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The Addiction of Mobile Games in Secondary School Students

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Abstract**:** Playing games on mobile devices is one of the most common pastimes in society. The games have got advantages such as reducing stress, providing enjoyment,a sense of chal- lenge and competition, fostering social interaction, and even mental escape from the real world, however negative effect of mobile games on students academic performance is the biggest worry. The control of this worry in the students of secondary schools of Grad 9th at Bannu division, Pakistan, is the studys main focus. We minutly examine the stages of mobile-game addiction. The progression in these stages are represented by differential equations. These coupled differential equations form a mathematical Model. We study different properties of the model including R0, the rate of transmission of game-addiction from one student to the other. Using mathematical techniques, we find the most effective parameters of game-addiction and intervene therein to design control strategies to stop further transmission of game-addiction. The results and recommendations obtained from these strategies are validated with help of numerical simulations.

Keywords: Mobile-Game, Game-addiction, Student's psychology, Basic reproductive number, Sensitivity Analysis, Mathematical modeling.

1. Introduction

Casual games that are played on smartphones are referred to as mobile games. Various studies on disproportionate use of mobile games conclude it negatively effects the student's academic performance. Though mobile game is played in brief amount of time, yet the game disturb the sleep pattern of the student and causes ethical issues like addiction and cyber bullying Merikivi et al. (2017). Smartphones portability and wireless connectivity let students/consumers play mobile games whenever and wherever they want Fabito (2017). Sun et al. (2015).The app of games is the most popular app category on both (ios) iPhone operating system and Android in terms of downloads. Addiction to mobile gaming is a developing issue that raises the danger of both physical and mental health issues for all users Chen, and Leung. (2016). An intense addiction to smartphone gaming can harm family relationships and causes problems in jobs and school-related Tasks Laconi et al. (2017).

Carter. (2017).] Advances in technology have transformed communication, impacting our day-to-day existence. In todays linked world, two significant breakthroughs in communication that are often mentioned are the Internet and mobile phones. Due to the explosive growth in mobile phone use that started in the 1990s, there are currently seven billion mobile connections and more than 3.5 billion individual mobile subscriptions worldwide Twum. (2017).

Teens usually use social media platforms to interact with others, like Twitter, YouTube, and Facebook.This behavior is extremely concerning because it may have an impact on their academic success. Massimini and Peterson (2009).

Mobile game addiction is a growing problem that puts consumers at risk for problems with their physical and mental health. Strong smartphone gaming addictions can strain relationships within the family and lead to difficulties completing work and school-related assignments. Furthermore, there is a strong correlation between IGD and lower academic accomplishment among children in learning situations. Mobile gaming addiction is a growing problem that endangers the physical and emotional well-being of its users. Nonetheless, Samaha and Hawi study on smartphone addiction revealed no link between the likelihood of smartphone addiction and academic success Allen and Anderson (2018). We in this work, formulate the mathematical model of the academic performance of the students of grade 9 at elementary level with special focus on the adverse effect of Mobile game-addiction. The initial rate of the transmission of the game-addiction from addicted to non-addicted is investigated. On the basis of sensitivity indices of the transmission parameters, some transmission parameters of game-addiction are intervened and control strategiesare designed. Numerical simulations are generated to validate the results of the control strategies.

2. Model Formulation

Here, we develop a mathematical model to analyze student's academic performance, with special focus to mobile game-addiction. The entire student body of grade 9 of elementary schools of Bannu division is divided in 7 compartments. Each compartment is governed by differential equation which represents the change that occur in density/ population of the students of particular class, with time. The seven compartments/classes that represent various phases of addiction to mobile games. The first compartment/class of the mathematical model is of potentially addicted of the mobile gamers, denoted by P. The population in this compartment is not addicted to mobile-game but can be indulge in mobile gaming if got company with properly addicted students. A, dentes the compartment of those students who have got addicted to mobile game. H, is the compartment of hard-working students of grade 9. Q_t, is the class of temporary game quitters and Q_p, is the compartment of permanent game quitters. D, denotes the class of the students dropped from the school and F, is the compartment of failed students. N(t) is the sum of the population in all compartments under consideration.

The description of the stages/state variables are given below.

