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MATHEMATICAL MODEL FOR THE PREVALENCE OF DISINFORMATION OVER SOCIAL FABRIC

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Abstract

The ensuing study analyzes the trend of disinformation appertaining to the coronavirus pandemic on social media platforms through mathematical modeling. We introduce a new SEHIR model with an additional compartment of people not reacting instantly or at all to the disinformation called hibernators, to obtain more clarity on the pattern of spread of fake news. The stability analyses of the prevalence free equilibrium have been provided in terms of basic reproduction number, and the existence and uniqueness of the solution have been proved using the fixed-point technique. Furthermore, we conduct a numerical simulation using an experimental survey. The findings are graphically depicted to show different scenarios for social media users across compartments.

1. Introduction

Disinformation has always been a part of media. Fake news hampers the facts, misleads the masses, and affects the social fabric of the world. One of the most active mediums that has raised the scope and extensive spread of disinformation is the social media. Nowadays, people are relatively active on social media; hence fake news spreads easily and swiftly, disturbing social accord. For example, false claims such as UV rays kill the COVID-19 virus, and neem leaves can cure corona infected people related to the recent pandemic of coronavirus has covered all the social media platforms. Hence, various social media forums have introduced timely algorithms in their systems to reduce or stop the spread of untruth news but have failed to eradicate it up to the desirable extent.

This study focuses on developing a mathematical model for the spread of disinformation through various social media platforms, affecting the nation's social fabric. Numerous studies show that the spread of misinformation related to COVID-19 through other resources is over 142 times faster than authentic resources such as CDC and WHO reports [25]. Two fights are running simultaneously down the line, the one of illness and the other of falseness. Misinformation entitled as infodemic by the World Health

Organization and said that the nation is not only fighting epidemic but also infodemic [27]. Navarro mentioned this media picks up the most extreme pictures it finds and uses them on different mediums everywhere, and that are, in fact, the improper messages [27].

Rumors like which one is better to fight the virus, hand soap or garlic, while only one of them is sufficient, can mislead the people and eventually end up with more complications [27]. A slew of fake stories is growing regarding the spreading plots of the COVID-19 virus in which one of the French news agencies mentioned that many social media accounts from Russia are passing conspiracies of connection of The USA in COVID-19 epidemic. In contrast, other disinformation specifies that the CIA created coronavirus to spoil China's economy. Some deceptively blame the charitable foundation run by Bill Gates, co-founder of Microsoft, for dispersing the virus [29].

However, such unverified news has adverse impacts on democracy, businesses, and citizens. For example, misinformation spread in India has affected the minority community and some business industries. Few facts checking websites of India said that out of the 1,447 fact-checks about coronavirus subjugated, turning up to 58% of them, comprising information about incorrect cures, rumors about the lockdown, and untruth plots about the roots of the virus. To exemplify, another false claim that spread in India was excluding meat from diet and depending only on vegetarian food could prevent coronavirus infection; following this disinformation regarding meat-eating, the Indian authorities concluded that the poultry industry suffered a deficit of 130bn rupees (£1.43bn) by April 2020 [26].

As mentioned by The New Indian Express, one of the surveys reveals that 69 percent of mass got the disinformation in lockdown, and WhatsApp was the primary source with 88.4 percent users responding to such rumors, while Facebook was the second with 42.5 respondents [26].

In January-February 2020, for over three weeks, approximately 2 million tweets covering intrigue theories related to the virus were printed and cited in an unpublished report of the US Global Engagement Center [27]. According to a report in the Washington Post, social media companies take various steps to verify, reduce, or stop the passage of false news. For instance, Google has created an SOS alert in six different languages of UN for COVID-19, such that the first information reaches the community from the WHO website only. Facebook announces the prohibition of advertisements highlighting cures for the coronavirus [27].

Numerous research and studies are going on to analyze the spread of fake news, which provided further study scope. A study uses epidemiological models, especially the SEIZ enhanced epidemic model that identifies cynics, to describe information cataracts in twitter due to news and rumors (Jin et al. [5]). Also, to describe the actual transmission pattern more accurately based on the new rumor spreading infective model, Zhao and Wang developed an ISRW dynamical model adding prevalence among people medium-to people (Zhao et al. [24]). In contrast, Khurana and Kumar used SIR model for fake news spreading through WhatsApp (Khurana and Kumar [6]). The authors established and investigated rumor propagation with truth-spreading through various mathematical models, and the threshold governing the dynamics of the system (Liu et al. [9]). In [13], Musa and Mohammed developed a deterministic model applying epidemiological model methods to explain fake news circulation.

