

REVIEW ARTICLE

Modelling the Dynamics of Crime Against Women by Incorporating Role of Technology

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Khurana S., Nishad A.K., Shekhar S. Modelling the Dynamics of Crime Against Women by Incorporating the Role of Technology. Indian J Forensic Med Pathol. 2025; 18(2): 292-300.

ABSTRACT

Background: Crime against women in India is a complicated and ubiquitous issue that, despite attempts, remains a substantial challenge. It can have serious and long-term consequences for their physical, emotional, and psychological well-being. Technology can help combat crime against women by providing tools and resources for preventing, reporting, and dealing with abuse and harassment.

Aim: To combat crime against women in India and create a safe environment for them.

Objectives: To investigate the effectiveness of technology in lowering crime against women.

Material: A nonlinear mathematical model has been constructed taking into account five interacting variables namely, targeted, susceptible, criminals, victims, and technology.

Result: Our model shows the presence of two equilibria: crime-free and crime-persistent. The crime-free equilibria (CFE) always exist, while crime-persistent equilibria (CPE) exist when criminality reproduction number (R_0^c) is greater than 1. Further, stability analysis has been carried out. Analysis demonstrated that when $R_0^c > 1$, crime-persistent equilibria is nonlinearly asymptotically stable under some restrictions on parameters. The impact of key parameters on the dynamics of crime against women is also investigated through numerical simulation.

Conclusion: According to the model study, the use of technology like installing Safetipin or another emergency app, addressing areas with poor safety, introducing wearable tech etc can effectively minimize crime against women in society.

KEYWORDS

• Mathematical model • Crime against Women • Stability analysis • Role of technology • Dynamical system

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➤ Received: 17-07-2024 ➤ Accepted: 16-06-2025



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INTRODUCTION

Any offense that warrants censure by the community and a penalty, typically in the form of a fine or incarceration, is considered a crime. Crime encompasses a wide range of illegal behavior. A civilized society's fundamental foundation is destroyed by crime. It prevents a nation from developing and instills dread in its populace. Even though crime will always exist in any society, it must be kept to a minimum. However, this is not the case in India, where the crime rate is steadily rising. One needs to look into the origins, frequency, and societal effects of crime in India to understand its nature and dynamics. Mathematical modelling could be a useful tool in understanding crime dynamics and analyzing its preventive techniques.^{1,2} has a well-written assessment of the possible advantages of mathematical modeling of crime. The underlying causes of crime and possible remedies have been the subject of several scientific studies.³⁻¹⁶ In particular, an economic model connecting the distribution of crimes and burglaries was also put forth by Chiu.¹⁶ He looked into the relationship between the amount of crime and the distribution of money, assuming that burglars have a set incarnation time and that they select the properties they target based on the quality of the residence. According to a finding presented by the authors, the model examined how wealthier neighborhoods may have lower crime rates while more regressive taxes lead to higher crime rates. Subsequently, Curtis *et al.*¹⁷ developed a model linking crime and security after analyzing that homes near burglarized homes have a higher probability of crime than homes far from them. They examined how technology affects crime statistics by demonstrating how enforcing security lowers the likelihood of crime. The foundation of their approach was the presumption of a stable population, which is again not always true in actual situations. Shukla *et al.*¹⁸ created a model that took into consideration the dynamic population, which includes the immigration and emigration of sensitive individuals as well as offenders, to close this gap. They examined the inverse relationship between crime and technological sophistication using stability theory. The model also concluded that stopping illegal immigration may lessen the burden of crime.

Crimes against women have garnered the greatest attention of all. It addresses a broad range of offenses, such as trafficking, acid attacks, female infanticide, dowry-related crimes, sexual assault, and domestic abuse. In India, women of all ages, castes, religions, and socioeconomic backgrounds are impacted by the pervasive problem of women's crime. According to NCRB¹⁹, these crimes against women are alarmingly common. According to data, there were 3,71,503 criminal cases against women in 2020 as compared to 79,037 in 1992. There were 4,28,278 recorded cases of crimes against women in 2021, up 15.3 % from the year before. The number reached 4.45 lakh cases in 2022. A total of 31.8% of crimes against women fell into the category of "Cruelty by husband or his relatives." This was followed by "rape" (7.4%), "kidnapping and abduction of women" (17.6%), and "assault on women with intent to outrage her modesty" (20.8%).

It is dangerous for women's lives, endangering their bodily and mental well-being as well as the welfare of their offspring. Women may experience social exclusion, be unable to work, lose their income, and be unable to participate in routine activities. The advancement of society, trust, and education are all harmed by these crimes against women. Bypassing the Criminal Law (Amendment) Act of 2013, which increased the severity of punishments for sexual offenses and created specialized courts to expedite sexual assault prosecutions in India, the Indian government has taken steps to combat violence against women. The Indian government has also been recommending State Governments establish "crime against women cells" in districts where none already exist, to provide sufficient counseling services and safe havens for abused women, to establish special courts for women, and to enhance the efficacy of programs designed to protect and rehabilitate abused women, with a focus on generating income to help the women become more self-sufficient and independent. Violence survivors are assisted by the One Stop Centers (Sakhi) initiative, the Beti Bachao, and the Beti Padhao movement. Indian women continue to face a multitude of crimes and discrimination despite efforts to address gender-based violence. It's critical to establish a culture in which women are respected, safe and allowed to realize their full potential.

