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The impact of inspection policies on reducing disease prevalence in public buildings: A systems dynamics approach

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ABSTRACT

The occurrence of the COVID-19 pandemic revealed new dimensions of urban resilience to communities. Failure to implement health protocols in public buildings has had a significant impact on the spread of the disease, and inspection has become necessary to enforce the rules. This study presents different inspection policies of public buildings to reduce disease prevalence. It evaluates and compares the implementation of these policies in the long run based on the systems dynamics approach. First, baseline modeling was performed without inspection to analyze the proposed policies, and disease prevalence was investigated. Then various proposed inspection and fines policies, including fixed inspection and fines rate (FIFF), fixed inspection rate with the variable fine rate (FIVF), and variable inspection and fines rate (VIVF), are introduced, and their system dynamics models are presented. The impact of each inspection policy on the violations rate and disease prevalence in public buildings has been investigated using long-term simulation. Based on the results, regulatory agencies can significantly reduce the rate of violations in public buildings and improve urban resilience to the epidemic by adopting proper inspection policies. The results can help city managers to adopt appropriate inspection policies.

1. Introduction

The dangers of epidemic catastrophes became clear to human societies after the outbreak of the COVID-19 disease. The COVID-19 epidemic caused severe economic, social and cultural damage [1,2]. By the end of March 2022, more than 6 million people had died from the disease [3]. Although the hope of overcoming the COVID-19 has increased with the development and distribution of the vaccine, experts believe that similar epidemic catastrophes will be very likely in the future [4]. However, there is still a possibility that mutated disease species will spread. Indeed, the world after COVID-19 will be different from before [5]. Countries are looking for preparedness to face pandemics, especially in cities, and urban resilience to epidemics has been considered by researchers [6,7].

According to the World Health Organization and relevant experts, the most critical measure for urban resilience against the pandemic is to prevent the spread of disease [8–10]. Although urban quarantine greatly impacted the spread of the disease in different countries [11], it caused people’s livelihood and economic problems in countries [12]. In the meantime, an adequate measure of urban resilience was the definition of health protocols for various places, including public buildings. Governments defined health protocols for various urban sites such as public transportation [13], religious places such as mosques [14], and public buildings (such as banks and offices) [15]. Adherence to the implementation of health protocols can simultaneously continue the daily activities of public buildings and prevent widespread disease in the city [16].

However, after announcing health protocols, the big challenge is properly implementing these protocols in various centers, including public buildings. Previous experiences have shown that managers and employees of public buildings fail to follow the rules in the absence of supervision and inspection [17]. Restrictions on resources, including human resources in inspection organizations, have made it necessary for inspection organizations to plan and manage the inspection of violators. In many cases, proper design and inspection can effectively reduce the rate of violations in various cases [18,19]. Researchers have proposed and used a variety of approaches to review and determine inspection policies [20,21]. Among the proposed approaches, the system dynamics approach has been increasingly considered by researchers due to its ability to simulate and evaluate the results of various policies in the long run [22,23]. It is essential to examine the impact of different inspection policies on public buildings adhering to health protocols during an
epidemic. In line with the issues raised, this study seeks to answer the following questions:

A) What are the most critical factors in spreading the epidemic in public buildings? How can the impact of these factors be examined using the system dynamics approach?

B) What are some examples of inspection policies that governments can take to reduce violations of public buildings?

C) Which inspection and fines policies are more effective?

About the contribution of the present study, this study addresses for the first time the issue of inspecting public buildings for health protocols. In this regard, issues such as client entry rates to buildings and the number of building staff, service rates, and the level of compliance with health protocols by staff have been considered. Also, in this study, for the first time, the effect of various inspection policies of public buildings on the risk of epidemic spread in public buildings, in the long run, is investigated.

After reviewing the literature in the second part, the definition of the problem is done in the third part. It is also validated by creating a basic model. In the fourth section, different inspection policies are presented and modeled to improve the conditions. By simulation, the results of each policy are reviewed in the long run. The fifth section presents an analysis and comparison between policies and managerial perspectives are presented. Finally, various contents and suggestions for future research are presented in the sixth section.

2. Literature review

This study investigates the issue of inspecting public buildings for compliance with health protocols using a system dynamics approach. Therefore, it is better to review the most important previous studies on "epidemics and public buildings" and "system dynamics and inspection problems."

