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Propagation Model and Simulation Study Based on Rumor Suppression Strategies on Social Media Platforms

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Abstract

【Purpose/Significance】In the social media environment, online rumors spread with high speed and broad scope, seriously disrupting social order. Consequently, governing online rumors has become a critical challenge in network society management. This study investigates approaches to online rumor governance from the perspective of social platform rumor suppression strategies, offering reference recommendations for scientifically and effectively controlling rumor propagation.

【Methodology/Process】Based on social platform rumor suppression strategies (warnings and account banning), this paper proposes an improved SIC1-2R propagation model, subsequently analyzes the rumor equilibrium points within the model and provides proofs. Finally, simulation experiments are conducted using MATLAB 2021a.

【Results/Conclusions】The results demonstrate that the new model has four rumor propagation equilibrium points (rumor-free equilibrium E0, pre-ban equilibrium E1, pre-unban equilibrium E2, and post-unban equilibrium E3), which are validated through simulation experiments. Additionally, both internal model parameters and temporal factors exert significant influence on the rumor propagation process.

【Innovations/Limitations】The innovations are twofold: (1) improvement of the traditional SIR propagation model based on social platform rumor suppression strategies (warnings and account banning); (2) discussion of the stability of rumor equilibrium points in the model across different stages (pre-ban, pre-unban, and post-unban). The primary limitations are that all data employed in the experiments are simulated values, some parameters are set empirically, and the governance strategies for online rumors are examined solely from the platform perspective, rendering the research conclusions insufficiently comprehensive.

Full Text

Research on Propagation Model and Simulation Based on Rumor Suppression Strategies of Social Platforms

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Abstract

[**Purpose/Significance**] In the social media environment, online rumors spread rapidly and extensively, seriously disrupting social order. Consequently, governing online rumors has become an urgent challenge in cyberspace management. This paper explores methods for online rumor governance from the perspective of social platform suppression strategies, providing reference suggestions for scientifically and effectively controlling rumor propagation.

[**Method/Process**] Based on social platform rumor suppression strategies (warnings and account suspension), this paper proposes an improved SIC1-2R propagation model, analyzes the rumor equilibrium points in the model, and provides theoretical proofs. Finally, simulation experiments are conducted using MATLAB 2021a.

[**Results/Conclusion**] The results demonstrate that the new model exhibits four rumor propagation equilibrium points (rumor-free equilibrium E_0, pre-suspension equilibrium E_1, pre-unblocking equilibrium E_2, and post-unblocking equilibrium E_3), which are validated through simulation experiments. Simultaneously, both internal model parameters and temporal factors significantly influence the rumor propagation process.

[**Innovation/Limitations**] The innovations are twofold: (1) The traditional SIR propagation model is improved by incorporating social platform rumor suppression strategies (warnings and account suspension); (2) The stability of rumor equilibrium points is discussed in stages (pre-suspension, pre-unblocking, and post-unblocking). The main limitations are that all data used in the experiments are simulated values, some parameters are set based on experience, and the study only examines online rumor governance strategies from the platform perspective, making the conclusions less comprehensive.

Keywords: rumor propagation; social platforms; suppression strategies; MATLAB simulation
Classification: G206

A rumor is defined as "an unverified statement or interpretation about matters, events, or issues of public interest, disseminated through public or non-public channels in a specific environment" [1]. The large-scale propagation of online rumors results from multi-agent participation, including both hidden Internet manipulators who fuel the flames and a vast number of ordinary disseminators. Online rumor propagation can trigger public panic and anxiety, damage government credibility, and consequently affect social stability, causing losses [2]. Therefore, online rumor governance has become an unavoidable critical issue in cyberspace management. Current research primarily focuses on debunking strategies [3], debunking modes [4], and debunking effectiveness [5-7], with debunking agents mainly limited to government and media [8]. Few scholars have explored online rumor governance from the perspective of social platform suppression strategies. Consequently, this paper proposes an improved SIC1-2R propagation model based on social platform rumor suppression strategies (warnings and account suspension) and conducts simulation studies. Theoretically, this research enriches the perspectives of existing rumor propagation models; practically, it provides reference and guidance for social platforms' online rumor governance.

