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Meenu
Research Scholar, Department of Mathematics, Shri Jagdishprasad Jhabarmal Tibrewala University Chudela, Jhunjhunu, Rajasthan, India

Dr. Bhawana
Assistant Professor, Department of Mathematics, Shri Jagdishprasad Jhabarmal Tibrewala University Chudela, Jhunjhunu, Rajasthan, India

Corresponding Author:
Dr. Bhawana
Assistant Professor, Department of Mathematics, Shri Jagdishprasad Jhabarmal Tibrewala University Chudela, Jhunjhunu, Rajasthan, India

Sensitivity analysis and stochastic modeling of a biscuit making plant

Meenu and Bhawana

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Abstract
Numerous industrial and other contexts commonly use standby systems. When all of redundant components start functioning at the same time, parallel redundancy takes place. A system is one where backup units, often known as standbys, are positioned behind the primary unit. Three varieties of standby exist generally: warm, cool, and hot. Standbys that are loaded similarly to the operational unit are referred to as hot standbys. This study uses RPGT to do a sensitivity analysis of a biscuit manufacturing factory with three units that have a consistent failure and repair rate. Tables and graphs are used to illustrate the impact of unit failure or repair rates on system performance metrics, with some units' rates remaining constant while others fluctuate for various units. Discussions follow.

Keywords: MTSF, RPGT, sensitivity analysis, availability

1. Introduction

Due to the significant contributions made by numerous reliability and operation researchers, studies on redundant systems are becoming more and more important. This is because the goal of studying redundant systems is to increase system use and optimize structure parametric ethics for various system types by various revamp policies. There are many real-world uses for these systems, particularly in industries. Studying system resilience through redundant components and enhanced preventative maintenance of operational and standby units is the aim of this paper. The system's standby units have three modes: degraded, failed, and operable. The main units have two modes: operable and failed. Both units are inspected subsequent to a failure in order to make out type of disappointment and select best repair strategy. The study makes use of Laplace transformation and RPGT to ascertain the system's dependability, availability, downtime, and cost effectiveness. Lastly, certain exceptional systemic cases have been discussed. Throughout the planning, manufacturing, and operating phases of both basic and sophisticated products and systems, reliability is a crucial notion. Customers anticipate dependability from the system and product they buy. In their daily work, practitioners encounter a variety of systems made up of one or more components, and when one of those components fails, the system as a whole or in part fails, decreasing the system's reliability. Bakeries should have high-quality designs with optimal availability and system parameters because modern items might range from simple to sophisticate. In order to achieve performance and dependability, modern engineering bakery factories must provide optimal manufacturing costs and minimal design cycle time. This study used RPGT, which is based on Markov modeling for modeling system parameters equations, to examine the transient behavior of a repairable biscuit manufacturing factory through sensitivity analysis. An investigation has been conducted on a biscuit making plant located in Haryana. The tilter structure and dough hopper (A), cutter and conveyor (B), metal detector, and rotating system (M) are the subunits that make up a biscuit manufacturing plant. A system is serene of multiple machinery, and in order to provide structure a high degree of reliability, we must use reliable components. In some situations, it is either impractical or prohibitively expensive to build highly reliable components. In these situations, incorporating spare components and providing upkeep and repairs as needed could result in increased dependability. Increased system reliability is also greatly aided by redundancy. Numerous industrial and other contexts commonly use standby systems. When all of redundant components start functioning at the same time, parallel redundancy takes place. The process of producing, summarizing, or evaluating the information gleaned from a research study is known as a literature review. According to recent studies, availability, maintainability, and reliability are important in practically every project involving engineered and manufactured goods. As a result, there are countless application areas and an almost infinite number of distinct components. A Markov procedure is a stochastic procedure with limited state automation. It is assumed that imminent states are contingent only on the current state and not on past events. None of the researcher has been attempt in these area/parameters. Anand and Malik (2012) [2] discussed the cost effective measures of computer using inspection. Computer organization has two identical units. Both units have software & hardware components. Ahmad and Kumar (2015) [6] concern a centrifuge classification with two identical cold standby units that take major and minor faults into account. Ritikesh and Goel (2015) [18] this paper discusses about the behavior analysis of a system which has a single unit which goes to degradation after having complete failure using the technique of RPGT. Zhang and Zeng (2016) [23] have studied the maintenance modeling of different systems consisting of a number of non-identical units. Ahmad and Kumar (2016) [4] analyzed the two stochastic models for a two-unit cold standby centrifuge system and compared them in this work. Malik and Goel (2016) examined the software's availability vs. cost, which consists of a dual-module framework that allows modules to operate at full and lowered capacity. Ram and Manglik (2016) [19] described a manufacturing system with three subsystems to depict the reliability activities of a device that is being studied. Markov and extra-adaptable methodologies are already accustomed to achieving mathematical analysis of this specific item. According to Renu et al. (2016) [20], the determination of the current learning stands to investigate the reliability of a two-unit standby organization in which single unit is operational and the additional is in standby mode. Markov procedures and regeneration point techniques are used to derive the many reliability features of interest, such as MTSF, busy period, and profit. Hassan et al. (2016) [13] State-dependent probabilistic Markov models were proposed as an alternative to traditional time-dependent frameworks for process plant accessibility analysis, and the study above also revealed that maintenance intervals have a significant impact on a manufacturing facility's availability as well as sustaining goal availability. Adlakha al. (2017) [3] has done study of a two subunit standby communiqué framework with assembling of unique unit at a time by carrying out a detail analysis. Kvassay and Zaitseva (2018) [16] develop a new method for their computation for systems that can be decomposed into disjoint modules. The method is based on the chain rule that is derived in this paper. Hua et al. (2018) [14] assessed the reliability of a phased-mission system using a reconfigured Markov model. The condition merging approach is used in mathematical modeling. Devi et al. (2018) [8] calculate the MTSF and system availability using RPGT. In this system, two units are initially in operation alongside a third similar unit in cold standby mode, with the concept of two kinds of disappointments and repair facilities using ordinary or expert servers. Devi and Kumar (2019) [10] discussed how the two-unit standby stochastic system has been determined through path analysis, which is then used to calculate the MTSF of the organization using modified RPGT. Devi et al. (2019) [10] discussed how the 'base state' of a three-unit standby stochastic system has been determined through path analysis, which is then used to calculate the MTSF and accessibility of the organization using modified RPGT. Gupta et al. (2020) [12] study on the two-unit cold standby stochastic system's MTSF and availability are determined in graphical form. The effectiveness of the system had been assessed using regenerative point process techniques. Gupta et al. (2020) [12] study on the two-unit cold standby stochastic system's MTSF and availability are determined in graphical form. Kumar (2020) [15] examined the effect of faults occurring owing to delays in restoration and replacement on a two-unit cold standby extractor system on reliability and availability. The system is investigated using a graphical analysis, and judgments on its dependability are drawn.