- P; The class of Potential addicts.
- A; The class of Addicted students
- H; The class of Hard working students.
- Q_t; The class of Temporary Quiet gammers.
- Q_p; The class of Permanent Quiet gammers.
- F; The class of failed students.
- D; The class of Dropout students.

The entire population $N(t)$ is:

$N(t) = P + A + H + Q_t + Q_p + F + D$

The following flow chart represent the mood/path of game-addiction.

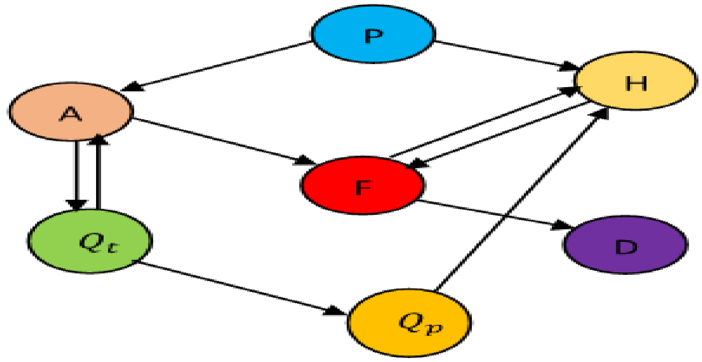

Figure 1: The flow of game-addiction in the students of Grade 9 in elementary schools.

2.1 The Formulation of the 1st Class P of the Student's Academic Performance Model

New students are enrolled in Grade 9 at the rate J. We assume that these newly admitted students are potentially addicted. During school hours these students interact with mobile game-addicted students at the rate β. Additionally, some students leave the school due to any reason at the rate d_1 while some die due to natural death at the rate μ. So the complete dynamics of the class P is:

$$\dot{P} = J - \beta PA - (\mu + d_1)P$$

Here, βPA is the term of interaction or saturated incident rate. Some of the students of class P, after interaction with addicted students, get addicted, the rest of the students keep working hard. The addicted students are placed in class A and those working hard are placed in class H.

2.2 The Formulation of the Addicted Class A

The susceptible/potentially-addicted Students after interaction with game-addicted students are affected at the $(1-k)\beta$ and enter the addicted class A. These newly addicted students are advised, and are punished for game-addiction as result these addicted students quit mobile- gaming. So we have the following differential equation:

$$\dot{A} = (1-k)\beta PA - (\gamma_1 + \mu)A + (1-k_2)\gamma_2 Q_t$$

Where $\dot{A}$ denotes the change that occur in the population size of the addicted class A.

2.3 The Formulation of the Hard Working Class H

The ratio k of the interacted students βPA do not accept the effect of interaction and keep continue academic activities as previous and enter the class H. Very small ratio k_4 of the hard working students face domestic issues or other natural issues and could not pass the examination and enter the failed class F. Also a small ratio $(1-k_5)\gamma_3$ of failed students restart hard working and enters the class H. The ratio k_3 of the permanent game quitter enter the hard working class. So the differential equation representing Hard working class is:

$$\dot{H} = k\beta PA - (\mu + k_4)H + (1-k_5)\gamma_3 F + k_3 Q_p$$

2.4 The Formulation of the Temporary Game Quitter Class Q_t

After completing transition period γ_2 at Q_t class, the ratio k_2 of temporary quitter, quit the mobile gaming permanently and are placed in the class Q_p. As result of different interventions like advice, punishment, and rewards, some students in the addicted class agree to quit the mobile-game and enters the class Q_t. The change in the population size of this class is governed by the differential equation:

$$\dot{Q}_t = k_1\gamma_1 A - (\mu + \gamma_2)Q_t$$

2.5 The Formulation of the Permanent Game Quitter Class Q_p

After completing the transition period γ_2 at Q_t the ratio k_2 of temporary quitter, quit the mobile gaming permanently and enter the class Q_p. Most of the game quitter restart hard work and enter the hard working class at the ratio k_3. The following differential equation represents the class of permanent game quitters.

