Criticality Analysis and Quality Appraisal of Innoson Injection Mould System

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ABSTRACT

The current dynamic and turbulent manufacturing environment has forced companies that compete globally to change their traditional methods of conducting business. Recent developments in manufacturing and business operations have led to the adoption of preventive maintenance techniques that is based on systems and process that support global competitiveness. This paper employed Monte Carlo Normal distribution model which interacts with a developed Obudulu model to assess reliability and maintenance of Injection Moulding machine. The failure rate, reliability and standard deviations are reliability parameter used. Monte Carlo Normal distribution was used to analyse the reliability and failure rate of the entire system. The result shows that failure rate increases with running time accruing from wear due to poor lubrication systems; while system reliability decreases with increase time (years). Obudulu model was used to evaluate the variance ration of failure between system components under preventive maintenance and those outside preventive maintenance. The result shows that at reliability +0.3 and failure rate -0.02, preventive maintenance should be done. Interaction between the Monte Carlo normal distribution and obudulu model shows that the total system reliability is 0.489 when maintained which is 49% and 0.412 (41%) when not maintained. Also quality of production increased during Preventive maintenance while system downtime reduced greatly. These models were programmed using Monte Carlo Excel tool package software, showing the graphs of reliability and failure rates for each system.

Key words: *Reliability*, failure rates, Preventive maintenance, quality control and system downtime.

1. INTRODUCTION

Although the technological achievements of the last 50 years can hardly be disputed, there is one weakness in all mankind's devices. That is the possibility of failure. The introduction of every new device must be accompanied by provision for maintenance, repair parts, and protection against failure.

System reliability can be defined as the probability that a system will perform its intended function for a specified period of time under stated conditions (Ahmadi andSoderholm, 2008). It is important because a company's reputation, customer satisfaction and system design costs can be directly related to the failures experienced by the system (Ansell and Phillip, 1994). It is also challenging since current estimation techniques require a high level of background in system reliability analysis, and thus familiarity with the system.

Reliability represents safety level in industry practice and may variant due to time-variant operation condition and components deterioration throughout a product life-cycle (Billinton and Wang, 1999). Reliability remains a product quality indicator of paramount importance in competitive manufacturing operations. Offering novel ideas in enhancing product reliability levels is a subject of continuous research. Among the most popular approaches that aid in boosting reliability in manufactured products has been channelled through design of experiments (Blischke, Murthy, 2000).

We use the concepts and methods of probability theory to compute the reliability of a complex system. In addition, we provide bounds on the probability of success that are often much easier to compute than the exact reliability (Ansell and Phillips, 1994). This is to identify the most likely failures and then identify appropriate actions to mitigate the effects of those failures.

Injection molding is the most commonly used manufacturing process for the fabrication of plastic parts. A wide variety of products are manufactured using injection molding, which vary greatly in their size, complexity, and application. The injection molding process requires the use of an injection molding machine, raw plastic material, and a mold (Besseris, 2008).

Analysis of reliability of injection molding systems using Monte Carlo Simulation (MCS) method will provides very accurate values. Consequently, the method looks promising since its convergence speed is independent of mathematical problems dimension and estimation is statistical, it gives a true good confidence level including the solution with a given probability distribution models (Ihueze and Ebisike, 2016).

The objective of this study therefore is to evaluate reliability, model maintenance and analyse quality of products of Innoson Injection mould system.

2. LITERATURE REVIEW

Dialynas and Zafiropoulos (2005) studied failure modes, effects and criticality analysis (FMECA) of power electronic devices using fuzzy logic. Deeptesh and Amit (2015) represented the generic process of failure Mode Effect and Critical Analysis for centrifugal pump failures after implementation of optimum strategies of maintenance. Cheng et al (2013) analysed the reliability of Metro Door System Based on FMECA. Atikpakpa et al (2016) evaluated failure and reliability of turbines used in Nigerian thermal plant. Faria and Azevedo, (2013) evaluated the reliability of failure delayed industrial systems, they handled stochastic models containing multiple processes with generalized distributions.

Ćatić et al (2011) carried out criticality analysis of the elements of the light commercial vehicle steering tie-rod joint. Kang et al (2016) undertook engineering criticality analysis on an offshore structure using the first-and second-order reliability method. Chang and He (2016) Studied the failure mode, effect and Criticality Analysis. In Applied Electronics (AE). Marhaug et al (2016). Carried out criticality analysis for maintenance purposes of platform supply vessels in remote areas, their method considers functional redundancy and the consequences of loss of function as criticality criteria at the main and sub-function levels.

