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Formulation and Computation of UPI Transaction Failure and Management Model

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Abstract

Unified Payments Interface (UPI) was established by National Payments Corporation of India (NPCI) and is regulated by the Reserve Bank of India (RBI), starting around 2016. UPI apps on mobile platforms facilitate the linking of multiple bank accounts to a single device and assists in performing all transactions within seconds. Sometimes these transactions fail due to multiple reasons. Here a mathematical model concerning the reasons for transaction failure and managing them are developed through a system of non-linear ordinary differential equations. Approximate analytical expressions for the rate of transaction failure due to insufficiency or exceedance, incorrect input data, bad internet connection and successful UPI transactions are derived using Adomian Decomposition Method and Variational Iteration Method which are compared to their numerical solution. This paper shows that a successful transaction depends on maintaining a proper account balance, following UPI transaction limits per day of the application you use, entering correct UPI PIN, receiver details and ensuring stable internet connection with sufficient speed.

Keywords: Unified Payments Interface, Transaction Failure, Successful Transaction, UPI PIN, Computational Techniques, Mathematical Model

Introduction

Unified Payments Interface (UPI), an acronym for Unified Payments Interface, is an environmentally friendly initiative taken in order to reduce the usage of paper in printing currency which therefore promotes cashless and cardless payments. Today, there is a plethora of UPI apps available which helps in managing multiple bank accounts through single device. National Payments Corporation of India (NPCI) developed this system which was made available to the public in the year 2016. Recently, UPI has made a record of transactions worth rupees 14 lakh crores. Now, UPI in India has become the world's largest payment market only because of 24/7 availability, instant fund transfers, single ID for multiple accounts, peer to peer payments, merchant payments, bill splitting, QR code payments, security features, integration with other services.

India has also shared the technology that is involved in UPI to several countries like France, Pakistan, Saudi Arabia, Nepal, and others. These transactions are time saving system which avoids user to stand in a long queue in banks or any other places they are supposed to pay. Even in competitive exam perspective, understanding the concept of UPI is very important because the candidates of Union Public Service Commission must be aware of the UPI's impact on the country's economy. Researchers predict that around the year 2026-2027, cashless transactions will raise to 90%.

Digital transactions are done through different modes, including credit card, debit card, mobile wallets, internet banking, mobile banking, e-commerce, cryptocurrencies, Immediate Payment Service (IPS), Bharat Interface for Money (BHIM) and so on. There are many third party apps available to perform this UPI transaction like Google pay, PhonePe, Amazon Pay, WhatsApp Pay, and Paytm, etc., while the NPCI's own application is BHIM UPI app. Also there is QR code scanner available in almost every shop in order to make contactless payments. Offers in the

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form of vouchers which comes with particular period or cash back are also given for users as a reward when they make a payment through UPI which encourages to use online transactions.

To utilize the UPI app, users must have registered mobile number linked to their bank account. Then after adding bank account to the UPI app, we must create a 4-digit UPI pin which is very important while we need to send money to anyone. People prefer UPI as it is safe, quick, convenient and helps in instant fund transfer between mobile devices. UPI has gained it's popularity mainly because of the user-friendly options and widespread acceptance by banks and service providers. Another reason for it's grand success include security. The users bank accounts are secured by PINs, fingerprints and multi-factor authentication. In the event of unauthorized access of the user accounts immediate notification will be sent to the user which helps them to take immediate action. These digital transactions have revolutionized the people's way of handling money. UPI has been designed to play an important role in shaping the country's economy ona global scale.

Through UPI, money can be sent to a person through their mobile number, UPI ID, bank account number, or by scanning QR code, or by saving the beneficiary list. It's crucial role to perform any UPI transaction using own device and never share UPI pin to anyone for security reasons. It is also recommended that before performing an online transaction of higher amount, just transfer one rupee to your family member's account to make sure whether the amount if transferred and the UPI app is working properly.

The Reserve Bank of India (RBI) advises against sharing PINs, OTPs, CVVs, or any other user credentials anywhere. Following the instructions given by our government and Reserve Bank of India we can make our bank account safe and secure against any malware. Nowadays, every bank has developed their own digital transactions software applications, which is really comfortable for many users and is also safe as it provides enhanced security and an effective customer service and support. Cashless transactions can significantly reduce the risk of theft. While performing online transactions, there may be some cases like the amount have been debited from your account but it has not been credited to the recipient's account. In this case, the user must immediately report to their bank as soon as possible in order to retrieve the amount. Delaying this action could result in financial loss. The RBI recently warned customers agains seeking help from strangers even in ATM and also instructed us to cover the keypad with our hands while entering PIN. So, whether we perform a digital transaction at home or outside we must be really very careful.

