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EFFECTS OF INDEPENDENT VARIABLES IN UNRELIABLE SINGLE-PRODUCT HEAVY MANUFACTURING CELL.

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Abstract- *The mass of industrial capital consists of systems that produce goods and delivery services. Because these systems are prone to failure depending on usage and age, interest in developing effective service strategies has grown exponentially. This paper consists of identifying, as well as the effect of two independent variables on both service policies and production/inventory management policies for a promising heavy-duty cell prone to single-product failures perspective Bangladesh. The age-oriented preventative maintenance (ARP) policy is superior to the classic block replacement policy (BRP). To reduce the loss incurred by the classic BRP, we consider a modified block replacement policy (MBRP) with control variables, such as independent variables, that occur significantly while the action of the PM occurs on the classic BRP. The purpose of this article is to determine the main effects and effects of the interaction of the control variable on production, since according to industrial historical data they are reliable, that is, significant (<0.05) in the case of MBRP, which will help to get a true idea, consisting of corrective and preventive maintenance costs as well as storage and inventory costs. We have worked to better understand its dynamic model to match the behavior of control variables on unreliable, fail-safe production of heavy production units, as well as the superiority and stochastic behavior of the production cell. Based on the simulation results of the statistical software SPSS 23, the MBRP under Hedging Point policy (HPP) parameters are obtained on the basis of the collected production data using a numerical approach that combines the design of the experiment and analysis of variance, so that we get a true idea of production as well as the stock by independent analysis variable main effects and interaction effects in preventive maintenance strategies.*

Keywords: Independent variable, Corrective maintenance, Preventive maintenance, Servicing time, Hedging point policy (HPP), Inventory control policy.

1. INTRODUCTION

The mass of industrial capital is made up of systems that produce goods and delivery services. As these systems often fail in terms of usage and age, interest in developing efficient maintenance strategies has grown exponentially. Moya et al. [1] proposed the control of setting up a system by an indicator. The increase in competition, globalization of businesses, moves towards total quality management, constant techno-logical changes, the supremacy of security and the implication of industry in environmental questions are some of the factors which have brought about great changes in the structure of companies. These modifications have been carried over to the production area, as this is the one most directly involved in the efficiency and sustainability of the industrial processes. This concern has been transferred to maintenance, traditionally considered a source of costs, and now associated with more strategic issues, from an approximation based on the concept of sustainability, thereby pursuing the strategic consensus. The implications in production and maintenance suggest the need to change the focus of maintenance policies, traditionally centered on short term issues (use of resources, costs, etc.) towards the consideration of longer-term goals (competitively, sustainability and strategy).

Multiple models have been developed for the optimization of maintenance. A system whereby the decision-making center can choose between multiple maintenance options, such as minimal repair of faulty components, replacement of faulty components and preventive maintenance. Murthy et al. suggest a model to obtain optimum decision making in a maintenance service operation. He describes the factors which contribute to the setting up of total productive maintenance programs (TPM), determining which contribute most to the development of maintenance systems. He also describes the timing of programmed replacement of components or consumables, and Sheu's et al. [2] objective is generalized age and block replacement of a system subject to shocks. Triantaphyllou et al. [3] develop model for determining the most important criteria in maintenance decision. Block replacement PM policy (BRP), under which units are replaced at failure or at fixed intervals kT (k = 1, 2, 3 etc.), irrespective of the unit age. Mathematical theory of reliability is proposed by Barlow and Proschan et al. [4], and mainly provide that the ARP is economically superior to the BRP. Although the BRP is more wasteful (i.e., almost new components are replaced when failures occur shortly before planned PM), it seems more practical to implement and to manage than the ARP since it does not require tracking unit ages and does not modify the PM planning after each maintenance operation.

