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Analysis of Hulling System in Rice Mill Plant With Variable Demand

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Abstract
This main objective of the present study is to analyse profit analysis of a Rubber Roller in hulling system used in rice-mill with change in demand of Rice. We consider two type of upstate when demand is more than or equal to supply and Supply is more than demand. When there is less demand or supply is more than demand the operative unit put in down state. preventive maintenance (PM) carried on during downtime There is a single server who visits the system immediately whenever needed to carry out preventive maintenance and repair. The analysis incorporates the Weibull distribution to model the failure and repair times of the hulling system components, Using semi Markov process and regenerative point techniques various reliability characteristics are obtained.
2020 Mathematics Subject Classification : 90B25, 60K10.

Keywords: Variable Demand, Main time betyween failure (MTBF), Preventive maintenance (PM),

1 Introduction
In the agro-industrial sector, rice milling plays a pivotal role in the processing chain of rice production, contributing significantly to food security and economic development in many regions worldwide. In this study, we focus on the stochastic reliability modeling and analysis of a rice mill hulling system, considering the impacts of variable demand and PM downtime constraints. This study aims to develop a comprehensive stochastic reliability model for rice mill. In the field of reliability one unit and two unit have been analyzed by large number of researchers such as Ashish kumar, Monika and kuntal devi[1] focuses on performance analysis of a redundant system with weibull failure and repair laws. Dolas, jaybhaye and deshmukh[2] has been carried out estimation the system reliability using weibull distribution. In this paper, the authors likely present a methodology for estimating system reliability based on the Weibull distribution. S. Bhardwaj, N. bhardwaj and V. kumar[3] has study of reliability of diesel locomotive engine using weibull distribution. Weibull distribution of two parameters represents a decreasing, increasing and constant failure rate. In this study, Weibull distribution having two parameters is to be used to predict the system reliability. further Hemant Kumar saw and V.K.Pathak[4] have extended their work in reliability modeling and analysis of single unit system with environmental failure and PM AT MOT. Hemant Kumar.Saw, V.K.Pathak[5] also analyzed Profit Analysis of Hulling system in rice mill plant with change in demand and PM at down state subject to maximum operation time. Nivedita Gupta, Ashish Kumar, and Monika Saini[6] investigate various reliability measures of generators used in STP through the RAMD approach at the component level. For this purpose, mathematical models using the Markovian birth-death process have been developed for all subsystems of the generator. Pundir, patawa and Gupta [7] investigate stochastic outlook of two non indentical unit paraallel system with priority in repair. The crux of the study is to investigate a two non-identical unit parallel system where priority is given to first unit. The system consists of two non-identical units arranged in parallel configuration. K Devi, A. kumar and M. Saini[8] analyzed Performance analysis of a non-identical unit system with priority and Weibull repair and failure laws. farther Kumar and Saini[9][10] analy Cost-benefit analysis of a single-unit system with preventive maintenance and Weibull distribution for failure and repair

activities and Analysis of a redundant system with priority and Weibull distribution for failure and repair.

The application of Semi-Markov and Regenerative Point Techniques in reliability modeling is a relatively recent development. The Weibull distribution has been widely used in reliability analysis due to its flexibility in modeling the distribution of failure times. Researchers have successfully integrated the Weibull distribution into various reliability models, enhancing their accuracy in predicting failure and repair times. There is a single server who visits the system immediately whenever needed to carry out preventive maintenance and repair. The unit works as good as new after preventive maintenance and repair. The unit works as good as new after preventive maintenance and repair. The failure and maximum operation times of the unit are distributed exponentially while the distributions of PM and repair times are taken as arbitrary. All random variables are assumed as independent and un-correlated.

2 Description and Assumptions of the System

In this study, the stochastic reliability of the system is analyzed by using weibull distribution for various reliability measures like mean time to Between failure(MTBF). The steady state Availability, when demand is more then production. The steady state Availability, when production is more then demand.busy period of the server due to repair.Busy period of the server due to PM.and Expected down time.

