INFODEMIC MECHANISM BASED ON THE SIR MODEL: A POPULATION MOBILITY PERSPECTIVE

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Ease of access and transmission of information through social media has led to ambiguity, the scope of misinformation, and uncertainty, especially during the time of public health emergencies when there is a huge demand for health information due to the lack of scientific knowledge of health knowledge among online users. Inaccurate health information will induce social disorders such as panic during the epidemic Covid-19 outbreak, which has drawn increasing attention from scholars and the government. The purpose of the study is to construct a dynamic misinformation fading model by initially considering the population mobility possibility based on the classic SIR model, thus making the infordemic spreading process more realistic and apparent. The proposed model helps to understand the impact of misinformation online by deriving and simulating the important parameters: misinformation-free equilibrium, spreading duration, and the social stability index to revealing the misinformation development trend. Finally, the research identifies more efficient measures that could be employed in times of government officials or companies during public health emergencies.

Keywords: Misinformation; Infodemic; SIR model; Population Mobility

MSC2020: 49J30, 47H09, 47H10, 47J20.

1. Introduction

In the era of the digital world, social media provides a platform for information dissertations, and it has expanded people's ability to express themselves in the age of the digital world. However, information diffusion through social media has its drawbacks. Authorities may employ it for efficient information dissemination and event management, while malicious entities may spread misinformation and fake news, which could have an impact dramatically on public opinion and government credibility.

Especially, since the outbreak of Covid-19, a respiratory virus that poses serious risks to public health on a global scale. Social media flourished misinformation related the covid-19. Additionally, inaccurate media coverage and online users' ignorance of science can exacerbate the public health crisis and social panic. Ultimately, misinformation could affect public order and social stability [1]. Thus, it is a significant social issue globally for online misinformation management.

Most scholars constructed the misinformation and rumor control model based on disease spreading due to the similarity between misinformation propagation and epidemic spreading[2–4]. The classic model was established by Zanette and H. [5] which is divided the population into three groups at S, I, R. Here S, I, R represent the people who are spreading

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the model (spreaders, similar to infective (spreaders), those who never heard misinformation (ignorant, similar to susceptible), and the ones who heard misinformation but do not spread it (stiflers, similar to recovered). Some scholars extended the model by considering the exposed nodes, which may become the infected nodes as a rate, as the SEIR model [6, 7]. The above misinformation-spreading mechanism has some pities. The most important point is the lack of considering the possibility of outflow for each conversion state (S, I, R), since, in reality, people may be leaving the online relevant misinformation community because of losing interest, obtaining scientific knowledge, or even authority debunking news. Thus, this research considered the population outflow possibility in each state for closing the real situation. The research addresses several problems by (1) extending the classic model by introducing the population outflow possibility in each conversion node, which is close to the realistic description of the misinformation spreading process. (2) multi-measure the misinformation trend by adopting several key parameters and derive the misinformation-free equilibrium and social stability index. The current study aims to clarify the process of misinformation spreading during public health emergencies and to identify the critical variables that affect misinformation control efficiency. The research proposes specific countermeasures to improve the effectiveness of online misinformation control and assist the authority in making decisions and preventing misinformation.

The rest of the paper is organized as follows: in section 2, the research reviews the existing literature on misinformation spreading and online information dissemination. In section 3, the research represents the proposed model including the definition spreading rule and formulation. Numerical simulations are presented in section 4. Followed by simulation analysis. In section 5. Lastly, section 6 discusses and concludes the remarks.

2. Literature Review

There is no doubt that misinformation and rumor spreading in-network caused severe consequences, for example, panic buying, property losses, social crisis, and confusing public opinion[2, 3, 8, 9]. Early research focused on the factors that influence the spreading of misinformation, which mainly divided into two aspects as internal factors such as users education[10], anxiety[2] and external factors such as spreading media[11], information characteristics[12]and topic type[13]. However, these researches emphasized factors under a static phenomenon ignoring a real-world network. More researchers proposed the dynamics of misinformation dissertation by adopting the complex network along with topological properties of social networks. For example, Zanette and H. [5] first studied misinformation propagation by establishing the SIR model (susceptible, infected, and recovered) based on the infectious disease transmission, in which the population is stratified into three health states: ignorant represent who never heard the misinformation, spreader represent who spread the misinformation and stiflers represent who know the misinformation but are not spreading it to others), misinformation is propagated according to the transition rate among three classes. Moreover, for closing the social network, in reality, several parameters were introduced in the model, such as memory effect [14], node dynamic behavior[15], anxiety[2] and debunking strategy[16]. However, the existing misinformation propagation model still explores the state propagation closing the actual circumstance. Thus, the current literature considers the population outflow possibility due to the authority debunking mechanism during the spreading period.

3. Proposed Model

3.1. Definitions and Propagation Rule

This study summarized the definitions of three spreading in table 1.

Table 1. Definitions of Three Spreading States

State	Definition	t
Ignorant (I)	People who are credulous, regarded as the potential spreaders	$I(t)$
Spreader (S)	User received misinformation and actively spread the misinformation	$S(t)$
Stifler/ Recover(R)	Due to the authority debunking, people who know the misinformation but do not have contagiousness.	$R(t)$

Misinformation spreading rules can be summarized as follows:

(1) Considering a population of K nodes(users) in the relevant online networks (for example social media network), and the population in the misinformation community at the time T is P(t), so the $P(t) = S(t) + I(t) + R(t)$.