2.1. Epidemics and public buildings

With the expansion of cities and offices, public buildings were created to provide services to the people. Various studies have been conducted on catastrophes related to public buildings. Most studies have dealt with disasters such as earthquakes, floods, fires, and hurricanes that cause physical damage to buildings and their occupants[24,25]. Some studies were on the disaster preparedness signs in public buildings and made suggestions for the location of the signs to prevent people from becoming more aware[26,27].

Although research into epidemics of diseases such as pandemic (H1N1) 2009 has a long history[28], the issue of post-COVID-19 epidemics has come to the attention of researchers. In the meantime, studies have examined the airborne transmission of COVID-19 in indoor environments such as banks and restaurants[29,30]. Orazio et al. investigated how public buildings resumed operations after the onset of epidemic diseases[31]. They proposed an agent-based model to estimate the prevalence of the virus in public buildings. Based on their results, masks are an essential strategy in preventing the spread of the disease. Bhagat and Linden examined the issue of air conditioning in environments such as banks and restaurants[29,30]. Orazio et al. used a system dynamics model to examine the control system of COVID-19 in Taiwan and studied its system behaviors[47]. They concluded that six critical loops created the epidemic control system in Taiwan. These loops are entrance control and quarantine, privacy and compliance with quarantine, mask-wearing culture and economic actions, mask production, mask supply and demand, testing capacity, and medical care capacity.

Scientific system dynamics in inspection problem analysis is first used by Batachareja et al. in safety issues[48]. With diagnoses and safety rules required by the mines, they examined the status of rules and inspections on the safety of mines by simulating system dynamics. Their results were the effectiveness of inspection policies on safety promotion. Due to the efficiency of the system dynamics, this view has been used in other studies on mine inspection[49-51].

Also, in the issue of the environment, the issue of inspection with a system dynamics approach has been used. Using evolutionary game theory and system dynamics, Cai et al. examined the issue of inspecting companies for compliance with environmental laws in their activities[52]. In this case, companies chose to follow and not follow the law. The government decided between inspecting and not inspecting. Results showed the effect of the penalty coefficient on the legitimacy of companies. In another study, Duan et al. used two system dynamics models to examine the issue of environmental pollution control through company inspections[53]. The proposed models were based on static and dynamic fines policies. They examined the interests of society resulting
from interactions between government and industry. The results of their study show that the implementation of combined inspection policies further enhances the overall interests of society.

Zhu et al. proposed a system dynamics model and examined the issue of food waste management, given the conflicting interests between government, food centers, and waste collection companies [54]. In the proposed model, the government adopts the policy of inspection and fines after legislation to prevent illegal behaviors. The simulation results indicate the need for inspection and fines to reduce food waste and effective waste management. Azmi and Tokai examined the impact of various inspection policies for collecting used vehicles and their replacement, tax policies, and related laws through simulation [55]. Then, using a system dynamics model, they estimated the number of used cars and electric vehicles in 2040 for Malaysia. Based on the results, the adoption of appropriate tax policies, proper inspection policies, and pollution standards increased the number of electric vehicles by 70%.

In conclusion, it can be said that due to the characteristics of the system dynamics approach, such as dynamics and simulation capability, the use of this approach in the analysis of inspection policies has been successful. It seems that the issue of inspecting public buildings to prevent the spread of an epidemic can be investigated using this approach.

3. Problem structure and formulation

3.1. Problem definition, assumptions, and dynamic hypothesis

Due to the problem of epidemic outbreaks and the increasing number of patients, numerous studies have led to the provision of health protocols for the continued operation of public buildings by international organizations such as the WHO, Food and Drug Administration (FDA), and public health authorities in various countries such as became England and Australia [33,56]. The most important common rules among most protocols include the following [57]:

- The use of masks by clients and employees inside the building
- Proper sufficient ventilation system to prevent the airborne transmission of SARS-CoV-2 on the buildings
- Observing the social distance between people inside the building (observing the maximum number of people allowed inside the building)
- Periodic disinfection of office equipment such as tables and chairs
- Observance of employees’ health rules (avoiding gatherings, avoiding unnecessary physical contact).