2.1 Related Research on Rumor Propagation Models

Online rumors are termed "information viruses" due to their similar transmission pathways and patterns to biological viruses; consequently, most rumor propagation studies are based on epidemic models [9]. Early research in this area can be traced back to the DK model proposed in the 1960s [10] and the subsequent MK model [11], which have served as foundational references for most subsequent studies in terms of research approaches and methodology. Currently, scholars extend classical propagation models primarily in three aspects.

First, by expanding or further subdividing node state types within models. For instance, Liao Shengqing et al. incorporated the role of debunkers into the SIR model to construct the SIAR propagation model [12]. Gu Yiran et al. added a latent state E between the susceptible state S and infected state I, proposing the SEIR rumor propagation model [13]. Considering that rumor spreaders exhibit varying degrees of belief in rumors, Tang Lianghongxu et al. further distinguished spreaders into potential and hardcore spreaders [14].

Second, by considering the behavioral attributes of nodes in models, which represents a primary characteristic differentiating rumor propagation from virus transmission. For example, Qu Nanwei et al. introduced user questioning behavior into an information behavior model, finding that questioning behavior can enhance debunking effectiveness within a certain range, but excessive questioning produces the opposite effect [15]. Wang Qiyue et al. considered the silence probability of suppressors in their model, noting that rumor propagation can suddenly erupt as silence probability increases [16]. Nekovee et al. incorporated user forgetting mechanisms as influencing variables, demonstrating that the initial propagation rate of rumors in scale-free networks far exceeds that in homogeneous networks [17].

Third, by considering disturbances from external environmental variables, primarily from government and media perspectives. For instance, Wang Xiwei et al. proposed the SCNDR model with reversal effects based on the SIR model, analyzing the impact of official debunking timing on rumor reversal efficiency [18]. Zhao Min et al. examined the effects of media coverage (positive and negative reporting) on rumor propagation, discussing the existence and stability of equilibrium points under both rumor-propagating and rumor-free scenarios [19].

2.2 Research on Social Platform Rumor Suppression Strategies

During online rumor propagation, if social platforms fail to implement any suppression measures, serious disruptions will occur to both the online community environment and platform operational order. Currently, social platforms commonly employ two rumor suppression measures: warnings and account suspension. Warnings involve attaching cautionary labels to users participating in rumor propagation (e.g., "abnormal,""dangerous,""caution") or specially displaying user pages (e.g., using red, yellow, orange, and green to indicate different risk levels), thereby reducing the credibility of information posted by rumor spreaders and people' s willingness to forward it. Research indicates that warning tags can awaken users' subconscious "danger" perception or prompt more careful consideration of current matters, effectively reducing rumor credibility on social media [20].

Account suspension represents a stricter rumor suppression strategy, primarily targeting rumor spreaders with repeated or severe violations. It achieves punishment by prohibiting various rights including posting, commenting, forwarding, and liking for a specified period. Suspension duration is typically determined by violation frequency or severity, such as 15 days, 30 days, or even permanent suspension. Suspension signifies a temporary "termination" of a user' s life in the virtual online world, easily evoking instinctive fear of death in users' subconscious [21]. Consequently, compared to warnings, suspension exerts greater deterrent effects on those attempting to create or forward rumors.

In practice, social platforms generally do not adopt a single suppression strategy in isolation but rather combine both strategies according to actual circumstances to maximize rumor containment.

2.3 Literature Review

Existing related research provides valuable references for this study, yet three main deficiencies remain.

First, current literature on rumor propagation models primarily focuses on the impacts of government, media, and user factors on the rumor propagation process, with few scholars examining the issue from the social platform perspective. As the primary channel for online rumor generation and propagation, social platforms play a crucial role in online rumor governance and warrant researchers' attention.

Second, current research on social platform rumor governance concentrates mainly on debunking-related topics, such as debunking strategies, methods, and effectiveness, with few scholars investigating the impact of warning and account suspension strategies on curbing rumor propagation.

Therefore, this study first introduces a new population state—restricted individuals C (users restricted by platform warnings or account suspension measures)—into the traditional SIR model, proposing the SIC1-2R model. It then derives the rumor propagation model' s equilibrium points in stages and conducts theoretical stability analysis. Finally, simulation experiments using MATLAB 2021a validate the stability of these equilibrium points. Additionally, this study analyzes the influence of various model parameters on the rumor propagation process and summarizes these influencing factors. The findings can enrich rumor propagation research, provide references for future similar studies, and offer theoretical guidance for social platforms to conduct rumor governance efficiently.