Shivakumar et al (2015) implemented FMEA in Injection Moulding Process. Pancholiand Bhatt (2016) conducted multicriteria FMECA based decision-making for aluminium wire process rolling mill through COPRAS-G.Gurwinder, S. G. and Atul G. (2016) carried out multi-state component criticality analysis for reliability improvement of process plant. Lu et al (2013) carried out failure mode effects and criticality analysis (FMECA) of circular tool magazine and ATC. Ibrahim and El-Nafaty(2016) assessed the reliability of fractionator column of the kaduna refinery using Failure Modes Effects and Criticality Analysis (FMECA). Beluet al (2013) implemented Failure Mode, Effects and Criticality Analysis in the production of automotive parts, this method provides improved quality and product reliability by identifying solutions and corrective actions to eliminate the failure mode or to damp the adverse effects.

Obviously, reliability is an important feature in the design and maintenance of a large-scale injection mould system, recent research has implemented various models of reliability for different process equipments, but little research has consideredvariance ration of failure between system components under preventive maintenance and those outside preventive maintenance. Studies that have examined reliability problems in industries have focused almost exclusively on comprehensive design for reliability measures. However the current study specifically considered quality appraisal of a indigenous company in Nigeria utilising the Monte Carlo Normal distribution to analyse the reliability and failure rate of the entire system.

3. METHODOLOGY

3.1. Monte Carlo Monte

Monte Carlo Normal Distribution model and Obudulu models were used to evaluate the assumptions of each component, and evaluating the reliability and failure rates of the individual components to get the entire system reliability and failure rate of the Injection Moulding machine. Monte Carlo Normal Distribution model analyses was used to establish relationships among the relevant study variables pertaining reliability of Injection Moulding machine, while the Obudulu model was developed to checkmate on points of failure and reliability. Reliability of Innoson Injection Mould system was analysed using Monte Carlo Normal Simulation, with the main objective of designing a model for its maintenance, which can be used to estimate its period for preventive maintenance. Also, quality of production was evaluated using quality productivity improvement tool, Statistical Process Control (SPC).

Reliability Calculation For Individual Components

$$\psi_{ʁt} = \frac{\psi_1 + \psi_2 + \psi_3 \ldots\ldots\ldots\ldots\ldots\psi_{ʁ}}{Ꭓ_8} \quad (1)$$

$$\psi_{ʁt} = \frac{Ꭓ_8\, \psi_{ʁ}}{Ꭓ_8} \quad (2)$$

System Failure Calculation For Individual Components

$$\phi_{(f)} = \frac{\phi_1 + \phi_2 + \phi_3 \ldots\ldots\ldots \phi_f}{ʧ} \quad (3)$$

$ɸ_{(f)} = ʧɸ_f / ʧ$ (4)

Reliability Calculation For DT Series System

DR_t = Hydraulic P(u) * Injection P(u) * Control P(u) * Mold P(u) * Clamping P(u) (5)

$$\sum_{i=1}^{m} cf(j) = c\sum_{i=1}^{m} f(j) \sum_{i=1}^{m} f(j) + g(1) = \sum_{i=1}^{m} cf(j) = \sum_{i=1}^{m} g(j) \quad (6)$$

$$\sum_{i=1}^{m} 1 = 1 + 1 + 1 + \cdots + 1 + m \sum_{i=k}^{m} 1 + m - k + 1 \quad (7)$$

$$\sum_{i=1}^{m} i = 1 + 2 + 3 + \ \ldots + m \ = m(m+1) = 2m + 0(m) \quad (8)$$

$$\sum_{i=1}^{m} i2 == 1 + 2 + 3 + \cdots + m = m(m+1)(2m+1) = m3 + m2 \quad (9)$$

Exponential Linear Models

$$\prod_{i=1}^{HR} k = \nabla p_1 \nabla p_2 \ldots \ldots \ldots \nabla pn = e^{-i\omega t} \quad (10)$$

$$\prod_{i=1}^{IR} k = \nabla p_1 \nabla p_2 \ldots \ldots \nabla pn = e^{-i\omega t2} \quad (11)$$

$$\prod_{i=1}^{CR} k = \nabla p_1 \nabla p_2 \ldots \ldots \nabla pn = e^{-i\omega t3} \quad (12)$$

$$\prod_{i=1}^{MR} k = \nabla p_1 \nabla p \ldots \ldots \ldots \nabla pn = e^{-i\omega t4} \quad (13)$$

$$\prod_{i=1}^{CLR} k = \nabla p_1 \nabla p_2 \ldots \ldots \nabla pn = e^{-i\omega t5} \quad (14)$$