Although technology cannot stop violence against women, but can be a very useful weapon in the battle against it. Technology can play a critical role in raising awareness and changing attitudes regarding crime against women in India. Installing Safetipin or another emergency app, addressing areas with poor safety, introducing wearable tech, spreading awareness through social media, etc are some of the possible technological ideas used to prevent crime against women. Thus, we have welcomed the role of technology in our study. It is an essential tool in the anti-violence against women activist's toolbox to raise awareness of the problems associated with crime against women and get society one step closer to ending it. Technology serves as a magnifying glass for gender inequity and gender-based violence in today's hyper-connected society. The Internet, social media, and mobile phones highlight misogyny, harassment, and stereotypes. Through education and opportunities to share their tales, technology may also be a tool for women's empowerment.

The structure of the paper is as follows: Section 2 provides the formulation of the model. In Sections 3 and 4, respectively, the endemic equilibrium's existence and stability analysis are carried out. Numerical simulations are performed and discussed in Section 5. The paper's conclusion is found in Section 6.

Formulation of mathematical model

To start, let us divide the entire population $N(t)$ into four separate compartments: the susceptible women's population (likely to become victim) $Y(t)$, the target population $X(t)$, the criminals $C(t)$, the women victims $V(t)$. It is believed that women are more prone to become victims, which places them in the susceptible class at a rate proportional to the targeted population, or $\gamma_1 X$. The flow of women from the susceptible class to the victim class, when they interact with criminals, is determined by βCY , which is the product of the densities of susceptible women and criminals. Furthermore, it is assumed that the targeted persons become members of the criminal class at a rate proportional to the density of criminals and the targeted individuals combined, i.e., $\gamma_2 XC$, and commit crimes while under the influence of criminals. Additionally, there exists a probability that offenders will discontinue their criminal activities and transfer to the targeted class at

a rate proportional to the criminal population, i.e., $\gamma_3 C$. Lastly, the natural death rate μ for each class is assumed to be proportionate to that class's density.

A new dynamic variable, $T(t)$, reflecting the degree of technology applied to deter crime, was incorporated into the model. The use of technology has profoundly changed how law enforcement combats criminal activity. Because the introduction of new technology aids in the reduction of crime, the rate of technological advancement must correspond to the rise of criminals. Therefore, let η be the rate at which new technology to control crime is applied, which is assumed to be proportional to criminals. Furthermore, it is claimed that technology becomes less effective or outdated at a rate of $\eta_0(T - T_0)$, where T_0 represents the baseline level of technology in the absence of crime.

Furthermore, it is considered that technology reduces the likelihood of being victimized by criminals. This can decrease the

victimization rate by a fraction $\left(1 - \frac{pT(t)}{K + T(t)}\right)$, with a saturating function $\frac{T(t)}{K + T(t)}$ depending

on the level of technology 'T'. The constant K limits the effectiveness of technology, whereas $p \in [0, 1]$ evaluates the change in the criminal's behavior towards committing the crime.

The proposed mathematical model is as follows:

$$\begin{aligned}\frac{dX(t)}{dt} &= A - \gamma_1 X(t) - \gamma_2 X(t)C(t) + \gamma_3 C(t) - \mu X(t), \\ \frac{dY(t)}{dt} &= \gamma_1 X(t) - \beta \left(1 - \frac{pT(t)}{K + T(t)}\right) C(t)Y(t) - \mu Y(t), \\ \frac{dC(t)}{dt} &= \gamma_2 X(t)C(t) - \gamma_3 C(t) - \mu C(t), \\ \frac{dV(t)}{dt} &= \beta \left(1 - \frac{pT(t)}{K + T(t)}\right) C(t)Y(t) - (\mu + \phi)V(t), \\ \frac{dT(t)}{dt} &= \eta C - \eta_0(T(t) - T_0),\end{aligned}\quad \dots(1)$$

where $X(0) \geq 0$, $Y(0) \geq 0$, $C(0) \geq 0$, $T(0) = T_0 > 0$,

Since $N(t) = X(t) + Y(t) + C(t) + V(t)$, rewriting the above model:

$$\begin{aligned}\frac{dN(t)}{dt} &= A - \mu N(t) - \phi V(t) \\ \frac{dT(t)}{dt} &= \gamma_1(N(t) - Y(t) - C(t) - V(t)) - \beta \left(1 - \frac{pT(t)}{K + T(t)}\right) C(t)Y(t) - \mu Y(t), \\ \frac{dC(t)}{dt} &= \gamma_2(N(t) - Y(t) - C(t) - V(t))C(t) - \gamma_3 C(t) - \mu C(t), \\ \frac{dV(t)}{dt} &= \beta \left(1 - \frac{pT(t)}{K + T(t)}\right) C(t)Y(t) - (\mu + \phi)V(t), \\ \frac{dT(t)}{dt} &= \eta C - \eta_0(T(t) - T_0),\end{aligned}\quad \dots(2)$$