3.1 User State Types in the Model

Based on the traditional rumor propagation SIR model, this study introduces a new propagation node C (restricted individuals), representing user groups restricted by social platform rumor suppression measures. According to different restriction types, C is further subdivided into C1 and C2, where C1 denotes users receiving warning penalties and C2 denotes users receiving account suspension penalties. Therefore, all nodes in this study are classified into the following types:

Susceptibles (S): Nodes in the netizen population that have never encountered rumor content or participated in rumor-related discussions but can easily transform into rumor spreaders upon contact with rumor information.

Spreaders (I): Nodes that actively transmit rumor information to others after encountering it.

Restricted individuals (C): User nodes restricted by platform rumor suppression measures due to violations, primarily including C1 and C2.

Recovered/Immune (R): Nodes familiar with rumor content but no longer influenced by it and having ceased rumor propagation.

3.2 Model Parameters

The parameters in the propagation model are described in Table 1.

Table 1 Parameter descriptions

Parameter	Description
Rumor propagation rate (α_1)	The probability that a susceptible individual S transforms into a spreader upon contacting rumor information transmitted by spreader I.
Restricted propagation rate (α_2)	The probability that a susceptible individual S transforms into a spreader upon contacting rumor information transmitted by restricted individual C1.
Platform warning rate (β)	The probability that a social platform implements warning measures against users who violate rumor propagation regulations, where the violation severity is relatively minor.
Platform suspension rate ( )	The probability that a platform suspends an account when a user is found to have committed serious violations.
Restriction escalation rate (δ)	The probability that a platform upgrades a warning to account suspension when a previously warned user commits another violation that meets suspension criteria.
User reactivation rate ( )	This term borrows from virology but with slightly different meaning. In virology, “reactivation rate” refers to the probability of a recovered patient becoming infectious again without re-exposure. In this paper, it primarily denotes the probability that a suspended user returns to being a rumor spreader after the suspension period expires.
Immunity rate of I ($_1$)	The rate at which spreaders transition to immune state.
Immunity rate of C1 ($_2$)	The rate at which warned users transition to immune state.
Immunity rate of C2 ($_3$)	The rate at which suspended users transition to immune state.

3.3 Evolution Rules and Assumptions of the Propagation Model

Based on the classification of rumor propagation nodes and parameter settings, this study constructs the SIC1-2R rumor propagation model (see Figure 1). The model’s evolution rules and assumptions are as follows:

1. When a susceptible individual S contacts a spreader I, they propagate ru-

mors with probability α_1 and become a rumor spreader. When S contacts a restricted individual C1 rather than I, due to platform warnings (e.g., cautionary labels), susceptibles have lower trust and propagate rumors with probability α_2 to become spreaders (the dashed line in the figure indicates that susceptibles do not directly become restricted individuals C1 but first transform into spreaders I).

2. After spreaders disseminate rumors, the platform may impose penalties. Minor violations receive warnings; severe violations receive account suspension. When warned users violate again, the platform escalates penalties to account suspension.
3. Assume the platform implements warning measures starting at time t = 0, while suspension measures begin at time t = t_0 with suspension duration T. During the suspension period, users are prohibited from posting, commenting, forwarding, and liking–i.e., they lose rumor propagation capability. After the suspension period ends, users may revert to rumor spreaders.
4. Rumor spreaders I, restricted individuals C1, and restricted individuals C2 become immune due to loss of interest in rumor content or fear of platform penalties, ceasing rumor propagation.

Figure 1 **[Figure 1: see original paper]** SIC1-2R propagation model

Based on the above population classifications and model evolution rules, this study constructs the following differential dynamical equations for the propagation model.