The RBI has announced three new features of Unified Payments Interface in India. The first feature is to make the users have a conversation with the Artificial intelligence powered system to start and end the transactions in a safe and secure environment. This feature is available available in all Indian languages and on all smart phones based UPI. The second feature raises the transaction limit of UPI lite. Previously, the transaction limit for UPI lite is ₹ 200. But now the transaction limit has been raised to ₹ 500. The third feature is to enhance offline transactions using Near Field Communications (NFC) technology. This feature will help to perform transaction even when there is no internet or weak network thereby reducing transaction declines. Also UPI have introduced Unstructured Supplementary Service Date (USSD) which allows users to make use of all UPI features in their basic phones itself, even if the user doesn't have smart phones or internet connection.

India has planned to take UPI to the global stage. By doing so, Indians can make cross-border transaction which paves the way towards international businesses. Also, UPI 2.0 introduces new features like invoice in the inbox and overdraft facilities. UPI Auto pay have simplified the process of repeating payments and subscription bills. Many government initiatives like Jan Dhan Yojana have encouraged users to utilize UPI for online transactions. In India, the growth of UPI reached it's peak particularly during COVID-19 pandemic because the users preferred contactless payments. Pandemic situation has also increased the rate of online shopping through e-commerce platforms that allows users to browse, select, see product details, add to cart and purchase them. The way of managing a business has also been revolutionized by these digital transactions. Continuous innovation and international expansion has helped a lot for UPI to reach this huge success. UPI has undergone widespread creativity to become an indispensable tool for daily transaction.

Numerous authors have worked on the consumer's point of view for the UPI transactions. Dr. Kapil et al., conducted a statistical analysis based on gender and age in New Delhi to study the significant difference between the age groups (Ahl, 2023). Also, Dr. Naveen Nandal et al., have carried out a survey of 200 customers based on the cashless transactions towards the country's economy and through the survey they have concluded that many people prefer digital payments (Nandal, 2021). Multiple regression analysis reveals the cosumer's perspective towards online banking services (Rupan et al., 2023). A literature review on mobile online/banking systems and e-commerce payment systems helps us in understanding consumer's acceptance of payment services (Aggarwal, 2023).

Dr. Kratika Neema et al. presented an explorative study on the history, benefits of UPI, different digital platforms, and the growth of UPI (Neema & Neema, 2016). An empirical study on UPI was carried out by Srinivas et al. in Tirupathi city to understand the growth of UPI (Srinivas, 2023). Again, an empirical study was carried out by Goyal et al. to analyze the consumer's awareness towards online transactions (Goyal & Monga, 2022). Radhika Basavaraj Kakade et al., detailed the objectives, interface, working mechanism of Unified Payment Interface (Kakade, 2017). Also data analysis was performed for four years to study the volume of transactions (Kumar et al., 2022).

Sankararaman et al. conducted a data-based study to understand the usage of digital payments based on age, education level, income and gender in Chennai city (Sankararaman & Suresh, 2021). Another data-based study collected from 253 respondents show the actual usage of UPI payments in the Indian market (Ungratwar, 2022). A questionnaire in the form of Google form is conducted to study the usage of digital transactions in the private bank sectors of Jaipur city (Goswami & Goswami, 2023). Additionally, a study was carried out to examine the adaptation and perception of the digital payment system provided by banks (Bhatt, 2023).

In this field, Geetanjali Sharma and Jai Deep Pandey developed a mathematical model describing transaction processing time in UPI using M|M|1 queuing model (Sharma & Pandey, 2021). Additionally, authors have framed technology acceptance model in UPI services of banks which clearly explains the UPI services and data analysis based on gender, age, education, occupation, monthly income and so on. Chawla et al. have analyzed in details about the regulations of bank in case of online transaction failure (Chawla, 2021).