Monte Carlo Simulation Model For Individual Component

Effective Improvement Tool

$${}_1^nY_r = \partial\lambda 3\left\lfloor \frac{dy}{dx}\nabla x_1 - \frac{dy}{dx}\nabla x_n \right\rfloor + \frac{dy}{dx}\nabla xnr \quad (15)$$

$\left\lfloor \frac{dy}{dx}\nabla x_1 - \frac{dy}{dx}\nabla xn \right\rfloor + \frac{dy}{dx}\nabla xnr$ is random selections of the time series for reliability.

$${}_1^nY_f = \partial\lambda 3\left\lfloor \frac{dy}{dx}\nabla x_1 - \frac{dy}{dx}\nabla xn \right\rfloor + \frac{dy}{dx}\nabla xnf \quad (16)$$

$\left\lfloor \frac{dy}{dx}\nabla x_1 - \frac{dy}{dx}\nabla xn \right\rfloor + \frac{dy}{dx}\nabla xnf$ is random selections of the time series for failure rate of the system.

Reliability Model Equation

$$yr = a0 + a1xi + a2xi2 + a3xi3 + \cdots akxik \quad i = 1,2 \ldots 5 \quad (17)$$

Where y_r denotes reliability in unit per month of the injection mould machine.

$x_{i1}\ x_{i2}\ x_{i3}\ x_{i4}$ and xi_5 denotes the input,component variables

$a0, a1, a2, a3, a4$ and $a5$ are the fixed but unknown estimators

x_{i1} = Hydraulic unit/Month
x_{i2} = Injection unit/Month
x_{i3} = Control unit/Month
x_{i4} = Mould unit/ Month
x_{i5} = Clamping unit/ Month

Obudulu Model Schedule Maintenance For Reliability and Failure Rates.

$$\varphi ɤ = \alpha 0 + \alpha 1\beta ɤ 1 + \alpha 2\, \beta ɤ 2 + \alpha 3 \beta ɤ_3 + \ldots <= 0.3 \quad (18)$$

$$\varphi ɟ = \alpha 0 + \alpha 1\beta ɟ 1 + \alpha 2\, \beta ɟ 2 + \alpha 3 \beta ɟ_3 + \ldots >= 0.02 \quad (19)$$

3.2. Source of Data

There are various methods of data collection, but for this work, data were personally obtained from the production and maintenance manager in Innoson Plastic Industries, Enugu State. Appendix 1, shows the raw data for reliability and failure rate; Table 2 shows downtime, while Table 3 display defective production of the five major components in Injection moulding machine, for a period of ten (10) years. Reliable data is needed to build strong reliability, and Injection Moulding Machines are no exception. In analyzing the reliability and corrective maintenance of Injection Moulding machine, Monte Carlo Normal Distribution Simulator and Obudulu model were used for the work. These software, employ the use of tables, graphs, standard formulas and models as an exploratory method intended to discover what the data seems to be saying by using simple arithmetic to summarize the data.

The data was extracted from the written records of failure kept by the maintenance personnel during each day. The records include the failures that occurred during the day, the action taken, the downtime, but the exact time of failure, that is the accuracy ofcomputing the mean time between failures (MTBF) of a particular system is in order of 8 – hours shift. The data selected have relationship with the reliability of Injection moulding machine.

Assumptions

1. Model to order preventive maintenance check points of every 0.03 difference lower than 0.03 is Obudulu model.
2. Preventive maintenance returns the service component to 0.90 reliability and failure rate of 0.014
3. System reliability and failure rates depends on its age and maintenance policy
4. Preventive maintenance has sufficient data to enable them to be suitable for application.