Before account suspension (rumor begins spreading, platform has not yet implemented suspension):

$$\frac{dS}{dt} = \lambda - \alpha_1 S(t)I(t) - \alpha_2 S(t)C_1(t) - \mu S(t)$$
$$\frac{dI}{dt} = \alpha_1 S(t)I(t) + \alpha_2 S(t)C_1(t) - (\beta + \phi_1)I(t) \quad (1)$$
$$\frac{dC_1}{dt} = \beta I(t) - \phi_2 C_1(t)$$
$$\frac{dR}{dt} = \phi_1 I(t) + \phi_2 C_1(t)$$

During suspension period (after rumor spreads, platform implements suspension):

$$\frac{dS}{dt} = \lambda - \alpha_1 S(t)I(t) - \alpha_2 S(t)C_1(t) - \mu S(t)$$
$$\frac{dI}{dt} = \alpha_1 S(t)I(t) + \alpha_2 S(t)C_1(t) - (\beta + \chi + \phi_1)I(t) \quad (2)$$

$$\frac{dC_1}{dt} = \beta I(t) - (\delta + \phi_2)C_1(t)$$
$$\frac{dC_2}{dt} = \chi I(t) + \delta C_1(t) - \phi_3 C_2(t)$$
$$\frac{dR}{dt} = \phi_1 I(t) + \phi_2 C_1(t) + \phi_3 C_2(t)$$

After suspension period ends:

$$\begin{aligned}
\frac{dS}{dt} &= \lambda - \alpha_1 S(t)I(t) - \alpha_2 S(t)C_1(t) - \mu S(t) \\
\frac{dI}{dt} &= \alpha_1 S(t)I(t) + \alpha_2 S(t)C_1(t) + \varepsilon C_2(t) - (\beta + \chi + \phi_1)I(t) \\
\frac{dC_1}{dt} &= \beta I(t) - (\delta + \phi_2)C_1(t) \\
\frac{dC_2}{dt} &= \chi I(t) + \delta C_1(t) - (\varepsilon + \phi_3)C_2(t) \\
\frac{dR}{dt} &= \phi_1 I(t) + \phi_2 C_1(t) + \phi_3 C_2(t)
\end{aligned} \tag{3}$$

In the above equations, S(t), I(t), C_1(t), C_2(t), and R(t) represent the proportions of susceptibles S, spreaders I, restricted individuals C_1, restricted individuals C_2, and immune individuals R in the total population at time t, respectively, with S(t) + I(t) + C_1(t) + C_2(t) + R(t) = 1.

4.1 Propagation Threshold and Equilibrium Points

Drawing from the definition of the basic reproduction number in epidemiology, we define it as the number of susceptibles infected by a single spreader during the propagation period. Referencing existing literature [22] on basic reproduction number calculation methods, this study derives the basic reproduction numbers for the rumor propagation model:

Before account suspension:

$$R_0^1 = \frac{\alpha_1 \lambda}{\mu(\beta + \phi_1)}$$

After account suspension:

$$R_0^2 = \frac{\alpha_1 \lambda}{\mu(\beta + \chi + \phi_1)}$$

Considering the model' s practical context, we seek equilibrium points in the bounded region:

$$D = \{(S, I, C_1, C_2, R) | S \geq 0, I \geq 0, C_1 \geq 0, C_2 \geq 0, R \geq 0\}$$

(1) Rumor-free equilibrium point. When $R_0^1 < 1$, the model' s rumor-free equilibrium point is:

$$E_0 = (\lambda/\mu, 0, 0, 0, R^*)$$

(2) Internal equilibrium points. When $R_0^2 > 1$, setting all left-hand sides of equations (1)-(3) to zero yields the system' s internal equilibrium points.

1) When $C_1 \neq 0, C_2 = 0$ (before platform implements suspension), there exists a rumor equilibrium point:

$$E_1 = (S^{(1)*}, I^{(1)*}, C_1^{(1)*}, 0, R^{(1)*})$$

where:

$$S^{(1)*} = \frac{\phi_2(\beta + \phi_1)}{\alpha_1\phi_2 + \alpha_2\beta}$$

$$I^{(1)*} = \frac{\lambda - \mu S^{(1)*}}{(\alpha_1\phi_2 + \alpha_2\beta)S^{(1)*}}$$

$$C_1^{(1)*} = \frac{\beta I^{(1)*}}{\phi_2}$$

2) When $C_1 \neq 0, C_2 \neq 0$ (platform has implemented suspension), two rumor equilibrium points exist: pre-unblocking equilibrium E_2 and post-unblocking equilibrium E_3.