Chang et al. (2020) [7] presence of brittle behavior of components usually is accompanied by a low strength. Agrawal et al. (2021) [4] discussed the profit analysis of a Water Treatment Reverse Osmosis (RO) Plant using the RPGT under specific conditions for scheme parameters. Numerical analysis is carried out for calculating the performance measures and their comparisons. Asi et al. (2021) [5] have investigated the five productive reliability methodologies relatively extensively to establish some basic guidelines for the probabilistic calculation of bridge pier scour. Torrado et al. (2021) [22] looked at the consequences of redundancy in computers at the design stage. Numerous results are offered for correlated systems made up of distributed systems. Singh and Gahlot (2021) [21] discussed the study of a PC research facility framework with n customers under star geography and k-out-of-n: G conspire. Garg and Garg (2022) [11] studied the presentation analysis of the briquette machine in view of a neglected fault with PM used the Artificial Bee Colony algorithm to optimize the assessment of system profit. Garg and Garg (2022) [11] studied the Performance analysis of the briquette machine considering a neglected fault with preventive maintenance used the Artificial Bee Colony algorithm to optimize the value of system profit. A system is one where backup units, often known as standbys, are positioned behind the primary unit. Unit ‘A’ is more perilous, hence a cold standby sub-unit is providing in the framework to enhance the accessibility and another parameters of the framework. To keep the best value of framework parameter a server upkeep facility is also providing, it is usually expected that server never fails, but almost server may not be continuously accessible or not fail due to one reason or another, hence requirements service/ treat sub-unit or same signify to do its intended purpose. Significance order to repair the sub-units and server are M > B > A. It can recover the second standby database up to the point at which the undesirable operation (logical corruption) took place. If there is a delay in applying logs (for instance, only apply logs every 12 or 24 hours), it can then either activate it and utilize it as the new primary database or open it read-only to extract the required data. Furthermore, in this chapter, RPGT is used to model the system parameters. A single, always-available repairman replaces the problematic unit and switches in the standby unit when a breakdown occurs. It is anticipated that the repairman will be available at all times. The repaired item should function as well as a brand-new one. In the event that another unit fails while the server is fixing a downed unit, it joins the back of the queue of failed units. A single, always-available repairman replaces the problematic unit and switches in the standby unit when a breakdown occurs.