The region of attraction²⁰ for the positive solution of model (2) is given by the set:

$$\Omega = \{(N, Y, C, V, T) \in R_+^5 : \\ 0 \leq Y \leq N \leq \frac{A}{\mu}, 0 \leq C \leq \frac{A}{\mu} \left(\frac{\gamma_2}{\gamma_3 + \mu} \right) = C_r,$$

$$0 \leq V \leq \frac{C_r \beta A}{\mu(\mu + \alpha)} \\ = V_k, 0 \leq T \leq \frac{\eta C_r + T_0}{\eta_0}\}.$$

Equilibrium Analysis

The two non-negative equilibria of the model system (2) mentioned above are as follows:

(i) Crime free equilibria (CFE)

$$E_0 \left(\frac{A}{\mu}, \frac{\gamma_1 A}{\mu(\gamma_1 + \mu)}, 0, 0, T_0 \right) \text{ always exists.}$$

(ii) Crime-persistent equilibria

$E^*(N^*, Y^*, C^*, V^*, M^*)$ exists provided

$$R_0^c = \frac{A\gamma_2}{(\gamma_1 + \mu)(\gamma_3 + \mu)} > 1, \quad (4)$$

where R_0^c is defined as criminality reproduction number (CRN).

Existence of Equilibria: The crime-free equilibria E_0 is straightforward to identify. Next, for crime-persistent equilibria to exist, set the model system (2) to zero:

$$A - \mu N - \phi V = 0, \quad (5)$$

$$\gamma_1(N - Y - C - V) - \beta \left(1 - \frac{pT}{K+T} \right) CY - \mu Y = 0, \quad (6)$$

$$\gamma_2(N - Y - C - V)C - \gamma_3 C - \mu C = 0, \quad (7)$$

$$\beta \left(1 - \frac{pT}{K+T} \right) CY - (\mu + \phi)V = 0 \quad (8)$$

$$\eta C - \eta_0(T - T_0) = 0 \quad (9)$$

From (5), (8) and (9) we get

$$N = \frac{A - \phi V}{\mu}, \quad (10)$$

$$V = \frac{\beta \left(1 - \frac{pT}{K+T} \right) CY}{(\mu + \phi)}, \quad (11)$$

$$T = \frac{\eta C}{\eta_0} + T_0 \quad (12)$$

Equation (7) gives

$$N - Y - C - V = \frac{\gamma_3 + \mu}{\gamma_2}. \quad (13)$$

Using (13) in (6) we get

$$\gamma_1 \left(\frac{\gamma_3 + \mu}{\gamma_2} \right) - \beta \left(1 - \frac{pT}{K+T} \right) CY - \mu Y = 0, \quad (14)$$

which implies

$$Y = \frac{\gamma_1 \left(\frac{\gamma_3 + \mu}{\gamma_2} \right)}{\left(\beta \left(1 - \frac{pT}{K+T} \right) C + \mu \right)} = g(C). \quad (15)$$

Using (10), (11), (12) and (15) in (13), we get

$$F(C) = \frac{A}{\mu} - \frac{\phi \beta \left(1 - \frac{pT}{K+T} \right) C g(C)}{\mu(\mu + \phi)} - g(C) \\ - C - \frac{\beta \left(1 - \frac{pT}{K+T} \right) C g(C)}{\mu + \phi} - \frac{\gamma_3 + \mu}{\gamma_2} = 0. \quad (16)$$

It can be easily noted from equation (16) that

$$(i) F(0) = \frac{A}{\mu} - \frac{\gamma_1(\gamma_3 + \mu)}{\mu\gamma_2} - \frac{\gamma_3 + \mu}{\gamma_2} > 0 (\text{say}),$$

$$(ii) F\left(\frac{A}{\mu}\right) = -\frac{\phi \beta \left(1 - \frac{pT}{K+T} \right) \frac{A}{\mu} g\left(\frac{A}{\mu}\right)}{\mu(\mu + \phi)} - g\left(\frac{A}{\mu}\right).$$

$$-\frac{\beta \left(1 - \frac{pT}{K+T} \right) \frac{A}{\mu} g\left(\frac{A}{\mu}\right)}{\mu + \phi} - \frac{\gamma_3 + \mu}{\gamma_2} < 0$$

Thus, $F(C^*) = 0$ for a unique C^* in $(0, C^*)$ provided $R_0^c > 1$. Hence, equilibria $E^*(N^*, Y^*, V^*, M^*)$ exists, whenever condition (4) is satisfied.

Stability Analysis

In this section, we will discuss the stability analysis crime free equilibria E_0 and crime-persistent equilibria E^* . Theorem 1 provides the necessary conditions for the local stability of both the E_0 and E^* equilibria. In Theorem 2, we examine the global stability aspects of the crime-persistent equilibria E^* .

Local Stability

Theorem 1. (i) The crime free equilibria (CFE) E_0 always exists and is unstable if $R_0^c > 1$.

(ii) The crime-persistent equilibria E^* whenever exists, is stable if Routh-Hurwitz criteria is satisfied.