Furthermore, a stochastic method was introduced in Moreno et al. [12] to obtain significant time profiles to examine the rumor model changes in complex heterogeneous networks. Some models, prevalence of any concept transmitted from individual to individual, are applied (Weng et al. [22]). Some authors have also studied the SIHR model, which considers users who forget the news after spreading it and some users who remember it (Zhao et al. [23]). The authors have identified features of fake news investigated using temporal, structural, and linguistic aspects of dispersion (Kwon et al. [7]). The inferences provided in Moreno et al. [12]; after a detailed study of the prevalence of the rumors for arbitrary scale-free networks point out various probable applications. The authors developed a model for the competitive prevalence of disinformation (Tambuscio et al. [20]). In [6], Khurana and Kumar defined the comparison between users who believe in fake news and the users who check facts.

Numerous researches have focused on reviewing the characteristics of rumor propagation, analyze features (Friggeri et al. [4]). One study discloses that people exposed to other info sources than the official ones are more susceptible to untruth claims (Mocanu et al. [11]). The study has also been carried out to identify distrustful memes (Ratkiewicz et al. [18]) while spread through Digg and Twitter platforms (Lerman and Ghosh [8]). The influential aspect of an individual's beliefs on each other behind spreading the disinformation was investigated in Acemoglu et al. [1] and Chierichetti et al. [2]. Prodigious efforts were made to generate operative classifiers to detect untruth content or fake accounts, displaying repeated patterns (Matsubara et al. [10] and Nguyen et al. [14]).

However, this subsequent paper studies the flow and prevalence of fake news on different social media platforms by developing a SEHIR model, which comprises a new compartment called *hibernators*, to analyze the widespread of false information. A mathematical model representing scenarios like the response and reaction of the users related to the news and its further identification as untruth news following eventual reduction has been established. Stability analysis is performed and the existence and uniqueness of the solution are verified through the fixed-point technique. Furthermore, a numerical simulation with an experimental survey is conducted to support our results and graphical representation is provided to exhibit different scenarios for the users throughout compartments.

2. The Fake News Model formulations

The total population of $N(t)$ is classified into five compartments:

- Susceptible $S(t)$: Number of feasible individuals relevant for spreading of disinformation.

- Exposed $E(t)$: Number of feasible individuals exposed to the fake news.
- Hibernators $H(t)$: Number of individuals not reacting instantly or at all to the disinformation at first.
- Infected $I(t)$: Denotes the wide variety of individuals in the age group 17-22 highly active over posting the disinformation and the recovered or the removed people.
- Recovered or removed $R(t)$: Signifies the range of individuals in the age group 46-55, inactive to spread the fake information.

μ is the rate of deactivation of users. The term gives the rate at which susceptible individual S gets influenced by the fake news spreader $\eta_1 SI$, where η_1 denotes the disinformation transmission coefficient and the transmission is given by $\eta_1 \varphi SA$. When $\varphi = 0$, then there will be no disinformation in society, and when $\varphi = 1$, then the individual will be proactive in posting the disinformation. The parameters β_2 and β_3 represent the transmission rates after completing the process of becoming a spreader and joining the classes I and H, respectively. λ and λ_A are the rates of recovered people from the compartments H and I, respectively. β_5 is the rate of recovered people from the compartment E.

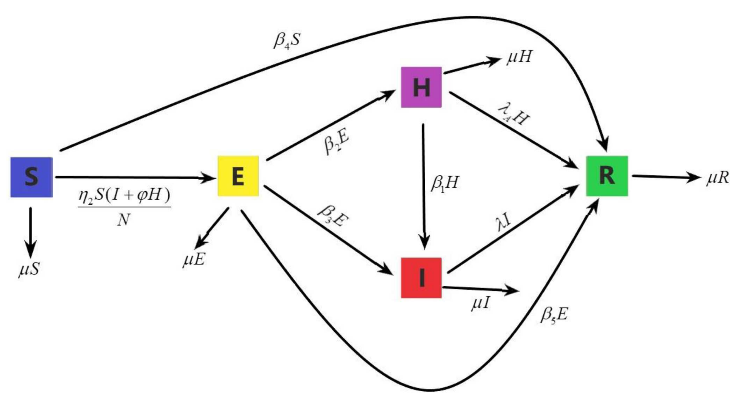

Figure 1. Transmission of disinformation over social fabric.

The mathematical model for the above system with initial conditions is given as under:

$$\frac{dS}{dt} = -\frac{\eta_2 S(I + \varphi H)}{N} - \beta_4 S - \mu S,$$

$$\frac{dE}{dt} = \frac{\eta_2 S(I + \varphi H)}{N} - (\beta_2 + \beta_3 + \beta_5)E - \mu E,$$

$$\frac{dH}{dt} = \beta_2 E - \lambda_A H - \beta_1 H - \mu H,$$

$$\frac{dI}{dt} = \beta_3 E + \beta_1 H - \lambda I - \mu I,$$

$$\frac{dR}{dt} = \beta_5 E + \beta_4 S + \lambda_A H + \lambda I - \mu R \tag{1}$$

and

$$S = E = H = I = R \geq 0 \text{ at } t = 0. \tag{2}$$

The total dynamics of the people obtained from the system (1) is

$$\frac{dN}{dt} = -\mu N.$$

Consider a positive invariant feasible region such that the solution of the system (1) is in this feasible region

$$\Gamma = \left\{(S, E, H, I, R) \in \mathbb{R}_+^5 : S + E + H + I + R = N \leq \frac{1}{\mu}\right\}, \tag{3}$$

where all the parameters of the model are non-negative.

