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Comparative Analysis of Two Single Unit Systems with Production Depending on Demand

Reetu Malhotra [1*] Gulshan Taneja[2]
1.Department of Applied Sciences, Chitkara University, Rajpura, Punjab,140401–India
2.Department of Mathematics, Maharshi Dayanand University, Rohtak, 124001–India
* E-mail of the corresponding author: reetu.malhotra@chitkarauniversity.edu.in

Abstract
The present paper gives the comparative analysis between two models with production depending on demand. The two models (Model 1 and Model 2) considered are on a cable manufacturing plant with the difference of scheduled maintenance. Model 1 considers a single unit system with scheduled maintenance whereas Model 2 is without scheduled maintenance. Initially, the system is in operative state and demand is greater than or equal to the production. As variation in demand affects the production of system, consequently, the system needs to be in down state when the numbers of produces are more than those demanded. This model has been compared with the model wherein the scheduled maintenance is carried out. Comparative study with respect to the availability and the profit has been made between two models. Semi-Markov processes and regenerative point technique have been used to obtain various measures of the system effectiveness for each model.
Keywords: Comparative Analysis, Single Unit System, Cable Manufacturing Plant, Variation in Demand, Scheduled Maintenance, Profit, Regenerative Point Technique

1. Introduction

In this era of competition, everyone expects trouble free performance of the system as on its failure many of the human activities would stop and even cease to exist. A trouble free performance cannot be guaranteed, but we can make it more reliable. Many researchers contributed a lot in the field of system reliability modeling and analyzed various single or two-unit systems under different situations considering various concepts, yet comparative analysis between two types of systems is reported very less in the literature. Goyal et al. [1], Kumar and Kumar [2], Kumar and Kapoor [3], Parashar and Taneja [6], Rizwan et al. [7], Taneja et al. [8], Zhang et al. [10] discussed single or two- unit standby systems under various assumptions and circumstances with working, failed or rest states only. All these studies have considered the demand as fixed. However, there exist many practical situations where the demand of the units produced is not fixed. Such a situation may be seen in General Cable Energy System [4], where demand for the Al/Cu wire does not remain constant i.e. it varies and hence sometimes Cable Energy System is put to down mode if demand is lesser than the production.

A system working under some specific condition cannot be considered as best one and hence it may be better or worse when compared with another similar system working under different conditions. To see which one system is better than the other similar system, it is highly significant to make a comparative study between those two models. Here, Two models – one (Model 1): the cost-benefit analysis of a single unit system with scheduled maintenance and variation in demand [9] and the other (Model 2) for analyzing the reliability modeling of a single unit system with varying demand but without scheduled maintenance [5] have been compared. In each of these two models, initially, the system is in operative state where demand is greater than or equal to the production. If the operative unit stops working, repairman repairs the failed unit. As variation in demand affects the production of system also, the system is required to be put to down state when the units produced are already in excess. The system in the down state is made operative as soon as the produced units are less in number than those demanded. Revenue in case of both types of up states i.e. when demand is greater than or equal to production and when demand is less than production have also been taken under consideration while carrying out the cost-benefit analysis. The loss incurred to the system when it is kept shut down due to less demand has also been taken into account. Comparative analysis between the two models has been made to see which and when the one model is better than the other.

2. Materials and Methods

In this study, comparative study between two models [5] and [9] has been made. In [5] and [9], the probabilistic analysis of the system is analyzed by making use of semi-Markov processes and regenerative point technique and have obtained various measures of system effectiveness such as Mean Time to System Failure, Availability when demand is greater than or equal to production, Availability when demand is less than production, Busy period of the repairman for repair, Expected number of visits by the repairman, Expected down time and Profit function.

3. Notations

λ	Failure rate of the operative unit
λ_1	Rate of decrease of demand so as to become less than production
λ_2	Rate of increase of demand so as to become greater than or equal to production
λ_3	Rate of going from upstate to downstate (reason behind this is that the demand is less than production and production goes on increasing and as a result we have lot of produces in the stock. This production needs to be stopped
λ_4	Rate of change of state from down to up when there is no produce with the system and demand is there
β_1	Rate of requirement of doing scheduled maintenance
β_2	Rate of doing scheduled maintenance
p_1	Probability that during the repair time demand is greater than or equal to production
p_2	Probability that during the repair time demand is less than production
AOD1	Availability that the system is in upstate when demand is not less than production in Model 1
AOD2	Availability that the system is in upstate when demand is not less than production in Model 2
AOP1	Availability that the system is in upstate when demand is less than production in Model 1
AOP2	Availability that the system is in upstate when demand is less than production in Model 2
C_0	Revenue per unit up time when demand is greater than or equal to production
C_1	Revenue per unit up time when demand is less than or equal to production
C_2	Cost per unit up time for engaging the repairman for repair
C_3	Cost per visit of the repairman
C_4	Cost of scheduled maintenance per unit time
C_5	Loss per unit time during the system remains down
L	Loss per unit time for doing scheduled maintenance
P1	Profit incurred to the system in Model 1
P2	Profit incurred to the system in Model 2
g(t),G(t)	p.d.f. and c.d.f. of repair time for the unit