(2) At the initial time($t = 0$), the whole population is ignorant until the first misinformation spread the misinformation online. In the transition diagram, is the population (users) inflow rate indicated by the users who engage in the online relevant misinformation environment? Meanwhile,ω_o as the population (users) outflow rate indicated the user who is not interested in the misinformation issue and withdraws from the misinformation online environment(shown in figure 1).

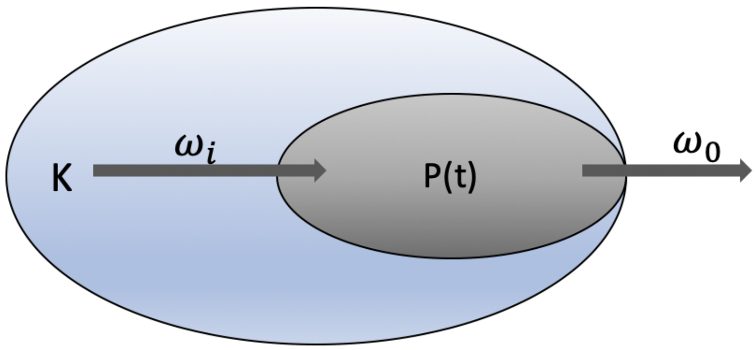

Figure 1. The Population Transition in the Misinformation Community

(3) When a spreader contact with the potential spreader, some of the people would be infected at the coefficient α, so the sum of people who influence by the spreader per time is $\alpha I(t)S(t)$.

(4) At the time t, some of the users who know the misinformation but do not have contagiousness become stiffer at the rate $\boldsymbol{\beta}$, so the sum of the non-spreader per time is $\beta S(t)$.

(5) Meanwhile, potential spreaders transfer into the non-spreader because of the authority debunking strategy at the rate of b, namely the misinformation control coefficient. The sum of the non-spreader converted by the potential spreaders per time is $bI(t)$.

3.2. Model Formulation

Based on the assumption above, figure 2 shows the three spreading state transformation progress. the number of potential communicators transforming to communicators in unit time at time t is αIS during the process of conversion from disseminators to non-disseminators; the increasement of potential disseminators due to population(user) inflowing into the misinformation crisis environment is $K\omega_i$; the population outflow due to not interested in the misinformation issue and official authority intervention reduce the potential disseminators as $w_0 I + bI$. Therefore, the variation of potential spreaders per unit time

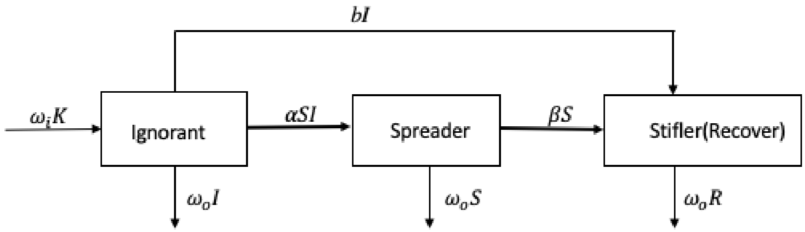

FIGURE 2. Structure of SIR model for misinformation spreading process

at time t can be expressed as $dI = (w_iK - \alpha IS - bI - w_0I)\,dt$. In the process of conversion from disseminators to non-disseminators, the increment per unit time at time t is αIS; Also, as the official authority debunking, the number of disseminators converted to non-disseminators is βS; and the number of disseminators reduced due to population outflows from misinformation crisis environments is w_0S, so the whole variation of change in disseminators per unit time at time t can be expressed as $dS = (\alpha IS - \beta S - \omega_0S)\,dt$.

The difference between the increment of non-disseminators per unit time $bI + \beta S$ and the decrease of non-disseminators caused by population mobility w_0S, that is, the change of non-disseminators per unit time at time t can be expressed as $dR = (\beta I + bI - w_0R)\,dI$. So the differential equation of the system 1 dynamics represents the model as follows:

$$\begin{cases} \frac{dI}{dt} = w_iI - \alpha IS - w_0I - bI \\ \frac{dS}{dt} = \alpha IS - (\beta + w_0)\,S \\ \frac{dR}{dt} = \beta S - w_0R + bI \end{cases} \tag{1}$$

The study focused on decreasing of the number of communicators in the related online misinformation environment. Furthermore, whether the development trend of misinformation events has a downward trend is another concern in the research. Additionally, we defined the equilibrium point as a transition point from an upward expansion trend to a downward trend. In the following, the propagation mechanism of misinformation events is studied by analyzing the crisis equilibrium point and its stability in Model 1.

Whether the misinformation crisis continues or not depends on the variables I and S due to the first of two equations (model 1) not containing the variable R. the planar system is composed of the first two equations as (system 2):

$$\begin{cases} dI/dt = \omega_iK - \alpha IS - \omega_0I - bI = X(I,S) \\ dS/dt = \alpha IS - (\beta + \omega_0)\,D = Y(I,S) \end{cases} \tag{2}$$

$(I,S) \in \{(I,S) \mid 0 \le I \le K, 0 \le S \le K, I + S \le K\}$,the feasible region represents a set of all potential spreaders and spreaders.