It is anticipated that the repairman will be available at all times.

2. Notations &Assumptions

- Two of the system's four units are currently in operation, while the other two are in cold standby mode.
- If more than 2 units malfunction, the system fails.
- y_i constant repair rates of units, i=1, 2,3, 4
- x_i constant failure rates of units, i=1,2,3, 4

: Full capacity of the system.

: Reduced capacity of the system.

: Failed states

- : Regenerative Point

4. System Transition State Diagram

Figure 1 shows the system's Transition State Diagram utilizing the Markov Process, taking into account a back mention assumptions and notations in the study.

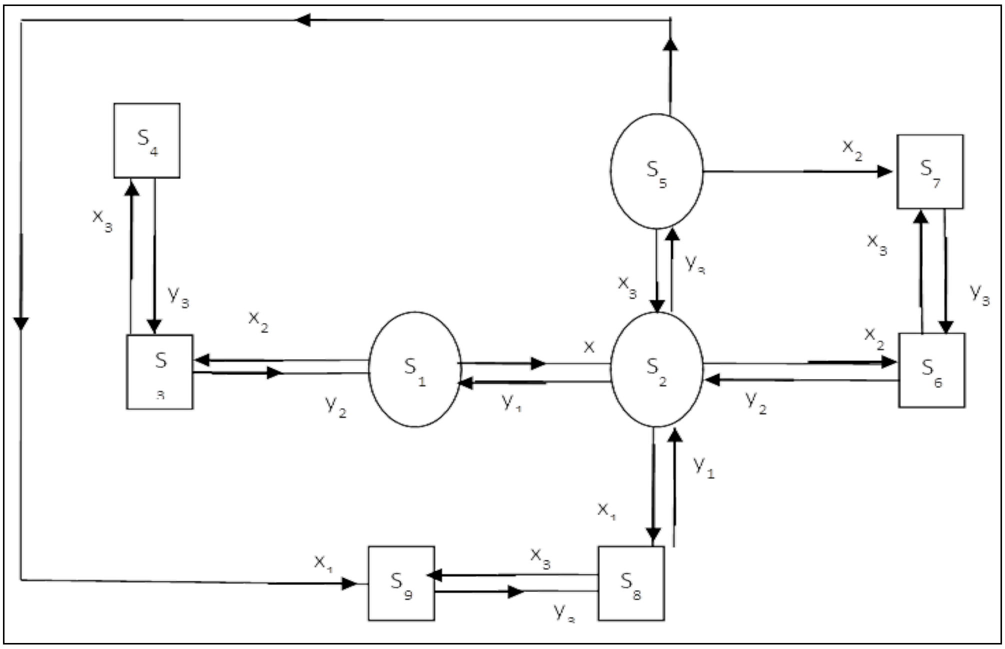

Fig 1: Transition Diagram of Biscuits Plant

S_0 = A(A)B, S_1 = aAB, S_2 = A(A)b, S_3 = A(A)bM,
S_4 = aABM, S_5 = aAb, S_6 = aAbM, S_7 = aaB, S_8 = aaBM,

4. Transition Probabilities [$q_{i,j}(t)$]

$q_{1,2}(t) = x_1\, e^{-(x_1+x_2)t}$; $q_{1,3}(t) = x_2\, e^{-(x_1+x_2)t}$; $q_{2,1}(t) = y_1\, e^{-(x_1+x_2+x_3+y_1)t}$

$q_{2,5}(t) = x_3\, e^{-(x_1+x_2+x_3+y_1)t}$; $q_{2,6}(t) = x_2\, e^{-(x_1+x_2+x_3+y_1)t}$