Proof. The Jacobian matrix J for the model system (2) is calculated as follows:

$$J = \begin{pmatrix} -\mu & 0 & 0 & -\phi & 0 \\ \gamma_1 & -a_{22} & -a_{23} & -\gamma_1 & a_{25} \\ \gamma_2 C^* & -\gamma_2 C^* & a_{33} & -\gamma_2 C^* & 0 \\ 0 & a_{42} & a_{43} & -(\mu + \phi) & a_{25} \\ 0 & 0 & \eta & 0 & -\eta_0 \end{pmatrix}.$$

where,

$$\begin{aligned} a_{22} &= \gamma_1 + \beta \left(1 - \frac{pT}{K+T} \right) C + \mu, a_{23} \\ &= \gamma_1 + \beta \left(1 - \frac{pT}{K+T} \right) Y, a_{25} \\ &= \beta C Y \frac{Kp}{(K+T)^2}, a_{33} \\ &= \gamma_2 (N - Y - V - 2C) - \gamma_3 - \mu, a_{42} \\ &= \beta \left(1 - \frac{pT}{K+T} \right) C, a_{43} = \beta \left(1 - \frac{pT}{K+T} \right) Y. \end{aligned}$$

Let the matrix J at E_0 and E^* be defined as J_0 and J^* . Then, J_0 is given by

$$J_0 = \begin{pmatrix} -\mu & 0 & 0 & -\phi & 0 \\ \gamma_1 & -\gamma_1 - \mu & -a_{23}^0 & -\gamma_1^0 & 0 \\ 0 & 0 & a_{33}^0 & 0 & 0 \\ 0 & 0 & a_{43}^0 & -(\mu + \phi) & 0 \\ 0 & 0 & \eta & 0 & -\eta_0 \end{pmatrix}.$$

Three eigen values of the above matrix are $-\gamma_1$, $-\mu$, $-\mu$ and $-\eta_0$. The other two eigen values can be obtained from the submatrix

$$\begin{pmatrix} a_{33}^0 & 0 \\ a_{43}^0 & -(\mu + \phi) \end{pmatrix}.$$

Clearly, the fourth eigen value is $-(\mu + \alpha)$ and the last eigen value a_{33}^0 is positive if $R_0^c > 1$, which make the system unstable and existence of crime-persistent equilibria is justified. Further, J is given by

$$J^* = \begin{pmatrix} -\mu & 0 & 0 & -\phi & 0 \\ \gamma_1 & -a_{22} & -a_{23} & -\gamma_1 & a_{25} \\ \gamma_2 C^* & -\gamma_2 C^* & a_{33} & -\gamma_2 C^* & 0 \\ 0 & a_{42} & a_{43} & -(\mu + \phi) & a_{25} \\ 0 & 0 & \eta & 0 & -\eta_0 \end{pmatrix},$$

where,

$$\begin{aligned} a_{22} &= \gamma_1 + \beta \left(1 - \frac{pT^*}{K+T^*} \right) C^* + \mu, a_{23} \\ &= \gamma_1 + \beta \left(1 - \frac{pT^*}{K+T^*} \right) Y^*, a_{25} \\ &= \beta C^* Y^* \frac{Kp}{(K+T^*)^2}, a_{33} \\ &= \gamma_2 (N^* - Y^* - V^* - 2C^*) - \gamma_3 - \mu, a_{42} \\ &= \beta \left(1 - \frac{pT^*}{K+T^*} \right) C^*, a_{43} = \beta \left(1 - \frac{pT^*}{K+T^*} \right) Y^*. \end{aligned}$$

The characteristic polynomial of J is given by

$$P(\lambda) = \lambda^5 + p_1 \lambda^4 + p_2 \lambda^3 + p_3 \lambda^2 + p_4 \lambda + p_5 = 0,$$

Where

$$p_1 = 2\mu + \phi + a_{22}^* - a_{33}^* + \eta_0.$$

$$\begin{aligned} p_2 &= \mu(\mu + \phi) + 2\mu(a_{22}^* - a_{33}^*) \\ &+ \phi(a_{22}^* - a_{33}^*) - a_{33}^* a_{22}^* \\ &+ (a_{43}^* - a_{23}^*) \gamma_2 C^* + \gamma_1 a_{42}^* \\ &+ \phi + a_{22}^* - a_{33}^*) \eta_0. \end{aligned}$$

$$\begin{aligned} p_3 &= -\mu^2(a_{33}^* - a_{22}^* - \eta_0) + \mu\phi(a_{22}^* - a_{33}^*) - 2\mu a_{22}^*(a_{33}^* + \eta_0) - 2\mu(a_{23}^* \gamma_2 C^* + a_{22}^* \eta_0) \\ &- \phi a_{22}^*(a_{33}^* - \eta_0) - \phi a_{32}^* \gamma_2 C^* + (\mu + \phi) \gamma_1 a_{42}^* + \mu\phi \eta_0 + (\phi + \mu) \gamma_2 C^* a_{43}^* \\ &+ \mu \gamma_2 C^* a_{43}^* - \gamma_1 (\gamma_2 C^* a_{43}^* + a_{33}^* a_{42}^*) - \phi a_{33}^* \eta_0 + \gamma_2 C^* (a_{22}^* a_{43}^* - a_{23}^* a_{42}^*) \\ &- \eta_0 (a_{22}^* a_{33}^* + a_{23}^* a_{32}^* - \gamma_1 a_{42}^* - \gamma_2 C^* a_{43}^*) - 2a_{25}^* \eta_0 \gamma_2 C^*. \end{aligned}$$