An extended UTAUT2 model was developed to examine the factors influencing user's continuance intention to adopt and use mobile payment applications in Goa (Castanha, 2022). This paper addresses the issue of transaction failure which is a real world problem and we have framed into a mathematical model as a system of non-linear ordinary differential equation. Here the reasons that we have taken includes insufficiency or exceedance, incorrect input data and bad internet connection. Insufficiency happens when we need to send some money than available in our bank account and exceedance happens when we cross the daily limits on number of UPI transaction which varies for every UPI apps but most commonly we are allowed to perform 10 transactions per day and ₹1 lakh per day. An incorrect input detail comprises of entering the wrong UPI PIN and receiver details which leads to transaction failure. Poor internet connection may result from adverse weather like heavy rainfall, distance between tower and devices, poor signal strength in specific area, network overload due to many users in that area. So based on these reasons, the parameters are considered and how to overcome these transaction failures and to increase the rate of successful UPI transaction is also discussed.

On the whole, by maintaining a proper account balance, following the limitations of UPI apps, entering correct input data and having a good internet connection will end in a successful UPI transaction within seconds. Thus in the Introduction section, we provide a detailed explanation about UPI and various research work carried out by authors in this discipline. In section 2, we will discuss about the mathematical model formulation and description of parameters involved in it. The mathematical model that we have developed can be used to understand the reasons for transaction failure and ways to increase successful UPI transactions. In section 3, we will see how the computational techniques like Adomian decomposition method and Variational iteration method to derive the analytical expression for the model. Then the initial conditions, numerical values of the parameters and the numerical solution are also determined in this section. In section 4, we demonstrate the behavior of each

parameter which is portrayed in the form of graph as a comparison between analytical and numerical solution. Validation between the analytical and exact solutions is achieved using MATLAB code. Through these graphs, we will understand which parameter reduces the rate of transaction failure. Finally, all references used in our work are cited appropriately.

Formulation of UPI Transaction Failure and Management Model

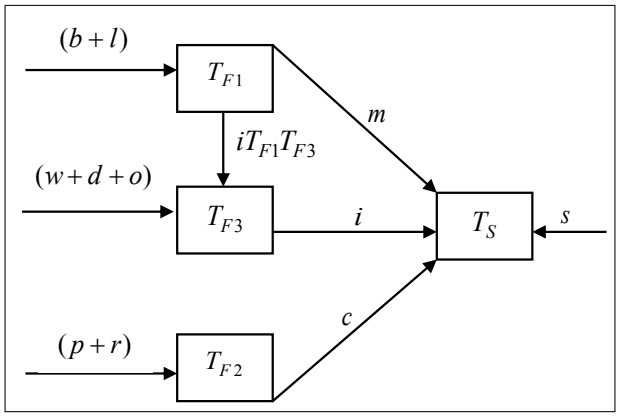
Based on the reasons of UPI transaction failure and to enhance the success rate of UPI transactions, a mathematical model is developed as a system of non-linear ordinary differential equations. The rate of UPI transaction failure due to insufficiency or exceedance (T_{F1}), incorrect input data (T_{F2}), bad internet connection (T_{F3}) are the variables denoting the rate of UPI transaction failures and (T_S) denote the rate of successful UPI transaction.

The insufficiency or exceedance is defined by the insufficient balance rate b and exceeding rate of daily limits on number of transactions l parameters. This could be overcome by maintaining rate of account balance and daily limits m. The parameters that represent incorrect input data include incorrect rate of UPI PIN p and incorrect rate of receiver details r which could be solved using correct rate of input data c. The bad internet connection depends on bad weather rate like heavy rainfall w, distance between tower and device d and network overload rate o. The internet speed rate is represented as i and the success rate of UPI transaction is denoted as s. This mathematical model comprises of a system of non-linear ordinary differential equations. The list of parameters and their description is described in Table 1. Additionally, a schematic diagram is given to understand the flow of transaction failure and management mathematical model.

$$\begin{aligned}
\frac{dT_{F1}}{dt} &= (b+l-m)T_{F1} - iT_{F1}T_{F3} \\
\frac{dT_{F2}}{dt} &= (p+r-c)T_{F2} \\
\frac{dT_{F3}}{dt} &= (w+d+o-i)T_{F3} \\
\frac{dT_S}{dt} &= mT_{F1} + cT_{F2} + iT_{F3} + sT_S
\end{aligned} \tag{1}$$