$q_{2,8}(t) = x_1\, e^{-(x_1+x_2+x_3+y_1)t}$; $q_{3,1}(t) = y_2\, e^{-(y_2+x_3)t}$; $q_{3,4}(t) = x_3\, e^{-(y_2+x_3)t}$

$q_{4,3}(t) = y_3\, e^{-y_3 t}$; $q_{5,2}(t) = y_3\, e^{-(x_1+x_2+y_3)t}$; $q_{5,7}(t) = x_2\, e^{-(x_1+x_2+y_3)t}$

$q_{5,9}(t) = x_1\, e^{-(x_1+x_2+y_3)t}$; $q_{6,2}(t) = y_2\, e^{-(x_3+y_2)t}$; $q_{6,7}(t) = x_3\, e^{-(x_3+y_2)t}$

$q_{7,6}(t) = y_3\, e^{-y_3 t}$; $q_{8,2}(t) = y_1\, e^{-(x_3+y_1)t}$; $q_{8,9}(t) = x_3\, e^{-(x_3+y_1)t}$; $q_{9,8}(t) = y_3\, e^{-y_3 t}$

$p_{i,j} = q^*_{i,j}(t)$

$p_{1,2} = x_1/(x_1+x_2)$; $p_{1,3} = x_1/(x_1+x_2)$; $p_{2,1} = x_1/(x_1+x_2+x_3+y_1)$; $p_{2,5} = x_3/(x_1+x_2+x_3+y_1)$

$p_{2,6} = x_2/(x_1+x_2+x_3+y_1)$; $p_{2,8} = x_1/(x_1+x_2+x_3+y_1)$; $p_{3,1} = y_2/(y_2+x_3)$; $p_{3,4} = x_3/(y_2+x_3)$

$p_{4,3} = 1$; $p_{5,2} = y_3/(x_1+x_2+y_3)$; $p_{5,7} = x_2/(x_1+x_2+y_3)$; $p_{5,9} = x_1/(x_1+x_2+y_3)$; $p_{6,2} = y_2/(x_3+y_2)$

$p_{6,7} = x_3/(x_3+y_2)$; $p_{7,6} = 1$; $p_{8,2} = y_1/(y_1+x_3)$; $p_{8,9} = x_3/(y_1+x_3)$; $p_{9,8} = 1$

5. Mean Sojourn Times [$R_i(t)$]

$R_1(t)=e^{-(x_1+x_2)t}$; $R_2(t)=e^{-(x_1+x_2+x_3+y_1)t}$; $R_3(t)=e^{-(y_2+x_3)t}$; $R_4(t)=e^{-y_3t}$

$R_5(t)=e^{-(x_1+x_2+y_3)t}$; $R_6(t)=e^{-(x_3+y_2)t}$; $R_7(t)=e^{-y_3t}$; $R_8(t)=e^{-(y_1+x_3)t}$; $R_9(t)=e^{-y_3t}$

$\mu_i=R_i^*(0)$

$\mu_1 = 1/(x_1+x_2)$; $\mu_2 = 1/(x_1+x_2+x_3+y_1)$; $\mu_3 = 1/(y_2+x_3)$; $\mu_4 = 1/y_3$; $\mu_5 = 1/(x_1+x_2+y_3)$

$\mu_6 = 1/(x_3+y_2)$; $\mu_7 = 1/y_3$; $\mu_8 = 1/(y_1+x_3)$; $\mu_9 = 1/y_3$

6. Data analysis and Discussions

MTSF (T_0): Regenerative un-failed states to which the framework can transit (initial state '2'), earlier incoming any fizzled state are: 'i' = 1, 2, 5 attractive 'ξ' = '1'

$T_0 = (V_{1,1}\mu_1+V_{1,2}\mu_2+V_{1,5}\mu_5)/\{1-(1,2,1)\}$

Availability of System (A_0): Regenerative states at which the framework is accessible are 'i' = 1, 2, 5attractive 'ξ' ='1'

$A_0 = (V_{2,1}\mu_1+V_{2,2}\mu_2+V_{2,5}\mu_5)/Z_1$

Busy Period of Server (B_0): Regenerative states where server is busy are $2 \le j \le 9$, attractive ξ = '1'

