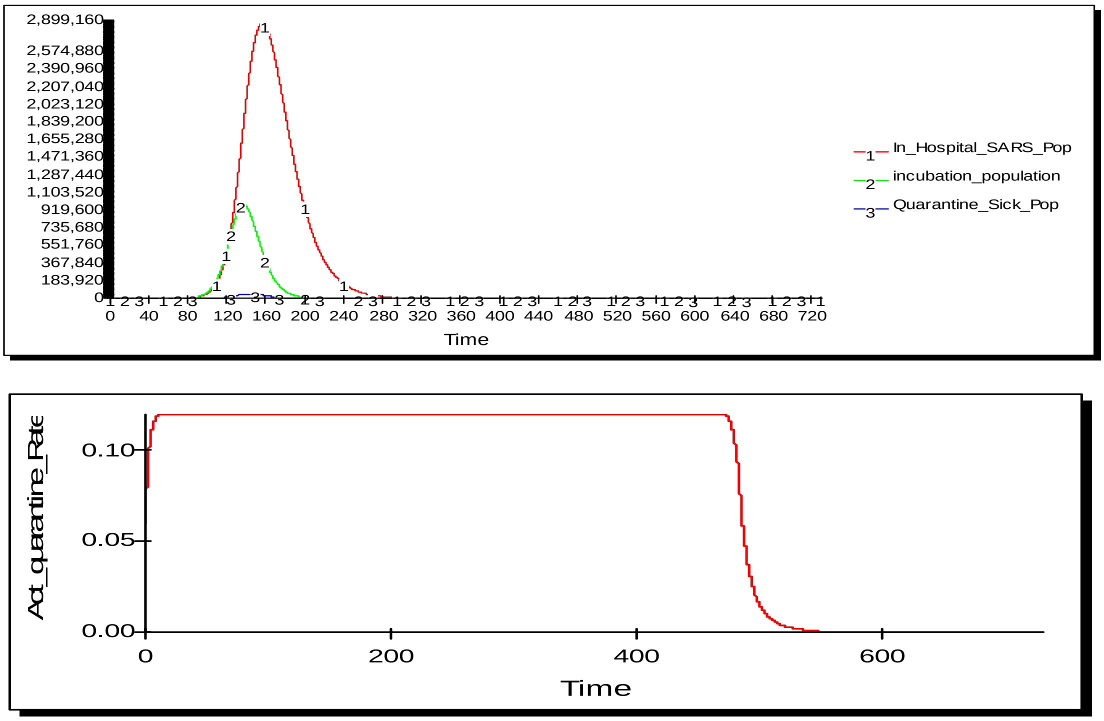


Figure 19: The Behavior of Scenario1: Base Run & Problem Statement

With a disease like SARS, the mortality rate (eventually 20 percent of those infected) was high enough, if quarantine procedures were not initiated quickly, what will be the result of uncontrolled? We can clearly get the answer through the *Figure 19*; the simulation outcomes show a severe SARS epidemic. More than half of the people in the Beijing city will be infected by SARS virus. No doubt, we have to take a serious look at epidemics when considering disaster scenarios. There are many ways by which the impact of an epidemic can play out. The real worry is if a contagious disease will not be controlled as quickly as possible, and we may face the realistic horror as the scenario 1.

5.2 Scenario2: Policy Design

In this model, we consider three strategies for preventing SARS epidemic in Beijing. They are respectively quarantine policies, government investment on protection policies, and the public protection policies. Through the simulation, we can clearly see the behavior in the following *Figure 20* to synchronously analyze the affectivity of the policies in the model.

Initial Value:

