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Automated Teller Machine Analysis under Host-Bank Systems through Telephone Network

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Abstract. The automated teller machine is a machine that provides different banking facilities to the customer any time without any human being. An automated teller machine (ATM) is the essential part of banking service. ATM provides the different facility to banking customers such as cash withdrawal, cash deposits, fund transfer etc. A person can operate different banking operation on ATM without any help of a clerk. Now days, ATM is the essential part of human life. The main feature of ATM is providing cash to the needy bank's customers. So, the failure of any component or system plays a very crucial role. This work demonstrates the performance of an ATM network. The different types of component failure such as failure of an ATM, telephone network, power supply etc. have taken for the study. In this work, we considered two types of power supply, power supply through electricity board and power supply through generator. All failure and repair rates are assumed to be constant. The various reliability characteristics of the ATM network system by using supplementary variable technique, Laplace transformation and Markov process have been discussed. Some particular examples are also explained.

Keywords: reliability characteristics, ATM network, sensitivity analysis

1 Introduction

An automated teller machine (ATM) is a computerized telecommunication device that makes available to the customers an access to financial transactions in a public space without the need for a bank clerk or teller. The bank customer is recognized by inserting a plastic ATM card that contains a unique card number and some security and safety information. ATM can offer significant benefits to both: banks and their customers. The machine can enable customers to take out cash at more convenient times and places than during banking hours at bank branches.

In context to the ATMs research, Sato et al.[18] studied on broad band ATM network design based on virtual path. They examined that the virtual path concept, which exploits the ATM's capabilities to construct a proficient and economic network. They discussed the characteristics and implementation techniques of virtual path. Biersack[3, 4] discussed the performance evaluation of forward error correction in ATM networks. Forward error correction (FEC) can be used if the packet loss rate in a network is higher than the loss rate requested by an application. FEC consents recovery from loss without re-transmission. In that research, the author developed a mathematical model for the performance of FEC and computes; the effectiveness of FEC for the three traffic scenarios, discussed the loss behavior of a cell multiplexer and the performance of forward error correction for two homogeneous and one heterogeneous traffic scenarios and computed the effectiveness of FEC for the three traffic scenarios. Kawamura et al.[11] discussed the self-healing ATM networks based on the virtual path concept. They discussed the characteristics of the virtual path and their influence on failure restoration and described a high speed restoration technique, which exploits the benefits of the virtual path.

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They also proposed for the realization of a reversion less restoration cycle and also discussed the feasibility of the distributed control operation. Rugimbana[17] studied on forecasting automated teller machine usage. The author studied the usage of a retail banking service innovation, users and non-users of automated teller machine in terms of demographic and perceptual variables and found that perceptual variable were far more effective as predictors of ATM service practice than respondent demographic variables. Eng et al.[8] explained a wireless broadband ad-hoc ATM local area network. They described the theory, design and ongoing prototyping of a wireless ATM LAN capable of supporting mobile users with multi MB/s access rate and employed a concept of ad-hoc networking in the layout of the PBS to PBS interconnection. They proposed a wireless ATM concept so as to provide seamless internet working with other wired ATM local and wide area network and a fast network restoration scheme to manage with the potential link or node failures in the ad-hoc network. Garrett[9] studied on service design for ATM and derived a rationale for the service design of the ATM forum's traffic management. The author has created the set of ATM service categories by first investigating the quality of service and traffic requirements for a reasonably complete list of applications. Passas et al.[16] discussed the quality of service oriented medium access control for wireless ATM networks. They presented the medium access control protocol (MAC) and the underlying traffic scheduling. They discussed that the MAC protocol is a hub based adaptive TDMA scheme which combines reservation and contention based access methods. They conclude that the medium access control for the radio interface of a wireless ATM network is an important system component. This protocol provides both efficient use of the scarce radio bandwidth and maintains quality of service guarantees over the wireless hop of ATM. Akyildiz and Jeong[2] presented a survey of satellite ATM network and described that the satellite ATM networks are better than terrestrial ATM networks. The main advantages of satellite ATM networks are remote coverage with rapid deployment, distance insensitivity, bandwidth on demand. They also discussed that the satellite networks would play an important role in the rapidly evolving information infrastructures. The authors found the basic requirements and a possible architecture for local area-metropolitan area network (LAN-MAN) interconnection using satellite ATM networks. Liu et al.[14] studied the mobility, location tracking and trajectory prediction in wireless ATM networks. They explored the fundamental issue of providing lifetime connectivity to ongoing periods commenced by mobile holders in a cell based wireless ATM network and proposed an approximate pattern matching algorithm good for any finite sequence comparisons. Iraschko et al.[10] studied the optimal capacity placement for path restoration in ATM mesh survivable networks. They studied that mesh restorable networks using path restoration with stub release are most capacity efficiently. Coventry et al.[6] discussed the usability and biometric verification at the ATM interface and described that biometric technique in general and focused upon the usability phases and problems associated with iris verification technology at the ATM user interface. They provided an overview of the user centered work focused upon the provision of biometric verification at the ATM user interface. McAndrews[15] studied a survey on automated teller machine network pricing and discussed the different price using in ATM architecture. De Lemos et al.[13] presented an immune inspired adaptable error detection framework for ATMs. This framework has two levels: one is local to a single ATM while the other is network wide. They employed an immune inspired one class supervised algorithm.