$$\begin{aligned} p_4 &= -\mu^2(a_{22}^* a_{33}^* + a_{33}^* \gamma_2 C^* - a_{22}^* \eta_0 + a_{33}^* \eta_0) + \gamma_2 a_{42}^* \eta_0 (\mu + \phi) \\ &- 2\mu(a_{25}^* \gamma_2 C^* \eta_0 + a_{22}^* a_{33}^* \eta_0 + a_{23}^* \gamma_2 C^* \eta_0) - 2\phi a_{25}^* \eta_0 \gamma_2 C^* - (\mu + \gamma_1) a_{25}^* \gamma_2 C^* \eta_0 \\ &+ a_{43}^* \eta_0 \gamma_2 C^* (\phi + \mu) - \gamma_2 \eta_0 (a_{32}^* a_{43}^* + a_{33}^* a_{42}^*) - a_{22}^* \gamma_2 C^* (a_{25}^* \eta_0 + a_{43}^* \eta_0) \\ &- \gamma_2 C^* a_{42}^* (a_{23}^* \eta_0 + a_{25}^* \eta_0) - \mu\phi(a_{22}^* a_{33}^* + a_{23}^* \gamma_2 C^* - a_{22}^* \eta_0 - \gamma_2 C^* a_{43}^*) \\ &- (\mu \gamma_1 - \phi a_{42}^*) (\gamma_2 C^* a_{43}^* + a_{33}^* a_{42}^*) + \phi \gamma_2 C^* (a_{22}^* a_{43}^* - a_{23}^* a_{42}^*) \\ &- a_{33}^* \eta_0 \phi (\mu + a_{22}^*) - \mu a_{23}^* \gamma_2 C^* a_{42}^* - \phi a_{33}^* \gamma_2 C^* \eta_0. \end{aligned}$$

$$\begin{aligned} p_5 &= -\mu(\mu + \phi)(a_{22}^* a_{33}^* \eta_0 + a_{32}^* a_{23}^* \eta_0 + a_{25}^* \gamma_2 C^* \eta_0) \\ &+ (\mu + \phi) \gamma_1 (a_{25}^* \gamma_2 C^* \eta_0 - \gamma_2 C^* a_{43}^* \eta_0 - a_{23}^* a_{42}^* \eta_0) - a_{25}^* \gamma_2 C^* \eta_0 \mu (a_{22}^* + a_{42}^*) \\ &+ \phi a_{25}^* \gamma_2 C^* \eta_0 (a_{22}^* + a_{42}^*) - \phi \gamma_2 C^* \eta_0 (a_{22}^* a_{43}^* - a_{23}^* a_{42}^*) \\ &- \mu \gamma_2 C^* \eta_0 (a_{22}^* a_{43}^* + a_{23}^* a_{42}^*). \end{aligned}$$

According to R.H criteria, E^* is locally stable if

$$\begin{aligned} p_5 > 0, p_1 p_2 - p_3 > 0, p_3(p_1 p_2 - p_3) - p_1(p_1 p_4 - p_5) > 0 \text{ and} \\ p_4(p_3(p_1 p_2 - p_3) - p_1(p_1 p_4 - p_5)) - p_5(p_2(p_1 p_2 - p_3) - (p_1 p_4 - p_5)) > 0 \end{aligned}$$

Global Stability

Theorem 2. When $R_0^c > 1$, the crime-persistent equilibria E^* exists and nonlinearly asymptotically stable provided the following requirements are met:

$$3\frac{\gamma_2}{\mu} < m_1 < \frac{\mu m_3 (\mu + \phi) \min\{D, F\}}{\phi^2}, \quad (18)$$

$$\frac{4\gamma_2}{(\gamma_1 + \mu)} < m_2 < \min\{A, B, E\}, \quad (19)$$

$$\max\{G, H\} < m_3 < \min\{D, F\}, \quad (20)$$

$$\max\{I, J\} < m_4 < \frac{\gamma_2 \eta_0}{2\eta^2}, \quad (21)$$

where

$$A = \frac{(\gamma_1 + \mu)\gamma_2}{4\gamma_1^2}, B = \frac{\gamma_2 \mu^2 (\gamma_1 + \mu)}{\beta + 2A^2 \left(1 - \frac{pT^*}{K+T^*}\right)}, C = \frac{4\gamma_2}{\gamma_1 + \mu}, D = \frac{\gamma_2 (\mu + \phi)}{(\gamma^*)^2 \beta^2 \left(1 - \frac{pT^*}{K+T^*}\right)^2}, E = \frac{\mu m_3 (\gamma_1 + \mu)}{\gamma_1^2}, F = \frac{m_2 (\gamma_1 + \mu) (\phi + \mu)}{4\beta^2 C^2 \left(1 - \frac{pT^*}{K+T^*}\right)^2}, G = \frac{4m_2 \gamma_1^2}{(\gamma_1 + \mu) (\phi + \mu)}, H = \frac{4\gamma_2^2}{\gamma_2 (\mu + \phi)}, I = \frac{2m_2 k^2 p^2 A^2}{\mu^2 \eta_0 K^2 (K+T^*)^2 (\gamma_1 + \mu)},$$

$$J = \frac{2m_3 A^2}{\eta_0 \mu^2 K^2 (K+T^*)^2 (\mu + \phi)}.$$

Proof. To ascertain the global stability of crime-persistent equilibria E^* , the following positive definite function is taken into consideration:

$$W = \frac{m_1}{2} (N - N^*)^2 + \frac{m_2}{2} (Y - Y^*)^2 + \left((C - C^*) - C^* \log \frac{C}{C^*} \right) + \frac{m_3}{2} (V - V^*)^2 + \frac{m_4}{2} (T - T^*)^2$$

where m_1, m_2, m_3 and are positive constants to be determined. We then differentiate W w.r.t t along the solutions of model system (2). For $\frac{dW}{dt}$ to be negative definite, the following inequalities must be satisfied by m_1, m_2 , and m_3 .