Lemma 2.1. *The closed set* Γ *is a positive invariant concerning the system* (1).

Proof. Adding all the terms in the system (1), we obtain the overall population, i.e.,

$$\frac{d}{dt}(N(t)) + \mu N(t) = 0,$$

where $N = S + E + H + I + R$ at any t. The population size is given by

$$N(t) = N(0) + \int_0^t (-\mu) N(\theta) d\theta.$$

Hence, after simplifying

$$N(t) = N_0 e^{-\mu t},$$

Thus, if $N(0) \leq \frac{1}{\mu}$, then for $t > 0$, $N(t) \leq \frac{1}{\mu}$.

Hence, the closed set Γ is a positive invariant concerning the system (1).

The prevalence of free equilibrium is defined by $E_0 = (S_0, 0, 0, 0, 0) = \left(\frac{1}{\mu}, 0, 0, 0, 0\right)$, and the primary reproduction number $\Re_0$ for the stability of system (1) is obtained by using the matrices F and V given as

$$F = \begin{pmatrix} 0 & \eta_2\varphi & \eta_2 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \text{ and } V = \begin{pmatrix} \beta_2 + \beta_3 + \beta_5 + \mu & 0 & 0 \\ -\beta_2 & \lambda_A + \beta_1 + \mu & 0 \\ -\beta_3 & -\beta_1 & \lambda + \mu \end{pmatrix}$$

and obtain

$$\Re_0 = \frac{\eta_2\phi\beta_2(\lambda + \mu) + \eta_2(\beta_1\beta_2 + \beta_3(\lambda_A + \beta_1 + \mu))}{(\beta_2 + \beta_3 + \beta_5 + \mu)(\lambda_A + \beta_1 + \mu)(\lambda + \mu)}$$

and using parameter values from Table 1, we get $\Re_0 = 2.9660 > 1$ which shows that the system (1) is unstable.

3. Stability Result

Theorem 3.1. *The prevalence-free equilibrium* E_0 *for* (1) *is locally asymptotically stable if* $\Re_0 < 1$.

Proof. To obtain prevalence free equilibrium at the point E_0, the Jacobian matrix is as follows:

$$J = \begin{bmatrix} -\beta_4 - \mu & 0 & \eta_2\phi & -\eta_2 & 0 \\ 0 & -(\beta_2 + \beta_3 + \beta_5 + \mu) & \eta_2\varphi & \eta_2 & 0 \\ 0 & \beta_2 & -(\beta_1 + \lambda_A + \mu) & 0 & 0 \\ 0 & \beta_3 & \beta_1 & -(\lambda + \mu) & 0 \\ \beta_4 & \beta_5 & \lambda_A & \lambda & -\mu \end{bmatrix},$$

$$\lambda_C^3 + a_1\lambda_C^2 + a_2\lambda_C + a_3 = 0,$$

$$a_1 = \beta_1 + \beta_2 + \beta_3 + \beta_5 + \lambda + \lambda_A + 3\mu,$$

$$a_2 = [(\lambda + \mu)(\beta_1 + \beta_2 + \beta_3 + \beta_5 + \lambda_A + 2\mu)$$

$$+ (\beta_2 + \beta_3 + \beta_5 + \mu)(\beta_1 + \lambda_A + \mu) - \eta_2(\varphi\beta_2 + \beta_3)],$$

$$a_3 = [\{(\beta_2 + \beta_3 + \beta_5 + \mu)(\beta_1 + \lambda_A + \mu)$$

$$- \eta_2\varphi\beta_2\}(\lambda + \mu) - \eta_2\beta_1\beta_2 - \eta_2\beta_3(\beta_1 + \lambda_A + \mu)].$$

The eigenvalues for the above Jacobian matrix about the equilibrium points are –0.0032, –0.2, 1.3960, –0.0972 and –1.5702. Hence the system is not locally asymptotically stable.

4. Endemic Equilibria

The endemic equilibrium of the system is denoted by $E_0^* = (S^*, E^*, H^*, I^*, R^*)$, where

$$E^* = \frac{\eta_2\lambda^* S^*(I^* + \phi H^*)}{N(\beta_2 + \beta_3 + \beta_5 + \mu)}, \quad H^* = \frac{\beta_2 E^*}{\lambda_A + \beta_1 + \mu},$$

$$I^* = \frac{\beta_3 E^* + \beta_1 H^*}{\lambda + \mu}, \quad R^* = \frac{\beta_5 E^* + \beta_4 S^* + \lambda I^* + \lambda_A H^*}{\mu}$$

and

$$\lambda^* = \frac{\eta_2\lambda^* S^*(I^* + \phi H^*)}{S^* + E^* + H^* + I^* + R^*}$$

which satisfies the equation $P(\lambda^*) = m_1(\lambda^*)^2 + m_2\lambda^* = 0,$ where m_1 and m_2 are given by

$$m_1 = (\beta_2 + \beta_3 + \beta_5 + \mu)(\lambda_A + \beta_1 + \mu)(\lambda + \mu),$$

$$m_2 = (\beta_2 + \beta_3 + \beta_5 + \mu)(\lambda_A + \beta_1 + \mu)(\lambda + \mu)(1 - \Re_0).$$