1. The unit work as new after Preventive maintenance.
2. Single server is provided for PM and repair both.
3. Both the failure and repair rate follow weibull distribution.
4. Rubber roller during preventive maintenance it is an down state.
5. Rubber roller in operative mode when demand is more then or equal to Production.
6. Rubber roller in operative mode when production is more then demand.

Notations

P_{ij} : Transition probabilities from S_i to S_j

$Q_{i,j}(t)$: Cumulative distribution function of transition time from S_i to S_j

$B_{0R}(t)$: Busy period of the server due to repair

$B_{0PM}(t)$: Busy period of the server due to Preventive maintenance

A_{0D} : Steady state availability when demand is More then Production of the system

A_{0P} : Steady state availability when production is More then demand of the system

DT_0 : Expected Down time

$\phi_i(t)$: Cdf of time to system failure when starting from state $B_0 = S_I \in$ B

$\mu_i(t)$: Mean Sojourn time in the state $B_0 = S_i \in B$,

$\eta > 0$: Common Shape Parameter.

PDF/ CDF : Probability density function/ cumulative density function

**/* :Laplace stieltjes transform (LST)/Laplace transform

$ / $\odot$: symbol for Laplace-Stieltjes transforms/ Symbol for Laplace-convolution

R_{PM} :Rubber roller in preventive maintenance

$OR_{d\geq p}$:Rubber roller in operative mode when demand is more then or equal to production.

$OR_{p>d}$: Rubber roller in operative mode when production is more then Demand.

R_D : Rubber roller in down state.

RF_r :Failed Rubber roller under repair.

λ / h / α / β / γ / δ / θ /χ / m / K / l : Scale parameter

Rates for the subsystem

gives the rates of transition from S_i to S_j 0 denotes for no transition to the mentioned state.

$s_i s_j$	S_0	S_1	S_2	S_3	S_4	S_5
S_0	0	$f_1(t)$	$f_2(t)$	0	0	0
S_1	$g_1(t)$	0	$f_3(t)$	$f_5(t)$	0	0
S_2	$g_2(t)$	0	0	0	0	0
S_3	$g_3(t)$	0	0	0	0	$f_4(t)$
S_4	$g_5(t)$	$f_6(t)$	0	0	0	0
S_5	$g_4(t)$	0	0	0	0	0

Upstate: $S_0 = (OR_{d\geq p})$; $S_1 = (OR_{p>d})$; **Down state** :$S_3 = (R_D)$;

Failed State : $S_2 = (RF_r)$; $S_4 = (RF_r)$; **Shut-down :** $S_5 = (R_{PM})$

3 Set of Notations

$f_1(t) = \lambda = \lambda\eta t^{\eta-1}e^{-\lambda t^{\eta}}$; $f_2(t) = \gamma = \gamma\eta t^{\eta-1}e^{-\gamma t^{\eta}}$

$f_3(t) = \beta = \beta\eta t^{\eta-1}e^{-\beta t^{\eta}}$; $f_4(t) = h\eta t^{\eta-1}e^{-ht^{\eta}}$

$f_5(t) = \alpha\eta t^{\eta-1}e^{-\alpha t^{\eta}}$; $f_6(t) = \text{m } \eta t^{\eta-1}e^{-mt^{\eta}}$

$g_1(t) = \text{k } \eta t^{\eta-1}e^{-kt^{\eta}}$; $g_2(t) = \text{l } \eta t^{\eta-1}e^{-lt^{\eta}}$

$g_3(t) = \chi = \chi\eta t^{\eta-1}e^{-\chi t^{\eta}}$; $g_4(t) = \theta\eta t^{\eta-1}e^{-\theta t^{\eta}}$