Lemma 1: Two-dimensional autonomous systems

$$\begin{cases} \frac{\mathrm{d}x}{\mathrm{d}t} = P(x,y) \\ \frac{dy}{dt} = Q(x,y) \end{cases}$$

It is an assumption that there is a continuous partial derivative B (x, y) in a single connected region G.

$$\frac{\partial(BP)}{\partial x} + \frac{\partial(BQ)}{\partial y}$$

If the sign is invariant and not always zero in any subfield, then there is no closed orbit completely contained in G. its assumption that the right of the equation (2) is zero, two possible solutions:

$$A_1 = \left(\frac{w_i K}{w_0 + b}, 0\right), \quad A_2 = \left(\frac{\beta + w_0}{\alpha}, \frac{K\alpha w_i - (\beta + w_0)(w_0 + b)}{\alpha(\beta + w_0)}\right)$$

The following equation would discuss the existence and stability of the equilibrium point as below:

(1) When $\frac{w_i K\alpha}{(\beta+w_0)(w_0+b)} < 1$, $\frac{K\alpha w_i - (\beta+w_0)(w_0+b)}{\alpha(\beta+w_0)} < 0$, A_2 not in the domain of definition S, only $A_1 \in S$. So A_1 possesses stability based on the symbols of the coefficients of characteristic equation p, q.

$$q_{A_1} = \begin{vmatrix} \frac{\partial X}{\partial I} & \frac{\partial X}{\partial S} \\ \frac{\partial Y}{\partial I} & \frac{\partial Y}{\partial S} \end{vmatrix} = \begin{vmatrix} -\omega_0 - b & -\frac{\alpha\omega_i K}{\omega_0+b} \\ 0 & \frac{\alpha\omega_i K}{\omega_0+b} - \beta - \omega_0 \end{vmatrix}$$

$$= (\omega_0 + b)(\beta + \omega_0) - K\alpha\omega_i > 0$$

$$p_{A_1} = -\left(\frac{\partial X}{\partial I} + \frac{\partial Y}{\partial S}\right) = -\left(\omega_0 - b - \beta - \omega_0 - \frac{K\alpha\omega_i}{\omega_0 + b}\right)$$

$$= \omega_0 + b + \frac{(\omega_0 + b)(\omega_0 + \beta) - K\alpha\omega_i}{\omega_0 + b} > 0$$

The point A_1 is locally asymptotically stable, and since only one equilibrium point A_1 in the definition domain S, it is impossible to have a closed trajectory. Meanwhile, the trajectory of system 1 from the inside of S will not exceed S, so the point A_1 is globally asymptotically stable. Furthermore, regardless of the number of communicators in the misinformation crisis environment at the initial time, the number of crisis communicators will not gradually expand but gradually decrease. Point A_1becomes the balance point of crisis calming.

(2) when When $\frac{w_i K\alpha}{(\beta+w_0)(w_0+b)} > 1$, initially, supposed that there is two equilibrium point of misinformation crisis calming A_1,$A_2 = \left(\frac{\beta+w_0}{\alpha}, \frac{K\alpha w_i - (\beta+w_0)(w_0+b)}{\alpha(\beta+w_0)}\right)$, the system 2 is globally stable at the equilibrium point A_2. however, $q_{A_1} = (\omega_0 + b)(\beta + \omega_o) - K\alpha\omega_i < 0$, so A_1 is not stable.

$$q_{A_2} = \begin{vmatrix} \frac{\partial x}{\partial I} & \frac{\partial x}{\partial S} \\ \frac{\partial y}{\partial I} & \frac{\partial y}{\partial S} \end{vmatrix} = \begin{vmatrix} \frac{(\beta+\omega_0)(\omega_0+b) - K\alpha\omega_i}{\beta+\omega_0} - \omega_0 - b & -(\beta + \omega_0) \\ \frac{K\alpha\omega_i - (\beta+\omega_0)(\omega_0+b)}{\beta+\omega_0} & 0 \end{vmatrix}$$

$$= K\alpha\omega_i - (\beta + \omega_0)(\omega_0 + b) > 0$$

$$p_{A_2} = -\left(\frac{\partial X}{\partial I} + \frac{\partial Y}{\partial S}\right) = \frac{K\alpha\omega_i - (\omega_0 + b)(\beta + \omega_0)}{\beta + \omega_0} + \omega_0 + b > 0$$

Thus A_2 is partial stability and S is a positively invariant set of the system 2. For proving A_2 is globally asymptotically stable in S, only verifying no existing the closed orbit in system 2.

Taking the function $B(L, D) = \frac{1}{D}$, thus:

$$\frac{\partial(BX)}{\partial I} + \frac{\partial(BY)}{\partial S} = -\alpha - \frac{\omega_0 + b}{S} < 0$$

According to lemma 1, planar system 2 without closed orbit in the area S. therefore, A_2 is globally asymptotically stable. Furthermore, once the spreader increasing, the scope of influence of misinformation crisis will continue expand, and the number of the potential communicators and communicators will eventually stabilize at the $\frac{\beta+\omega_o}{\alpha}$ and $\frac{K\alpha\omega_i - (\omega_o+b)(\omega_o+\beta)}{\alpha(\beta+\omega_o)}$.