Several approaches have been proposed in order to improve the performance of the classical BRP: (1) Barlow and Hunter proposed the concept of minimal repair at failure (i.e., a minimally repaired system is restored to its "condition just prior to failure"); (2) Cox et al. [5] and Blaming et al. [6] proposed renewable theory and also replacement strategies. The concept of inactivity (i.e., if the unit fails not long before the planned PM, it is maintained in a down state until the next PM) A key assumption of both the basic EOQ and EPQ models is that stock outs are not permitted. Assuming that the lead time and demand are known and constant, this means that an order will be placed when the inventory available is exactly sufficient to cover the demand during that lead time. Under conditions of demand certainty, however, it is possible to prove that, assuming customers are always willing, although not necessarily happy, to wait for delivery, planned backorders can make economic sense, even if they incur some actual or implied cost. Relaxing the basic EOQ and EPQ models' assumption that stock outs are not permitted led to the development of both EOQ and EPQ models for the two; (3) Bhat et al. [7], Tango et al. [8] and Murthy and Nguyen et al. [9] proposed extended block replacement policy with used items. By using used items (i.e., if the equipment fails not long before the PM, then the unit is replaced with a used item).

The main objectives of this paper is to identify major control variables in a mono-product failure-prone manufacturing system and to analyze the effects of the control variables in a mono-product failure-prone heavy manufacturing system. The rest of the report is organized as follows: Chapter-2 Description of mono-product failure-prone manufacturing system literature review. Chapter-3 presents Methodology of MBRP/HPP. The analytical approach based on collected data describe the design of experiments; analysis of variance to be significant is presented in Chapter-4. presents the Design of Experiments**.** Chapter-5. presents the analyzing procedure of SPSS Statistics. independent variables in SPSS statistics and performance analysis on MBRP and specifically describes behavior of the and the co-relation of production with above independent variables inventory control parameter initial preventive time T_{MB1}, stock capacity (S) & servicing time (S_T) which are mainly based on main effects and interaction effects to verify the model policy is significant for 1% chart and 5% chart at 0.05 level. Finally, Chapter-6 presents the conclusions, Chapter-7 presents the acknowledgement Chapter-8 presents the References, chapter-9 presents the nomenclature.

2. DESCRIPTION OF MONO-PRODUCT FAILURE-PRONE MANUFACTURING SYSTEM

2.1 Variable Selection

From our better understanding, we know that dependent variable should measure at the continuous level i.e., it is an interval or ratio variable.

The independent variables should each consist of two or more categorical, independent (unrelated) groups. Now those independent variables which effects the reduction of machinability. In previous work [10] the authors considered consist random probability of production time. He also selected buffer stock capacity etc. was selected for independent variables for dependent variables. For the Bangladesh perspective, the author like to select new independent variable which is random servicing time with other independent variables (random probability of production time, buffer stock capacity), etc

2.2 System Description

The production system considered in this study is a production cell comprising a machine to manufacture a single product. The production cell can produce a maximum capacity of u_{max} to satisfy a constant finished good rate of the request, with $u_{max} > d$. The cell is subject to a failure, characterized by the random T_f variables with a general probability distribution. The production machine is repaired to fail at a random time T_{cm} and preventively maintained for a random period of time T_{pm} where T_{cm} and T_{pm} are random variables with general probability distributions. From a practical point of view, the probability density function of stochastic events may be obtained from historical failure data and maintenance. A default or expected dividend PM, manufacturing cell is removed until the end of the maintenance activity. Therefore, the demand for finished products is satisfied by the security stocks and all unanswered requests are backlogged. After the resumption of the production, manufacturing cell is able to meet demand backlogged without interrupting the normal process. As shown in Figure 2, the goal is to file the rate of production and preventive maintenance strategy that minimizes average total cost of maintenance and inventory per unit time.

2.3 Model Assumptions

The model under consideration includes the following commonly admitted assumptions.

1. Precise servicing as far as possible is considered.
2. Failures are instantaneously detected.
3. The failure rate increases in time, and consequently, the likelihood of machine breakdown is reduced by PM.
4. All necessary resources are limited available when needed.

5. PM and CM actions restore the manufacturing cell and also as good as for new operational state. And
6. Proper trained supervision (through supervisor) with respect to time before planned PM.