Table 1: List of Parameters

Symbol	Meaning
T_{F1}	Rate of transaction failure due to insufficiency or exceedance
T_{F2}	Rate of transaction failure due to incorrect input data
T_{F3}	Rate of transaction failure due to bad internet connection
T_S	Rate of successful UPI transactions
b	Insufficient balance rate
l	Exceeding rate of daily limit on no. of transactions
m	Maintenance rate of account balance and daily limits
i	Rate of internet speed
p	Incorrect rate of UPI Pin
r	Incorrect rate of receiver details
c	Correct input data rate
w	Bad weather rate like heavy rainfall
d	Distance between device and tower
o	Network overload rate
s	Success rate of UPI transactions



Schematic Diagram for UPI Transaction Failure and Management Model

Analytical Solution using Computational Techniques

The analytical solution of our model equation (1) is obtained using computational techniques like Adomian decomposition method and the Variational iteration method. The analytical solution is nothing but an expression which satisfies the given system of non-linear ordinary differential equations. In both the methods, series of iterations is conducted to reach the approximate solution and the solutions are in the form of infinite series.

Adomian Decomposition Method

This method was developed by George Adomian between the 1970s and 1990s (Adomian, 1990; Adomian, 1994). It involves decomposing the given equation into linear L, non-linear N and remaining linear part R. Then the invertible operator L^{-1} which represents integration is applied to both sides of our model equation. The non-linear terms are derived using Adomian polynomials. In our model, the non-linear term is represented as $T_{F1}T_{F3} = \sum_{n=0}^{\infty} A_n$ where; $A_0 = T_{F1_0}T_{F3_0}, A_1 = T_{F1_0}T_{F3_1} + T_{F1_1}T_{F3_0}, \ldots$ applying the invertible operator L^{-1} and assuming the solution to be in the form of infinite series we get,

$$\sum_{n=0}^{\infty} T_{F1_n} = T_{F1}(0) + L^{-1}\left[(b+l-m)\sum_{n=0}^{\infty} T_{F1_n}\right] - L^{-1}\left[i\sum_{n=0}^{\infty} A_n\right]$$
$$\sum_{n=0}^{\infty} T_{F2_n} = T_{F2}(0) + L^{-1}\left[(p+r-c)\sum_{n=0}^{\infty} T_{F2_n}\right]$$
$$\sum_{n=0}^{\infty} T_{F3_n} = T_{F3}(0) + L^{-1}\left[(w+d+o-i)\sum_{n=0}^{\infty} T_{F3_n}\right]$$
$$\sum_{n=0}^{\infty} T_{S_n} = T_S(0) + L^{-1}\left[m\sum_{n=0}^{\infty} T_{F1_n}\right] + L^{-1}\left[c\sum_{n=0}^{\infty} T_{F2_n}\right] + L^{-1}\left[i\sum_{n=0}^{\infty} T_{F3_n}\right] + L^{-1}\left[s\sum_{n=0}^{\infty} T_{S_n}\right] \quad (2)$$

Expanding the series and comparing the like terms, we get the solution as follows:

$$\begin{aligned} T_{F1} &= T_{F1}(0) + (b+l-m)T_{F1_0}t - i(T_{F1_0}T_{F3_0})t + \ldots \\ T_{F2} &= T_{F2}(0) + (p+r-c)T_{F2_0}t + \ldots \\ T_{F3} &= T_{F3}(0) + (w+d+o-i)T_{F3_0}t + \ldots \\ T_S &= T_S(0) + mT_{F1_0}t + cT_{F2_0}t + iT_{F3_0}t + sT_{F1_0}t + \ldots \end{aligned} \quad (3)$$

Variational Iteration Method

Ji Huan He proposed this method in 1999. The solution is obtained using a correctional formula which is as follows for our model (He, 1999; Trisilowati et al., 2021; Adebisi, 2018; Peter et al., 2018; Rangkuti et al., 2014; Ullah et al., 2022). Variational Iteration method is implemented to several non-linear ordinary differential equations, partial differential equations, heat transfer problems and so on. The correction functional helps us to derive the successive terms of the solution. Several mathematical models particularly infectious disease models are most probably solved by using Variational Iteration Method (VIM) as it is the easier way to derive the successive iterations using the correction functional. The correction functional for our model is given as follows:

$$\begin{aligned} T_{F1_{n+1}}(t) &= T_{F1_n}(t) - \int_0^t \frac{dT_{F1_n}(s)}{ds} - (b+l-m)T_{F1_n}(s) + iT_{F1_n}(s)T_{F3_n}(s)ds \\ T_{F2_{n+1}}(t) &= T_{F2_n}(t) - \int_0^t \frac{dT_{F2_n}(s)}{ds} - (p+r-c)T_{F2_n}(s)ds \\ T_{F3_{n+1}}(t) &= T_{F3_n}(t) - \int_0^t \frac{dT_{F3_n}(s)}{ds} - (w+d+o-i)T_{F3_n}(s)ds \\ T_{S_{n+1}}(t) &= T_{S_n}(t) - \int_0^t \frac{dT_{S_n}(s)}{ds} - mT_{F1_n}(s) - cT_{F2_n}(s) - iT_{F3_n}(s) - sT_S(s)ds \end{aligned} \quad (4)$$