Based on the clarification, when $\frac{K\alpha\omega_i}{(\beta+\omega_o)(\omega_o+b)} < 1$, there exists a unique crisis-calm equilibrium point $\left(\frac{\omega_i K}{\omega_o+b}, 0\right)$ in the feasible domains. Thus, the number of spreaders in the final crisis trends to 0, In other words, the influence scope of the crisis event will gradually decrease until it is calmed down;when $\frac{K\alpha\omega_i}{(\beta+\omega_o)(\omega_o+b)} > 1$,there is a unique crisis persistence point $\left(\frac{\beta+\omega_o}{\alpha}, \frac{K\alpha\omega_i-(\beta+\omega_o)(\omega_o+b)}{\alpha(\beta+\omega_o)}\right)$in feasible region, which means the number of disseminators eventually tends to be a constant $\frac{K\alpha\omega_i-(\beta+\omega_o)(\omega_o+b)}{\alpha(\beta+\omega_o)}$.Namely, the impact of the misinformation crisis will continue in a certain range. Thus:

$$W = \frac{K\alpha\omega_i}{(\beta+\omega_o)(\omega_o+b)} = 1 \tag{3}$$

is the threshold to distinguish whether the crisis is subsided. Except equilibrium point, the research further explored that the misinformation spreading duration and spreading ability impact on the misinformation crisis issue. The next section would clarify the definition and derive the equation of the average duration of the crisis and spreading ability.

3.3. Average duration time and social crisis index

The definition of average duration time is the time consumed by communicators converted into non-disseminators in the misinformation environment. Let the disseminators transform to non-disseminator at the ratio of β in unit time, namely, the number of transformations is β S. Assuming that the outflow rate of user communicator is ω_0, namely, the number of outflows is w_0S. Thus, the number of disseminators in unit time decreases is $\beta S + w_0$, and the average duration time is $\frac{1}{\beta+w_0}$.

The Social Crisis Index I_0indicated the average number of people infected within the average duration time in the misinformation crisis environment. The study adopted the index to measure social stability after the misinformation crisis. The average number of people spreading misinformation during the crisis reflects the user's attention and public panic, which indicates the negative impact of crisis events on society. Therefore, the social crisis index is a parameter that can be used to describe the negative impact of crisis events. By comparing the change rate of the social crisis index, we can predict the hidden dangers of social crisis, which is helpful to improve the stability of society.

Based on the definition, let μ denote the individual residence time in the misinformation environment, and dS represents the variation in the number of communicators per unit time of stay. Moreover, the transformation of communicators spreading state is mainly related to the population outflow rate and the coefficient of misinformation crisis transfer rate, so the number of communicators reduced per unit time is $(\beta S + w_0)\, d\mu$. Namely, the function of residence time and number of communicators in the misinformation environment as follow:

$$dS = -(\omega_0+\beta)\, S d\mu$$

so

$$\frac{dS}{d\mu} = -(\omega_0+\beta)\, S$$

namely $S(\mu) = S(0)e^{-(\omega_0+\beta)\mu}$, let ξ denotes as the spreading time of one communicator, so the probability of ξin the interval $(0, \mu]$ is:

$$p(0 < \xi \leq \mu) = |I(\mu) - I(0)| = 1 - e^{-(\omega_0+\beta)\mu} = \int_0^{\mu} (\omega_0+\beta)\, e^{-(\omega_0+\beta)x} dx$$

Probability density function is $f(x) = (\omega_0 + \beta)\, e^{-(\omega_0+\beta)\mu}, \mu \in [0, +\infty)$.

$$\begin{aligned} EX &= \int_0^{+\infty} x f(x) dx = \int_0^{+\infty} x\,(\omega_0 + \beta)\, e^{-(\omega_0+\beta)x} dx \\ &= -\, x e^{-(\omega_0+\beta)x} \Big|_0^{+\infty} + \int_0^{+\infty} e^{-(\omega_0+\beta)x} dx \\ &= \frac{1}{\omega_0 + \beta} \end{aligned}$$

Potential spreader transfer spreader at the ratio of α, namely, the number of the spreader is $k\alpha$. One spreader is able to spread $\frac{K\alpha}{\beta+\omega_o}$ people in the average duration time. So the crisis index is:

$$I_0 = \frac{K\alpha}{\beta + \omega_o} \tag{4}$$

4. Numerical Simulations

Through the model analysis, three indicators: crisis average duration time, social crisis index, and crisis equilibrium point, measure the misinformation propagation mechanism and the misinformation development trend. Based on the discussion above, the smaller the value of the three indicators, the more conducive to the control of misinformation issues. The three indicators would be numerical simulations as follows: crisis average duration time, social crisis index, and trend of social crisis.

4.1. Crisis average duration time

The average duration is $1/(\beta + \omega_o)$, so the main factors affecting the indicator are the crisis transfer rate coefficient and the population outflow rate. Figure 3 shows the trend of the average duration time in a three-dimensional graph, which reflects that the crisis average duration time decrease with the increase of crisis transfer rate and population outflow. Therefore, it is necessary to increase the crisis transfer rate and the population outflow to shorten the crisis average duration time.