Obviously, $m_1 \geq 0$ and $m_2 \geq 0$ whenever $\Re_0 < 1,$ so that $\lambda^* = \frac{-m_2}{m_1} \leq 0.$

The endemic equilibrium does not hold for $\Re_0 < 1.$

5. Existence and Uniqueness of Solution

Fixed point technique used in Zhao et al. [23] is employed to show that the solution of (1) is unique. We have

$$\frac{d}{dt}(S(t)) = G_1(t, S(t)),$$

$$\frac{d}{dt}(E(t)) = G_2(t, E(t)),$$

$$\frac{d}{dt}(H(t)) = G_3(t, H(t)),$$

$$\frac{d}{dt}(I(t)) = G_4(t, I(t)),$$

$$\frac{d}{dt}(R(t)) = G_5(t, R(t)). \tag{4}$$

By Lemma 2.1, equation (4) can be written as follows:

$$S(t) - S(0) = \int_0^t G_1(\tau, S)d\tau,$$

$$E(t) - E(0) = \int_0^t G_2(\tau, E)d\tau,$$

$$H(t) - H(0) = \int_0^t G_3(\tau, H)d\tau,$$

$$I(t) - I(0) = \int_0^t G_4(\tau, I)d\tau,$$

$$R(t) - R(0) = \int_0^t G_5(\tau, R)d\tau. \tag{5}$$

Theorem 5.1. *The kernel* G_1 *holds the contraction and Lipschitz condition if the inequality* $0 \leq \eta_2(M_4 + \psi M_3) + \beta_4 + \mu < 1$ *holds.*

Proof. Let

$$\| G_1(t, S) - G_1(t, S_1) \| \leq [\eta_2(M_4 + \psi M_3) + \beta_4 + \mu] \| S - S_1 \|.$$

Suppose that $d_1 = \eta_2(M_4 + \psi M_3) + \beta_4 + \mu$, where $\| S \| \leq M_1$, $\| E \| \leq M_2$, $\| H \| \leq M_3$, $\| I \| \leq M_4$ and $\| R \| \leq M_5$ are bounded functions.

So

$$\| G_1(t, S) - G_1(t, S_1) \| \leq d_1 \| S(t) - S_1(t) \|. \tag{6}$$

Thus, the Lipschitz condition G_1 is obtained.

If $0 \leq \eta_2(M_4 + \psi M_3) + \beta_4 + \mu < 1$, then G_1 is a contraction. Similarly, the Lipschitz condition $\{G_i / 2 \leq i \leq 5\}$ is given by

$$\| G_2(t, E) - G_2(t, E_1) \| \leq d_2 \| E(t) - E_1(t) \|,$$

$$\| G_3(t, H) - G_3(t, H_1) \| \leq d_3 \| H(t) - H_1(t) \|,$$

$$\| G_4(t, I) - G_4(t, I_1) \| \leq d_4 \| I(t) - I_1(t) \|,$$

$$\| G_5(t, R) - G_5(t, R_1) \| \leq d_5 \| R(t) - R_1(t) \|,$$

where $d_2 = \beta_2 + \beta_3 + \beta_5 + \mu$, $d_3 = \beta_1 + \lambda_A + \mu$, $d_4 = \lambda + \mu$ and $d_5 = \mu$ are bounded functions, if $0 \leq d_i < 1$, $i = 2, 3, 4, 5$, then $\{G_i / 2 \leq i \leq 5\}$ are contractions.

The recursive solution of the system (5) is given by

$$Z_{1n}(t) = S_n(t) - S_{n-1}(0) = \int_0^t [G_1(\tau, S_{n-1}) - G_1(\tau, S_{n-2})]d\tau,$$

$$Z_{2n}(t) = E_n(t) - E_{n-1}(0) = \int_0^t [G_2(\tau, E_{n-1}) - G_2(\tau, E_{n-2})]d\tau,$$

$$Z_{3n}(t) = H_n(t) - H_{n-1}(0) = \int_0^t [G_3(\tau, H_{n-1}) - G_3(\tau, H_{n-2})]d\tau,$$

$$Z_{4n}(t) = I_n(t) - I_{n-1}(0) = \int_0^t [G_4(\tau, I_{n-1}) - G_4(\tau, I_{n-2})]d\tau,$$

$$Z_{5n}(t) = R_n(t) - R_{n-1}(0) = \int_0^t [G_5(\tau, R_{n-1}) - G_5(\tau, R_{n-2})]d\tau \tag{7}$$