$g_5(t) = \delta\eta t^{\eta-1}e^{-\delta t^{\eta}}$

4 Mathematical Analysis of the System

4.1 Transition Probabilities

Simple probabilistic considerations yield the following non-zero transition probabilities:

$$dQ_{01}(t) = f_1(t).\overline{F_2(t)}.dt = \lambda\eta t^{\eta-1}e^{-\lambda t^{\eta}}.e^{-\gamma t^{\eta}}.dt \quad (1)$$

$$dQ_{02}(t) = f_2(t).\overline{F_1(t)}.dt = \gamma\eta t^{\eta-1}e^{-\gamma t^{\eta}}.e^{-\lambda t^{\eta}}.dt \quad (2)$$

$$dQ_{13}(t) = f_3(t).\overline{G_1(t).F_5(t)}.dt = \beta\eta t^{\eta-1}e^{-\beta t^{\eta}}.e^{-\alpha t^{\eta}}.e^{-kt^{\eta}}.dt \quad (3)$$

$$dQ_{14}(t) = f_5(t).\overline{G_1(t).F_3(t)}.dt = \alpha\eta t^{\eta-1}e^{-\alpha t^{\eta}}.e^{-\beta t^{\eta}}.e^{-kt^{\eta}}.dt \quad (4)$$

$$dQ_{10}(t) = g_1(t).\overline{F_3(t).F_5(t)}.dt = k\eta t^{\eta-1}e^{-kt^{\eta}}.e^{-\alpha t^{\eta}}.e^{-\beta t^{\eta}}.dt \quad (5)$$

$$dQ_{35}(t) = f_4(t).\overline{G_3(t)}.dt = h\eta t^{\eta-1}e^{-ht^{\eta}}.e^{-\chi t^{\eta}}.dt \quad (6)$$

$$dQ_{30}(t) = g_3(t).\overline{F_4(t)}.dt = \chi\eta t^{\eta-1}e^{-\chi t^{\eta}}.e^{-ht^{\eta}}.dt \quad (7)$$

$$dQ_{41}(t) = f_6(t).\overline{G_5(t)}.dt = m\eta t^{\eta-1}e^{-mt^{\eta}}.e^{-\delta t^{\eta}}.dt \quad (8)$$

$$dQ_{40}(t) = g_5(t).\overline{F_6(t)}.dt = \delta\eta t^{\eta-1}e^{-\delta t^{\eta}}.e^{-mt^{\eta}}.dt \quad (9)$$

$$dQ_{20}(t) = g_2(t).dt = l\eta t^{\eta-1}e^{-lt^{\eta}}.dt \quad (10)$$

$$dQ_{50}(t) = g_4(t).dt = \theta\eta t^{\eta-1}e^{-\theta t^{\eta}}.dt \quad (11)$$

Further the non-zero P_{ij}'s can be evaluated as follows:

$$P_{ij} = \int_0^\infty dQ_{ij}$$

$$P_{01} = \frac{\lambda}{\lambda+\gamma}; \quad P_{02} = \frac{\gamma}{\lambda+\gamma}; \quad P_{13} = \frac{\beta}{\alpha+\beta+k}; \quad (12)$$

$$P_{14} = \frac{\alpha}{\alpha+\beta+k}; \quad P_{10} = \frac{k}{\alpha+\beta+k}; \quad P_{35} = \frac{h}{h+\chi}; \quad (13)$$

$$P_{30} = \frac{\chi}{h+\chi}; \quad P_{41} = \frac{m}{\delta+m}; \quad P_{40} = \frac{\delta}{\delta+m}; \quad (14)$$

$$P_{50} = 1; \quad P_{20} = 1; \quad (15)$$

By this transition probabilities, it can be verified that:

$$P_{01} + P_{02} = 1; \qquad P_{13} + P_{14} + P_{10} = 1;$$

$$P_{35} + P_{30} = 1; \qquad P_{41} + P_{40} = 1; \qquad P_{50} = P_{20} = 1;$$

4.2 Mean Sojourn Times

The main sojourn times (μ_i) in the generative state "i" is defined as the time of stay in that state before transition to any other state. If T denotes the sojoun time in the regenerative state 'i', then :

$$(\mu_i) = E(T) = P(T > t);$$

$$\mu_0 = \int_0^\infty \overline{F_1(t).F_2(t)} = \int_0^\infty e^{-(\lambda+\gamma)t^{\eta}}.dt = \frac{\Gamma(\frac{1}{\eta}+1)}{(\lambda+\gamma)^{\frac{1}{\eta}}}$$

$$\mu_1 = \int_0^\infty \overline{F_3(t).F_5(t)G_1(t)}dt = \frac{\Gamma(\frac{1}{\eta}+1)}{(\alpha+\beta+k)^{\frac{1}{\eta}}}$$