$$\dot{Q}_p = k_2\gamma_2 Q_t - (\mu + k_3)Q_p$$

2.6 The Formulation of the Class of Failed Students F

The students in this compartment come from all other compartments because the reasons of failure are diverse. The hardworking students enter the class F at ratio k4 and those from addicted class at the ratio (1 − k1)γ1. After failure the ratio k5γ3 of the failed student quit education and are placed in class D of the dropped students. The ratio (1 − k5)γ3 star hard work and join the class H. The differential equation governing this class is:

$$\dot{F} = k_4 H + (1 - k_1)\gamma_1 A - (\mu + \gamma_3)F$$

2.7 The Formulation of the Class of Dropped Students D

Students quit education for different reasons but the most common reason is failure. In our mathematical model we have assumed failure as the only reason of dropout. The governing equation is as follow:

$$\dot{D} = k_5\gamma_3 F - \mu D$$

Combining all these differential equation we obtain the following Mathematical Model ofMobil Game-addiction.

$$\dot{P} = J - \beta PA - (\mu +$$
$$\dot{A} = (1 - k)\beta PA - (\gamma_1 + \mu)A + (1 -$$
$$\dot{H} = k\beta PA - (\mu + k_4)H + (1 - k_5)\gamma_3 F + k_3 Q_p$$
$$\dot{Q}_t = k_1\gamma_1 A - (\mu + \gamma_2)Q_t \quad \dot{Q}_p = k_2\gamma_2 Q_t - (\mu + k_3)Q_p \qquad ($$
$$\dot{F} = k_4 H + (1 - k_1)\gamma_1 A - (\mu + \gamma_3)F$$
$$\dot{D} = k_5\gamma_3 F - \mu D$$

The values of numerous model's parameters are presented in the table below. (1).

Table 1: Table with disparate parameter values

ı	ːer definition
	h-grade rate of admission
	ıl from school
	ıl shift toward an A ratio
	o, proceeding to Q_t
	ratio, which advances to Q_p
	ratio, which goes toward hardworking
	ıo of H to F as a result of tragedy
	; from F to D, the ratio
	lity of Intration and Transmission of
	. to P, gaming addiction
	.te
	ɔact of guidance, sanctions, or incentives on individuals with addictions
	ınsitional Phase at Q_t
	ion Phase at F

3. Model Analysis

The Basic Reproduction Number, Invariant Region and well posedness of the model are explored in this section.

3.1 Invariant Region

The model's state variables and parameters are all non-negative. The total population involved in the model is denoted by N and is obtained by adding all the compartments of the model. Adding the populations in different compartments we have:

$$\dot{N} = J - (\mu + d_1)N \quad (2)$$

(3)

The region Ω of the population under consideration is given by

$$\Omega = (P, A, H, Q_t, Q_p, F, D) \in R^7 \ , N \leq \frac{J}{\mu + d} \ .$$

From equation (2), *using standard comparison theorem, we have*

$$N \leq N(0)e^{-(\mu+d_1)t} + \frac{J}{(\mu + d_1)}\left(1 - e^{-(\mu+d_1)t}\right) .$$

So

$N \le \frac{J}{(\mu+d_1)}$ as $t \to \infty$.

This shows that the model is well-posed and the states are forward bounded.

3.2 Reproduction Number R_0

R_0 represents the reproduction number, which is the number of secondary cases of game- addiction resulting from the placement of one game-addicted student in a class of potentially addicted pupils. The reproduction is found via the matrix of the next generation (Twum, 2017).

$$f = \begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \end{pmatrix} = \begin{pmatrix} \beta P A \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

The members of the prospective class who developed a game addiction are indicated by the entries in the column of matrix f.