Models For Statistical Process Control (SPC)

Productivity Improvement Tool

For $\overline{X}$ Chart

Upper Control Limit, $UCL_{\overline{X}} = \overline{X} + A_2\overline{R}$ (20)

Lower Control Limit $LC_{\overline{X}} = \overline{X} - A_2\overline{R}$ (21)

For R Chart

Upper Control Limit, $UCL_R = D_4R$ (22)

Lower Control Limit $LC_R = D_3R$ (23)

For S Chart

Upper Control Limit, $UCL_S = \frac{B_4S}{2}$ (24)

Lower Control Limit $LC_S = \frac{B_3S}{2}$ (25)

Where $\overline{X}$, R and S Charts are control charts for variables. While A_2, B_3, B_4, D_3, and D_4 are obtained from Statistical Quality Control tables. (Laplante, Philip, 2005).

4. RESULTS AND DISCUSSION

4.1. Discussion Of Results

From tables 7-13, Innoson Injection Mould system was evaluated to be reliable 27.59% of the time and the system will be down 72.41% of the time. Also, the Hydraulic system is reliable 71.78% of the time, it will be down 28.22% of the time. Furthermore, the Injection system is reliable 74.95% of the time, it will be down 25.05% of the time. Likewise, the control system is reliable 75.66% of the time, it will be down 24.34% of the time. In addition, the mold system is reliable 73.64% of the time, it mold system will be down 26.36% of the time: while the clamping system is reliable 74.87% of the time, it will be down 25.13% of the time.

From Table 3, Obudulu Model service as threshold for system maintenance, with failure rate improvement as a result of maintenance of 0.02 and reliability rate improvement as a result of 0.3 maintenance.

From table 4, analysis of SPC monitor during corrective maintenance 2012 shows the following;

For the X-chart in defective production 2012, it indicates that the process has highest defective production. S-chart shows how the defective production varies, supporting excess defective production. R-chart explains the process as high of defective production still.Management has to think of implementing preventive maintenance. While from table 5, analysis of SPC monitor during preventive maintenance 2014, shows the following; X-chart showed out of control from defective production.R-chart showed implementation of preventive maintenanceS-chart showed out of defective production control with its peak in March.Preventive maintenance was effectively done which reflected in the output.

4 CONCLUSION

This paper has presented a rapid method for reliability analysis using Monte Carlo Normal Distribution Model which interacts with Obudulu Model, showing reliability and availability are parallel; thus showing that system failures is as a result of inconsistent continuous running without proper implementation of preventive maintenance programmes. Furthermore, It can forecast outcome showing how system eventually collapses if preventive maintenance measures are not implemented 48.97% with maintained and 41.17% without, dependent on age. The information obtained from the study can be used for effective monitoring of the Production systems and the data obtained and the reliability analysis can be used by the systems Manufacturers to improve on the machines. Also, the paper help to provide guidelines for quality control practices.

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APPENDIX

Table 1: Raw Data of Reliability and Failure Rate For Individual Components

YEARS	HYDRAULIC SYSTEM R_1	HYDRAULIC SYSTEM λ_1	INJECTION SYSTEM R_2	INJECTION SYSTEM λ_2	CONTROL SYSTEM R_3	CONTROL SYSTEM λ_3	MOLD SYSTEM R_4	MOLD SYSTEM λ_4	CLAMPING SYSTEM R_5	CLAMPING SYSTEM λ_5
FE2004	0.600	0.015	0.700	0.008	0.600	0.015	0.700	0.008	0.500	0.013
MA2004	0.600	0.015	0.700	0.008	0.600	0.015	0.700	0.008	0.500	0.013
AP2004	0.600	0.015	0.700	0.008	0.600	0.015	0.700	0.008	0.500	0.013
MY2004	0.600	0.015	0.700	0.008	0.600	0.015	0.700	0.008	0.500	0.013
JN2004	0.992	0.012	0.800	0.012	0.992	0.012	0.800	0.012	0.992	0.012
JY2004	0.992	0.012	0.800	0.012	0.992	0.012	0.800	0.012	0.992	0.012
AG2004	0.994	0.014	0.800	0.012	0.994	0.014	0.800	0.012	0.994	0.014
SP2004	0.994	0.014	0.800	0.012	0.994	0.014	0.800	0.012	0.994	0.014
OC2004	0.993	0.014	0.800	0.012	0.993	0.014	0.800	0.012	0.993	0.014
NV2004	0.993	0.014	0.800	0.012	0.993	0.014	0.800	0.012	0.993	0.014
DM2004	0.992	0.012	0.900	0.012	0.992	0.012	0.900	0.012	0.992	0.012
JA2005	0.992	0.012	0.900	0.012	0.992	0.012	0.900	0.012	0.992	0.012
FE2005	0.994	0.014	0.900	0.012	0.994	0.014	0.900	0.012	0.994	0.014
MA2005	0.994	0.014	0.900	0.012	0.994	0.014	0.900	0.012	0.994	0.014
AP2005	0.994	0.014	0.900	0.012	0.994	0.014	0.900	0.012	0.994	0.014
MY2005	0.993	0.014	0.850	0.003	0.993	0.014	0.850	0.003	0.993	0.014
JN2005	0.992	0.012	0.850	0.003	0.992	0.012	0.850	0.003	0.992	0.012
JY2005	0.991	0.010	0.850	0.003	0.991	0.010	0.850	0.003	0.991	0.010