Apart from this, some other researchers have also done good work in this field. Dilijonas et al.[7] suggested a value based service quality system management framework. The authors applied an application of sustainability concept. By using this concept, the performance quality and service management excellence has been increased. Kumbhar[12] developed an instrument for measuring service quality and satisfaction of customers. This study is used for assessment of e service quality. The author concludes that the eleven dimension of service quality are reliable. Camilli et al.[5] investigated the relationship between usability and user experience. The authors also studied on redesign process for an automated teller machine. Wang et al.[19] presented a formal design and modeling of automated teller machine. The authors used real time process algebra method. This work was also useful for improving safety operation and quality service of the system. The controllability, reliability, maintainability and quality of design also have been improved. Duvey et al.[1] provided a comparative study on various protocols. The authors described the different security aspects of the ATM. The authors concluded that transaction through DynaPass is very much secure.

Many researchers have done a lot of work in this field but they did not find the different reliability characteristics of ATM architecture containing the main components of the system. In this work, the authors have tried to find the possible reliability characteristics and sensitivity analysis of ATM architecture by using mathematical modeling, Laplace transformation, supplementary variable techniques and Markov process that is the reliability analysis, MTTF analysis, sensitivity of reliability and sensitivity of MTTF of the ATM system that contains the main components of ATM architecture such as automated teller machine, telephone network, bank computer, host computer, power supply in parallel (through electricity board and generator).

In this paper, the authors developed a mathematical model that represents the different states of the system. With the help of this model the authors developed and solved the different differential equations and find out the different transition state probabilities. By using these state probabilities, the authors find the up and down state probability and different reliability characteristics. The authors also examine the critical review of graph of different reliability characteristics.

2 Assumptions, model description and notations

The following assumptions are used with this model:

- At the starting stage, all the components are in good conditions.
- The ATM model contains three states, good, degraded and failed.
- There are six types of failures (failure of the host computer, failure of bank computer, failure of automated teller machine, and failure of power supply (through electricity board and generator)) exist.
- Failure and repair rates are constant.
- After repairing, the ATM system works like a new one.

An ATM network contains many substructures such as a host computer, bank computer, automated teller machine, telephone network and power supply through electricity board or the generator. In this work, the authors have used these six subsystems. Here we have considered the power supply through electricity board and power supply through the generator in parallel mode. If one of the power supplies is failed, then the proposed system is in partial working condition, but both power supplies are failed then the proposed system is completely failed. Similarly, if one of the components (host computer, automated teller machine, telephone network) is failed, then the system is also completely failed, but if the particular bank computer is failed and other subsystem is in proper working mode then the system is in partial working mode. The ATM system configuration and state transition diagram have been shown in Fig. 1 and Fig. 2 respectively.

The notations used in this model are shown in Tab. 1:

Table 1: Notations

t	Time scale in months.
s	Laplace transforms variable.
$P_0(t)$	Probability at time t in state 0.
$P_i(t)$	Probability at time t in i^{th} state; $i = 1, 2, 3$
$P_j(x,t)$	Probability density function that the system is in jth state and has an elapsed repair time of x; $j = 4, 5, 6, 7$
λ_{HC}	Failure rate of Host Computer.
λ_{BC}	Failure rate of Bank Computer.
λ_{TN}	Failure rate of Telephone Network.
λ_{M}	Failure rate of Machine.
λ_{PSE}	Power Supply failure though electricity board.
λ_{PSG}	Power Supply failure though generator.
μ	Repair rate from failed state to good state.