sick_pop =300, incubation_population =100, Reference_Density =0.00001

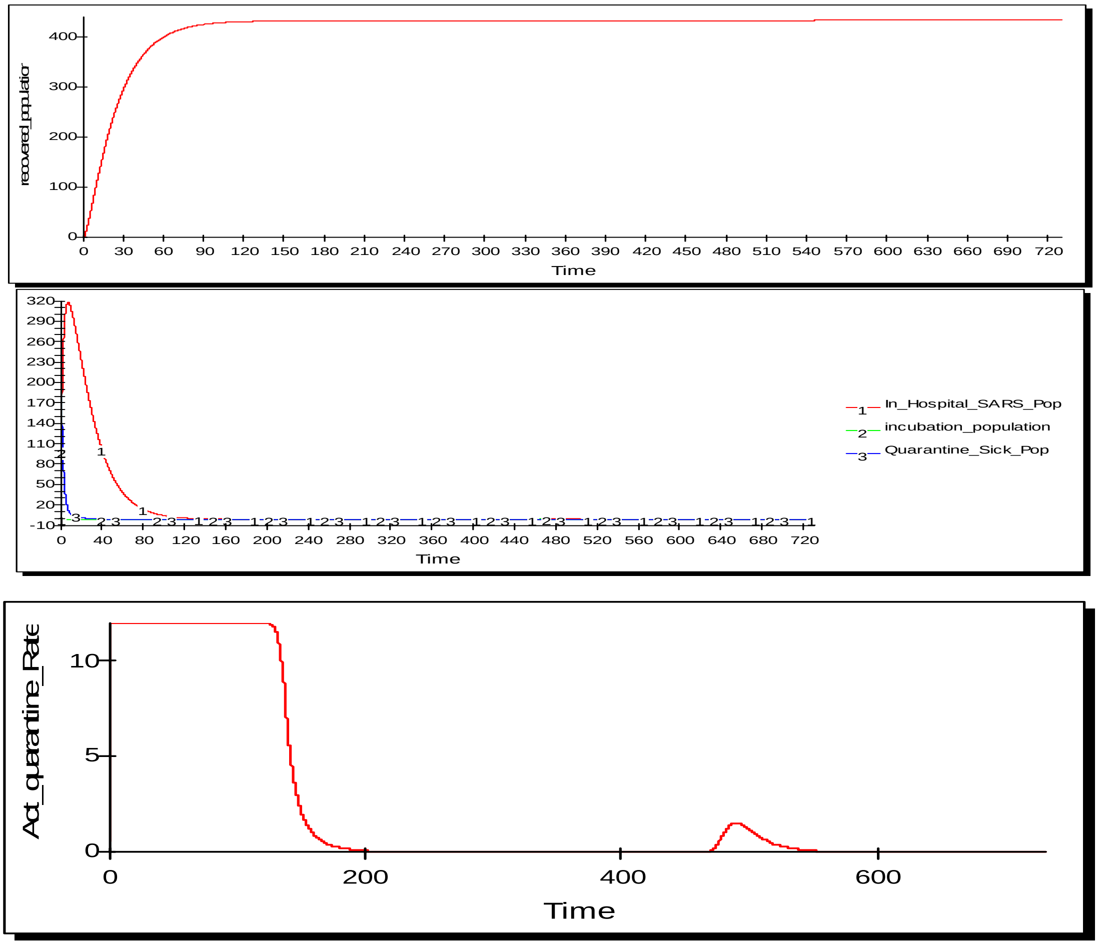


Figure 20: The Behavior of Scenario2: Policy Design

Assume that the initial number of SARS sick population is 300 and the amount of the incubation population is 100. Set the reference safety density, how many sick persons per 100 is considered to be safe or acceptable, as 0.00001. According to the *Figure 23*, it is easy to find that the number of recovered population and sick people effectively diminish, however, in the second year, about 500 days later, the SARS comes back. The time delays in the system beget the small range oscillation.

5.3 Scenario3: An Ideal Scenario

Through the policy test, we totally agree that the public quarantine policies and protection policies really effectively and dramatically reduce the bad large SARS contagion, and halt the degree of epidemic. In 2003, human beings stopped the serious spread of SARS disease; however without vaccine and immunity, what will happen later?

No doubt, the next issue we have to face is how to prevent the back of SARS epidemic. How can we halt the tendency of the comeback of SARS and other global pandemic? Through the section of policy design, after analyzing the simulation behaviors, we can find that the value of reference density is a key point.

Initial Value: sick_pop =300, incubation_population =100, Reference_Density =0.000001