Researchers have repeatedly recommended the need for proper ventilation inside various areas such as buildings [58,59]. This has led to installing ventilation systems in most buildings during the epidemic. Also, due to the short-term presence of clients inside the building, it is not difficult for them to follow health protocols. However, due to long-term presence, work fatigue, and lack of supervision, there is a tendency for non-compliance with the protocols by building employees who work one shift (usually 6–10 h a day) inside the building. Reports indicate that many employees inside public buildings disobey the law [60]. Given the daily presence of many citizens in public buildings, it seems that if adequate inspections of public buildings are not carried out, it will only lead to a widespread outbreak of the disease in the city.

After stating the problem, the problem is simulated for a public building, the assumptions made in the problem are stated below. Also, to satisfy the problem assumptions and quantify the parameters, a study was conducted in Isfahan (a city in the center of Iran). The following assumptions are intended to simulate the problem mentioned for public buildings:

Assumption 1. The public buildings under study are of one type of use. With this assumption, the buildings in service will have common features such as the same working hours. (Isfahan houses many public buildings such as banks, commercial complexes, and offices. Non-governmental banks were selected as a representative of public buildings for review. There are 800 non-governmental banks in the city.)

Assumption 2. Given that public buildings are of the same type, the health protocols for public buildings are the same. (The most important health protocols in Isfahan banks are masking, proper ventilation, and social distancing.)

Assumption 3. The maximum number of people inside the building is a certain amount according to the protocols. (The average number of bank staff in each bank is 13, of whom ten are accountable to clients. The maximum number of clients allowed in the bank is 10)

Assumption 4. The daily working hours of the public building are specified. (According to research, the working hours of Isfahan banks are 7:00 a.m. to 2:00 p.m., and services are provided to clients from 7:30 a.m. to 1:30 p.m.)

Assumption 5. The maximum available inspection capacity average is a certain amount. (According to the number of health protocol inspectors in Isfahan Municipality, the maximum inspection capacity of each bank is eight inspections per month.)

The values of the cases mentioned in the assumptions and explanations about the city of Isfahan are summarized in Table 1.

According to the above assumptions, now the dynamic hypothesis can be explained. During the day and the bank working hours, the clients enter the bank building randomly but at a specific rate. They tend to be served as soon as possible by the bank staff and exit. The service is based on the number of bank staff. Each bank staff can serve four people per hour. As a result, every 15 min, the number of employees the clients leave the bank. Three events may occur during this time interval. The first case is when the number of clients in the bank is less than ten people. In this case, due to the existing social distance, the service is provided correctly and without the risk of infection, and the clients leave the bank building, and no one inside the bank will wait for the turn and service. The second case is when the number of clients present in the terminal is more than ten people, and the bank staff adhere to the implementation of health laws. In this case, the service for ten people is provided correctly and with low infection risk and exit, but some clients have to wait for the service in the queue. The third incident is when the number of clients present in the terminal is more than ten, and the bank staff do not adhere to the implementation of health laws. In this case, the service for ten people is associated with a high risk of leaving the bank. Also, some clients have to wait in line for service.

With the initial definition of the problem and related assumptions, the modeling of the initial model (base model) for one bank is done without any inspection. The purpose of building a basic model is to identify the behavioral pattern of the system and its main components.

3.2. Base model structure: current situation

As mentioned in the initial model, a bank is considered that no inspection is done. As a result, employees do not consider themselves committed to law enforcement due to the difficulty of complying with the protocols. Based on the dynamic system approach, a cause-and-effect

| No | Features (assumption) | Quantities in case of Isfahan |
|----|-----------------------|-----------------------------|
| 1  | Type of public building | non-governmental banks (800 banks in Isfahan) |
| 2  | Critical health protocols | Masking, proper ventilation, and social distancing |
| 3  | Maximum available inspection capacity | Eight inspections per month for each bank |
| 4  | Daily working hours | 7:30 a.m. to 1:30 p.m. (6 h) |
This counter is reset to zero at the end of each day by the (BPED) variable.

### 3. Basic model simulation: non-inspection policy

In system dynamics, the basic model simulation is performed with two objectives. The first goal is to evaluate the validation of the model by analyzing the sensitivity of the parameters. The second goal is to identify the primary conditions of the system without applying control policies and measures. In this regard, simulations were performed for one month to validate the basic model and examine the initial conditions in terms of the number of violations and the number of people at risk of disease. Also, the first five days to eliminate the disturbances have been added to the beginning of the simulation. Relationships between variables in the flow diagram are shown in Appendix A.