$B_0 = 1-(\mu_j/D)$

Expected Fractional Number of Inspections by the repair man (V_0): Regenerative states where repair man does this job j = 2, 5 'ξ' = '1', number of visit by repair man is given by $V_0 = (V_{1,2}+V_{1,5})/D$

6.1 Sensitivity Analysis

Besides, the above after sections portray two sensitivity analysis scenarios and relating brings about plain and graphical structures broke down. Sensitivity analysis regarding variation in failure rates Enchanting y $=y_1=y_2=y_3=\beta_4 = 0.50$ and changeable breakdown rates

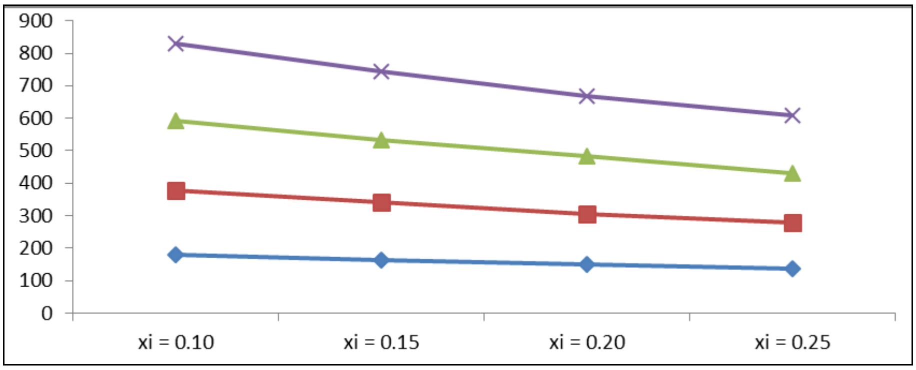

Fig 2: MTSF

Managements can draw conclusions that are appropriate for them from graph 42.

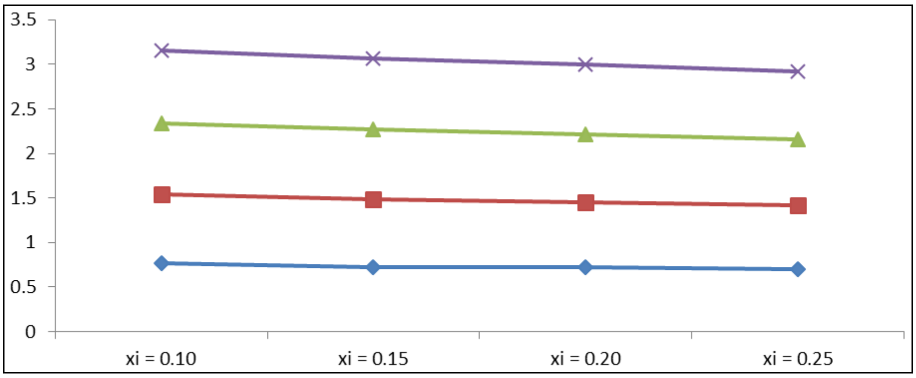

Fig 3: Availability of System (A_0)

A_0 be supposed to be large on behalf of a superior system, as publicized in graph 3, where A_0 reaches its maximum with very low unit disappointment rates. In measure up to the columns, standards A0 turn down supplementary rapidly as the assessment of 0.10 rises; therefore, unit needs to be better designed and of higher quality in order to have a lower failure rate.

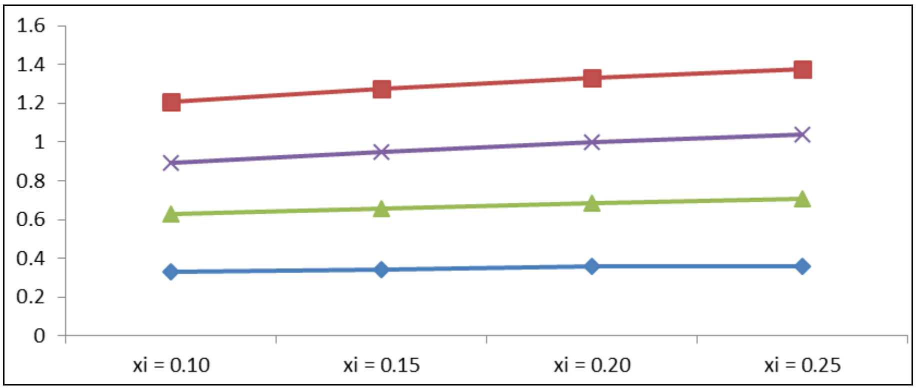

Fig 4: Server of the Busy Period (B_0)

Unit 'A' should have the best quality and design to ensure that its breakdown rate be as low as likely in addition to the other units. This is because, as we can perceive on Graph 4, B_0 is small when all of the unit's failure rates are very small and its value increases more speedily as unit's failure rate increases.