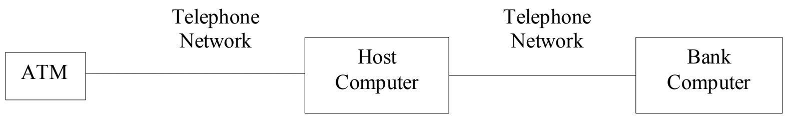

Fig. 1: System Configuration

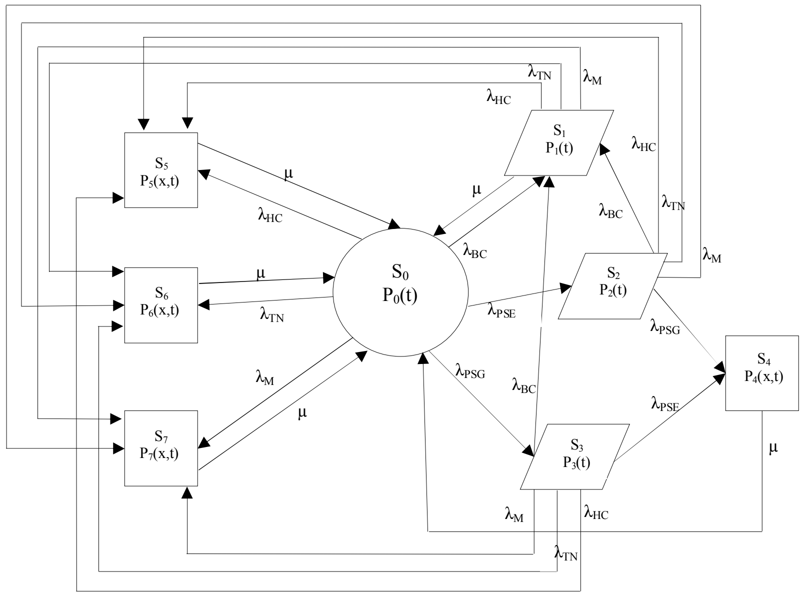

Fig. 2: State Transition Diagram

So, based on transition diagram, the following state descriptions are

S_0 : In this state, all components are in good conditions; therefore this state is a good state.

S_1 : In this state, the bank computer is failed with the failure rate λ_{BC}, but other components are in working condition, therefore this state is degraded.

S_2 : In this state, the power supply through electricity board is failed with the failure rate λ_{PSE}, but other components are in working condition, therefore this state is degraded.

S_3 : In this state, the power supply through generator is failed with the failure rate λ_{PSG}, but other components are in working condition, therefore this state is degraded.

S_4 : In this state, both power supplies are failed, therefore this state is failed state.

S_5 : In this state, the host computer is failed with the failure rate λ_{HC}, therefore this state is failed state.

S_6 : In this state, the telephone network is failed with the failure rate λ_{TN}, therefore this state is failed state.

S_7 : In this state, the machine is failed with the failure rate λ_M, therefore this state is failed state.

3 Formulation of the model

With the help of state transition diagram and Markov, the following sets of differential equations are developed.

$$\left[\frac{\partial}{\partial t} + \lambda_{BC} + \lambda_{PSE} + \lambda_{PSG} + \lambda_M + \lambda_{TN} + \lambda_{HC}\right] P_0(t) = \mu P_1(t) + \sum_j \int_0^\infty P_j(x,t)\mu dx; \quad j = 4 \text{ to } 7 \tag{1}$$

$$\left[\frac{\partial}{\partial t}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\mu\right]P_1(t)=\lambda_{BC}\left[P_0(t)+P_2(t)+P_3(t)\right] \tag{2}$$

$$\left[\frac{\partial}{\partial t}+\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG}\right]P_2(t)=\lambda_{PSE}P_0(t) \tag{3}$$

$$\left[\frac{\partial}{\partial t}+\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSE}\right]P_3(t)=\lambda_{PSG}P_0(t) \tag{4}$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\mu\right]P_j(x,t)=0; \qquad j=4\,\text{to}\,7. \tag{5}$$

Boundary conditions are,

$$P_4(0,t)=\lambda_{PSG}P_2(t)+\lambda_{PSE}P_3(t) \tag{6}$$

$$P_5(0,t)=\lambda_{HC}\left[P_0(t)+P_1(t)+P_2(t)+P_3(t)\right] \tag{7}$$

$$P_6(0,t)=\lambda_{TN}\left[P_0(t)+P_1(t)+P_2(t)+P_3(t)\right] \tag{8}$$

$$P_7(0,t)=\lambda_{M}\left[P_0(t)+P_1(t)+P_2(t)+P_3(t)\right]. \tag{9}$$

Initially $P_0(0)=1$ and other probabilities are zero. Taking Laplace Transformations from Eq. (1) to 9, we get

$$\left[s+\lambda_{BC}+\lambda_{PSE}+\lambda_{PSG}+\lambda_M+\lambda_{TN}+\lambda_{HC}\right]\overline{P}_0(s)=1+\mu\overline{P}_1(s)+\sum_j\int_0^\infty\overline{P}_j(x,s)\mu dx;\ j=4\,\text{to}\,7 \tag{10}$$