$$E_2 = (S^{(2)*}, I^{(2)*}, C_1^{(2)*}, C_2^{(2)*}, R^{(2)*})$$
$$E_3 = (S^{(3)*}, I^{(3)*}, C_1^{(3)*}, C_2^{(3)*}, R^{(3)*})$$

where:

$$S^{(2)*} = S^{(3)*} = \frac{(\beta + \chi + \phi_1)(\delta + \phi_2)}{\alpha_1(\delta + \phi_2) + \alpha_2\beta}$$

$$I^{(2)*} = \frac{(\lambda - \mu S^{(2)*})(S^{(2)*} + \phi_2)}{(\alpha_1\phi_2 + \alpha_2\beta)S^{(2)*}}$$

$$C_1^{(2)*} = \frac{\beta I^{(2)*}}{\delta + \phi_2}$$

$$C_2^{(2)*} = \left(\frac{\chi}{\phi_3} + \frac{\delta}{\phi_3(\delta + \phi_2)}\right) I^{(2)*}$$

$$I^{(3)*} = \frac{\lambda - \mu S^{(3)*}}{(\alpha_1\phi_2 + \alpha_2\beta)S^{(3)*}}$$

$$C_1^{(3)*} = \frac{\beta I^{(3)*}}{\delta + \phi_2}$$

$$C_2^{(3)*} = \left(\frac{\chi}{\varepsilon + \phi_3} + \frac{\delta}{(\delta + \phi_2)(\varepsilon + \phi_3)}\right) I^{(3)*}$$

4.2 Stability Analysis of Equilibrium Points

Theorem 1. When $R_0^1 < \frac{\alpha_1\phi_2}{\alpha_1\phi_2+\alpha_2\beta}$, the rumor-free equilibrium E_0 is locally asymptotically stable.

The Jacobian matrix of system (1) at E_0 is:

$$J_0 = \begin{bmatrix} -\mu & -\alpha_1 S^* & -\alpha_2 S^* \\ 0 & \alpha_1 S^* - (\beta+\phi_1) & \alpha_2 S^* \\ 0 & \beta & -\phi_2 \end{bmatrix}$$

Let its three eigenvalues be $\sigma_1 = -\mu$, σ_2, and σ_3, where σ_2 and σ_3 must satisfy the characteristic equation $|\sigma I - J_0| = 0$. The signs of σ_2 and σ_3 can be determined through the characteristic equation coefficients p and q:

$$p = -[(\alpha_1 S^* - (\beta+\phi_1)) + (-\phi_2)] = (\beta+\phi_1) - \alpha_1 S^* + \phi_2 > 0$$

$$q = \begin{vmatrix} \alpha_1 S^* - (\beta+\phi_1) & \alpha_2 S^* \\ \beta & -\phi_2 \end{vmatrix} = \phi_2(\beta+\phi_1) - \alpha_1\phi_2 S^* - \alpha_2\beta S^*$$

$$= \phi_2(\beta+\phi_1) - (\alpha_1\phi_2 + \alpha_2\beta)S^*$$

$$= \phi_2(\beta+\phi_1) - (\alpha_1\phi_2 + \alpha_2\beta)\frac{\lambda}{\mu}$$

$$= (\beta+\phi_1)\left[\phi_2 - \frac{\mu(\beta+\phi_1)}{\alpha_1\phi_2+\alpha_2\beta}R_0^1\right]$$

Therefore, when $R_0^1 < \frac{\alpha_1\phi_2}{\alpha_1\phi_2+\alpha_2\beta}$, we have $q > 0$. According to the relationship between characteristic equation coefficients and roots, we can determine that $\sigma_1 < 0$, $\sigma_2 < 0$, and $\sigma_3 < 0$. By the Hurwitz criterion [23], E_0 is locally asymptotically stable.

Theorem 2. When $R_0^1 > 1$, the pre-suspension rumor equilibrium E_1 is locally asymptotically stable.