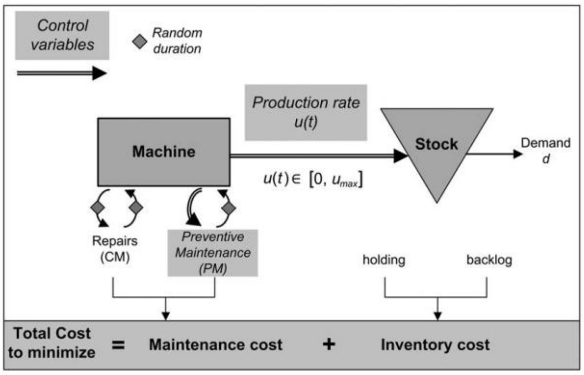


Fig. 2 Consideration of mono-product failure-prone heavy manufacturing system [1].

2.4 Theory overview

Joint consideration of production planning and corrective maintenance problems in manufacturing systems has been tackled using the optimal control theory. To control the flow rates of parts through a system subject to random failures and repairs, Kimemia and Gerschwin et al. [11] and Akella and Kumar [12] introduced an algorithm for the computer control of production in flexible manufacturing systems. The HPP entails the build-up and preservation of a final product safety stock while the machine is operational in order to hedge against future shortages caused by machine failures. The optimality of the HPP has been demonstrated for failure and repair times described by homogeneous Markov processes, and therefore, for a failure replacement maintenance strategy, in the case of constant demand rate and stochastic demand rate is presented as below:

$$u(t) = \begin{cases} umax & \text{if } x(t)<S \\ d & \text{if } x(t)=S \\ 0 & \text{under maintenance action} \end{cases}$$

where S is the capacity of the buffer stock, also called point in the optimal control sphere, x (t) the hedge is the stock level at a specified time t, and u (t) is the cell production rate of making a specified level of stock x (t). This policy results in the accumulation buffer stock with excess capacity ($u = u_{max}$), which must then be held at its maximum level S (u = d) to compensate for disruptions due to failures PM or actions (u = 0). Kimemia and Gerschwin et al. [11] and Akella and Kumar et al. [12] represents the optimal control of production rate in a failure prone manufacturing system.

3 METHODOLOGY

3.1 Methodology of ARP/HPP and BRP/HPP

We know, a cost comparison of the ARP/HPP and BRP/HPP has never been tackled in the literature. Indeed, computations of the exact maintenance and inventory total cost during a maintenance cycle with the ARP or the BRP differ, and they are hard to obtain without simplifying assumptions. In fact, all proposed analytical approaches are limited to the analysis of only one maintenance cycle based on the renewal theory, and the main simplifying assumptions used are just between (1) no- breakdowns are always during the build-up of the finished goods inventory and (2) unmet demand during maintenance interventions is lost, such that the inventory periodically reaches the same level (i.e., the buffer level) after Corrective maintenance or preventive maintenance [13, 14, 15]

3.2 Methodology of MBRP/HPP

According to the effective dynamic and stochastic behavior of the manufacturing cell, we propose to relax these restrictive assumptions. Figures. 3.1–3.3 illustrate some possible scenarios of the manufacturing cell real dynamics according to the inventory level evolution under the ARP/HPP, the BRP/HPP, and the MBRP/HPP, respectively. Figure 3.1 highlights that the maintenance cycle begins when production resumes after a maintenance action (CM or PM), and lasts until the next failure (if $T_f < T_A$), or until the next PM, if the machine does not fail before the age threshold ($T_f > T_A$). During maintenance periods, the inventory level decreases with a rate equal to (-d) and possibly drops below 0 (in case of shortage), which results in penalty costs. Once operational, the inventory level increases at rate (u_{max}-d). If the manufacturing cell machine does not fail or if its age is below TA during the build- up phase of the safety stock, then the inventory level can reach the hedging point S, and is maintained until the occurrence of the next maintenance event (CM or PM). Note that failures or PM actions may occur during the build-up phases, and that the evolution of the inventory level is not periodic as is the case in the majority of the proposed analytical model.