$$\left[s+\lambda_{HC}+\lambda_{TN}+\lambda_M+\mu\right]\overline{P}_1(s)=\lambda_{BC}\left[\overline{P}_0(s)+\overline{P}_2(s)+\overline{P}_3(s)\right] \tag{11}$$

$$\left[s+\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG}\right]\overline{P}_2(s)=\lambda_{PSE}\overline{P}_0(s) \tag{12}$$

$$\left[s+\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSE}\right]\overline{P}_3(s)=\lambda_{PSG}\overline{P}_0(s) \tag{13}$$

$$\left[s+\frac{\partial}{\partial x}+\mu\right]\overline{P}_j(x,s)=0; \qquad j=4\,\text{to}\,7 \tag{14}$$

From boundary conditions,

$$\overline{P}_4(0,s)=\lambda_{PSG}\overline{P}_2(s)+\lambda_{PSE}\overline{P}_3(s) \tag{15}$$

$$\overline{P}_5(0,s)=\lambda_{HC}\left[\overline{P}_0(s)+\overline{P}_1(s)+\overline{P}_2(s)+\overline{P}_3(s)\right] \tag{16}$$

$$\overline{P}_6(0,s)=\lambda_{TN}\left[\overline{P}_0(s)+\overline{P}_1(s)+\overline{P}_2(s)+\overline{P}_3(s)\right] \tag{17}$$

$$\overline{P}_7(0,s)=\lambda_{M}\left[\overline{P}_0(s)+\overline{P}_1(s)+\overline{P}_2(s)+\overline{P}_3(s)\right] \tag{18}$$

On solving these equations, we get the solution,

$$\overline{P}_0(s)=\frac{1}{(s+c)-\mu\lambda_{BC}\left\{\frac{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)}{(s+c_1+\mu)(s+c_2)(s+c_3)}\right\} -\left\{\frac{c_1(s+c_1+\lambda_{BC}+\mu}{(s+c_1+\mu)}+\frac{c_1\lambda_{BC}\lambda_{PSE}}{(s+c_1+\mu)(s+c_2)}+\frac{(c_1+\lambda_{PSG})\lambda_{PSE}}{(s+c_2)}+\frac{(c_1+\lambda_{PSE})\lambda_{PSG}}{(s+c_3)}\right\}\overline{S}(s)} \tag{19}$$

$$\overline{P}_1(s)=\lambda_{BC}\left[\frac{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)}{(s+c_1+\mu)(s+c_2)(s+c_3)}\right]\overline{P}_0(s) \tag{20}$$

$$\overline{P}_2(s)=\frac{\lambda_{PSE}\overline{P}_0(s)}{(s+c_2)} \tag{21}$$

$$\overline{P}_3(s)=\frac{\lambda_{PSG}\overline{P}_0(s)}{(s+c_3)} \tag{22}$$

$$\overline{P}_4(s)=\lambda_{PSG}\lambda_{PSE}\left[\frac{1}{(s+c_2)}+\frac{1}{(s+c_3)}\right]\left(\frac{1-\overline{S}(s)}{s}\right)\overline{P}_0(s) \quad (23)$$

$$\overline{P}_5(s)=\lambda_{HC}\left[\begin{array}{l}1+\frac{\lambda_{BC}\{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)\}}{(s+c_1+\mu)(s+c_2)(s+c_3)}\\+\frac{\lambda_{PSE}}{(s+c_2)}+\frac{\lambda_{PSG}}{(s+c_3)}\end{array}\right]\left(\frac{1-\overline{S}(s)}{s}\right)\overline{P}_0(s) \quad (24)$$

$$\overline{P}_6(s)=\lambda_{TN}\left[\begin{array}{l}1+\frac{\lambda_{BC}\{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)\}}{(s+c_1+\mu)(s+c_2)(s+c_3)}\\+\frac{\lambda_{PSE}}{(s+c_2)}+\frac{\lambda_{PSG}}{(s+c_3)}\end{array}\right]\left(\frac{1-\overline{S}(s)}{s}\right)\overline{P}_0(s) \quad (25)$$

$$\overline{P}_7(s)=\lambda_{M}\left[\begin{array}{l}1+\frac{\lambda_{BC}\{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)\}}{(s+c_1+\mu)(s+c_2)(s+c_3)}\\+\frac{\lambda_{PSE}}{(s+c_2)}+\frac{\lambda_{PSG}}{(s+c_3)}\end{array}\right]\left(\frac{1-\overline{S}(s)}{s}\right)\overline{P}_0(s). \quad (26)$$