with $S_0(t) = S(0)$, $E_0(t) = E(0)$, $H_0(t) = H(0)$, $I_0(t) = I(0)$ and $R_0(t) = R(0)$. Applying the norm to $Z_{1n}(t)$ in equation (7), we have

$$\| Z_{1n}(t) \| = \| S_n(t) - S_{n-1}(0) \| = \left\| \int_0^t [G_1(\tau, S_{n-1}) - G_1(\tau, S_{n-2})]d\tau \right\|$$

$$\leq \int_0^t \| [G_1(\tau, S_{n-1}) - G_1(\tau, S_{n-2})] \| d\tau$$

by Lipschitz condition (6),

$$\| Z_{1n}(t) \| \leq d_1 \int_0^t \| Z_{1(n-1)}(\tau) \| d\tau. \tag{8}$$

Similarly,

$$\| Z_{2n}(t) \| \leq d_2 \int_0^t \| Z_{2(n-1)}(\tau) \| d\tau,$$

$$\| Z_{3n}(t) \| \leq d_3 \int_0^t \| Z_{3(n-1)}(\tau) \| d\tau,$$

$$\| Z_{4n}(t) \| \leq d_4 \int_0^t \| Z_{4(n-1)}(\tau) \| d\tau,$$

$$\| Z_{5n}(t) \| \leq d_5 \int_0^t \| Z_{5(n-1)}(\tau) \| d\tau. \tag{9}$$

Thus,

$$S_n(t) = \sum_{j=1}^{n} Z_{1j}(t), \quad E_n(t) = \sum_{j=1}^{n} Z_{2j}(t), \quad H_n(t) = \sum_{j=1}^{n} Z_{3j}(t),$$

$$I_n(t) = \sum_{j=1}^{n} Z_{4j}(t), \quad R_n(t) = \sum_{j=1}^{n} Z_{5j}(t).$$

Theorem 5.2. *A solution of the system* (1) *exists if there exists* t_1 *such that* $t_1 d_i < 1$.

Proof. Using equations (8), (9) and recursive technique, the inequalities are obtained as

$$\| Z_{1n}(t) \| \leq \| S_n(0) \| [d_1 t]^n,$$

$$\| Z_{2n}(t) \| \leq \| E_n(0) \| [d_2 t]^n,$$

$$\| Z_{3n}(t) \| \leq \| H_n(0) \| [d_3 t]^n,$$

$$\| Z_{4n}(t) \| \leq \| I_n(0) \| [d_4 t]^n,$$

$$\| Z_{5n}(t) \| \leq \| R_n(0) \| [d_5 t]^n. \tag{10}$$

Thus, equation (10) is a continuous solution of the system (1).

Assume that

$$S(t) - S(0) = S_n(t) - W_{1n}(t), \quad E(t) - E(0) = E_n(t) - W_{2n}(t),$$

$$H(t) - H(0) = H_n(t) - W_{3n}(t), \quad I(t) - I(0) = I_n(t) - W_{4n}(t),$$

$$R(t) - R(0) = R_n(t) - W_{5n}(t)$$

so

$$\| W_{1n}(t) \| \leq \int_0^t \| G_1(\tau, S) - G_1(\tau, S_{n-1}) \| d\tau \leq d_1 \| S - S_{n-1} \| t.$$

By repeating the method, we obtain $\| W_{1n}(t) \| \leq [t]^{n+1} d_1^{n+1} h.$ Hence, $t_1 \| W_{1n}(t) \| \leq [t_1]^{n+1} d_1^{n+1} h.$ As n approaches to ∞, this implies $\| W_{1n}(t) \| \to 0.$ Similarly, $\| W_{in}(t) \| \to 0,$ for $i = 2, 3, 4, 5$ can be obtained. Hence the theorem is proved.

To prove uniqueness, assume $S_1(t),$ $E_1(t),$ $H_1(t),$ $I_1(t)$ and $R_1(t)$ as another solution. Then

$$S(t) - S_1(t) = \int_0^t (G_1(\tau, S) - G_1(\tau, S_1)) d\tau,$$

$$\| S(t) - S_1(t) \| \leq \int_0^t \| (G_1(\tau, S) - G_1(\tau, S_1)) \| d\tau.$$

From Lipschitz condition (6),

$$\| S(t) - S_1(t) \| \leq d_1 t \| S(t) - S_1(t) \|.$$

Thus,

$$\| S(t) - S_1(t) \| (1 - d_1 t) \leq 0. \tag{11}$$

Theorem 5.3. *The system* (1) *has a unique solution if* $(1 - d_1 t) > 0$ *holds*.

Proof. Assume that equation (11) holds. Then $\| S(t) - S_1(t) \| = 0.$ Therefore, $S(t) = S_1(t).$

Likewise, the same equality can be shown for *E*, *H*, *I* and *R*.