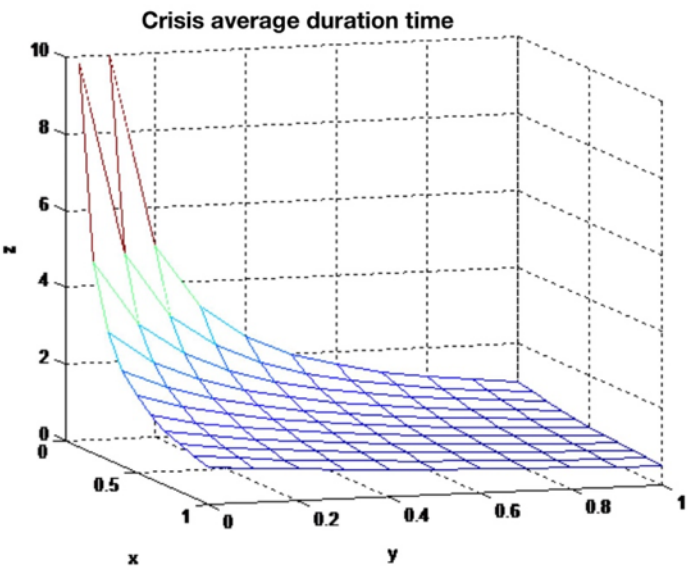

Figure 3. The trend of the average duration time in a three-dimensional graph

4.2. Social Crisis index I_0

According to equation (4), the main factors affecting the social crisis index are average duration time, the total population in the misinformation environment, population outflow rate, and crisis transfer rate coefficient. The value of the crisis index is linearly related to the crisis propagation coefficient and the total population of the crisis environment. Namely, the increasement in the crisis propagation coefficient and the total population will increase the crisis index linearly. Other parameters are fixed as $K = 10000, \alpha = 0.03, \omega_o = 0.05; K = 10000, \alpha = 0.03, \beta = 0.2$, Figure 4 shows that the population outflow rate and crisis transfer rate are inversely proportional to the social crisis index. Moreover, the size of the social crisis index decreases rapidly with the increase of the propagation rate and the population outflow rate at the early stage of misinformation propagation.

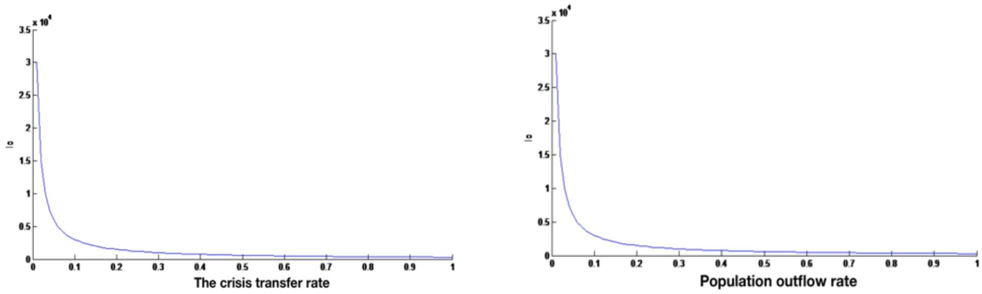

FIGURE 4. (Left) The Influence of Crisis Transfer Coefficient on Social Crisis Index and (Right) Impact of population outflow rate on social crisis index

4.3. Trend of Social Crisis

According to equation 3, W is a threshold to determine whether misinformation crisis is calm or not; In case of other parameters fixed $K = 10000, \omega_i = 0.01, \omega_0 = 0.4, b = 0.7, \beta = 0.6$, different value of spreading rate $\alpha(0.01, 0.03)$ result in $W = 0.91 < 1$ and $W = 2.73 > 1$. As shown in the figure 5 (left) $W < 1$, the number of the spreader tends to be 0, and the misinformation crisis gradually stabilized the crisis calm point is globally asymptotically stable in the feasible region; (right) $W > 1$, the crisis consistency point is globally asymptotically stable in the feasible region. The next session would verify the global stability of the equilibrium point by numerical simulation.

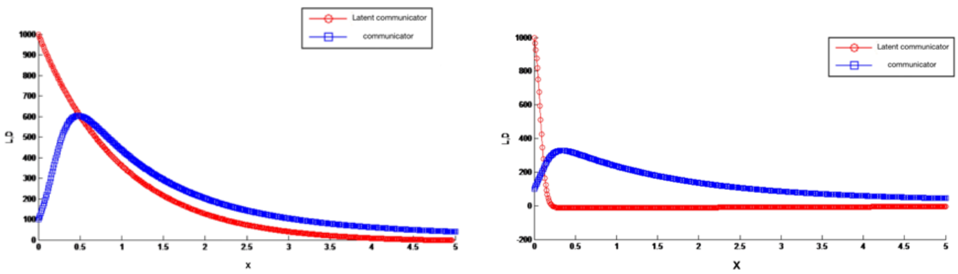

FIGURE 5. The trend of latent Communicators and Communicators when (A) $W < 1$; when (B) $W > 1$

5. Simulation Analysis

From the model formulation, when $W > 1$, the solution of the model tended to the equilibrium point of crisis persistence; when $W < 1$, the solution of the model tended to the crisis calming point. The average duration of the crisis and the size of social crisis index will also affect the solution of the model. The next section will these three variables' impact on the number of communicators in the crisis environment.

5.1. Population

Both equilibrium points and social crisis index are affected by the population in the misinformation community based on formula 3 and 4. If the population in the misinformation environment is too large ($K > 1$), then $W > 1$ and the value of the social crisis index will be immense. Figure 6 shows the impact of different value of population (with K=10000,60000,800000) on the number of communicators ($\omega_i = 0.01, \alpha = 0.3, \beta = 0.2, \omega_0 = 0.1$).