$$F = \begin{pmatrix} \frac{\partial(f_1)}{\partial(A)} & \frac{\partial(f_1)}{\partial(H)} & \frac{\partial(f_1)}{\partial(Q_t)} & \frac{\partial(f_1)}{\partial(Q_p)} & \frac{\partial(f_1)}{\partial(F)} & \frac{\partial(f_1)}{\partial(D)} \\ \frac{\partial(f_2)}{\partial(A)} & \frac{\partial(f_2)}{\partial(H)} & \frac{\partial(f_2)}{\partial(Q_t)} & \frac{\partial(f_2)}{\partial(Q_p)} & \frac{\partial(f_2)}{\partial(F)} & \frac{\partial(f_2)}{\partial(D)} \\ \frac{\partial(f_3)}{\partial(A)} & \frac{\partial(f_3)}{\partial(H)} & \frac{\partial(f_3)}{\partial(Q_t)} & \frac{\partial(f_3)}{\partial(Q_p)} & \frac{\partial(f_3)}{\partial(F)} & \frac{\partial(f_3)}{\partial(D)} \\ \frac{\partial(f_4)}{\partial(A)} & \frac{\partial(f_4)}{\partial(H)} & \frac{\partial(f_4)}{\partial(Q_t)} & \frac{\partial(f_4)}{\partial(Q_p)} & \frac{\partial(f_4)}{\partial(F)} & \frac{\partial(f_4)}{\partial(D)} \\ \frac{\partial(f_5)}{\partial(A)} & \frac{\partial(f_5)}{\partial(H)} & \frac{\partial(f_5)}{\partial(Q_t)} & \frac{\partial(f_5)}{\partial(Q_p)} & \frac{\partial(f_5)}{\partial(F)} & \frac{\partial(f_5)}{\partial(D)} \\ \frac{\partial(f_6)}{\partial(A)} & \frac{\partial(f_6)}{\partial(H)} & \frac{\partial(f_6)}{\partial(Q_t)} & \frac{\partial(f_6)}{\partial(Q_p)} & \frac{\partial(f_6)}{\partial(F)} & \frac{\partial(f_6)}{\partial(D)} \end{pmatrix}$$

$$F = \begin{pmatrix} \beta\frac{J}{(\mu+d_1)} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

For simplification, we represent F as

$$F = \begin{pmatrix} N_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}_{(GAFS)}$$

where GAFS stands for game-addiction free state, that is when the density/population of game-addicted class is zero. and

$$v = \begin{pmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \end{pmatrix} = \begin{pmatrix} \beta PA - (\gamma_1 + \mu)A + (1 - k_2)\gamma_2 Q_t \\ k\beta PA - (\mu - k_4)H + (1 - k_5)\gamma_3 F + k_3 Q_p \\ k_1\gamma_1 A - (\mu + \gamma_2)Q_t \\ k_2\gamma_2 Q_t - (\mu + k_3)Q_p \\ k_4 H + (1 - k_1)\gamma_1 A - (\mu + \gamma_3)F \\ k_5\gamma_3 F - \mu D \end{pmatrix}.$$

The members of the Game Addicted class who enroll in or withdraw from the course are rep- resented by the v of the column matrix, ignoring those coming from the potentially addicted class.

$$V = \begin{pmatrix} \frac{\partial(v_1)}{\partial(A)} & \frac{\partial(v_1)}{\partial(H)} & \frac{\partial(v_1)}{\partial(Q_t)} & \frac{\partial(v_1)}{\partial(Q_p)} & \frac{\partial(v_1)}{\partial(F)} & \frac{\partial(v_1)}{\partial(D)} \\ \frac{\partial(v_2)}{\partial(A)} & \frac{\partial(v_2)}{\partial(H)} & \frac{\partial(v_2)}{\partial(Q_t)} & \frac{\partial(v_2)}{\partial(Q_p)} & \frac{\partial(v_2)}{\partial(F)} & \frac{\partial(v_2)}{\partial(D)} \\ \frac{\partial(v_3)}{\partial(A)} & \frac{\partial(v_3)}{\partial(H)} & \frac{\partial(v_3)}{\partial(Q_t)} & \frac{\partial(v_3)}{\partial(Q_p)} & \frac{\partial(v_3)}{\partial(F)} & \frac{\partial(v_3)}{\partial(D)} \\ \frac{\partial(v_4)}{\partial(A)} & \frac{\partial(v_4)}{\partial(H)} & \frac{\partial(v_4)}{\partial(Q_t)} & \frac{\partial(v_4)}{\partial(Q_p)} & \frac{\partial(v_4)}{\partial(F)} & \frac{\partial(v_4)}{\partial(D)} \\ \frac{\partial(v_5)}{\partial(A)} & \frac{\partial(v_5)}{\partial(H)} & \frac{\partial(v_5)}{\partial(Q_t)} & \frac{\partial(v_5)}{\partial(Q_p)} & \frac{\partial(v_5)}{\partial(F)} & \frac{\partial(v_5)}{\partial(D)} \\ \frac{\partial(v_6)}{\partial(A)} & \frac{\partial(v_6)}{\partial(H)} & \frac{\partial(v_6)}{\partial(Q_t)} & \frac{\partial(v_6)}{\partial(Q_p)} & \frac{\partial(v_6)}{\partial(F)} & \frac{\partial(v_6)}{\partial(D)} \end{pmatrix}$$