Assuming the initial value as $T_{F1_0} = 1, T_{F2_0} = 1, T_{F3_0} = 1 and\ T_{S_0} = 0.2$ and for n = 0, 1, 2, … the solution of our model is obtained as follows.

$$\begin{aligned} T_{F1} &= T_{F1_0} + (b+l-m)T_{F1_0}t - i(T_{F1_0}T_{F3_0})t + \ldots \\ T_{F2} &= T_{F2_0} + (p+r-c)T_{F2_0}t + \ldots \\ T_{F3} &= T_{F3_0} + (w+d+o-i)T_{F3_0}t + \ldots \\ T_S &= T_{S_0} + mT_{F1_0}t + cT_{F2_0}t + iT_{F3_0}t + sT_{F1_0}t + \ldots \end{aligned} \quad (5)$$

The initial values of the system of equations in (1) is assumed to be T_{F1} = 1, T_{F2} = 1, T_{F3} = 1, T_S = 0.2. The numerical values of the parameters are chosen to be b = 5, l = 11, m = 10, i = 5, p = 23, r = 26, c = 50, w = 10, d = 8, o = 6, s = 16. And, the numerical solution of equations (3) and (5) are obtained by substituting the above mentioned numerical values of the parameters. Thus, the numerical solution is as follows:

$$\begin{aligned} T_{F1} &= 1 + t \\ T_{F2} &= 1 - t \\ T_{F3} &= 1 + 19t \\ T_S &= 0.2 + 68.2t \end{aligned} \quad (6)$$

Results and Discussions

The analytical solution of this model (3) and (5) are compared to the numerical solution (6) and demonstrated in the form of a graph. The comparison between the analytical and numerical solution validates the accuracy of the model. The solid line, square and circle represent the numerical solution, analytical solution using Adomian decomposition method and Variational iteration method. These graphical results help us by providing a clear

understanding of behavior of each parameter in the system of non-linear ordinary differential equations. The MATLAB code used to plot the analytical and numerical solutions in the form of graph is represented in Appendix A.

Figures 1(a) to 1(d) represents the rate of transaction failure due to insufficiency of bank balance and exceedance of transaction limit per day versus time. From Figures 1(a) and 1(b), it is evident that as the insufficient balance rate b and exceeding rate of daily limits on number of transaction l rises, the rate of transaction failure T_{F1} also rises. From Figures 1(c) and 1(d), we observe that as the maintenance rate of account balance & daily limits m and internet speed rate i goes high, the rate of transaction failure T_{F1} goes down.