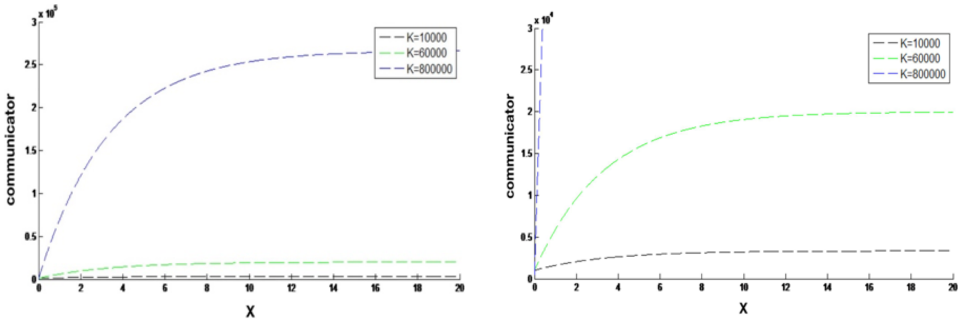

FIGURE 6. Impact of different value of population in crisis environments on the number of communicators

As figure 6 shows, the K value significant influences the development trend of misinformation spreading. The larger value K could lead the more spreaders in the misinformation crisis events. When the population is small (K=10000), the number of disseminators increases slightly initially and then trends to be stable while k=60000, the increase in the number of communicators at k = 60000 is higher than that at k = 10000, and the crisis in a stable and controllable state; However, When k=900000, the rate of increase in the number of communicators is significantly higher than in the first two cases, making the scope of the crisis expand rapidly. Based on formula 3, if crisis events have the same conditions, the number of communicators increases faster in the high-population-intensive community, making authority management more difficult. In other words, at the condition (such as the same crisis transfer coefficient, spreading coefficient, and misinformation control coefficient), In an online community with a small population, a misinformation crisis can be gradually calmed down only by taking lighter measures. However, for the large population community, due to the rapid outbreak of the population accumulation crisis, it would be out of control if authorities did not take decisive and effective measures.

5.2. Population Outflow Rate

The outflow of the population in a crisis environment will significantly influence the value of crisis equilibrium point, crisis duration, and social stability index. The research adopted numerical experiments to simulate the changing trend of the number of communicators in the crisis environment with different population outflow rate $\omega_0 = 0, 0.3, 0.05 (K = 100000, \omega_i = 0.5, \alpha = 0.3, b = 0.6, \beta = 0.2)$.

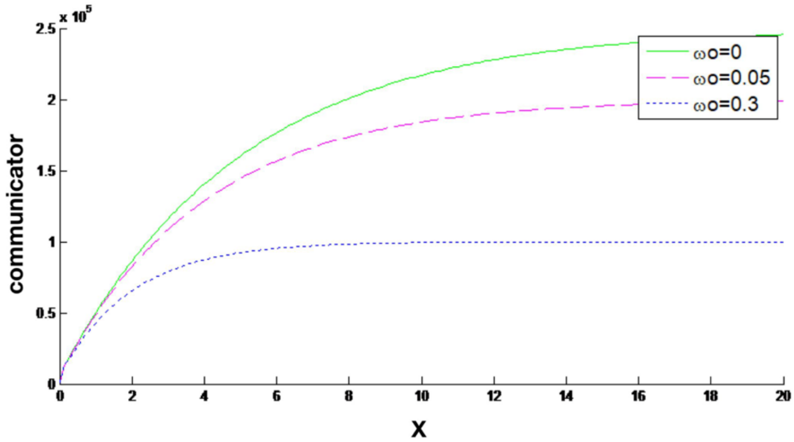

FIGURE 7. population outflow rate impact on the number of spreaders

As shown figure 7 shows a Higher population outflow rate with the slower growth rate of misinformation spreaders. Since the number of spreaders is small in the early stage, the population outflow rate has little effect on the crisis development. The growth rate of the number of communicators under the three different conditions is the same. While population size is more prominent as time goes by, the growth rate of communicators has changed. When the population outflow rate is higher ($\omega_0 = 0.3$), the growth rate of the spreaders is significantly low, and the number of spreaders tends to be stable; when the population outflow rate is less than $0.1 (\omega_0 = 0, \omega_0 = 0.03)$, the number of spreaders will keep constantly increasing for a while. Furthermore, the research proposed two ways to increase the population outflow rate in a crisis environment.

5.3. Crisis Transfer Rate β

Another way to decrease the number of spreaders is by increasing the crisis transfer rate coefficient. Figure 8 shows the changing trend of the number of disseminators when $\beta = 0, 0.03, 0.5$ while set the parameters as K=100000, $\omega_i = 0.5, \alpha = 0.3, \omega_0 = 0.05, b = 0.6$.