We perform simulation for two modes to investigate the effect of clients arrival rate in the bank (CAR). Except for the (CAR), the rest of the simulation conditions for the two simulated modes are precisely the same. The (CAR) in the first case has a possible Poisson distribution with an average of 40 people per hour, and in the second case has a Poisson distribution with an average of 30 people per hour. The simulation results are shown in Fig. 3 for daily number of the bank violation (the daily number of high-risk cases of disease spread in the bank), and the daily number of people with risk of infection (DNPR).

As can be seen in Fig. 3 (a) and (b), in primary conditions, the increase in the rate of clients entering the banks causes congestion and non-observance of social distance. Non-compliance with health protocols such as masks and proper ventilation will create high-risk conditions for the spread of the disease and increase the number of patients with the disease.

### 4. Inspection and fines policies

As seen in the basic model, increasing client visits to the bank and non-compliance with health protocols due to lack of inspection can cause the spread of the disease. In this section, the proposed policies of inspection and fines to reduce the banks violations are introduced and their diagrams are presented.

#### 4.1. Policy 1: fixed inspection and fixed fine rate (FIFF)

The first inspection policy is that the inspector randomly and suddenly enters the bank. If he observes a violation, he fines the bank, ends the inspection, and leaves the bank. In this policy, the inspection rate of

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**Fig. 1.** Cause-and-effect diagram of basic model.
the bank is fixed, and the fine amount is a fixed amount. The cause and effect diagram of the first FIFF policy can be seen in Fig. 4. The flow diagram of the FIFF is in Appendix B.

In explaining the cause and effect diagram of Fig. 4, two factors affect the degree of adherence of bank staff to health protocols. The first factor is the bank inspection rate, which the higher it is, the more compliance with the rules. After an open inspection of the bank, the bank staff are affected by the inspector’s presence and, for various reasons (such as fear of fines), can enforce the law. As a result, adherence to the law will increase as the bank’s inspection rate increases.

But another effective factor in bank staff’s adherence to health protocols is bank staff behavior. Studies show that many factors such as age, gender, and education affect the behavior of individuals in compliance with health protocols [61, 62]. In this study, the difference between employees’ behavior is expressed by the term risk-taking. In explaining this factor effect, the last bank inspection, the fear of the inspector’s presence inside the bank decreases over time, and bank staff turn to non-compliance with the law. The rate of forgetfulness and reduction of regularity depends on the behavior of bank staff, which is expressed here by the term bank staff risk-taking. The more risk-taking the bank staff are, the sooner the fear of inspection will disappear and the faster the bank staff will return to the past, i.e., non-compliance with the law. The impact of human behavior on law enforcement has been confirmed in several studies [60, 63, 64]. To better understand the concept of risk-taking used in this study, the degree of adherence to the law over time for three samples of bank staff with different risk-taking is shown in Fig. 5. As shown in this figure, after each bank inspection, the percentage of adherence to the law in all bank staff reaches the highest value (i.e., 100%). But over time, high-risk bank staff forget the inspector more quickly and return to pre-inspection procedures and non-compliance.
4.2. Policy 2: fixed inspection and variable fine rate (FIVF)

In the second policy of inspection and fines, the inspector is inspected randomly and at a fixed rate like in the first policy. Nevertheless, unlike the FIFF policy, the amount of fines is not fixed. The inspector determines the amount of the bank’s fine by viewing bank information such as cameras and reviewing bank records such as past violations. The amount of the fine affects the level of riskiness of the bank staff. Increasing the number of fines based on records decreases bank staff’s risk-taking. The causal diagram of the second inspection politics is shown in Fig. 6. The flow diagram of the FIVF is in Appendix B.

Fig. 7 shows a comparison between the behavior of a high-risk bank staff in the face of two types of policies of fixed fines and fines based on records of violations. An explanation can be provided for the effect of variable fines shown in Fig. 7. Studies have shown that progressive fines commensurate with violations can significantly impact law-abiding behavior [65]. Accordingly, in Fig. 7, variable fines commensurate
with the extent of the violation affect the risk of bank employees and slow down the process of forgetting the last inspection. A bank staff who is at high risk will commit more offenses and, as a result, will be fined more. As a result of higher and proportionate fines for violations, the bank staff’s risk-taking is reduced, and his violations are reduced. Therefore, it changes the staff behavior from high-risk to medium-risk and low-risk.