$$V = \begin{pmatrix} \beta\frac{J}{(\mu+d_1)} - (\gamma_1 + \mu) & 0 & (1 - k_2)\gamma_2 & 0 & 0 & 0 \\ k\beta\frac{J}{(\mu+d_1)} & -(\mu + k_4) & 0 & k_3 & (1 - k_5)\gamma_3 & 0 \\ k_1\gamma_1 & 0 & -(\mu + \gamma_2) & 0 & 0 & 0 \\ 0 & 0 & k_2\gamma_2 & -(\mu + k_3) & 0 & 0 \\ (1 - k_1)\gamma_1 & k_4 & 0 & 0 & -(\mu + \gamma_3) & 0 \\ 0 & 0 & 0 & 0 & k_5\gamma_3 & -\mu \end{pmatrix}.$$

For simplicity we write V as:

$$V = \begin{pmatrix} \beta\frac{J}{(\mu+d_1)} - U_1 & 0 & (1 - k_2)\gamma_2 & 0 & 0 & 0 \\ k\beta\frac{J}{(\mu+d_1)} & -U_2 & 0 & k_3 & (1 - k_5)\gamma_3 & 0 \\ k_1\gamma_1 & 0 & -U_3 & 0 & 0 & 0 \\ 0 & 0 & k_2\gamma_2 & -U_4 & 0 & 0 \\ (1 - k_1)\gamma_1 & k_4 & 0 & 0 & -U_5 & 0 \\ 0 & 0 & 0 & 0 & k_5\gamma_3 & -\mu \end{pmatrix} \quad (GAFS).$$

$$R_0 = \frac{\beta J}{k\beta J - (\mu + d_1)(\gamma_1 + \mu) + (1 - k_2)\gamma_2(\mu + d_1)}.$$

3.3 Sensitivity Analysis of R_0

The normalized forward sensitivity index of a variable to a parameter is defined as the ratio of the relative change in the variable to the relative change in the parameter. If the variable is a differentiable function of the parameter, the sensitivity index can be defined using partial derivatives Twum (2017).

Definition 4.1. *The following formula defines the normalized forward sensitivity index of a variable u that depends differentially on a parameter p:*

$$\Upsilon_p^u = \frac{\partial u}{\partial p} \frac{p}{u}.$$

We find the sensitivity indices of the eight parameters involved in R_0.

Table 2: the model's parameters' descriptions and values

Parameter	parameter value	index at parameters value
J	0.09	1.0484
K	0.0304	0.0484
k_2	0.018	-0.0032
B	0.0272	1.0484
μ	0.00004	-0.0063
γ_1	0.275	-1.2229
γ_2	0.04	0.1747
d_1	0.0068	-1.0423

We choose 5 parameters of R_0 to intervene, based on their sensitivity indices. Accordingly we design 3 control strategies.

3.4 Numerical Simulation

We intervene the parameters β, k_2, γ_1, γ_2 and d_1. Using Matlab, we generate numerical simulations for the 3 control strategies. Table of the strategies is shown below:

Table 3: Strategies

set	β	k_2	γ_1	γ_2	d_1
strategy 1	0.0272	0.018	0.275	0.04	0.0068
strategy 2	0.00272	0.2	0.575	0.03	0.068
strategy 3	0.000272	0.5	0.75	0.01	0.7