Where,

$$c=\lambda_{BC}+\lambda_{PSE}+\lambda_{PSG}+\lambda_M+\lambda_{TN}+\lambda_{HC} \quad (27)$$

$$c_1=\lambda_{HC}+\lambda_{TN}+\lambda_M \quad (28)$$

$$c_2=\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG} \quad (29)$$

$$c_3=\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSE} \quad (30)$$

$$\begin{aligned}\overline{P}_{up}(s)&=\overline{P}_0(s)+\overline{P}_1(s)+\overline{P}_2(s)+\overline{P}_3(s)\\&=\left[\begin{array}{l}1+\lambda_{BC}\left\{\frac{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)}{(s+c_1+\mu)(s+c_2)(s+c_3)}\right\}\\+\frac{\lambda_{PSE}}{(s+c_2)}+\frac{\lambda_{PSG}}{(s+c_3)}\end{array}\right]\overline{P}_0(s)\end{aligned} \quad (31)$$

$$\begin{aligned}\overline{P}_{down}(s)&=\overline{P}_4(s)+\overline{P}_5(s)+\overline{P}_6(s)+\overline{P}_7(s)\\&=\left[\begin{array}{l}\lambda_{PSE}.\lambda_{PSE}\left\{\frac{1}{(s+c_2)}+\frac{1}{(s+c_3)}\right\}\\+c_1\left\{\begin{array}{l}1+\lambda_{BC}\left\{\frac{(s+c_2)(s+c_3)+\lambda_{PSE}(s+c_3)+\lambda_{PSG}(s+c_2)}{(s+c_1+\mu)(s+c_2)(s+c_3)}\right\}\\+\frac{\lambda_{PSE}}{(s+c_2)}+\frac{\lambda_{PSG}}{(s+c_3)}\end{array}\right\}\end{array}\right]\left(\frac{1-\overline{S}(s)}{s}\right)\overline{P}_0(s).\end{aligned} \quad (32)$$

4 Particular examples

4.1 Reliability analysis

For the reliability of the ATM system, putting the repair zero in Eq. (31), the reliability of the ATM network is given by,

$$\begin{aligned}R(t)=&\frac{\lambda_{PSG}.e^{-(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG})t}}{(\lambda_{BC}+\lambda_{PSG})}+\frac{\lambda_{PSE}.e^{-(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSE})t}}{(\lambda_{BC}+\lambda_{PSE})}\\&+\frac{(-\lambda_{PSG}-\lambda_{PSE}).e^{-(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG}+\lambda_{PSE})t}}{(\lambda_{BC}+\lambda_{PSG}+\lambda_{PSE})}\\&+\frac{(\lambda_{BC}^3+2\lambda_{BC}^2.\lambda_{PSG}+\lambda_{BC}.\lambda_{PSG}^2+2\lambda_{BC}^2.\lambda_{PSE}+\lambda_{BC}.\lambda_{pSG}.\lambda_{PSE}+\lambda_{BC}.\lambda_{PSE}^2)e^{-(\lambda_{HC}+\lambda_{TN}+\lambda_M)t}}{(\lambda_{BC}+\lambda_{PSG})(\lambda_{BC}+\lambda_{PSE})(\lambda_{BC}+\lambda_{PSG}+\lambda_{PSE})}.\end{aligned} \quad (33)$$

Now, putting the values of different failures $\lambda_{BC}=0.005$, $\lambda_{HC}=0.002$, $\lambda_{TN}=0.006$, $\lambda_{PSG}=0.008$, $\lambda_{PSE}=0.009$, $\lambda_M=0.007$ in the Eq. (33), the numeric values and graph of reliability of the system is given as in Tab. 2 and Fig. 3 respectively.

4.2 Mean time to failure (mttf) analysis

We obtain MTTF by putting the repair rate $\mu=0$ and letting the Laplace variable 's' approaches to zero in the Eq. (31), we get

$$MTTF=\frac{\begin{array}{l}1+\frac{\lambda_{BC}}{(\lambda_{HC}+\lambda_{TN}+\lambda_M)}+\frac{\lambda_{BC}.\lambda_{PSE}}{(\lambda_{HC}+\lambda_{TN}+\lambda_M)(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG})}\\+\frac{\lambda_{BC}.\lambda_{PSG}}{(\lambda_{HC}+\lambda_{TN}+\lambda_M)(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSE})}\\+\frac{\lambda_{PSE}}{(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSG})}+\frac{\lambda_{PSG}}{(\lambda_{BC}+\lambda_{HC}+\lambda_{TN}+\lambda_M+\lambda_{PSE})}\end{array}}{(\lambda_{BC}+\lambda_{PSG}+\lambda_{PSE}+\lambda_{HC}+\lambda_{TN}+\lambda_M)}. \quad (34)$$