The Jacobian matrix of system (1) at E_1 is:

$$J_1 = \begin{bmatrix} -\alpha_1 I^{(1)*} - \alpha_2 C_1^{(1)*} - \mu & -\alpha_1 S^{(1)*} & -\alpha_2 S^{(1)*} \\ \alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} & \alpha_1 S^{(1)*} - (\beta+\phi_1) & \alpha_2 S^{(1)*} \\ 0 & \beta & -\phi_2 \end{bmatrix}$$

Let $M_1 = -J_1$. The sequential principal minors Δ_i $(i = 1, 2, 3)$ of matrix M_1 are:

$$\Delta_1 = |\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} + \mu| > 0$$

$$\Delta_2 = \begin{vmatrix} \alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} + \mu & -\alpha_1 S^{(1)*} \\ -(\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*}) & \alpha_1 S^{(1)*} + (\beta + \phi_1) \end{vmatrix}$$

$$= ((\beta + \phi_1) - \alpha_1 S^{(1)*})(\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} + \mu) + \alpha_1 S^{(1)*}(\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*})$$

where $(\beta + \phi_1) - \alpha_1 S^{(1)*} = (\beta + \phi_1)\left(1 - \frac{\alpha_1 \phi_2}{\alpha_1 \phi_2 + \alpha_2 \beta}\right) > 0$ when $R_0^1 > 1$.

$$\Delta_3 = \phi_2 \times \Delta_2 + \beta \times A_{32} = \phi_2[(\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} + \mu)(\beta + \phi_1) - \alpha_1 \mu S^{(1)*}] - \alpha_2 \mu \beta S^{(1)*}$$

$$= \phi_2[(\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} + \mu)(\beta + \phi_1)] - \mu S^{(1)*}(\alpha_1 \phi_2 + \alpha_2 \beta)$$

$$= \phi_2(\alpha_1 I^{(1)*} + \alpha_2 C_1^{(1)*} + \mu) > 0$$

Therefore, when $R_0^1 > 1$, we have $\Delta_1 > 0$, $\Delta_2 > 0$, and $\Delta_3 > 0$, making M_1 a positive definite matrix with all negative eigenvalues. By the Hurwitz criterion [23], E_1 is locally asymptotically stable.

Theorem 3. When $R_0^2 > 1$, both the pre-unblocking rumor equilibrium E_2 and the post-unblocking equilibrium E_3 are locally asymptotically stable.

The Jacobian matrix of system (2) at E_2 is:

$$J_2 = \begin{bmatrix} -\alpha_1 I^{(2)*} - \alpha_2 C_1^{(2)*} - \mu & -\alpha_1 S^{(2)*} & -\alpha_2 S^{(2)*} & 0 \\ \alpha_1 I^{(2)*} + \alpha_2 C_1^{(2)*} & \alpha_1 S^{(2)*} - (\beta + \chi + \phi_1) & \alpha_2 S^{(2)*} & 0 \\ 0 & \beta & -(\delta + \phi_2) & 0 \\ 0 & \chi & \delta & -\phi_3 \end{bmatrix}$$

Let $M_2 = -J_2$. The sequential principal minors Δ_i $(i = 1, 2, 3, 4)$ are all positive when $R_0^2 > 1$, making M_2 positive definite with all negative eigenvalues. By the Hurwitz criterion [23], E_2 is locally asymptotically stable. Similarly, E_3 can be proven to be locally asymptotically stable.

Simulation and Stability Analysis of Model Equilibrium Points

The initial proportions of each population state were set as S(0)=0.7, I(0)=0.1, $C_1(0)$=0.05, $C_2(0)$=0.05, R(0)=0, with simulation experiments conducted accordingly.

1) Validation of E_0 stability: With parameters α_1=0.3, α_2=0.1, β=0.15, $_1$=0.1, $_2$=0.15, λ=0.1, =0.25, we calculate $E_0 = (\lambda/\mu, 0, 0, 0, 1-\lambda/\mu) = (0.4, 0, 0, 0, 0.6)$ and $R_0^1 = 0.48 < \frac{\alpha_1\phi_2}{\alpha_1\phi_2+\alpha_2\beta} = 0.75 < 1$. According to Theorem 1, E_0 is locally asymptotically stable. As shown in Figure 2(a), the susceptible population proportion gradually decreases from its peak of 0.7 and stabilizes at 0.4, while the spreader proportion gradually declines to zero, terminating rumor propagation. The simulation results align with Theorem 1. To further validate E_0' s local stability, 10 groups of different initial S, I, C_1 values were tested. Figure 2(b) shows that all i-s phase trajectories converge to E_0, demonstrating that under Theorem 1's conditions, any initial population proportions will evolve toward equilibrium E_0.