4.3. Policy 3: variable inspection and variable fine rate (VIVF)

Due to the limited number of inspectors in inspection organizations, the inspection rate of all buildings is also limited and fixed. There are

![Diagram](image-url)

Fig. 7. Comparison of bank staff behavior in observing health protocols in the face of fixed and variable fine policies.

![Diagram](image-url)

Fig. 8. Cause and effect diagram of policy 3: variable inspection and fines rate (VIVF).
two general approaches to assigning inspectors to public buildings and inspection rates. In the first approach, the assignment of the inspector to each building is the same, and as a result, the inspection rate of the buildings is equal to each other. In the second approach, the total number of inspections is constant. However, the allocation of inspectors to buildings is variable, and as a result, the inspection rate of buildings will be variable. In the third policy, the inspection rate of buildings is determined based on information about the average number of violations in recent days. The inspection rate of the building increases with the increase of violations. Also, in this policy, the fine amount, like the second policy, will be variable based on their violations. To better understand the third policy of inspections and fines, Fig. 8 shows the cause-and-effect diagram of this policy for inspections and fines of two banks. The flow diagram of the VIVF is in Appendix B.

As shown in Fig. 8, there are two service providers and an inspection organization with a fixed amount of inspection rate. The inspection rate of each bank is variable and calculated based on relative violations. Also, the fine policy of the two banks is variable based on the number of violations.

5. Compare and analyze the results of inspection policies

In the urban management system, there are many public buildings, such as banks, which has its clients and bank staff, and the city administration has the task of supervising and inspecting all of them. This section compares and evaluates the effect of different inspection and fines policies on the long-term situation of banks. An inspection organization with a limited number of inspectors with two banks is considered. The results for two banks can be generalized to three or more banks. Four scenarios were considered for different inspection policies.

- In Scenario 0, the simulation is constant under the conditions of no inspection policy, ie NI.
- In Scenario 1, the simulation is constant under the conditions of policy 1, ie FIFF.
- In Scenario 2, the simulation is constant under the conditions of policy 1, ie FIVF.
- In Scenario 3, the simulation is constant under the conditions of policy 1, ie VIVF.

All assumptions in the construction of the basic model (type of buildings, working hours, total number of inspectors, and other items) are valid for the scenarios. All conditions (parameters such as bank entry rate, number of bank staff) in the simulation for four identical scenarios were considered. The violations’ number in each scenario is equal to the sum of the violations of the two banks in that scenario. The simulations are performed for six months, and the results for the number of monthly violations and people with high risk of infection in the different inspection and fines policies are shown in Table 2.

After analyzing Table 2 data, the following results are obtained:

- All inspection policies have reduced staff misconduct and thus reduced the likelihood of disease outbreaks. According to different dimensions.
- Variable fine policy based on the number of violations has had a 20% reduction in violations compared to the variable fine policy.
- A comparison of the third policy with the second policy shows that the variable inspection rate compared to the equal inspection rate of banks has reduced bank violations by 15% and reduced the number of people at risk by 25%.

Also Fig. 9 shows the cumulative trend of violations and the number of people at risk in different policies over six months, respectively. Although at first, the extent of violations and the number of people at risk in different policies do not differ significantly, over time, the impact of policy implementation has become more apparent.

As can be seen in Fig. 9, the third inspection scenario, i.e., the second approach of inspection allocation along with the covert inspection
policy and fines based on the number of violations, will have the most significant impact on reducing violations and thus preventing the spread of disease. Given that the number of inspectors in all three inspection policies is the same, the third inspection policy can be suggested to city managers as a practical approach to prevent the spread of disease in public buildings.

5.1. Sensitivity analysis

Sensitivity analysis in dynamic system models is performed to validate the model. Sensitivity analysis also recognizes the effect of environmental components on the model. This section analyzes the effect of two parameters, “Client entry rate” and “Existing inspection capacity” on the prevalence of the disease.

5.1.1. The effect of client arrival rate on the results under different inspection policies

To investigate the effect of clients arrival rate in the bank (CAR) on the prevalence of the disease, by changing this rate, simulations were performed for all policies in several ways. The simulation results for the number of violations of bank staff and the number of people at risk of disease are shown in Fig. 10.

As shown in Fig. 10, increasing the client entry rate increases the number of violations committed by bank staff. Also, the number of people on the line is significantly increased due to the increase in the population inside the bank and the bank staff violations number. However, the implementation of inspection policies has slowed the growth of violations.