4. Comparative Analysis of the Two Models

Various graphs have been plotted for the MTSF, the availability and the profit with respect to rates/loss per unit time for different values of rates/costs. Some have been shown here and the others not to avoid space. Following interpretations can be made from the graphs:

- **Figure 1** depicts the behavior of the MTSFs (M1, M2) of the Model 1 and Model 2 with respect to the rate of doing scheduled maintenance (β_2). It can be interpreted from the graph that M1is greater than or equal to or less than M2 according as β_2< or = or > 0.0011. So, if $\beta_2 < 0.0011$, one should not opt for Model 1. That is, Model 2 should be adopted in this case. If $\beta_2 > 0.0011$, Model 1 is preferred. The values of other parameters per hour are taken as: λ_1=0.008/hr; λ_2=0.004/hr; λ_3=0.0002/hr; λ_4=2/hr; λ=0.1/hr; β_1=0.0001/hr; p_1=0.535; p_1=1-p_2.
- **Figure 2** depicts the behavior of the availabilities (AOD1, AOD2) of the Model 1 and Model 2 when demand is not less than the production with respect to the rate of doing scheduled maintenance (β_2). It can be observed from the graph that the availability (AOD1) increases strictly as rate of doing scheduled maintenance increases whereas the availability (AOD2) remains almost unaffected. It can also be interpreted from the graph that AOD2 is greater than or equal to or less than AOD1 according as β_2< or = or > 0.00293. So, if $\beta_2 < 0.00293$, one should opt for Model 2. That is, Model 2 should be adopted in this case; otherwise Model 1 is preferred. The values of other parameters are taken as: λ_1=0.008/hr; λ_2=0.004/hr; λ_3=0.0002/hr; λ_4=2/hr; β_1=0.0001/hr; p_1=0.535; p_2 =1-p_1.
- **Figure 3** depicts the behavior of the availabilities (AOP1, AOP2) when demand is less than the production of the Model 1 and Model 2 with respect to the rate of doing scheduled maintenance (β_2). It can be interpreted from the graph that AOP2 is greater than or equal to or less than AOD1 according as β_2< or = or > 0.000513. So, if $\beta_2 < 0.000513$, one should opt for Model 2, otherwise Model 1 is preferred. The values of other parameters hour are taken as: λ_1=0.008/hr; λ_2=0.004/hr; λ_3=0.0002/hr; λ_4=2/hr; β_1=0.0001/hr; β_2=.001029/hr; p_1=0.535; p_2=1-p_1, C_0 = INR 4000, C_1=INR 1000, C_2=INR 400, C_3 = INR 500, C_5 = INR 400. Following conclusions have been drawn through the graph:

- The differences P1-P2 decreases as loss per unit time for doing scheduled maintenance increases and has higher value for lower value of cost C_4.
- For C_4=500, P1-P2 > or = or < 0 according as L< or = or > 11402.3. Hence, the Model 1 is better than the Model 2 if L is < 11402.3.
- For C_4=1500, P1-P2 > or = or < 0 according as L < or = or >10445.2. Hence, the Model 1 is better than the Model 2 if L is > 10445.2.
- For C_4=2500, P1-P2 > or = or < 0 according as L < or = or > 9050.57. Hence, the Model 1 is better than the Model 2 if L is > 9050.57.

5. Conclusion

Some cut-off points have been obtained and some more can be obtained with respect to various costs/rates from which we are able to decide when and which model is profitable. So, under a given situation/condition, one can choose a better model in the light of the comparative study made as above taking the numerical values of various rates/costs etc. as existing there for such systems. Thus, the user can have more benefits choosing the better model on this basis of cut-off points.

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Reetu Malhotra is currently working as an associate professor in Department of Mathematics, Chitkara University, Rajpura, Punjab. Her qualification is MSc. (Mathematics), MPhil.. (Mathematics), CSIR UGC NET qualified, Ph.D. (persuing). She had a teaching experience of about 11 years. Her areas of interest are "Reliability Modeling", "Queuing Theory" and "Optimization". She has various publications in National/International conferences and in Journal of repute. She has also coauthored three books of Mathematics.