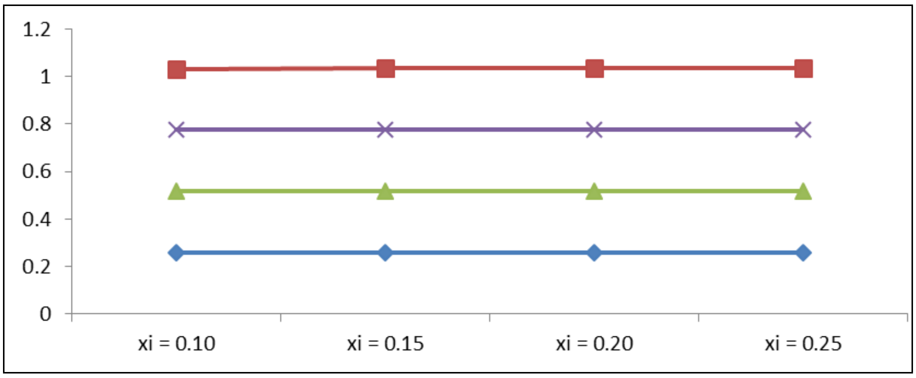

Fig 5: Expected Fractional Numbers of Inspections by Repairman (V_0)

It is seen that the estimation increases more quickly when sub-unit rise disappointment rate is expanded; figure 5 illustrates this same tendency.

Scenario 2: consequence of modify of repair rates on classification parameter enchanting $x = x_1 = x_2 = x_3 = x_4 = 0.10$ and untrustworthy repair rates

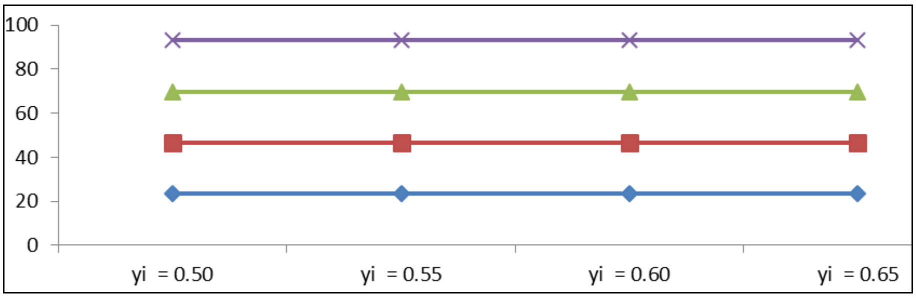

Fig 6: MTSF

According to fig. 6, show that repair rates of individual units have no bearing on MTSF.

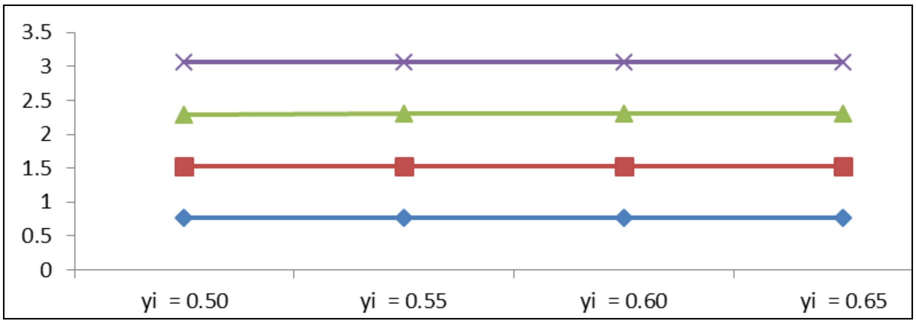

Fig 7: Availability of System (A_0)

The upstairs 7, it is established that convenience is smallest amount when the disappointment rate of unit be upper limit and its assessment is 0.7685.