Figure 3.2 and Figure 3.4 show the evolution of the dynamics of the inventory level under the joint BRP/HPP and MBRP/HPP policies during several maintenance cycles [kT, (k +1)T], where T denotes T_B and T_{MB1} for the BRP/HPP and the MBRP/HPP, respectively. The following scenarios can be observed during the production/ maintenance process:

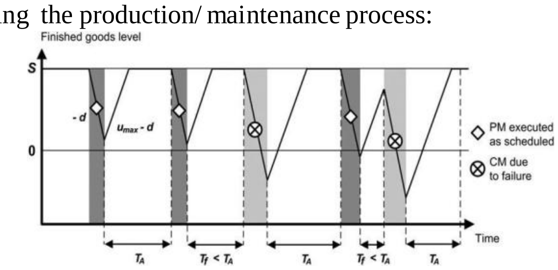


Fig. 3.1 Evolution of the dynamics of the system under the ARP/HPP [1]

1. Interval [T, 2T]: The maintenance cycle begins with a PM activity during which the inventory level decreases at a rate equal to (-d). At the end of the PM operation, once the system becomes operational, and the inventory level increases at rate (u_{max} -d) and is

then maintained at level S.

2. Interval [2T, 3T]: If no failure occurs, the manufacturing cell process is shut down and a PM activity is performed at the beginning of the maintenance cycle. A failure then occurs and triggers a corrective intervention, which is completed before the end of the cycle. Production resumes shortly before the next PM action scheduled at instant 3T. The repaired machine then survives until the next scheduled PM action.
3. Interval [3T, 4T] : Under the BRP/HPP (Figure 3.2), a PM action is performed as scheduled, which triggers a fall in the inventory level to a negative value and the replacement of a relatively new component. The manufacturing cell becomes operational and does not fail until the next PM scheduled at instant 4T, allowing the inventory level to increase and to reach level S.

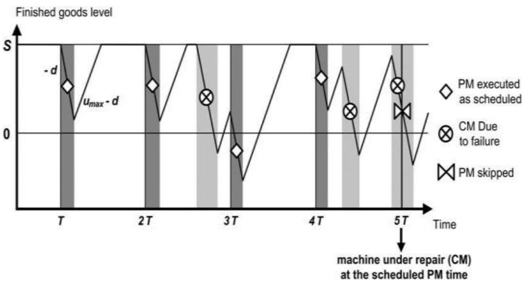


Fig. 3.2 Evolution of the dynamics of the system under the BRP/HPP [1]

Under the MBRP/HPP (Figure 3.3), the PM activity is simply skipped and the inventory level rises faster, up to its maximum level S, since a repaired machine has resumed production during interval [3T-T_{MB2}, 3T] and survived until 3T. It can be noted that the MBRP/HPP is less wasteful than the BRP/HPP; in fact the MBRP/HPP will generate fewer PM actions, and thus fewer new operational equipment's that will be removed and rejected, and consequently, less inventory shortages.

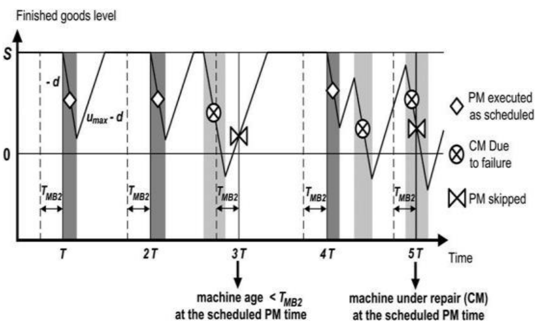


Fig. 3.3 Evolution of the dynamics of the system under the MRP/HPP [1]

4. Interval [4T, 5T]:

Both the BRP/HPP and MBRP/HPP have the same dynamic behavior, since no repaired machine resumes production during interval [5T-T_{MB2}, 5T]. Several breakdowns occur in fairly quick succession during [4T, 5T], such that the threshold level is never reached. The last failure occurs before instant 5T and repairs end after the scheduled PM activity. In this case, the scheduled PM activity is skipped for both the BRP/HPP and the MBRP/HPP.