6. Validation of SEHIR Model through Experimental Survey

In this section, an experimental survey is given to validate SEHIR model. In this survey, we have considered 2000 individuals as a sample and classified them according to age in Table 1.

Table 1. Age classification of 2000 individuals

Age (in years)	Male	Female
17 to 22	477	423
23 to 35	330	310
36 to 45	213	187
46 to 55	35	25

For this experiment, we have surveyed 2000 handlers and considered the most commonly used social media applications. The number of users in percentages is given below in Figure 2.

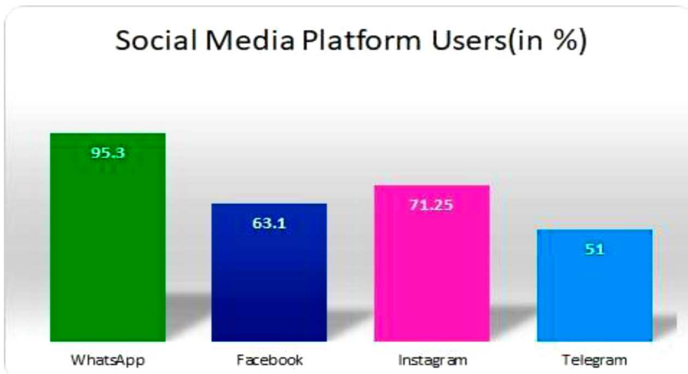

Figure 2. Social media application users in percentage.

Following are the restrictions/guidelines for participants, which must be considered for the survey:

(1) No users are allowed to send news/messages outside the sample population.

(2) After sharing each news/message, user must complete the pre-assigned survey form.

(3) Users are limited to send news/messages only on the prescribed social media platforms.

(4) Users must forward the news/message only to the new recipients and avoid reverting to the sender if at all possible.

Methodology

Initially, each news/message received on any social media platform cannot be classified as true or fake news. However, after receiving the number of complaints regarding news/messages, it is possible to analyze the truthfulness of it. In this experiment, 24 participants from the sample population received one message on WhatsApp, later all these participants were allowed to forward this message on social media applications such as WhatsApp, Facebook, Instagram and Telegram, specifically to the population of the given sample. After sharing the message, each participant was instructed to submit a dully-filled survey form on the online platform. All the responses were collected on an hourly basis, and details of sharing news/messages are given below in Table 2.

Table 2. Message sharing on social media platforms

Time (Hrs)	WhatsApp	Facebook	Instagram	Telegram
0	24	0	0	0
0.5	116	100	56	117
1	230	231	179	291
1.5	307	300	281	263
2	347	360	335	361
2.5	392	401	399	402
3	570	600	556	554
3.5	889	715	763	703
4	1086	988	1023	856
4.5	1002	900	981	910
5	891	791	871	923
5.5	771	712	691	647
6	659	613	631	593
6.5	565	572	513	407
7	487	394	290	254
7.5	425	361	312	301
8	377	331	363	287
8.5	346	313	318	149

9	316	289	271	197
9.5	257	260	227	154
10	188	200	179	198
10.5	147	156	131	131
11	120	113	107	125
11.5	93	89	70	83
12	70	72	51	52
12.5	47	43	31	29
13	38	41	28	21
13.5	11	7	10	5
14	1	2	0	3
14.5	0	1	0	0
15	0	0	0	0

The graphical representation of message sharing on the social media platforms for each application is given below.

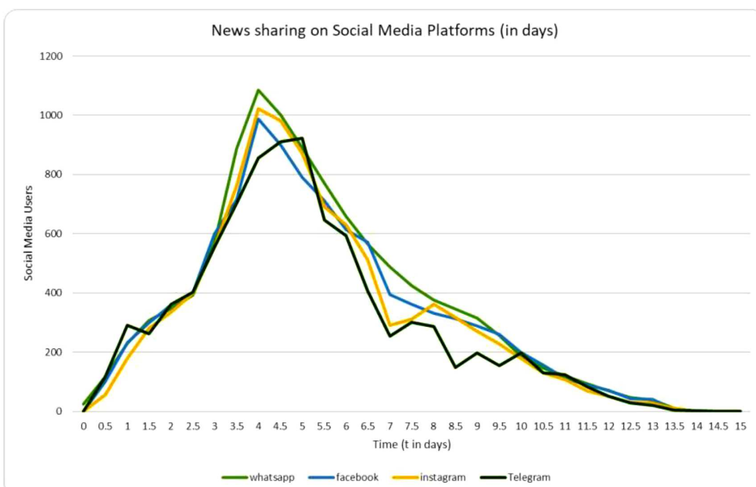

Figure 3. Real-time message sharing by SMU v/s time (*t*).

7. Model Simulation and Graphical Representation

In this section, the graphical representation of model (1) is given to approximate the real-time message sharing data given in Table 2 using MATLAB (R2015a).