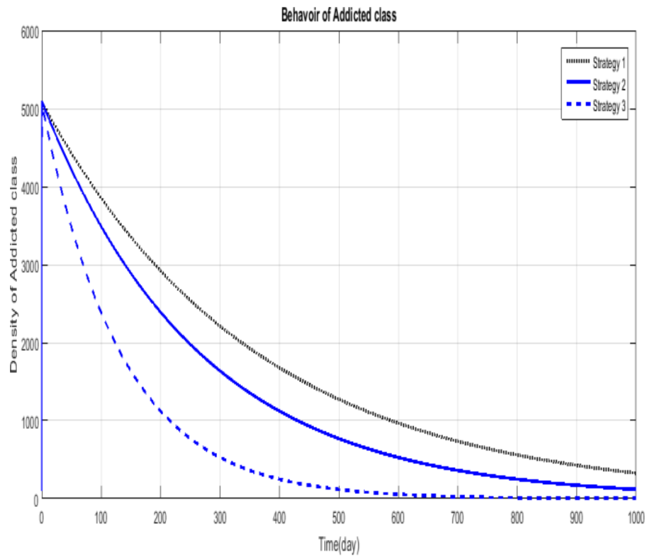

Figure 2: The effect and comparison of control strategies on class of game-addicted, A.

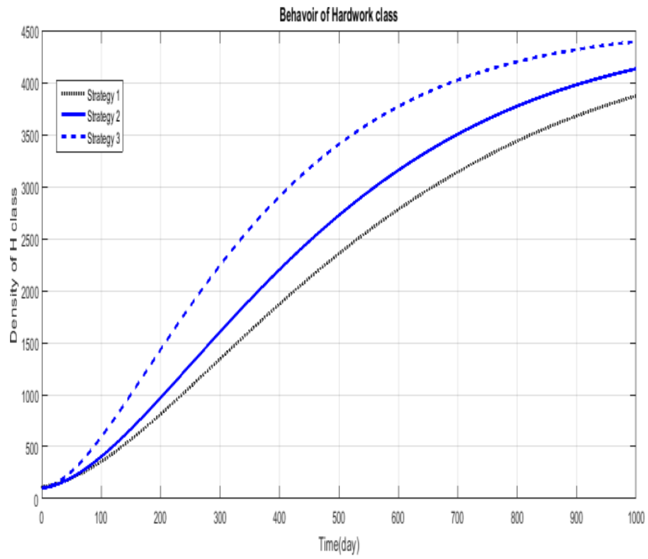

Figure 3: The effect and comparison of control strategies on class of hard-worker H.

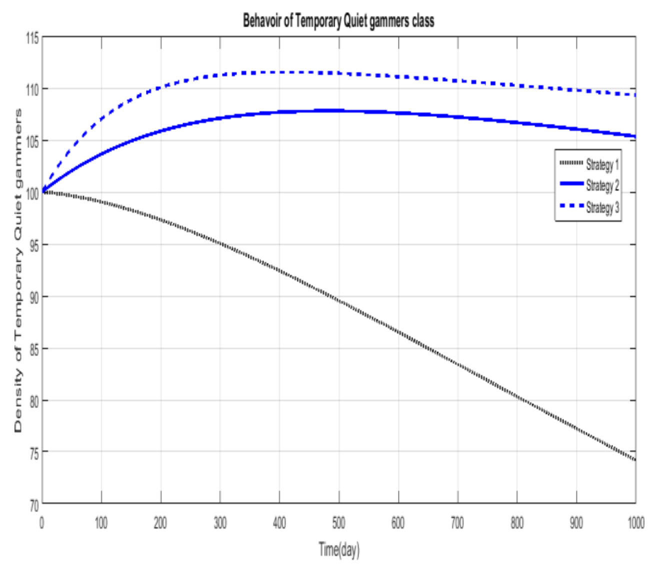

Figure 4: The effect and comparison of control strategies on class of temporary game quitter class Qt.