The maintenance cycles with both the BRP/HPP and the MBRP/HPP begin with a PM intervention (if not skipped), and have a constant duration T_B and T_{MB1}, respectively, during which the system can fail several times. Once again, the inventory level is not periodic unless restrictive assumptions are used.

Where we have non-negligible PM and CM durations, and when combined with an inventory control policy, the BRP/HPP should lead to consecutive inactivity periods during which the inventory can be low and can result in finished goods shortage costs, as well as in the wastage of components.

A simulation model that combines discrete and continuous changes was developed for verifying the control variables only for MBRP as for analysis of variance is significant is done by using a statistical software SPSS 23.

4. DESIGN OF EXPERIMENTS

For each joint preventive maintenance and production/inventory control policy, two (for the ARP/HPP and BRP/HPP) or three (for the MBRP/HPP) independent variables and one dependent variable (the incurred cost) are considered. In this chapter we are going to verify the MBRP. We define a new variable S_T for servicing time, such that $T_{MB2} = S_T * T_{MB1}$ and $0 \leq S_T \leq 1$, to make sure that $T_{MB2} \leq T_{MB1}$. The design of experiments defines how the control factors can be varied to determine the effects of the main factors and their interactions on the incurred cost of production with a minimal set of simulation experiments.

Due to the convexity property of the cost function, complete for the MBRP/HPP policy a factorial analysis 2^2 is considered here by which designs of experiments are carried out. Four replications were conducted for each combination, and 16 (2^2*4) simulation runs were made for the MBRP/HPP. Detection & verification of the residual error is also obtained. Non- significant effects are ignored or added to the residual error. Mean value and standard error are obtained for main effects and interaction effects.

Using SPSS 15, the control variables T_{MB1}, S, S_T are verified about their effects on production from the collected production historical data from a failure-prone manufacturing unit of a company. The homogeneity of the variances and the residual normality condition are also verified.

4.1 Detailed Simulation Result

The resolution approach and the results are detailed in a step-by-step manner for the basic case presented in Table 4.1. The manufacturing system considered here is designed to produce at a maximum production rate 25% higher than the demand rate. The stochastic time variables that describe the time between failures and the CM and PM durations follow Iibull and Lognormal distributions, respectively (the first and second values within parentheses indicate the mean and the standard deviation for the lognormal distribution).

We are going to simulate total 16 runs so here we only simulate ANOVA by collection data such as: 23.00, 24.00, 25.00, 30.00, 46.00, 36.00, 35.00, 39.00 32.00, 29.00, 30.00, 30.00, 31.00, 36.00, 30.00, 32.00 which all of its units/day.

Now we are going to simulation run by SPSS 23 for analysis of variance with T_{MB1}, S_T with historical prod value which is given in Table 4.1.

Table 4.1 Observed/Historical data parameters of this experiment case

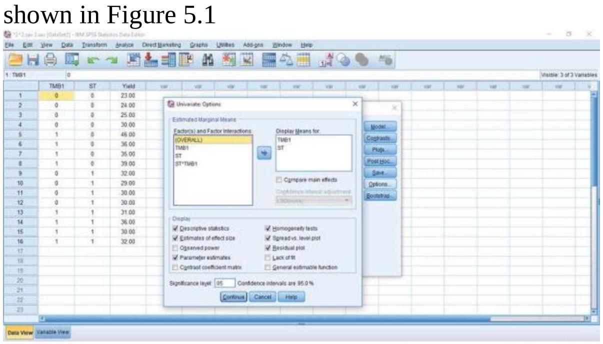
Normal Prod	T_{MB1}	S_T	$T_{MB1} * S_T$
23.00	46.00	32.00	31.00
24.00	36.00	29.00	36.00
25.00	35.00	30.00	30.00
30.00	39.00	30.00	32.00

4.2 Hypothesis assumptions:

We should go our hypothesis assumptions is: (1) T_{MB1} will have no significant effect on yield. (2) S_T will have no significant effect on yield. By ANOVA analysis, if there is no significant effect on yield i.e. significant value or p-value>0.05 then the hypothesis is accepted. When significant value or p-value<0.05 then the hypothesis is rejected i.e. our hypothesis is null which mean that our result is significant.