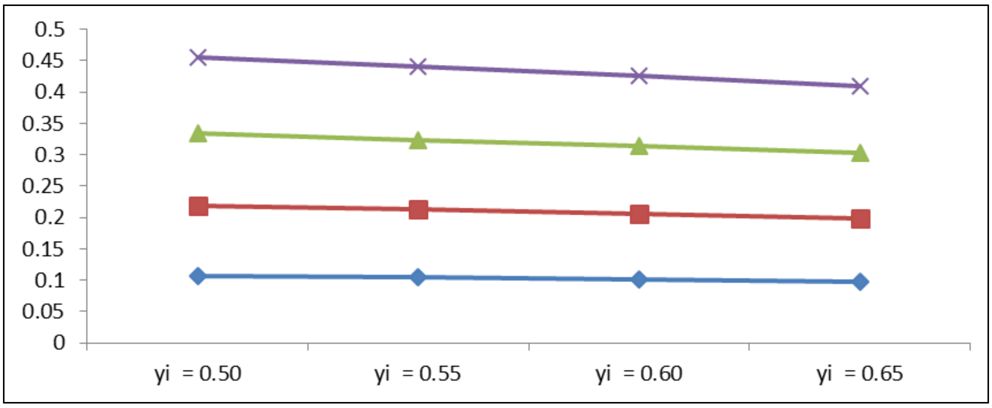

Fig 8: Server of Busy Period (B_0)

Figure 8, shows that the bustling time frame diminishes with the increment in repair paces of unit and is least amount subsequently repair pace of unit first is Minimum in contrast with the repair paces of different units.

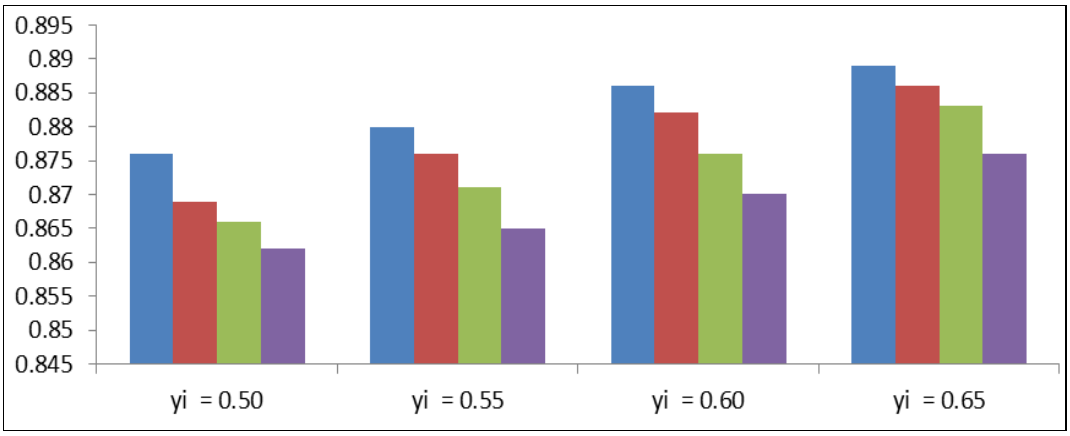

Fig 9: Expected Fractional No. of Inspections by the Repairman (V_0)

Figure 9 show that when going in segments from top to bottom, no. of calls commencing the attendant be supposed to be minimised.

7. Conclusion

From above tables and graph we see that the result obtained using RPGT is same as obtained by using RPT. But in RPGT one attained the result very easily and quickly without writing any state equations and without any cumbersome procedures, long calculations and simplifications. The models developed for this study are designed to produce increasingly plausible outcomes as the failure rates of different frameworks increased, followed by a breakdown in framework accessibility. The system's availability, the profit function, and the anticipated number of repairman inspections are all observed to decrease with an increase in malfunction rate and to increase by repair rate, based on the analytical and figure discussions. Increased repair rates result in a decrease in the MTSF breakdown and the busiest period of the server. The system cannot reach production after a limit, i.e. a recession occurs. In addition, the perfect presentation level has been well-known, and real-world amalgamation of disappointment and fix rates has what's more been settled.

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