The parametric value used for simulation is given in the following Table 3:

Table 3

Parameters	Description	Value (calculated)
μ	Deactivation rate of users	0.00325
η_2	Contact rate	0.7985
β_1	The rate at which hibernator individual becomes infected	0.69918
β_2	The rate at which exposed individual become hibernator	0.21763
β_3	The rate at which exposed individual become infected	0.71845
β_4	The rate at which susceptible become recovered	0.19675
β_5	The rate at which exposed become recovered	0.097
λ	Removal or recovery rate of *I*	0.23715
λ_A	Removal or recovery rate of *H*	0.299675

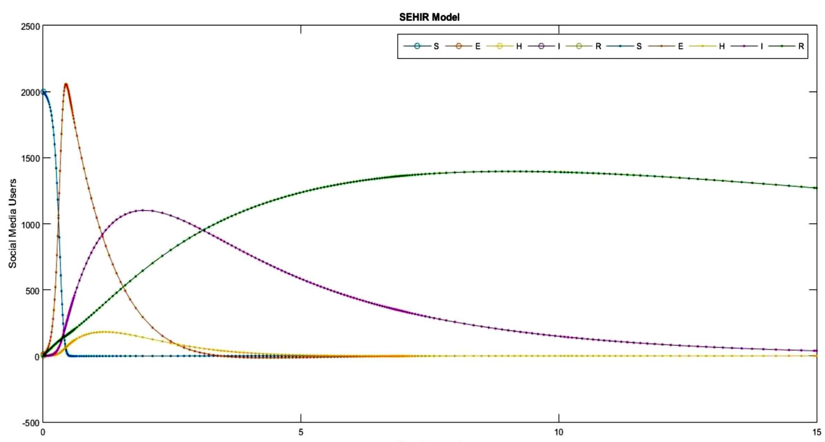

Figure 4. Simulated news/message sharing by SMU v/s time (t).

Initially, in Figure 4, the number of susceptible individuals is quite high and due to the virtual domain, sudden fall in the susceptible individual over time has been observed. The red line represents the number of exposed individuals. In the beginning, since the number of susceptible individuals is high, the number of exposed individuals suddenly increases. After a sudden fall in susceptible individuals, the number of exposed individuals also decreases. The yellow line represents the number of hibernators which is gradually increasing over time and due to the decrease in the number of infected individuals (the purple line), the number of hibernators also decreases. From Figure 4, it can be observed that as the number of exposed individuals increases, the number of infected individuals also increases. But the decrease in the number of infected individuals is not sudden like in the case of exposed individuals because the infected individuals will continue sharing news/messages over time due to unawareness of the news/messages. However, after authentication of news/messages over time, the number of infected individuals starts decreasing. The green line represents the number of recovered/removed individuals from the infected ones. From Figure 4, it can be observed that the number of recovered/removed individuals continuously increases as the number of infected individuals decreases over time. Besides, the number of recovered or removed individuals also increases over time as more people are getting aware of fake news.

8. Conclusion and Discussion

The study investigates the stream and occurrence of disinformation on different social media platforms affecting the social fabric of the nation by developing a SEHIR model and representing scenarios like response and reaction of the user related to the news through a mathematical model and its further identification as a piece of untruth news following eventual reduction. Evidently, from Figure 2, the number of people pertinent to spreading fake news decreases over time. Besides, from Figure 3, it can be interpreted that in the beginning, the number of people bare to receive the misinformation increases, and eventually due to a decrease in the number of relevant individuals concerning time, the number of exposed people also decreases time. Moreover, Figure 4 shows that the number of individuals within the age group 17-22 getting trapped in the cycle of fake news and becoming a medium to spread it is increasing concerning time since the people exposed to the misinformation also increases. Besides, as the number of people who are medium of spreading fake news increases, the numbers of dormant individuals who are not reacting instantly or at all to the disinformation will also increase over time, and a similar scenario is followed for the decreasing trend. It has also been observed that as many people become aware of the disinformation, the number of people in the range of age group 46-55 that are inactive to spread the fake information also increases over time. Furthermore, the numerical simulation represents the comparison based on users' rate of change for different compartments.

The trend visible in Figure 3, representing the sharing of false news on social media, obtained through experimental survey approximately, fits the trend followed by the purple line (line showing the individuals active in sharing the fake news) in Figure 4 calculated by numerical simulation of the model. Hence, the fitting of the trend validates the model. Moreover, it can be noticed from the experimental survey data of Table 2 that from the day of sharing, the number of people sharing news increases till the fourth day, since people might not be aware of the fakeness of the news initially. However, after the fourth day, it gradually started to decrease and eventually stopped reaching 15 days, exhibiting people's awareness about the news. This similarity can be easily observed from the data in Table 2 and matched approximately with the purple line showing infected people (people active in sharing fake news) in Figure 4.