5 ANALYZING PROCEDURE OF SPSS STATISTICS

Fig. 5.1 Transformation of variables in window. Click the model button and there would be presented as shown in Figure 5.1



1.Click the Continue button we should be returned to the Univariate dialogue box.

2. Now click the OK button. This will generate the output.

3. It is important to say that, the simulation result except between-subjects factors, descriptive statistics, levene's test of equality of error variances, test between subject effects.

5.2 Test of between-subject's effects of independent variables:

The only column of the concern F column or F-ratio & the significance level is the p-value.

T_{MB1}

So, the 1st thing we discuss is the $T_{MB1.}$ So, the 1st factor is T_{MB1} and the p-value is 0.001 and of course has less than 0.05 which is the test probability less than 0.05 with 95% confidence level. So, we should be rejected null hypothesis for the 1st factor which is $T_{MB1.}$ There is a 0% chance of getting result random chance which is good shown in Table 5.2.

This p-value could be calculated from an analogue Table (5% & 1% significant Table).

S_T

The 2th factor of our examine is Servicing time $S_{T.}$ Its p-value is 0.465 which is not very good. It is greater than 0.005. So, in this case we would fail to reject the null hypothesis.

Table 5.2 Test of between-subject's effects

Tests of Between-Subjects Effects

Dependent Variable: Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	376.500a	3	125.500	11.720	.001	.746
Intercept	16129.000	1	16129.000	1506.210	.000	.992
TMB1	240.250	1	240.250	22.436	.000	.652
ST	4.000	1	4.000	.374	.552	.030
TMB1 * ST	132.250	1	132.250	12.350	.004	.507
Error	128.500	12	10.708			
Total	16634.000	16				
Corrected Total	505.000	15				

a. R Squared = .746 (Adjusted R Squared = .682)

T_{MB1} & S_T

The next factor we want to discuss the combination of two T_{MB1} & S_T. So, the interaction of T_{MB1} & S_T and the p-value of this interaction is 0.032. It is also less than 0.005. So, we would be rejected the null hypothesis for 3rd factor which is T_{MB1} & S_T. There is a 0% chance of getting result random chance which is good shown in Table 5.2

5.3 Descriptive statistics of independent variables

Table 4.1 indicates how much way last in each group the month on 4 repetition. The mean of estimate and descriptive statistics is not found in same. It is mainly due to that, in the descriptive statistics, the mean is found by dividing the summation. In the other hand, the mean of estimate is considered on the based upon the sample size.

Estimate marginal means (T_{MB1})

T_{MB1} at 0 is 27.8750 tons/day

And T_{MB1} at 1 is 35.6250 tons/day.

T_{MB1} is an independent variable which is random probability of distribution of production time. We need to analyze the main effect of this independent variable, where our dependent variable is prod/yield.

Profile plot is given in Figure 5.1. The graph presents the information of production on the estimated marginal means (tons/day) with respect to 2 repetition (rep) (per unit) in estimated marginal means of yield in case of T_{MB1} (0 & 1).

It is briefly indicating that while production is going on, in case of T_{MB1} at 0, the estimated marginal means is 27.8750 at repetition (rep) 1. The production sets also at repetition (rep) 2 while production steadily to reach approximately 35.6250 in case of in case of T_{MB1} at 1.

shown as in figure 5.1.