$$\begin{aligned} \gamma_1^2 m_2 &< \frac{1}{3} m_1 \mu \left(\gamma_1 + \beta C \left(1 - \frac{pT^*}{K+T^*} \right) + \mu \right), \\ m_2 \gamma_1^2 &< \frac{1}{4} \gamma_2 \left(\gamma_1 + \beta C \left(1 - \frac{pT^*}{K+T^*} \right) + \mu \right), \\ m_1 \phi^2 &< \frac{1}{3} m_3 \mu (\mu + \phi), \\ \gamma_2 &< \frac{1}{3} m_1 \mu, \\ m_2 \gamma_1^2 &< \frac{1}{33} \gamma_2 \left(\gamma_1 \left(1 - \frac{pM^*}{K_1 + M^*} \right) + \beta C^* + \mu \right), \end{aligned}$$

$$\begin{aligned} m_3 \beta^2 C^2 \left(1 - \frac{pT^*}{K+T^*} \right)^2 &< \frac{1}{4} m_2 (\phi + \mu) \left(\gamma_1 + \beta C \left(1 - \frac{pT^*}{K+T^*} \right) + \mu \right), \\ m_2 p^2 Y^2 \frac{K^2}{(K+T^*)^2 (K+T)^2} &< \frac{1}{2} \eta_0 m_4 \left(\gamma_1 + \beta C \left(1 - \frac{pT^*}{K+T^*} \right) + \mu \right), \\ \gamma_2^2 &< \frac{1}{4} m_3 \gamma_3 (\mu + \phi), \\ m_3 \beta^2 \left(1 - \frac{pT^*}{K+T^*} \right)^2 (Y^*)^2 &< \frac{1}{4} (\mu + \phi) \gamma_2, \\ m_3 \frac{Y^2}{(K+T^*)^2 (K+T)^2} &< \frac{1}{2} \eta_0 m_4 (\mu + \phi), \\ \eta^2 m_4 &< \frac{1}{2} \eta_0 \gamma_2. \end{aligned}$$

Positive m_1, m_2, m_3 and m_4 can be readily selected from the aforementioned inequalities as long as the corresponding conditions of (18), (19), (20) and (21) are met.

Numerical Simulation and Discussion

Here, we use the MATLAB to numerically solve the model and explain the graphical results. Initially, we estimate the population's natural death rate, (i.e. μ). India's average life expectancy is 70.42 years 21; this corresponds to $\mu = 0.00003891$ each day. The values of the other parameters, displayed in the table 1 below, were taken as given.

Fitted or estimated parameter values for present model.

Parameters	Description	Baseline value (per year)
A	Immigration Rate	100
μ	Natural death rate	0.00003891
γ_1	Rate of flow from X to Y	0.00009
γ_2	Crime committing rate of X	0.0000000011
γ_3	Rate of flow from C to X	0.0006
β	Rate at which Y are getting victimised under the influence of criminals	0.00000000001
ϕ	Death rate of victims	0.002
η	rate at which new technology to control crime against women is applied	0.0000032
η_0	rate at which the technology becomes less effective or outdated.	0.005
p	the efficacy of technology in controlling crime against women	0.4
K	Constant which limits the effect of technology	50
T_0	Baseline level of technology present before crime	50

It may be concluded that for the above set of parameters, crime-persistent equilibria E^* exist and is nonlinearly stable. The equilibrium values of E^* is given by $N^* = 2443687.81108$, $\gamma^* = 1214667.29395$, $C^* = 645735.19076$, $V^* = 2458.053635$, and $T^* = 463.27$. For the specified set of parameters, the eigenvalues of the Jacobian matrix that correspond to the E^* are -0.00002 , -0.00004 , -0.0005 , -0.002 , and -0.004 . The Routh Hurwitz condition shows that E^* is locally asymptotically stable since all of the eigenvalues are negative.

Model (2) is solved for a variety of variables using the previously defined parameters, and the outcome is graphically depicted. The behavior of the victims $V(t)$ and criminals $C(t)$ with regard to time ' t ' is depicted in Figures 1, 2, and 3 for various values of γ_1 , γ_2 , and γ_3 , respectively. The graphs revealed that while victims and criminals show a fall as γ_2 drops, the number of victims and criminals decreases as γ_1 or γ_3 grows. The behavior of γ_1 is illustrated by the fact that as γ_1 rises, more technology will be implemented, which will result in reduced victims. Figure 4 shows the behavior of technology $T(t)$ and victims $V(t)$ with respect to time ' t ' for different values of η . The graph makes it clear that when η increases, victims $V(t)$ decline, and technology $T(t)$ increases. The behavior of victims $V(t)$ and criminals $C(t)$ is depicted in Figure 5 in both the presence and absence of technology. The impact of the technology is seen by the decrease in victims $V(t)$ and criminals $C(t)$. Together, these indicate that the prevalence of crime can be reduced by raising the values of γ_1 and γ_3 and decreasing the value of γ_2 .