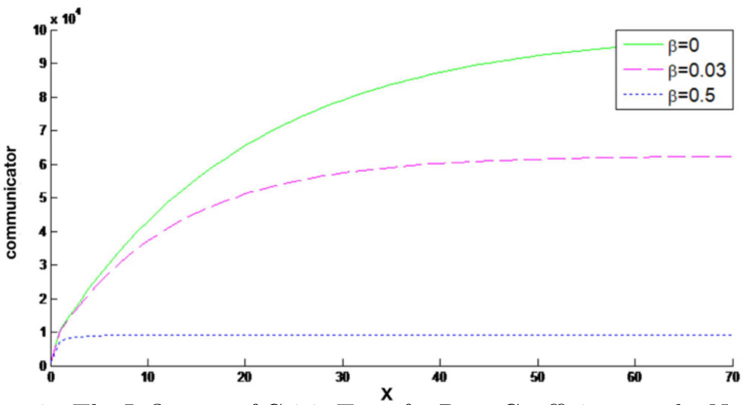

FIGURE 8. The Influence of Crisis Transfer Rate Coefficient on the Number of Spreaders

As shown in figure 8, the rate of increase in the number of disseminators varies within a short period after the crisis with different values of β. When the value of β is high ($\beta = 0.5$), the number of communicators only slightly increases in a short time and then enters a steady state. When the value of β is low ($\beta = 0, \beta = 0.03$), the number of disseminators continues to grow, and the number of disseminators is much higher than that at $\beta = 0.5$. Therefore, the coefficient of the misinformation transfer rate is a critical factor in whether the crisis can be calmed. Stephen and Tsang[17] demonstrated that trust plays an essential role in participation in authorities' policies and can promote people's active cooperation with the policies. Li, Wang [18] believed that rational public decision-making could be guided by improving public participation mechanisms. Therefore, the crisis transfer rate can be increased in two ways. One is to establish a reliable platform for communication with the public. People have a channel to express their demands by understanding the needs of the people, government could timely respond to effectively dredge the panic of the people so as to enhance public trust. At the same time, the authority can also share relevant information on crisis events with the public through this platform to ensure that the crisis information received by the public is timely and accurate. Second, strengthening trust repair.

5.4. **Spreading Rate Coefficient** α

Figure 9 (A) and (B) show the different spreading rate coefficient $\alpha(\alpha = 0.03, \alpha = 0.1, \alpha = 0.4)$ impact on the communicators and potential communicators when other parameters are fixed ($K = 30000, \omega_i = 0.05, b = 0.6, \beta = 0.2$).

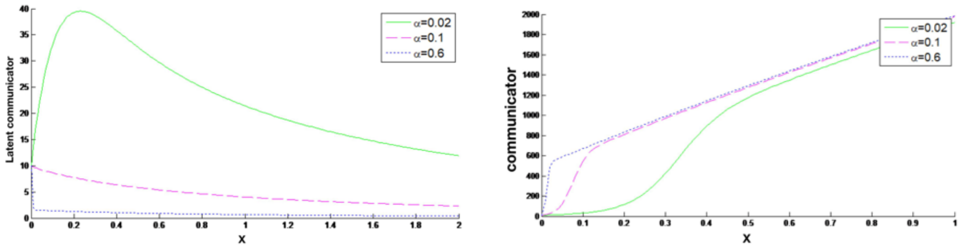

FIGURE 9. (A) Spreading Rate Coefficient Impact on the Number of Potential Communicators (Spreaders) (B) Spreading Rate Coefficient Impact on the Number of Communicators (spreader)

Figure 9 shows that the spreading coefficient has a significant impact on the number of potential communicators and spreaders at the early stage of the crisis. The growth rate of the propagator when $\alpha = 0.6$ is much higher than that when $\alpha \leq 0.1$. in the early stage. The greater the rate of decline of potential communicators the faster the growth of the number of communicators in the early stages of the crisis, meanwhile the fewer potential communicators when the crisis tends to be stable. Therefore, controlling the coefficient of crisis spreading rate in the initially stage is effective crisis management. Li [18] explored that crisis would enter a stable period sooner when the authority disclosure the misinformation information. Moreover, improving the authority's credibility can effectively inhibit the breeding of misinformation.

Thus, the coefficient of crisis transmission rate can be reduced through three ways after the outbreak of crisis events. firstly, in the early stage of a misinformation outbreak, the public is in a state of high demand for crisis information, official account should publish relevant information about the crisis in time. Otherwise, people learn from other sources of negative or fake news, which will make people's awareness of the crisis information deviate from the objective track. Secondly, the authority or government needs to increase credibility.

High credible authority is more appealing and persuasive for the public. therefore, it mainly improves the credibility of the authority from three aspects. Transparent public power and the information asymmetry between the government and the public will weaken the public's trust in the government. decision-making mechanism, and building a fair administrative culture can the government's credibility be improved, and the government can be more credible when it discloses relevant information about crisis events. Third, the authority needs to improve the predicting mechanism to quickly respond to the crisis and reduce the crisis brought about by the loss of personnel and property. Meanwhile, it can monitor the development of crisis events and take corresponding management measures according to the development of events.