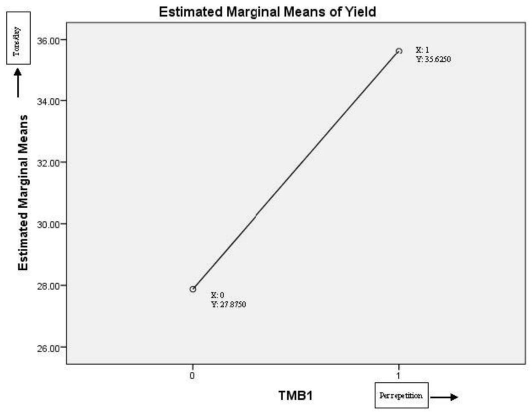


Fig. 5.1 Profile plot of T_{MB1} (in case of 0 & 1)

Estimate marginal means (S_T)

S_T at 0 is 31.2500 tons/day
And S_T at 1 is 32.2500 tons/day.

T_{MB1} is an independent variable which is random probability of distribution of production time. We need to analyze the main effect of this independent variable, where our dependent variable is prod/yield.

Profile plot is given in Figure 5.1. The graph presents the information of production on the estimated marginal means (tons/day) with respect to 2 repetition (rep) (per unit) in estimated marginal means of yield in case of T_{MB1} (0 & 1).

It is briefly indicating that while production is going on, in case of T_{MB1} at 0, the estimated marginal means is 31.2500 at repetition (rep) 1. The production sets also at repetition (rep) 2 while production steadily to reach approximately 32.2500 in case of in case of T_{MB1} at 1. shown as in figure 5.2.

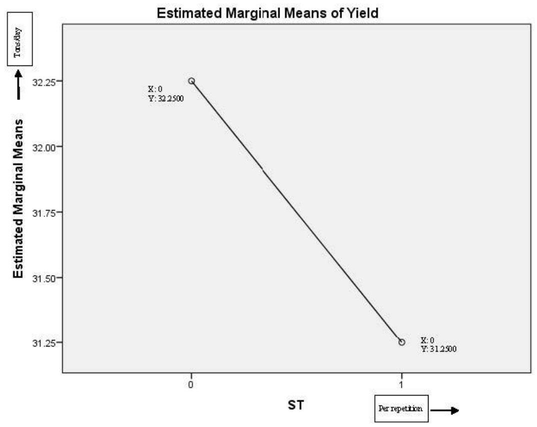


Fig. 5.2 Profile plot of S_T (in case of 0 & 1)

6. CONCLUSION

ANOVA analyses are carried out on the collected data, as presented in Table 4.1 for the MBRP/HPP is simulated by SPSS 23 version. Marginal mean of predicted value with collected data (production, tons/day) with respect to 2 no. repetition (per unit) with random duration is occurred at 0 & 1. Marginal mean of T_{MB1} at 0 is 27.8750 and T_{MB1} at 1 is 35.6250 is obtained. Similarly, marginal mean of S_T at 0 is 31.2500 and S_T at 1 is 32.2500 is also obtained. The marginal mean for these three independent variables is obtained in significant level, i.e. p-value>0.05

The model is satisfactory for 0.05% confidence level such as (1) Corrected Model, at $F(3,12) = 11.720$, Significant, p=.001 (from Table 5.2), (2) Intercept, at $F(1,12) = 1506.210$, Significant, p=.000 (from Table 5.2), (3) T_{MB1} at $F(1,12) = 20.532$, Significant, p=.001 (from Table 5.2), (4) T_{MB1} & S_T at $F(1,12)= 12.068$, Significant, p=.005 (from Table 5.2).

The model does not satisfy for 0.05% confidence level such as (1) S_T at $F(1,12) = 0.570$, non-Significant, p=0.465 (>0.05) (from Table 5.2).

These result means that our three independent variables with respect to production are not significant at all. The interaction effects T_{MB1} & S_T which are significant. So, random servicing time for modified block replacement policy (MBRP) is satisfactory i.e. significant for applying beneficial advantages. The R^2 adjusted value has a value of 66.8%, which implies that average good expected significant percent (%) which is 73.4% of the total variability is explained by the model. So, our three estimated independent variables are significant in term of Alpha level in term of 95% confidence level i.e. 0.05 level.

7. ACKOWLEDGEMENT

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9. NOMENCLATURE

Symbol	Meaning	Unit
T_{MB1}	Initial random amount of time with general distribution	(s)
S_T	Servicing time	(s)