AG2005	0.991	0.010	0.850	0.003	0.991	0.010	0.850	0.003	0.991	0.010
SP2005	0.992	0.012	0.850	0.003	0.992	0.012	0.850	0.003	0.992	0.012
OC2005	0.990	0.010	0.850	0.003	0.990	0.010	0.850	0.003	0.990	0.010
NV2005	0.990	0.010	0.850	0.003	0.990	0.010	0.850	0.003	0.990	0.010
DM2005	0.990	0.010	0.850	0.003	0.990	0.010	0.850	0.003	0.990	0.010
JA2006	0.980	0.009	0.850	0.003	0.980	0.009	0.850	0.003	0.980	0.009

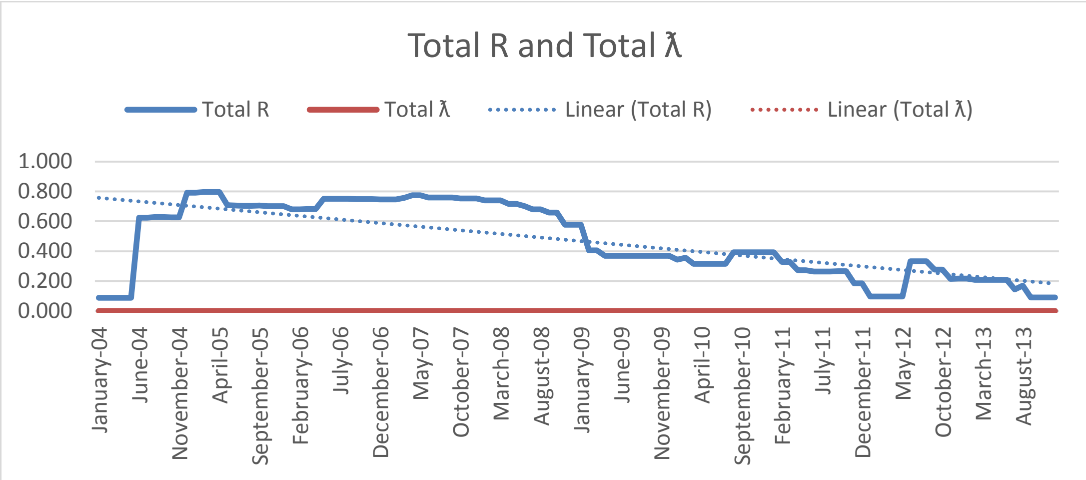

Figure 1: Total Reliability And Failure Rate

Table 2 : Total Reliability and Failure Rates

Years	Total R	Total ƛ	Years	Total R	Total ƛ
January-04	0.088	0.00000000019	March-05	0.796	0.00000000040
February-04	0.088	0.00000000019	April-05	0.796	0.00000000040
March-04	0.088	0.00000000019	May-05	0.707	0.00000000002
April-04	0.088	0.00000000019	June-05	0.705	0.00000000002
May-04	0.088	0.00000000019	July-05	0.703	0.00000000001
June-04	0.625	0.00000000025	August-05	0.703	0.00000000001
July-04	0.625	0.00000000025	September-05	0.705	0.00000000002
August-04	0.629	0.00000000040	October-05	0.701	0.00000000001
September-04	0.629	0.00000000040	November-05	0.701	0.00000000001
October-04	0.627	0.00000000040	December-05	0.701	0.00000000001

November-04	0.627	0.00000000040	January-06	0.680	0.00000000001
December-04	0.791	0.00000000025	February-06	0.680	0.00000000001
January-05	0.791	0.00000000025	March-06	0.682	0.00000000001
February-05	0.796	0.00000000040	April-06	0.682	0.00000000001