5.5. Population Inflow Rate ω_i

The figure 10 shows $\omega_i(0, 0.03, 0.2)$ impact on the communicators, and the parameters as $\alpha = 0.3, k = 3000, \omega_0 = 0.05, b = 0.6, \beta = 0.2, k = 3000$, As figure 10 shows that

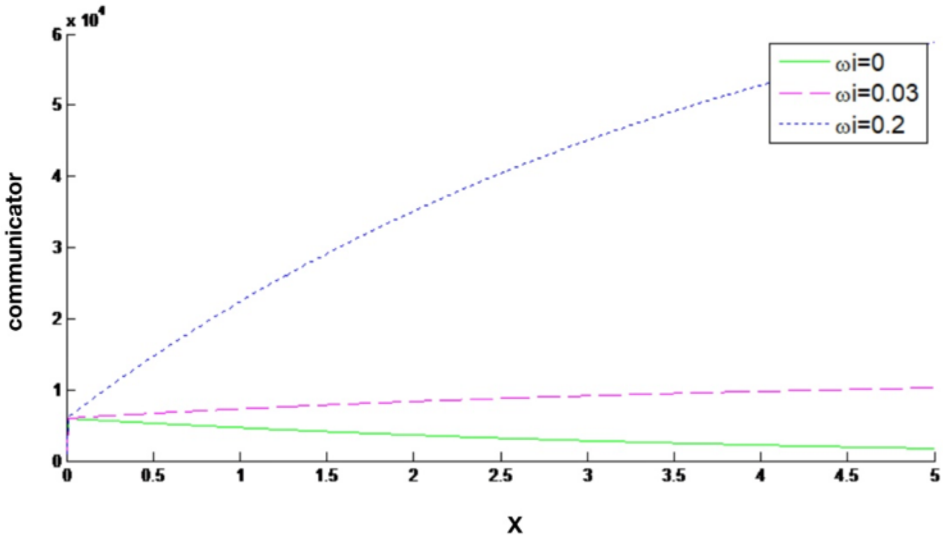

Figure 10. The Number of Spreaders is Affected by the Different ω_i

more population inflows significantly increase the number of disseminators. The population inflows had a significant impact on the number of communicators in the early stages of the crisis. When the population inflow rate is low $\omega_i = 0, \omega_i = 0.03$, the number of spreaders is increasing due to the rapid spread of the network environment and the complexity of the physical environment. Therefore, when calming crisis events, it is necessary to reduce the population inflow rate. Mainly from two aspects to manage the inflow rate of population. Mainly through two aspects to control the transmission, one is to control the spread of negative news on the network media, the rapid spread of network media, and the characteristics of a non-real-name system, making the spread of negative news on the network more quickly. On the other hand, it is to increase the coverage of official information and strengthen the control of crisis information disseminated through other channels. This reduces population inflows in crisis settings, thereby reducing the rate of population inflows.

5.6. Misinformation Control Coefficient b

Figure 11 shows the changing trend of the number of potential communicators with the different control coefficient b (0, 0.1, 0.5), other parameters set as $k = 30000, \alpha = 0.2, \omega_0 = 0.1, \omega_i = 0.2, \beta = 0.1$.

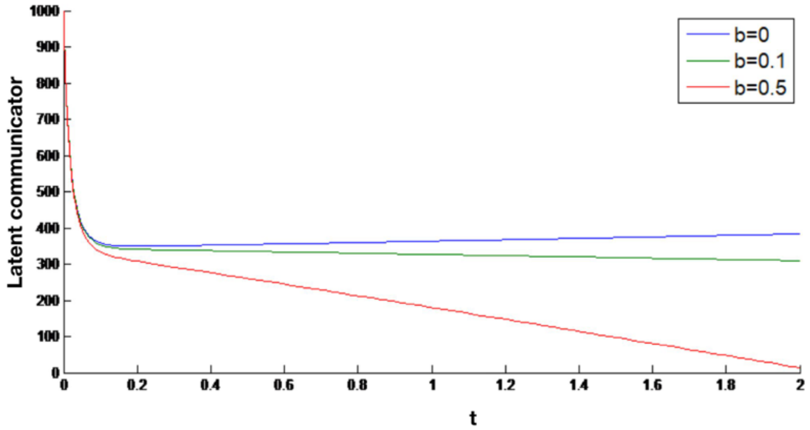

FIGURE 11. The influence of misinformation controlling coefficient on the number of potential crisis communicators

As shown in Figure 11, when b is larger (b=0.5), the number of potential disseminators continues to decrease from the initial state until it is 0, then there is no spreaders increasement. So that the development of the crisis will decline; When b is small (b = 0, b = 0.1), the number of potential disseminators tends to be significantly higher. The increase of potential communicators is mainly due to the lack of sensitivity and awareness of the public about the crisis. Li, Wang[18] found that it is easier to control the misinformation crisis when the public is more rational. Therefore, in the early stage of crisis management, authority can increase b by improving the public's awareness of crisis events and psychological intervention after the outbreak of the crisis. In the process of crisis management, people's s crisis awareness is a significant factor but most people's crisis awareness is weak, and not sensitive enough to the crisis. When a crisis occurs, the ability to deal with the crisis is also relatively poor. Therefore, on the one hand, under normal social conditions, the authority should improve the users' or people's psychological quality in the face of crisis and their cognitive ability to crisis events, and enhance the public's ability to identify negative or fake information on the crisis.

6. Conclusion

The study conducted a dynamic mathematic model based on the conversion of three types of population: potential spreaders, spreaders, and non-spreaders. 1) The model complements the relevant studies on the intervention of external control strategies and proposes specific measures. For closing the actual situation, the research considered the outflow rate of each conversion node. 2) The study verifies the effect of average duration time, crisis equilibrium point, and social stability index on the development trend of infodemic in public health issues. 3) Finally, the influence of the three factors on the spread of crisis events is analyzed through numerical experiments. Therefore, the research suggested calming the misinformation by increasing the population outflow rate, the coefficient of crisis transfer rate and fading rate, and reducing the coefficient of spreading rate and the population inflow rate.

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