Table 2: Reliability vs. Time

Time	Reliability	Time	Reliability
0	1	8	0.8832
1	0.985042	9	0.876407
2	0.970173	10	0.855197
3	0.955399	11	0.8414
4	0.940729	12	0.827745
5	0.926169	13	0.814235
6	0.911724	14	0.800872
7	0.897399	15	0.787659

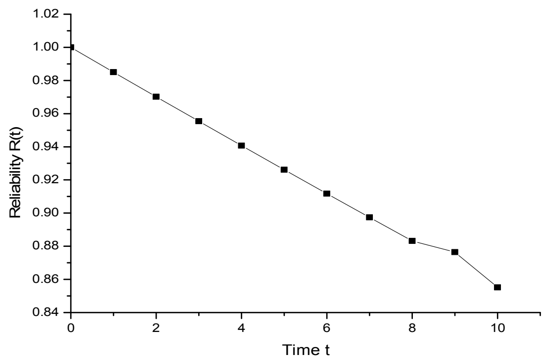

Fig. 3: Reliability as function of time

Putting $\lambda_{BC} = 0.005$, $\lambda_{HC} = 0.002$, $\lambda_{TN} = 0.006$, $\lambda_{PSG} = 0.008$, $\lambda_{PSE} = 0.009$, $\lambda_M = 0.007$ and varying λ_{BC}, λ_{HC}, λ_{PSG}, λ_{PSE}, λ_{TN} & λ_M respectively as 0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007, 0.008, 0.009 in Eq. (34), we obtain the variation of MTTF with respect to failure rates as shown in Tab. 3 and Fig. 4.

Table 3: MTTF vs Failure rates

Variations in λ_{BC}, λ_{HC},	MTTF					
λ_{PSG}, λ_{PSE}, λ_{TN}	λ_{BC}	λ_{HC}	λ_{PSG}	λ_{PSE}	λ_{TN}	λ_M
0.001	54.787879	61.035525	65.02463	65.134099	80.842391	88.160709
0.002	55.589744	57.560023	63.572319	63.780663	74.710743	80.842391
0.003	56.312576	54.469147	62.281359	62.579309	69.487179	74.710743
0.004	56.96649	51.700482	61.128526	61.507936	64.976049	69.487179
0.005	57.560023	49.204749	60.094658	60.54834	61.035525	64.976049
0.006	58.100423	46.942467	59.163824	59.685413	57.560023	61.035525
0.007	58.593879	44.881589	58.32269	58.906525	54.469147	57.560023
0.008	59.045698	42.995803	57.560023	58.201058	51.700482	54.469147
0.009	59.460458	41.263282	56.866304	57.560023	49.204749	51.700482

4.3 Sensitivities analysis

Sensitivity to a factor is defined as the partial derivative of the function with respect to that factor. These factors are failure rates in the following analyses.

(a) Reliability Sensitivity

We can find out the sensitivity analysis of reliability by differentiating the equation of reliability with respect to different failure rate λ_{BC}, λ_{HC}, λ_{PSG}, λ_{PSE}, λ_{TN} & λ_M respectively, by using the values of $\lambda_{BC} = 0.005$, $\lambda_{HC} = 0.002$, $\lambda_{TN} = 0.006$, $\lambda_{PSG} = 0.008$, $\lambda_{PSE} = 0.009$,. We find $\frac{\partial R(t)}{\partial \lambda_{BC}}$, $\frac{\partial R(t)}{\partial \lambda_{HC}}$, $\frac{\partial R(t)}{\partial \lambda_{TN}}$, $\frac{\partial R(t)}{\partial \lambda_M}$, $\frac{\partial R(t)}{\partial \lambda_{PSG}}$ and $\frac{\partial R(t)}{\partial \lambda_{BC}}$ and taking $t = 0$ to 10, we obtain the Tab. 4 and Fig. 5.