$$\mu_2 = \int_0^\infty \overline{G_2(t)}dt = \frac{\Gamma(\frac{1}{\eta}+1)}{l^{\frac{1}{\eta}}}$$

$$\mu_3 = \int_0^\infty \overline{F_4(t).G_3(t)}dt = \frac{\Gamma(\frac{1}{\eta}+1)}{(h+\chi)^{\frac{1}{\eta}}}$$

$$\mu_4 = \int_0^\infty \overline{F_6(t).G_5(t)}dt = \frac{\Gamma(\frac{1}{\eta}+1)}{(m+\delta)^{\frac{1}{\eta}}}$$

$$\mu_5 = \int_0^\infty \overline{G_4(t)}dt = \frac{\Gamma(\frac{1}{\eta}+1)}{\theta^{\frac{1}{\eta}}}$$

The unconditional mean time

$$m_{ij} = \int_0^\infty t.dQ_{ij}$$

Taken by the system to transit for any state j when it has taken from epoch of entrance into regenerative state is mathematically stated as

$$m_{01} + m_{02} = \mu_0; \qquad m_{13} + m_{14} + m_{10} = \mu_1;$$

$$m_{35} + m_{30} = \mu_3; \qquad m_{41} + m_{40} = \mu_4; \qquad m_{50} = \mu_5; \qquad m_{20} = \mu_2;$$

4.3 Main Time to Between Failure

$\phi_i(t)$ is defined as the CDF of first passage time from i^{th} state to a failed state we have the following recursive relations for $\phi_i(t)$

$$\phi_0(t) = Q_{01}(t) \ \$ \ \phi_1(t) + Q_{02}(t). \tag{16}$$

$$\phi_1(t) = Q_{10}(t) \ \$ \ \phi_0(t) + Q_{14}(t) + Q_{13}(t) \ \$ \ \phi_3(t). \tag{17}$$

$$\phi_3(t) = Q_{30}(t) \ \$ \ \phi_0(t) + Q_{35}(t) \tag{18}$$

Taking Laplace-Stieltjes Transforms (L.S.T.) on both side and solving we get ,The MTBF when the system starts from the state S_0 is given by

$$MTSF = \lim_{s \to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{D\prime(0)-N\prime(0)}{D(0)} = \frac{N}{D}$$

Where,

$$N = \mu_0 + \mu_1 P_{01} + \mu_3 P_{13} P_{01}$$

And

$$D = 1 - P_{01}P_{10} - P_{01}P_{13}P_{30}$$

4.4 Availability When Demand is More then Production

$M_i(t)$is the probability that the system up initially in state $S_i \in E$ is up upto time t without visiting to any other regenerative state, we have is

$$M_0(t) = e^{-(\lambda+\gamma)t}$$

Recursive relation giving point wise availability $A_i(t)$ given as follows:

$$A_{0D}(t) = M_0(t) + Q_{01}(t) \odot A_{1D}(t) + Q_{02}(t) \odot A_{2D}(t). \tag{19}$$

$$A_{1D}(t) = Q_{10}(t) \odot A_{0D}(t) + Q_{13}(t) \odot A_{3D}(t) + Q_{14} \odot A_{4D}(t). \tag{20}$$

$$A_{2D}(t) = Q_{20}(t) \odot A_{0D}(t). \tag{21}$$

$$A_{3D}(t) = Q_{30}(t) \odot A_{0D}(t) + Q_{35}(t) \odot A_{5D}(t). \tag{22}$$

$$A_{4D}(t) = Q_{40}(t) \odot A_{0D}(t) + Q_{41}(t) \odot A_{1D}(t). \tag{23}$$

$$A_{5D}(t) = Q_{50}(t) \odot A_{0D}(t). \tag{24}$$

Taking Laplace-Stieltjes Transforms (L.S.T.) of above equation and solving the steady - state availability is given by

$$A_{0D} = \lim_{s \to 0} (s. A_{0D}^*(s)) = \frac{N_1}{D_1}$$

$$A_{0D} = \frac{\mu_0(1-P_{14}P_{41})}{\mu_0(1-P_{14}P_{41}) + \mu_1 P_{01} + \mu_2 P_{02}(1-P_{14}P_{41}) + \mu_3 P_{01} P_{13} + \mu_4 P_{01} P_{14} + \mu_5 P_{01} P_{13} P_{35}}$$