Dr Gulshan Taneja is currently working as Professor in the Department of Mathematics, M.D. University, Rohtak, Haryana, India. He had a wide range of teaching as well as research experience of about 25 years. He is Associate Editor/Editor/Reviewer of many International Journals in Mathematics/Engineering. He has supervised 8 Ph.D. theses and 8 M.Phil. dissertations in Mathematics/ Statistics. Currently, 8 are being supervised by him. Dr Taneja has published over 100 Research Papers in various Journals of International repute and proceedings of the National/International conferences. He has delivered many Invited talks/Extension lectures in India as well as Abroad. He chaired sessions in number of National / International Conferences and

acted as a Resource person in Refresher Courses also. He participated in around 35 National/International conferences. He is the writer of the four blocks of a Course run by IGNOU, New Delhi, INDIA and has also edited four books published by the same University. He is one of the editors of the proceedings of two National Conferences in India and is member of various academic societies/ associations. His areas of interest are "Reliability Modeling", "Queuing Theory" and "Optimization".

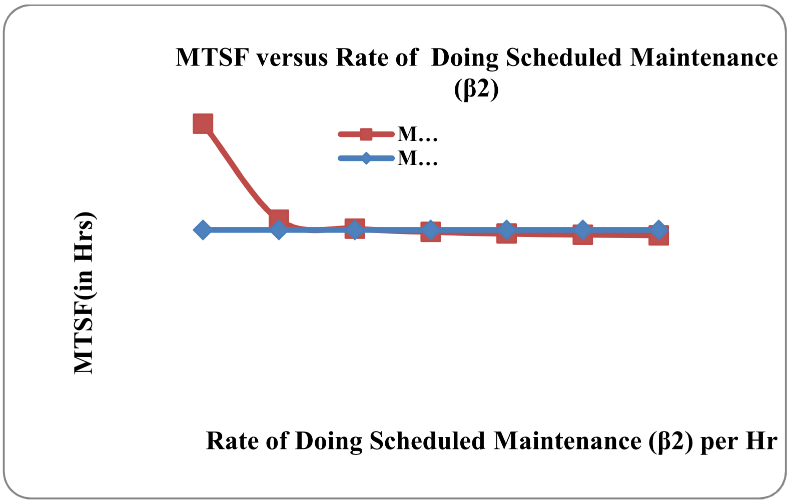

Figure 1. MTSF versus Rate of Doing Scheduled Maintenance (β_2)

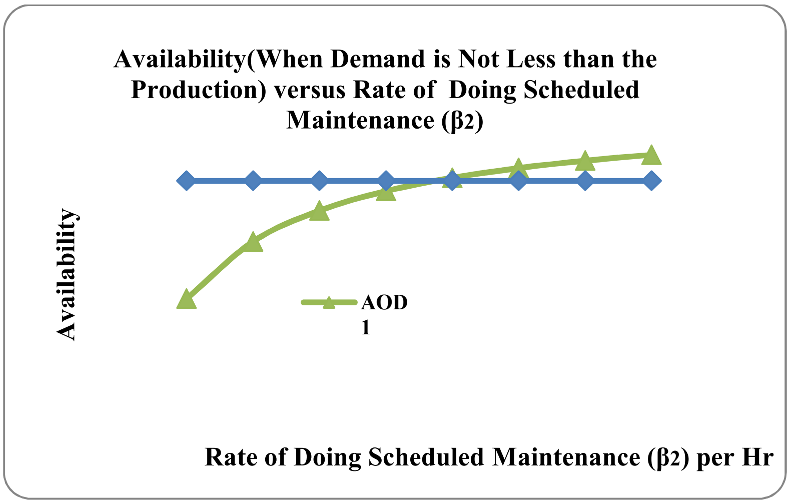

Figure 2: Availability(when demand is not less than the production) versus Rate of Doing Scheduled Maintenance (β_2)

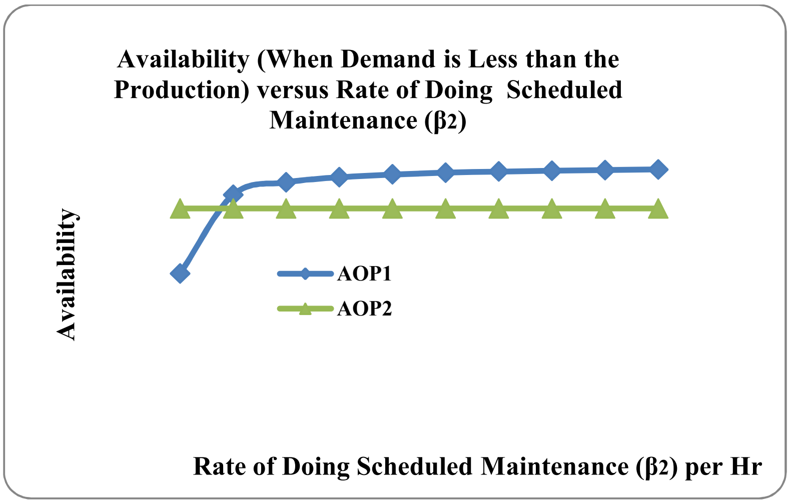

Figure 3: Availability(when demand is less than the production) versus Rate of Doing Scheduled Maintenance (β_2)