5.1.2. The effect of existing inspection capacity on the results under different inspection policies

Another critical parameter that should investigate its impact on the bank violations is the amount of inspection available. By analyzing the results, the government can decide whether to hire an inspector. Thus, the number of inspections available for each bank increased from 5 inspections per month to 25 inspections, and each time a simulation was performed for six months. The simulation results for different inspection policies are shown in Fig. 10.

As shown in Fig. 11, except for the non-inspection policy, the number of violations decreases with the increasing inspection of banks. Among the inspection policies, the third policy maintained its advantage over other policies in reducing bank violations.

6. Conclusions

Given the significant increase in COVID-19 cases worldwide, governments seek to create urban resilience to epidemic catastrophes. Implementing health protocols in public buildings can prevent the spread of disease during the activities of offices and businesses. This study examined compliance with health protocols through inspection and penalty policies based on the system dynamics approach.

Initially, a basic model without inspection was created by defining the problem of the implementation of health protocols within the bank. Then, using the data of Isfahan city, daily bank violations and the number of people at risk of disease were investigated through simulation. Next, three inspection and penalty policies were presented, including inspection and fixed fine (FIFF), fixed inspection and variable fine (FIVF), and variable inspection and fines (VIVF). After drawing a cause-and-effect diagram and a flow chart for policies, the long-term impact of policy implementation on banks’ violations was compared.

Based on the simulation results, the variable inspection and penalty policy has the most significant impact on reducing banks’ violations and can be used as a selected policy by city managers.

As suggestions for future studies, numerous other policies can affect the prevalence of the disease that was not examined in this study. Increasing working hours, in-person services via the internet, and online inspections of public buildings are some of the policies that can be considered through modeling system dynamics in future studies. Also, by developing the proposed dynamic system model, the effect of inspection systems on the safety of public buildings against other disasters such as fire and building collapse can be studied in future works.
CRediT authorship contribution statement

Nasim Nahavandi: Writing – review & editing, Validation, Supervision, Resources, Project administration. Mohammad-Ali Gorji: Writing – original draft, Visualization, Software, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A

Table A1
Relationships between variables in the flow diagram of the base model

| No | Parameters                                      | Quantities                                                                 |
|----|-------------------------------------------------|---------------------------------------------------------------------------|
| 1  | DCE: Distribution of clients entrance to the bank| DCE = POISSON(3,3)                                                        |
| 2  | CAR: Clients arrival rate in the bank           | CAR = INT(DCE)                                                            |
| 3  | BP: Bank population                             | BP(t) = BP (t - dt) + (CAR - PDR - EDR) * dt                              |
|    | INIT BP = 0                                     |                                                                           |
| 4  | EDD: The end of day discharge of population    | EDD = PULSE(1000,73,72)                                                   |
| 5  | PDR: population departure rate from the bank   | PDR = PULSE((IF(BP > 10) THEN(10) ELSE (BP)),2,3)                        |
| 6  | CS: Clients served                              | CS(t) = CS (t - dt) + (PDR - BPER) * dt                                  |
|    | INIT CS = 0                                     |                                                                           |
| 7  | PCL: Protocols compliance level                 | PCL = 0.2                                                                |
| 8  | PDT: Probability of disease transmission       | PDT = IF (BP > 10) THEN((PDR)*(1-POP)) ELSE (0)                           |
| 9  | BPER: bank people exit rate                    | BPER = BPED, BPED = PULSE(1000,73,72)                                    |
| 10 | IRVB: Increase rate of bank’s violations        | IRVB = IF(PDT > 0) THEN(1) ELSE (0)                                      |
| 11 | DBV: Daily bank’s violations                    | DBV(t) = DBV(t - dt) + (IRVB - RVBD) * dt                                |
|    | INIT DBV = 0                                    |                                                                           |
| 12 | IRPR: Increase rate of people at risk of infection| IRPR = IF(PDT > 0) THEN(PDT + INT(PDR)) ELSE (0)                          |
| 13 | DNIP: Daily number people at risk of infection | DNIP(t) = DNIP(t - dt) + (IRPR - RPRD) * dt                              |
|    | INIT DNIP = 0                                   |                                                                           |

Appendix B

Flow diagrams of inspection and fines policies.
Fig. A1. Flow diagram of policy 1: fixed inspection and fines rate (FIFF)
Fig. A2. Flow diagram of policy 2: fixed inspection rate with variable fine rate (FIVF)
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