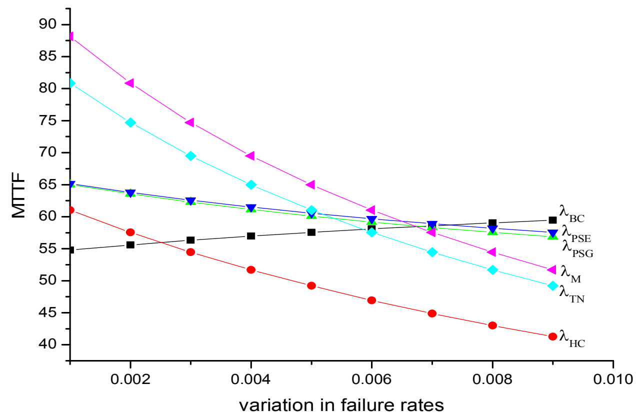

Fig. 4: MTTF as function of failure rate

Table 4: Reliability Sensitivity vs Time

Time	$\frac{\partial R(t)}{\partial \lambda_{BC}}$	$\frac{\partial R(t)}{\partial \lambda_{HC}}$	$\frac{\partial R(t)}{\partial \lambda_{TN}}$	$\frac{\partial R(t)}{\partial \lambda_{M}}$	$\frac{\partial R(t)}{\partial \lambda_{PSG}}$	$\frac{\partial R(t)}{\partial \lambda_{PSE}}$
0	0	0	0	0	0	0
1	0.000046	-0.985042	-0.985042	-0.985042	-0.008727	-0.007753
2	0.000363	-1.940345	-1.940345	-1.940345	-0.033848	-0.030057
3	0.00119	-2.866198	-2.866198	-2.866198	-0.073849	-0.065545
4	0.002743	-3.762918	-3.762918	-3.762918	-0.12731	-0.112938
5	0.005209	-4.630845	-4.630845	-4.630845	-0.192899	-0.171035
6	0.008751	-5.470343	-5.470343	-5.470343	-0.269368	-0.238717
7	0.013509	-6.281794	-6.281794	-6.281794	-0.355552	-0.314934
8	0.019604	-7.065602	-7.065602	-7.065602	-0.450357	-0.398707
9	0.027137	-7.822182	-7.822182	-7.822182	-0.552766	-0.489122
10	0.036192	-8.551968	-8.551968	-8.551968	-0.661825	-0.585327

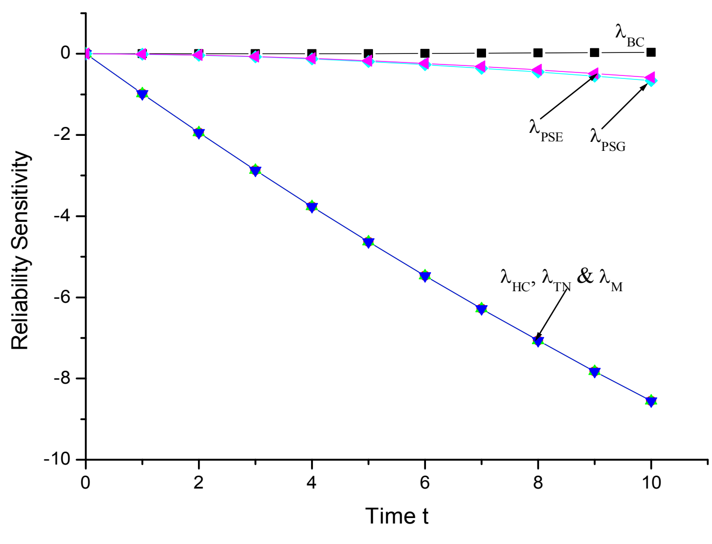

Fig. 5: Sensitivity of reliability as function of time

(2) MTTF Sensitivity

We can find out the sensitivity analysis of MTTF by differentiating the equation of MTTF with respect to different failure rate λ_{BC}, λ_{HC}, λ_{PSG}, λ_{PSE}, λ_{TN} & λ_M respectively, by using the values of $\lambda_{BC} = 0.005$, $\lambda_{HC} = 0.002$, $\lambda_{TN} = 0.006$, $\lambda_{PSG} = 0.008$, $\lambda_{PSE} = 0.009$. We find . Varying the failure rates respectively as 0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007, 0.008, 0.009 in the partial derivatives of MTTF, we obtain Table 5 and Fig 6.We can find out the sensitivity analysis of MTTF by differentiating the equation of MTTF with respect to different failure rate λ_{BC}, λ_{HC}, λ_{PSG}, λ_{PSE}, λ_{TN} & λ_M respectively, by using the values of $\lambda_{BC} = 0.005$, $\lambda_{HC} = 0.002$, $\lambda_{TN} = 0.006$, $\lambda_{PSG} = 0.008$, $\lambda_{PSE} = 0.009$, $\lambda_M = 0.007$. We find . Varying the failure rates respectively as 0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007, 0.008, 0.009 in the partial derivatives of MTTF, we obtain Tab. 5 and Fig. 6.