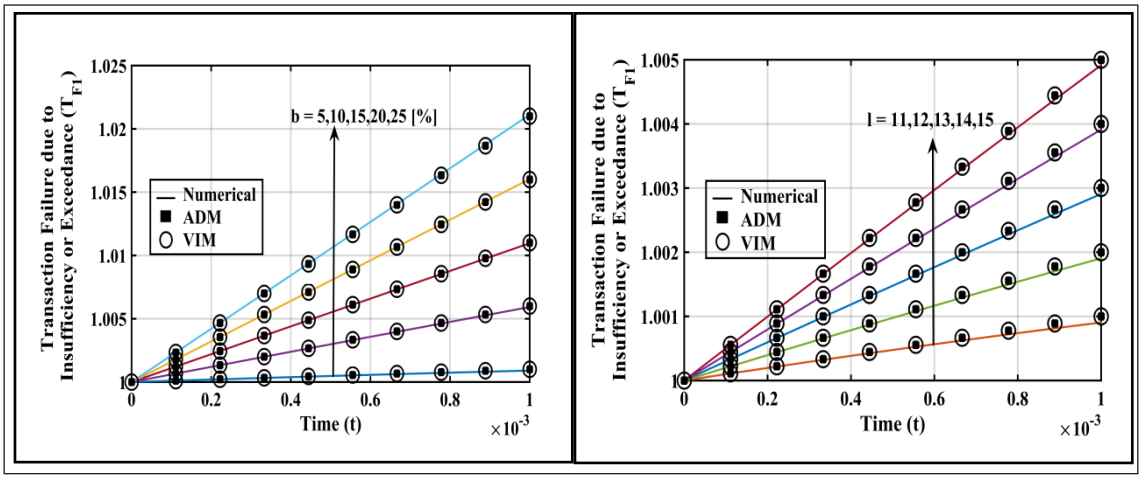


Fig. 1(a) **Fig. 1(b)**

Fig. 1(c) **Fig. 1(d)**

Fig. 1: The Rate of Transaction Failure due to Insufficiency or Exceedance T_{f1} versus Time with Respect to The Parameters Insufficient Balance Rate b (Fig. 1a), Exceeding Rate of Daily Limits on Number of Transaction l (Fig. 1b), Maintenance Rate of Account Balance & Daily Limits m (Fig. 1c) and Internet Speed Rate i (Fig. 1d).

Figures 2(a) to 2(c) represents the rate of transaction failure due to incorrect input data versus time. In Figures 2(a) and 2(b), it is evident that as incorrect rate of UPI pin p and receiver details r tends high, the rate of transaction failure T_{F2} also increases. From Fig. 2c, as the correct input data rate c goes high, the rate of transaction failure T_{F2} tends down.

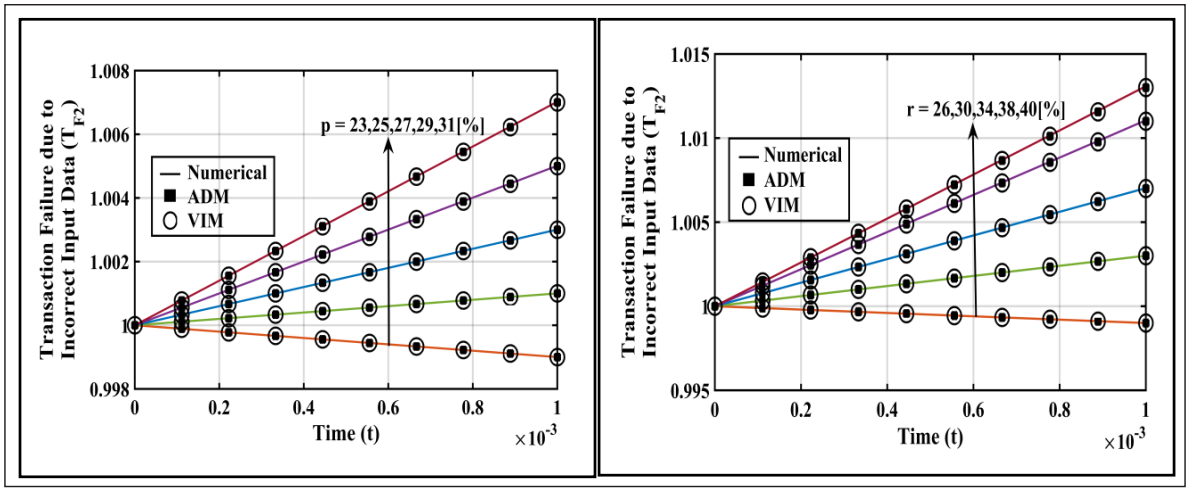


Fig. 2(a) **Fig. 2(b)**

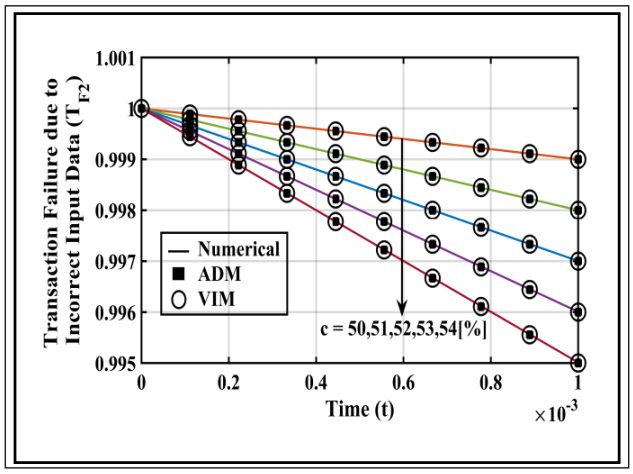


Fig. 2(c)

Fig. 2: The Rate of Transaction Failure due to Incorrect Input Data T_{F2} versus Time with Respect to Incorrect UPI Pin Rate p (Fig. 2a), Incorrect Rate of Receiver Details r (Fig. 2b) and Correct Rate of Input Data c (Fig. 2c).