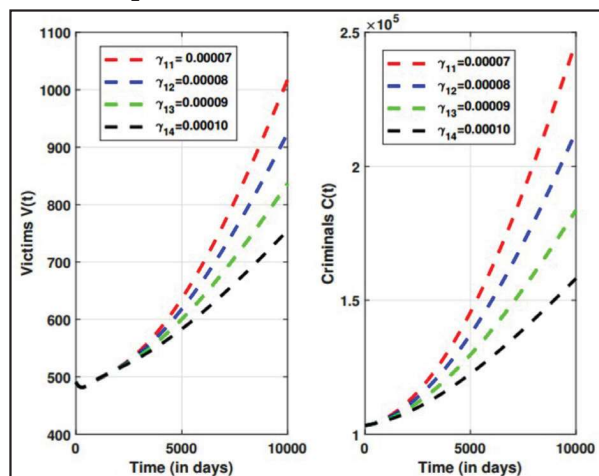


Figure 1: Variation in victims $V(t)$ and criminals $C(t)$ population with variation in γ_1

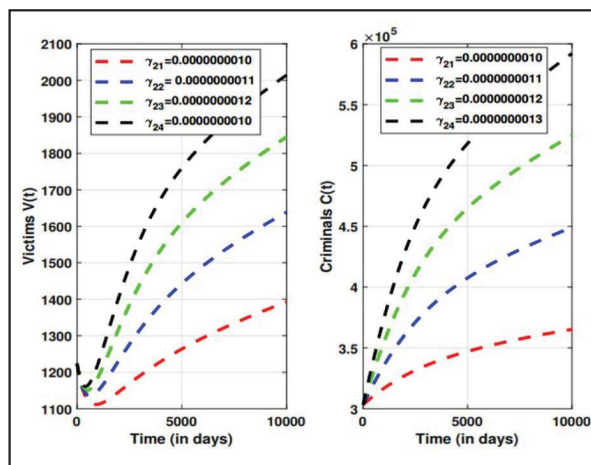


Figure 2: Variation in victims $V(t)$ and criminals $C(t)$ population with variation in γ_2

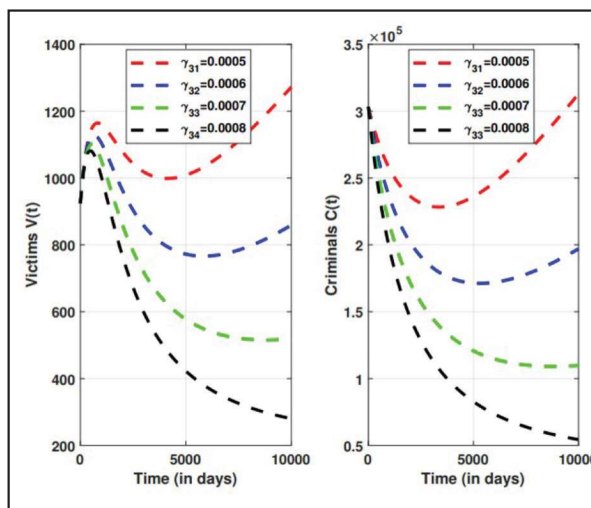


Figure 3: Variation in victims $V(t)$ and criminals $C(t)$ population with variation in γ_3

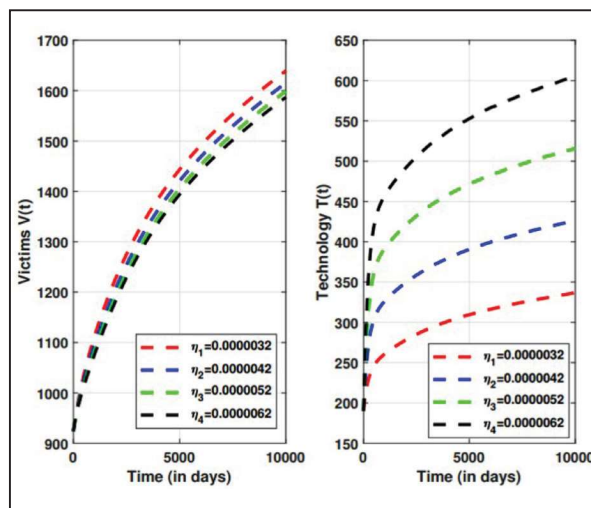


Figure 4: Variation in victims $V(t)$ population and technology $T(t)$ with variation in η