Figure 2 [**Figure 2: see original paper**] Stability analysis of rumor-free equilibrium E_0: (a) Propagation dynamics of each group at E_0; (b) i-s phase trajectory at E_0

2) Validation of E_1 stability: With parameters α_1=0.3, α_2=0.2, β=0.15, $_1$=0.15, $_2$=0.1, λ=0.2, =0.15, we obtain $E_1 = (S^{(1)*}, I^{(1)*}, C_1^{(1)*}) = (0.50, 0.42, 0.62)$ and $R_0^1 = 1.33 > 1$. According to Theorem 2, E_1 is locally asymptotically stable. Figure 3(a) shows that the susceptible proportion first rises then falls, stabilizing at 0.50, while spreader and restricted C_1 proportions gradually rise and stabilize at approximately 0.42 and 0.62, respectively. With unchanged parameters, 10 different initial values were tested, with results shown in Figure 3(b). Despite varying initial values, all i-s phase trajectories converge to E_1, confirming Theorem 2.

Figure 3 [**Figure 3: see original paper**] Stability analysis of pre-suspension equilibrium E_1: (a) Propagation dynamics of each group at E_1; (b) i-s phase trajectory at E_1

3) Validation of E_2 and E_3 stability: With parameters α_1=0.5, α_2=0.3, β=0.15, =0.1, δ=0.2, =0.05, $_1$=0.15, $_2$=0.2, $_3$=0.25, λ=0.2, =0.15, we calculate $E_2 = (S^{(2)*}, I^{(2)*}, C_1^{(2)*}, C_2^{(2)*}) = (0.65, 0.25, 0.10, 0.26)$ and $R_0^2 = 1.66 > 1$. By Theorem 3, E_2 is a local equilibrium of system (2). Figure 4(a) shows that all population proportions gradually rise to peaks then slowly decline, stabilizing at t=30 time steps, indicating rumor propagation has reached equilibrium. Ten different initial state values confirm E_2' s stability, with all phase trajectories converging to E_2 (Figure 4(b)). Similarly, system (3) reaches stable states at post-unblocking equilibrium E_3, with all i-s phase trajectories converging to E_3 (Figure 5), validating Theorem 3.

Figure 4 [**Figure 4: see original paper**] Stability analysis of pre-unblocking equilibrium E_2: (a) Propagation dynamics of each group at E_2; (b) i-s phase trajectory at E_2

Figure 5 [**Figure 5: see original paper**] Stability analysis of post-unblocking equilibrium E_3: (a) Propagation dynamics of each group at E_3; (b) i-s phase trajectory at E_3

Analysis of Rumor Propagation Influencing Factors

To simulate the impact of different factors on rumor propagation, model parameters were set as shown in Table 2.

Table 2 Model propagation parameter settings

Parameter	Value
α_1	0.15
α_2	0.15
β	0.05
	0.25
δ	0.18
	0.05
$_1$	0.15
$_2$	0.15
$_3$	0.15
λ	0.05
	0.05
S(0)	0.7
I(0)	0.1
$C_1(0)$	0.05
$C_2(0)$	0.05

Direct Influencing Factors Within the Model

The basic reproduction number R_0^2 formula shows that parameters α_1, β, , $_1$, λ, and directly affect rumor propagation. Simulation experiments further analyze how parameter variations influence propagation dynamics. Figures 6(a)-(e) illustrate the impact of each parameter on spreader proportion.

Figures 6(a)-(b) show that spreader rate α_1 and influx rate λ are positively correlated with spreader proportion—higher propagation rates and influx rates produce larger spreader peaks and accelerate peak arrival. This occurs because higher propagation rates enhance spreaders' infectious capability, while faster influx rapidly expands the susceptible population base, exposing more netizens to "infection" risk. Figures 6(c)-(e) demonstrate that increased warning rate β, suspension rate , and outflow rate gradually reduce spreader peak proportions and final rumor scale. Warnings and suspension directly penalize spreaders, creating strong deterrence, while higher outflow rates remove more individuals from the rumor propagation network, preventing them from fueling spread.