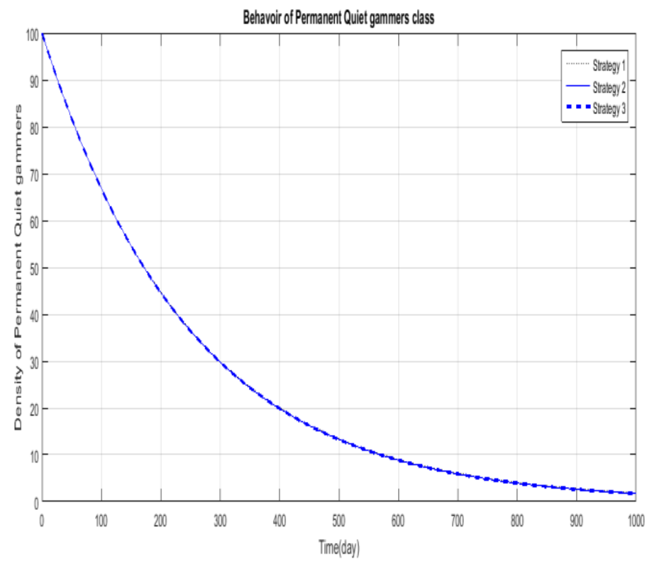

Figure 5: The effect and comparison of control strategies on class of permanent game quitter class *Qp*.

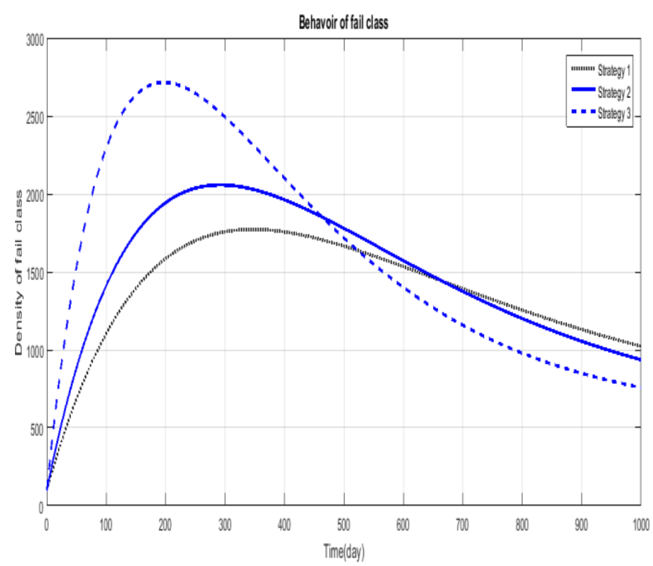

Figure 6: The effect and comparison of control strategies on class of failed students, F.

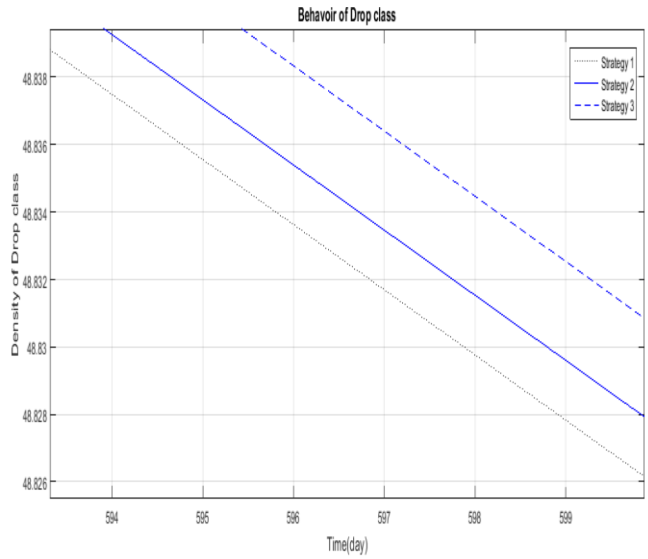

Figure 7: The effect and comparison of control strategies on class of dropped students D.

4. Conclusion

The students of secondary school level of grade 9, were divided in 7-groups P, A, H, Q_t, Q_p, F and D. The time change in these group were represented by time-derivative. A Mathematical model was formulated. Two properties, sensitivity analysis and initial rate of game addiction, were particular focused. It was found that β, γ_1, k_2 , γ_2, d_1 are most suitable parameters for intervention. On the basis of the magnitude of interventions 3 control strategies were designed. The results of the figures obtained with help of numerical simulations show that using strategy 1 we can handle the issue in about three years. And using strategy 2 we can handle the issue within 1000 days. While using strategy 3 we can overcome the said addiction in about 2 years.

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