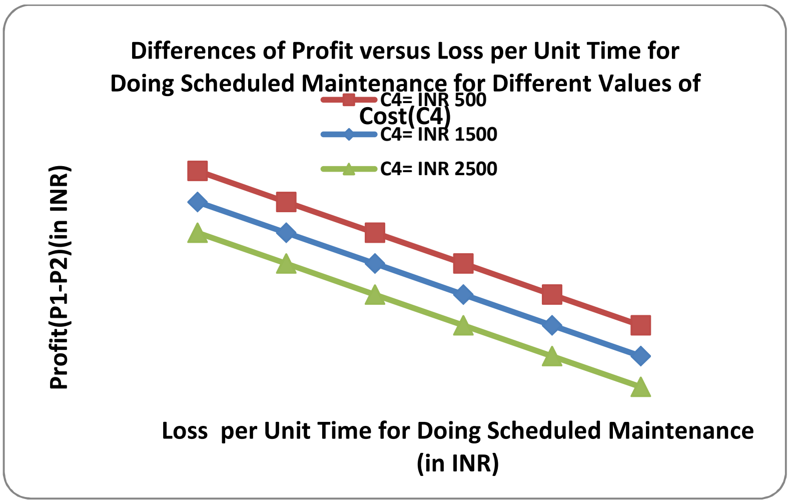

Figure 4: Difference of Profit (P1-P2) versus Loss per Unit Time (L) for Doing Scheduled Maintenance for different values of Cost (C_4)

Table 1.Which and when one model is better than the other has been presented in the following table:

<table>
<tr><th rowspan="2">Fixed Parameter</th><th rowspan="2" colspan="2">Comparison with respect to</th><th colspan="3">Which model is better (according to different situations)</th></tr>
<tr><th>Model 1 is better if</th><th>Model 2 is better if</th><th>Both the models are equally good</th></tr>
<tr><td>λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr, β_1=0.0001/hr,p_1=0.535, p_2=1-p_1.</td><td colspan="2">MTSF</td><td>$\beta_2 > 0.0011$</td><td>$\beta_2 < 0.0011$</td><td>$\beta_2 = 0.0011$</td></tr>
<tr><td>λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr,p_1=0.535, p_2=1-p_1,β_2=0.002/hr</td><td colspan="2">MTSF</td><td>$\beta_1 < 0.000013$</td><td>$\beta_1 < 0.000013$</td><td>$\beta_1 = 0.000013$</td></tr>
<tr><td>λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr, β_1=0.0001/hr,p_1=0.535, p_2=1-p_1.</td><td colspan="2">Availability(AOD)</td><td>$\beta_2 > 0.00293$</td><td>$\beta_2 < 0.00293$</td><td>$\beta_2 = 0.00293$</td></tr>
<tr><td>λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr,p_1=0.535, p_2=1-p_1,β_2=0.002/hr</td><td colspan="2">Availability(AOD)</td><td>$\beta_1 > 0.000013$</td><td>$\beta_1 < 0.000013$</td><td>$\beta_1 = 0.000513$</td></tr>
<tr><td>λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr,p_1=0.535, p_2=1-p_1,β_1=0.00001/hr</td><td colspan="2">Availability (AOP)</td><td>$\beta_2 > 0.000513$</td><td>$\beta_2 < 0.000513$</td><td>$\beta_2 = 0.000513$</td></tr>
<tr><td>λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr,p_1=0.535, p_2=1-p_1,β_2=0.002/hr</td><td colspan="2">Availability (AOP)</td><td>$\beta_1 > 0.000063$</td><td>$\beta_1 < 0.000063$</td><td>$\beta_1 = 0.000063$</td></tr>
<tr><td rowspan="3">λ=0.1/hr, λ_1=0.008/hr, λ_2=0.004/hr, λ_3=0.0002/hr,λ_4=2/hr,p_1=0.535, p_2=1-p_1,β_2=0.002/hr, β_1=0.00001/hr C_0 = INR 4000, C_1=INR 1000, C_2=INR 400, C_3 = INR 500, C_5 = INR 400.</td><td rowspan="3">Profit</td><td>C_4=500</td><td>L< 11402.3.</td><td>L > 11402.3</td><td>L = 11402.3.</td></tr>
<tr><td>C_4=1500</td><td>L <10445.2</td><td>L >10445.2</td><td>L = 10445.2</td></tr>
<tr><td>C_4=2500</td><td>L< 9050.57</td><td>L > 9050.57</td><td>L = 9050.57</td></tr>
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