Fig. 3 represents the rate of transaction failure due to bad internet connection versus time. From Fig. 3, it is apparent that as the bad weather rate like heavy rainfall w goes up, the rate of transaction failure due to bad internet connection T_{F3} also goes up.

Fig. 4 represents the rate of successful UPI transaction versus time. From Fig. 4, it is observe that as the internet speed rate i, the rate of successful UPI transaction T_S also increases.

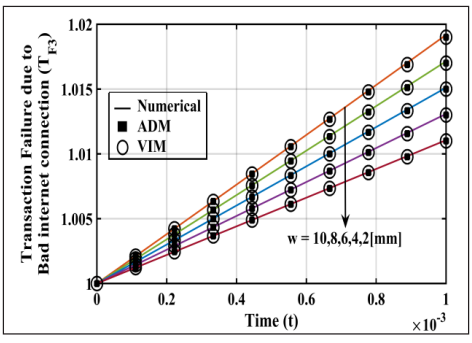


Fig. 3: The Rate of Transaction Failure due to Bad Internet Connection T_{F3} versus Time with Respect to the Parameter Bad Weather Rate Like Heavy Rainfall w (Fig. 3).

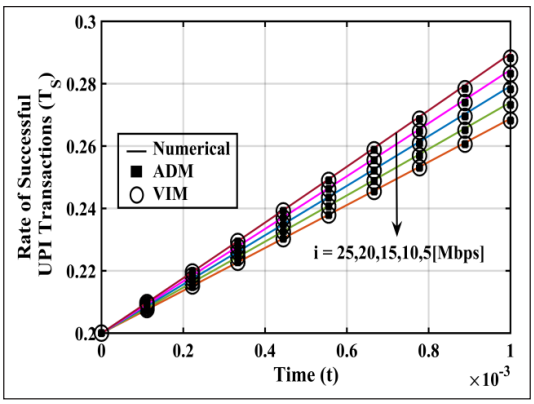


Fig. 4: The Rate of Successful UPI Transactions T_S versus Time with Respect to the Parameter Internet Speed Rate i (Fig. 4).

These figures clearly depict the behavior of each parameter in the system of non-linear ordinary differential equations. Hence, a notable efficiency between the analytical solution of the model using Adomian Decomposition Method (ADM) & Variational Iteration Method (VIM) and the numerical solution is established.

Conclusion

Thus, the mathematical model concerning the reasons for UPI transaction failure and management has been developed effectively. Analytical expressions for the rate of transaction failure due to insufficiency or exceedance (T_{F1}), incorrect input data (T_{F2}), bad internet connection (T_{F3}) and rate of successful UPI transaction (T_S). The behavior of each parameter is clearly understood in the form of graphical representation. The validation between analytical and numerical solution has been carried out successfully. We see that, the maintaining rate of account balance & daily limits m, correct input data rate c and internet speed rate i parameters reduces the rate of UPI transaction failure to a greater extent successfully.

A good internet speed, giving correct input data, maintaining the account balance and not exceeding the daily limits on number of transactions ends in a successful UPI transaction within seconds.

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Conflict of Interests

The authors declare that they have no conflict of interests.

Appendix A

```
function main1
options=odeset('RelTol',1e-6,'Stats','on');
X0=[1;1;1;0.2];
tspan=[0,0.001];
tic
[t,X]=ode45(@TestFunction,tspan,X0,options);
toc
figure
hold on
%plot(t,X(:,1));grid;
%plot(t,X(:,2));grid;
%plot(t,X(:,3));grid;
plot(t,X(:,4));grid;
return
function[dx_dt]=TestFunction(t,x)
b=5;l=11;m=10;n=25;p=23;r=26;c=50;w=90;d=8;o=6
;s=16;
dx_dt(1)=((b+l-m)*x(1))-(n*x(1)*x(3));
dx_dt(2)=(p+r-c)*x(2);
dx_dt(3)=(w+d+o-n)*x(3);
dx_dt(4)=m*x(1)+c*x(2)+n*x(3)+s*x(4);
dx_dt=dx_dt';
```

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