4.5 Availability When Production is More Then Demand

Proceedings the similar fashion as in the steady availability of the system is given by

$$A_{0P} = \lim_{s \to 0} (s \,. A_{0P}^*(s)) = \frac{N_2}{D_1}$$

$$A_{0P} = \frac{\mu_1 P_{01}}{\mu_0(1-P_{14}P_{41})+\mu_1 P_{01}+\mu_2 P_{02}(1-P_{14}P_{41})+\mu_3 P_{01}P_{13}+\mu_4 P_{01}P_{14}+\mu_5 P_{01}P_{13}P_{35}}$$

4.6 Busy period of the Server Due to Repair

Proceedings the similar fashion as in the steady state busy period of server due to repair of the system is given by

$$B_{0R} = \lim_{s \to 0} (s \, . B_{0R}^{*}(s)) = \frac{N_3}{D_1}$$

$$B_{0R} = \frac{\mu_4 P_{01} P_{14} + \mu_2 P_{02}(1-P_{14}P41)}{\mu_0(1-P_{14}P_{41})+\mu_1 P_{01}+\mu_2 P_{02}(1-P_{14}P_{41})+\mu_3 P_{01}P_{13}+\mu_4 P_{01}P_{14}+\mu_5 P_{01}P_{13}P_{35}}$$

4.7 Busy Period of the Server Due to PM

Proceedings the similar fashion as in the steady state busy period of server due to preventive maintenances of the system is given by

$$B_{0PM} = \lim_{s \to 0} (s \, . B_{0PM}^{*}(s)) = \frac{N_4}{D_1}$$

$$B_{0PM} = \frac{\mu_5 P_{01} P_{13} P_{35}}{\mu_0(1-P_{14}P_{41})+\mu_1 P_{01}+\mu_2 P_{02}(1-P_{14}P_{41})+\mu_3 P_{01}P_{13}+\mu_4 P_{01}P_{14}+\mu_5 P_{01}P_{13}P_{35}}$$

4.8 Expected Down Time

The total function of the time for which the system is down state is given by.

$$DT_0 = \lim_{s \to 0} (s. \; DT_0^{*}(s)) = \frac{N_5}{D_1}$$

$$DT_0 = \frac{\mu_3 P_{01} P_{13}}{\mu_0(1-P_{14}P_{41})+\mu_1 P_{01}+\mu_2 P_{02}(1-P_{14}P_{41})+\mu_3 P_{01}P_{13}+\mu_4 P_{01}P_{14}+\mu_5 P_{01}P_{13}P_{35}}$$

4.9 Profit Analysis

The expected profit P per unit time incurred to the system is given by

$$P = C_0 A_{0D} - C_1 A_{0P} - C_2 B_{0R} - C_3 B_{0PM} - C_4 DT_0$$

Where

C_0 = Revenue per unit up time when demand is more then production.
C_1 = Revenue per unit up time when demand is less then production.
C_2 = Cost per unit up time for server for repair of failed unit.
C_3 = Cost per unit up time for server for repair of preventive maintenances.
C_4 = Loss per unit time during the system remains down.

Case studies with discussions :

(I) When shape parameter $\eta = 0.5$ then failure of the unit due to abrupt, wear-out, and intermittent failures, adaptive maintenance, repair by regular repairman time distribution reduces to:-