Table 5: MTTF Sensitivity vs Time

Variations in λ_{BC}, λ_{HC}, λ_{PSG}, λ_{PSE}, λ_{TN} & λ_M	$\frac{\partial MTTF}{\partial \lambda_{BC}}$	$\frac{\partial MTTF}{\partial \lambda_{HC}}$	$\frac{\partial MTTF}{\partial \lambda_{TN}}$	$\frac{\partial MTTF}{\partial \lambda_{M}}$	$\frac{\partial MTTF}{\partial \lambda_{PSG}}$	$\frac{\partial MTTF}{\partial \lambda_{PSE}}$
0.001	845.2158	-3692.8057	-6669.608	-8034.2731	-1541.9501	-1438.0174
0.002	760.5151	-3271.4812	-5639.3188	-6669.608	-1367.3773	-1273.3394
0.003	686.8298	-2920.5947	-4839.9544	-5639.3188	-1218.3955	-1133.0352
0.004	622.4163	-2624.8944	-4205.6617	-4839.9544	-1090.4499	-1012.7315
0.005	565.8536	-2373.1125	-3692.8057	-4205.6617	-979.9308	-908.9685
0.006	515.9755	-2156.7648	-3271.4812	-3692.8057	-883.9512	-818.984
0.007	471.8184	-1969.356	-2920.5947	-3271.4812	-800.1829	-740.5541
0.008	432.5816	-1805.8385	-2624.8944	-2920.5947	-726.7333	-671.8737
0.009	397.5956	-1662.2371	-2373.1125	-2624.8944	-662.0531	-611.4673

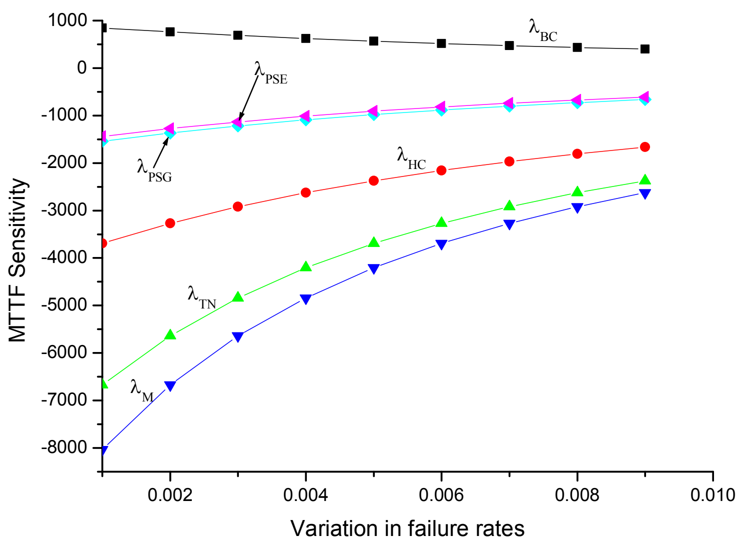

Fig. 6: Sensitivity of MTTF as function of failure rates

5 Result and discussion

By putting the values of different failure rates, we draw the graphs such as graph of reliability, MTTF, Sensitivity of Reliability & Sensitivity of MTTF. The graph of reliability shows the constant decrement when the time passes. With the help of graph of reliability, we observe that there are slightly changed at $t = 9$. Fig.

4 shows the graph of MTTF as a function of failure rate. This graph shows that the MTTF with respect to both power supplies are nearly same. We also observe that the MTTF with respect to failure of the host computer is very sharply decreases. Fig. 5 and 6 shows the sensitivity of reliability and MTTF. The graph of sensitivity of reliability and MTTF shows that the system is very sensitive with respect to failure of the host computer, telephone network and failure of automated teller machine. It is very interesting to observe that the value of sensitivity of reliability with respect to failure of the host computer, telephone network and automated teller machine is exactly same and also the graph of sensitive to MTTF shows the equally sensitive to both types of power failures.

6 Conclusion

Recently, ATM has been the essential part and plays a very important role in human life. With the help of ATM, we can withdraw cash and fund transfer at any time without any help of a clerk. So, the failure of ATM affects the human being to not only the banking sector. Comparing with the past work, the proposed work is very useful to the bankers to identify the effects of failure of different sub components of ATM networks. In this work, the authors have tried to find the possible reliability characteristics and sensitivity analysis of ATM architecture by using mathematical modeling, Laplace transformation, supplementary variable techniques and Markov process. In this study, we find the reliability, MTTF, Sensitivity of Reliability & Sensitivity of MTTF of the system that contains the main components of ATM architecture such as automated teller machine, telephone network, bank computer, host computer, power supply in parallel (through electricity board and generator). With the help of these reliability characteristics we can observe the effects of failure of different components of the system as well as the sensitivity analysis of the system. In this work, we observed that the host computer, telephone network and automated teller machine are the main critical components of the system. With the help of sensitivity of MTTF, one can observed that the system is almost equally sensitive with respect to both power supplies.

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