Figure 6 [**Figure 6: see original paper**] Direct effects of internal parameters: (a) Impact of α_1; (b) Impact of λ; (c) Impact of β; (d) Impact of ; (e) Impact of

Indirect Influencing Factors Within the Model

Parameters not included in the R_0^2 formula serve as indirect influencing factors, primarily comprising restricted propagation rate α_2, escalation rate δ, and reactivation rate . Parameters α_2 and δ indirectly affect spreader I through restricted C_1, while influences spreader proportion through restricted C_2. Figure 7(a)-(c) shows these effects. Figure 7(a) indicates that higher α_2 increases spreader peaks, showing that enhanced C_1 propagation capability expands rumor scale, while more frequent escalation of penalties reduces impact scope. Figure 7(c) shows that increased significantly affects the final stable state rather than the peak, as primarily influences post-unblocking "rebound" intensity. Higher reactivation rates produce stronger rebounds, with more individuals reverting to spreaders. Thus, effectively reducing is crucial for preventing rumor resurgence and secondary public opinion crises.

Figure 7 [**Figure 7: see original paper**] Indirect effects of internal parameters: (a) Impact of α_2; (b) Impact of δ; (c) Impact of

External Temporal Influencing Factors

Beyond model parameters, when platforms implement suspension and suspension duration also affect rumor scale and speed. Figure 8(a) shows that as t_0 increases (later platform intervention), spreader peaks grow substantially—earlier intervention yields better suppression effects. During initial rumor outbreaks, few netizens notice the content and active spreaders are limited, with propagation confined to specific platforms before "breaking out" —the optimal window for prevention. Figure 8(b) indicates that longer suspension periods reduce rumor peaks, but not indefinitely. When unblocking occurs after the peak, extended suspension cannot further reduce scale. Therefore, appropriately extending suspension into the rumor decline phase better controls propagation.

Figure 8 [**Figure 8: see original paper**] Effects of external temporal parameters: (a) Impact of t_0; (b) Impact of suspension duration T

Numerical analysis of internal and external influencing factors reveals three factor types: promoting factors, suppressing factors, and temporal factors. Promoting factors (α_1, α_2, , λ) accelerate rumor spread, while suppressing factors (β, , δ,) hinder propagation. Temporal factors concern intervention timing (suspension start time and duration). Figure 9 summarizes all influencing factors in the SIC1-2R model.

Figure 9 [**Figure 9: see original paper**] Influencing factor analysis diagram of SIC1-2R model

Countermeasures and Conclusions

Based on the SIC1-2R model and simulation results, we propose the following countermeasures for social platforms to scientifically govern online rumor propagation:

1. Establish dedicated content review departments to strengthen fact-checking of user posts, reduce unverified information, clean platform garbage content, and create a harmonious community environment (reduce α_1).
2. Enhance platform guidance, establish rumor monitoring systems, and promptly release debunking information to reduce public interest and willingness to forward rumors (reduce α_2).
3. Improve punishment mechanisms for rumor spreaders by increasing warning/suspension frequency and extending suspension duration to raise violation costs and deter potential spreaders (increase β, , δ).
4. Strengthen science popularization and cultural education to improve public literacy and critical thinking, enabling correct understanding of rumor hazards and voluntary resistance (reduce).
5. Implement timely control measures after emergencies and appropriately extend suspension periods to stifle rumors in infancy and prevent escalation (reduce t_0, increase T).

This study constructs the SIC1-2R model by incorporating social platform rumor suppression strategies (warnings and suspension) into the traditional SIR framework. The new model exhibits four equilibrium points: rumor-free equilibrium E_0, pre-suspension equilibrium E_1, pre-unblocking equilibrium E_2, and post-unblocking equilibrium E_3, all validated through simulation. Experiments show that propagation rates, reactivation rates, and influx rates promote rumor spread, while warning rates, suspension rates, escalation rates, and outflow rates suppress it. Additionally, suspension timing and duration significantly affect propagation dynamics.

Limitations include: (1) All experimental data are simulated values with some parameters set empirically—future work should use real case data; (2) The study only examines platform-based governance, neglecting other key actors (government, media, citizens)—future research should develop multi-agent governance models.

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