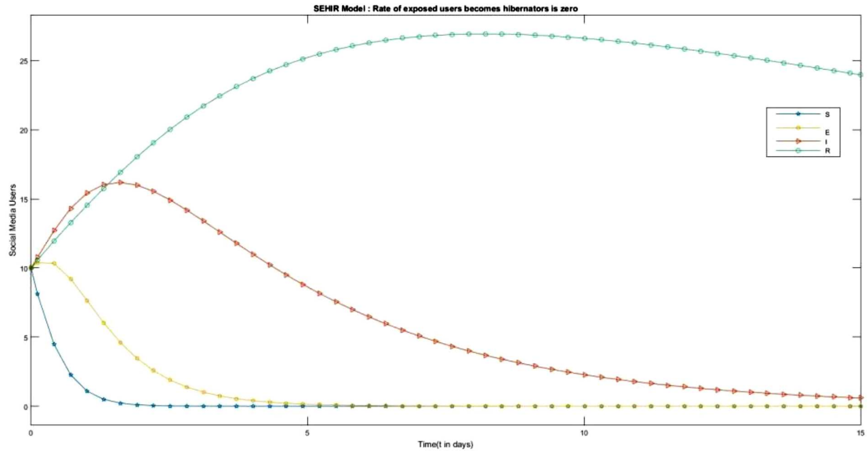

Figure 5. Number of users v/s time when the rate of hibernators is zero.

In contrast to considering the hibernators as zero, it increases the number of infected users and affects the rate of recovery of users from the fake news.

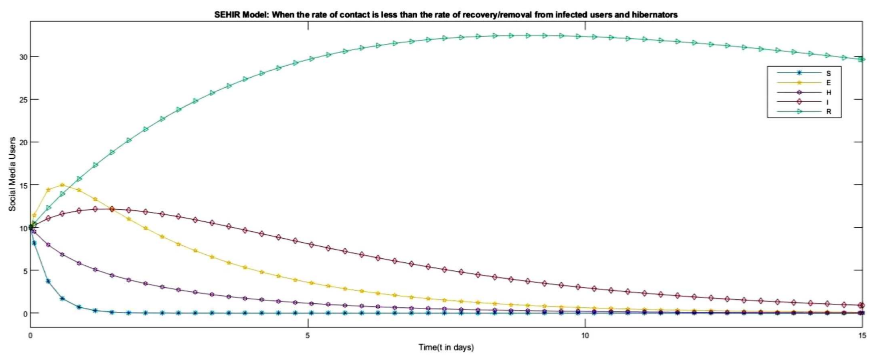

Figure 6. Number of users v/s time when the rate of contact is less than the rate of recovery or removal from infected users and hibernators.

Figure 6 represents the flow when the number of people coming in contact with disinformation is considered less than the rate of people getting aware of the false news and the number of people who are dropped from the chain of the spreader and even the people who are dormant towards spreading the news, then it will reduce the prevalence of false news.

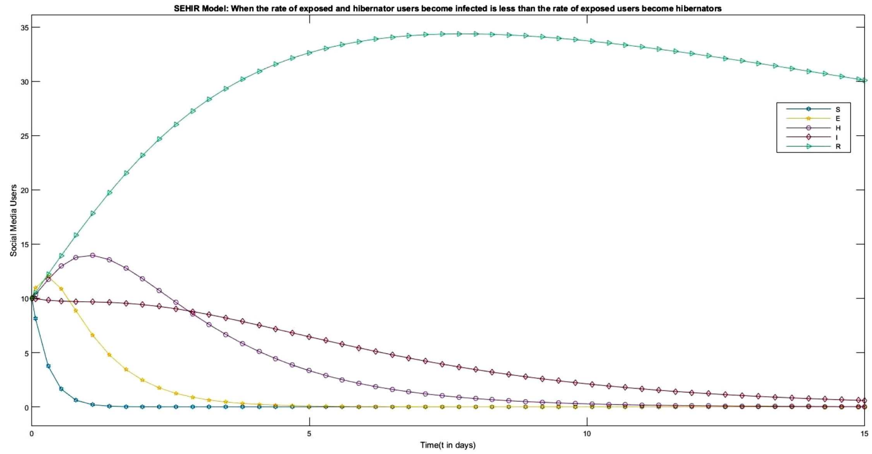

Figure 7. Number of users v/s time when the rate of exposed and hibernator users who became infected is less than the rate of exposed users became hibernators users.

Figure 7 exhibits the behavior that when the number of hibernators (inactive users) increases, the rate of people infected by the fake news will be reduced, which will eventually decline the spread.

Moreover, from the experimental survey, we can also observe that the highest sharing took place through WhatsApp compared to other platforms. It can be observed from the green line in Figure 3. In contrast to other users, the explanation for such a pattern might be WhatsApp is a comparatively private network, while other networks have a larger global audience and are considered public. Hence, it makes its users more cautious before sharing any news since it is visible publically, and the possibility of these users getting acquainted regarding the fake news is more than private users of WhatsApp. Besides, when a message is shared through WhatsApp, its verification becomes quite challenging. Hence, one can say that WhatsApp might have changed its policies owing to this issue.

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