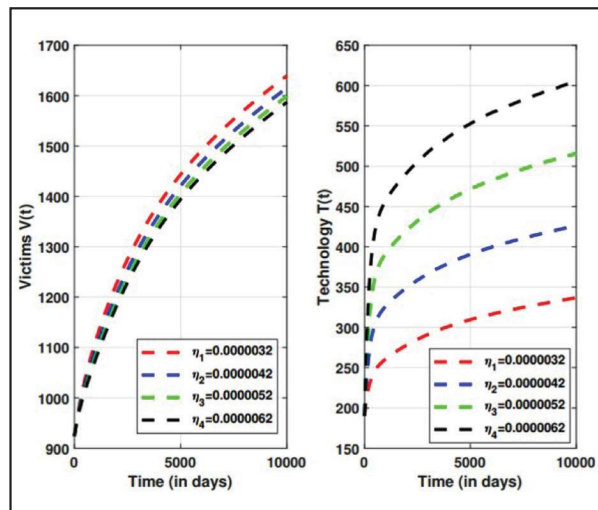


Figure 5: Victims $V(t)$ and criminal $C(t)$ population with and without technology impact

CONCLUSION

Women have long been victims of various sorts of physical and psychological abuse and violence around the world. A woman's health and well-being can be significantly impacted by the long-lasting impacts of violence. We considered an epidemic modelling approach to describe the dynamics of crime against women as criminal behavior is considered to be contagious. Technology incorporation into crime prevention techniques has transformed safety and crime detection, even as traditional law enforcement measures and community vigilance continue to be vital. Consequently, the role of technology is explored, and a new compartment is included. In light of this, this study presents a nonlinear mathematical model to examine the dissemination of crime against women and its mitigation tactics. There are two equilibria in the proposed model: the crime-free equilibrium (CFE) and the crime-persistent equilibrium (CPE). The CFE exists and is locally asymptotically stable when $R_0^c < 1$. On the other hand, CFE becomes unstable and CPE appears when $R_0^c > 1$. The CPE exhibits both local and nonlinear stability under specific conditions. The analysis points to a decrease in crime and victims when technology is incorporated like installing Safetipin or another emergency app, addressing areas with poor safety, introducing wearable tech, spreading awareness through social media, etc. This will assist policymakers in implementing technological controls to avoid crime against women.

Conflict of Intestate: The authors have no conflicts of interest to declare.

REFERENCES

1. Gordon M.B., A random walk in the literature on criminality: a partial and critical view on some statistical analyses and modelling approaches. *Eur J Appl Math.* 2010; 21: 283-306.
2. Khurana S. and Shekhar S., Mathematical Models Studying Crime Dynamics: A Review on Adopted Approaches. *Indian J Forensic Med Pathol.* 2022; 14 (3 Special): 223-230.
3. Gordon M.B., Iglesias J.R., Semeshenko V., Nadal J.P., Crime and punishment: the economic burden of impunity. *Eur Phys J B.* 2009; 68(1): 13344.
4. Fernandez A., Crime prevention. Wilan Publishing, New York; 2005.
5. Levitt S., The effect of prison population size on crime rates: Evidence from overcrowding litigation. *QJ Econ.* 1996; 111(2): 31951.
6. Phan D., Gordon M.B., Nadal J.P., Social interactions in economic theory: an in-sight from statistical mechanics. *Cognit Econ.* 2004: 335-58.
7. Becker G.S., Crime and punishment: An economic approach. *Journal of Political Economy.* 1968; 76(2): 169-217.
8. McMillon D., Simon C.P., Morenoff J., Modeling the Underlying Dynamics of the Spread of Crime. *PLoS ONE.* 2014; 9(4): e88923.
9. Campbell M. and Ormerod P., Social Interactions and the Dynamics of Crime. Tech. Rep., Volterra Consulting. 1998.
10. Srivastav A.K., Ghosh M., Chandra P., Modeling dynamics of the spread of crime in a society. *Stochastic Analysis and Applications.* 2019; 37(6): 991-1011.
11. Gonzalez-Parra G., Chen-Charpentier B., Kojouharov H.V., Mathematical modelling of crime as a social epidemic. *Journal of Interdisciplinary Mathematics.* 2018; 21(3): 623-643.
12. Glaeser E.L., Sacerdote B., Scheinkman J. A., Crime and Social Interactions. *Quarterly Journal of Economics.* 1996; 111(2): 507-48.
13. Athithan S., Ghosh M., Li X. Z., Mathematical modelling and optimal control of corruption dynamics. *Asian Eur J Math.* 2018; 11(6): 1850090.
14. Zhao H., Feng Z., Chavez C.C., The Dynamics of Poverty and Crime. *Journal of Shanghai Normal University.* 2015; 43(5): 486-495.

15. Misra A.K., Modeling the effect of police deterrence on the prevalence of crime in the society, *Applied Mathematics and Computation*. 2014; 237: 531-545.
16. Chiu W. H., Madden P., Burglary and income inequality. *Journal of Public Economics*. 1998; 69(1): 123-141.
17. Curtis J.P., Smith F.T., Ye X., Modelling Burglaries in Streets, *Mathematics in Industry*. 2010; 15(3): 777-783.
18. Shukla J.B., Goyal A., Agrawal K., Kushwa H., Role of technology in combating social crimes: A modeling study. *European Journal of Applied Mathematics*. 2013; 24(4): 501-514.
19. NCRB Report, <https://ncrb.gov.in/en>.
20. Shukla J.B., Singh V., Misra A.K., Modeling the spread of an infectious disease with bacteria and carriers in the environment. *Nonlinear Anal. RWA*. 2011; 12: 2541-2551.
21. United Nations - World Population Prospects. <https://population.un.org/wpp/>.