$f_1(t) = \frac{\lambda}{2\sqrt{t}} e^{-\lambda\sqrt{t}}$; $f_2(t) = \frac{\gamma}{2\sqrt{t}} e^{-\gamma\sqrt{t}}$; $f_3(t) = \frac{\beta}{2\sqrt{t}} e^{-\beta\sqrt{t}}$; $f_4(t) = \frac{h}{2\sqrt{t}} e^{-h\sqrt{t}}$;
$f_5(t) = \frac{\alpha}{2\sqrt{t}} e^{-\alpha\sqrt{t}}$; $f_6(t) = \frac{m}{2\sqrt{t}} e^{-m\sqrt{t}}$; $g_1(t) = \frac{k}{2\sqrt{t}} e^{-k\sqrt{t}}$; $g_2(t) = \frac{l}{2\sqrt{t}} e^{-l\sqrt{t}}$
$g_3(t) = \frac{\chi}{2\sqrt{t}} e^{-\chi\sqrt{t}}$; $g_4(t) = \frac{\theta}{2\sqrt{t}} e^{-\theta\sqrt{t}}$; $g_5(t) = \frac{\delta}{2\sqrt{t}} e^{-\delta\sqrt{t}}$

(II)When shape parameter $\eta = 1.0$ then repair/ failure of the unit, adaptive maintenance, time distribution reduces to exponential then:-

$f_1(t) = \lambda e^{-\lambda t}$; $f_2(t) = \gamma \; e^{-\gamma t}$; $f_3(t) = \beta e^{-\beta t}$; $f_4(t) = h e^{-ht}$;

$f_5(t) = \alpha e^{-\alpha t}$; $f_6(t) = m e^{-mt}$; $g_1(t) = k e^{-kt}$; $g_2(t) = l e^{-lt}$;

$g_3(t) = \chi e^{-\chi t}$; $g_4(t) = \theta e^{-\theta t}$; $g_5(t) = \delta e^{-\delta t}$

(III)When shape parameter $\eta = 2.0$ then failure /arrival time of the server/repair time distributions reduces to rayleigh having the pdf:-

$$f_1(t) = 2\lambda e^{-\lambda t^2}; \quad f_2(t) = 2\gamma\ e^{-\gamma t^2}; \quad f_3(t) = 2\beta e^{-\beta t^2}; \quad f_4(t) = 2he^{-ht^2};$$
$$f_5(t) = 2\alpha e^{-\alpha t^2}; \quad f_6(t) = 2me^{-mt^2}; \quad g_1(t) = 2ke^{-kt^2}; \quad g_2(t) = 2le^{-lt^2};$$
$$g_3(t) = 2\chi e^{-\chi t^2}; \quad g_4(t) = 2\theta e^{-\theta t^2}; \quad g_5(t) = 2\delta e^{-\delta t^2}$$

5 Graphical Analysis:

To see the behaviour of different parameter on the system, we take shape parameter η = 0.5, 1, 2 from Figure 1 we abserve that MTBF decreases as the failure γ increases from 0.4 to 0.8