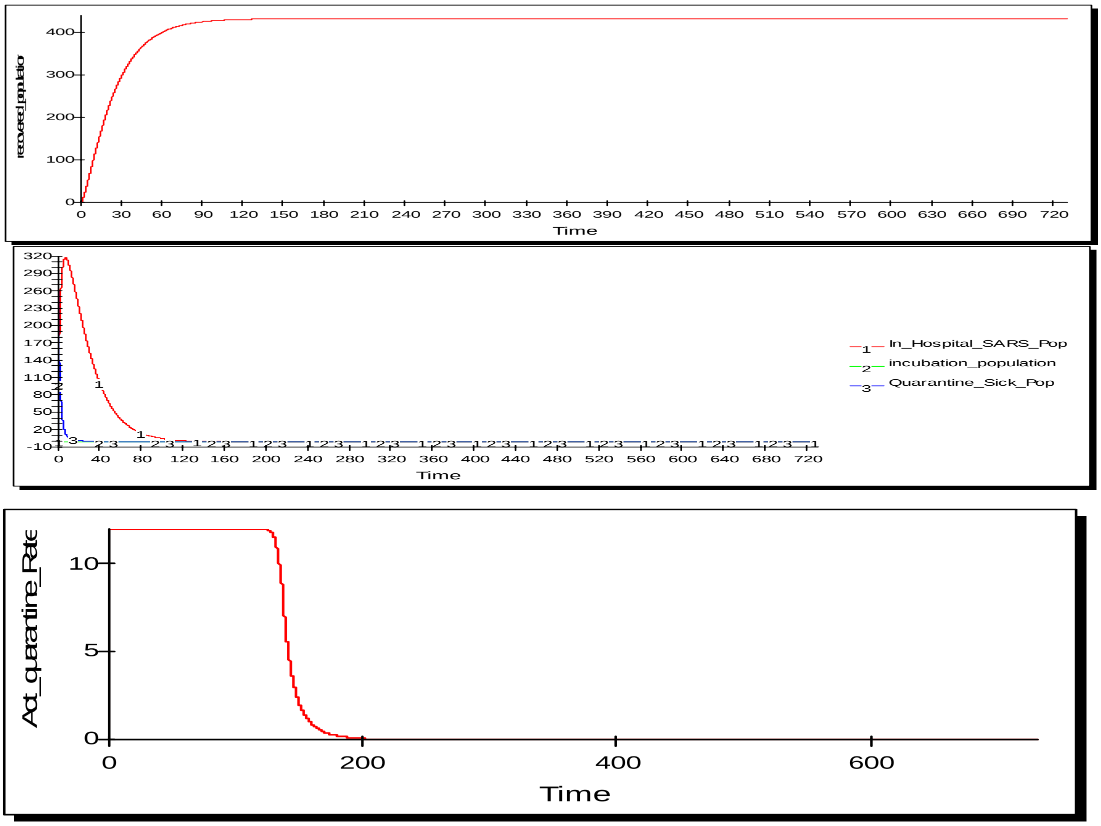


Figure 21: The Behavior of Scenario3: An Ideal Scenario

In this scenario, we decrease the reference density to a smaller number, which means there will be more attention paid to prevent SARS in the society. When the government showed both courage and effectiveness in correcting the initial statistical confusions and gave daily reports of the incidence via TV, newspaper and radio, set the reference safety density as 0.000001. According to the *Figure 21*, it is easy to find that the number of recovered population and sick people effectively diminish. The panic subsided quickly. Moreover, in the second year, there is no oscillation; the SARS epidemics do not come back. This policy certainly effectively diminishes and even retards the restoration of the SARS epidemic.

6 Conclusion

Complex system such as SARS epidemics with many variables, long time delays, nonlinearities and uncertainty about the cause and effect, is harder to explain and estimate without the use of system dynamics. Using system dynamics method, we have learnt how to create a map of the complicated causal inter connections within all variables so that we can chart a clear route of disease infection. Providing a method of eliciting mental models about problems and visualizing them as models helps the public and government to understand the structure and enhance the accuracy of data provided from surroundings with dynamic complexity, long time information and material delays.

The leading-edge computer simulation techniques help us see the outcome of policies and use system dynamics models to analyze effective policy options. The goal of this system thinking and system dynamics modeling is to improve our understanding of the ways in which our performance is related to its internal structure and operating policies, and then to use that understanding to design high leverage policies for preventing SARS epidemic.

6.1 Major Findings and Results

Expected Outcomes and Insight:

The system dynamics model described in the paper shows how the delayed feedback mechanisms inherent in the complex SARS transmission structure influence the behavior patterns overtime. It emphasizes the difference between the actual and perceived conditions as a basis for changes in the structure. The model aims to present the clear and detailed understanding of the delayed transmission system to eliminate the misperceptions of the basic dynamics.

Beijing's SARS outbreak case yields important lessons for global public health and crisis management. From panics to scientific policies in Beijing's SARS events, we could find that transparency is the most powerful 'weapon' to curb public panic and the spread of rumors, which could have stirred more panic. We cannot overcome the threat of SARS without an open and prompt public information system.

To sum up, the response time and the strength of control measures have significant effects on the scale of the outbreak and the lasting time of the SARS. Detect the SARS cases early, then isolate infected persons swiftly, take the treatment quickly. According to these policies, we can gradually control the disease and actually break the chain of transmission.

6.2 Limitation and Future Work

Future work should certainly focus on other epidemiological parameters in a variety of circumstances and use SARS-specific parameters to construct more detailed models of transmission that realistically incorporate the effects of heterogeneities in specific settings. In addition to the control measures considered here, I expect other aspects of SARS transmission, such as the duration of acquired immunity, the effect of seasonality on transmission rates, and the role, if any, of animal reservoirs, will be important determinants of the future course of the SARS epidemic.

On the other hand, it's a simple hypothesis. In the real model, the situation will be much more complicated. Every city is not an isolated point. The movement of people between cities connects all surrounding cities into a very complex system. We can try to enrich the creation of a multi-city disease model and the incorporation of travel statistics to give the public another reference point to reduce the contagion by travel.

Finally, with the development of antibiotics, advanced medical procedures, global communications and much improved epidemiology, this syndrome, SARS, will not be a worldwide health threat. The world works together to find its cause, cure the sick, stop its spread and finally we will definitely crack the SARS.

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