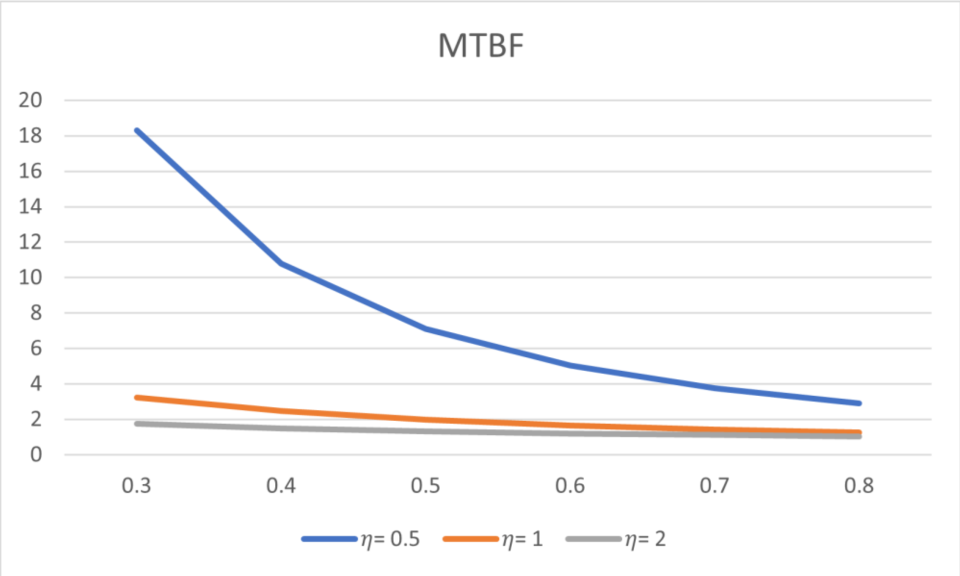

Figure 1: MTBF

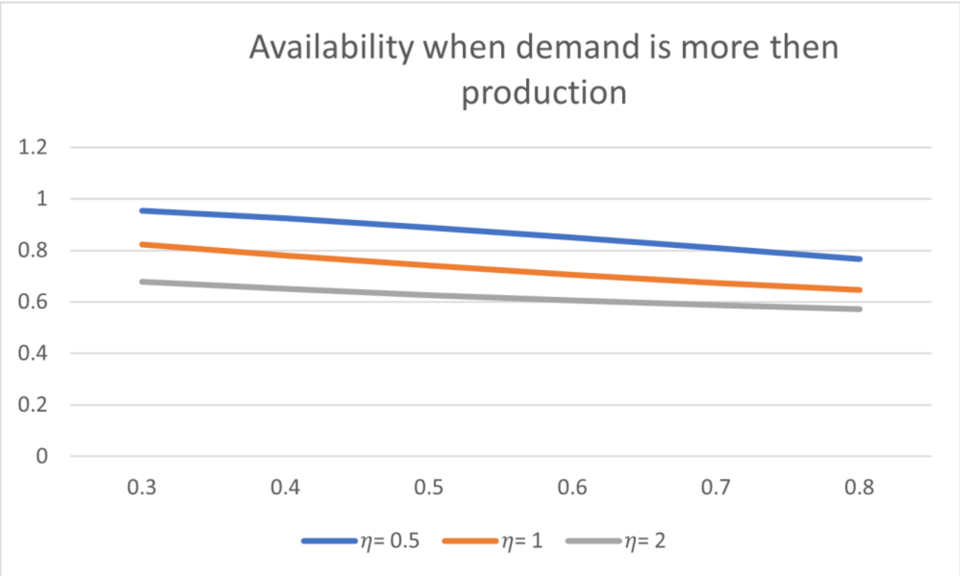

Figure 2: Availability when demand is more then production

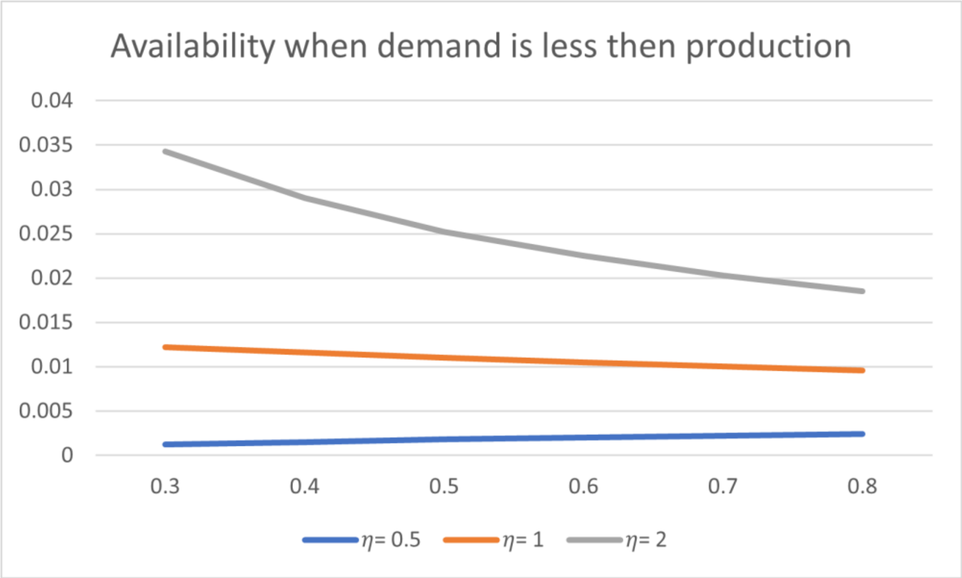

Figure 3: Availability when demand is less then production

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