Table 3: Obudulu Model Reliability and Failure Rates

YEARS	HYDRAULIC SYSTEM R_1	HYDRAULIC SYSTEM λ_1	INJECTION SYSTEM R_2	INJECTION SYSTEM λ_2	CONTROL SYSTEM R_3	CONTROL SYSTEM λ_3	MOLD SYSTEM R_4	MOLD SYSTEM λ_4	CLAMPING SYSTEM R_5	CLAMPING SYSTEM λ_5
January-04	0.6	0.015	0.7	0.008	0.6	0.015	0.7	0.008	0.5	0.013
February-04	0.6	0.015	0.7	0.008	0.6	0.015	0.7	0.008	0.5	0.013
March-04	0.6	0.015	0.7	0.008	0.6	0.015	0.7	0.008	0.5	0.013
April-04	0.6	0.015	0.7	0.008	0.6	0.015	0.7	0.008	0.5	0.013
May-04	0.6	0.015	0.7	0.008	0.6	0.015	0.7	0.008	0.5	0.013
June-04	0.992	0.012	0.8	0.012	0.992	0.012	0.8	0.012	0.992	0.012
July-04	0.992	0.012	0.8	0.012	0.992	0.012	0.8	0.012	0.992	0.012
August-04	0.994	0.014	0.8	0.012	0.994	0.014	0.8	0.012	0.994	0.014
September-04	0.994	0.014	0.8	0.012	0.994	0.014	0.8	0.012	0.994	0.014
October-04	0.993	0.014	0.8	0.012	0.993	0.014	0.8	0.012	0.993	0.014
November-04	0.993	0.014	0.8	0.012	0.993	0.014	0.8	0.012	0.993	0.014
December-04	0.992	0.012	0.9	0.012	0.992	0.012	0.9	0.012	0.992	0.012
January-05	0.992	0.012	0.9	0.012	0.992	0.012	0.9	0.012	0.992	0.012
February-05	0.994	0.014	0.9	0.012	0.994	0.014	0.9	0.012	0.994	0.014
March-05	0.994	0.014	0.9	0.012	0.994	0.014	0.9	0.012	0.994	0.014
April-05	0.994	0.014	0.9	0.012	0.994	0.014	0.9	0.012	0.994	0.014
May-05	0.993	0.014	0.85	0.003	0.993	0.014	0.85	0.003	0.993	0.014
June-05	0.99	0.012	0.85	0.003	0.992	0.012	0.85	0.003	0.992	0.012

	2									
July-05	0.99 1	0.01	0.85	0.003	0.991	0.01	0.85	0.003	0.991	0.01
August-05	0.99 1	0.01	0.85	0.003	0.991	0.01	0.85	0.003	0.991	0.01
September-05	0.99 2	0.012	0.85	0.003	0.992	0.012	0.85	0.003	0.992	0.012
October-05	0.99	0.01	0.85	0.003	0.99	0.01	0.85	0.003	0.99	0.01
November-05	0.99	0.01	0.85	0.003	0.99	0.01	0.85	0.003	0.99	0.01
December-05	0.99	0.01	0.85	0.003	0.99	0.01	0.85	0.003	0.99	0.01
January-06	0.98	0.009	0.85	0.003	0.98	0.009	0.85	0.003	0.98	0.009
February-06	0.98	0.009	0.85	0.003	0.98	0.009	0.85	0.003	0.98	0.009
March-06	0.98 1	0.009	0.85	0.003	0.981	0.009	0.85	0.003	0.981	0.009
April-06	0.98 1	0.009	0.85	0.003	0.981	0.009	0.85	0.003	0.981	0.009
May-06	0.98 2	0.01	0.89	0.015	0.982	0.01	0.89	0.015	0.982	0.01
June-06	0.98 2	0.01	0.89	0.015	0.982	0.01	0.89	0.015	0.982	0.01
July-06	0.98 2	0.01	0.89	0.015	0.982	0.01	0.89	0.015	0.982	0.01
August-06	0.98 2	0.01	0.89	0.015	0.982	0.01	0.89	0.015	0.982	0.01
September-06	0.98 1	0.009	0.89	0.015	0.981	0.009	0.89	0.015	0.981	0.009
October-06	0.98 1	0.009	0.89	0.015	0.981	0.009	0.89	0.015	0.981	0.009
November-06	0.98 1	0.009	0.89	0.015	0.981	0.009	0.89	0.015	0.981	0.009
December-06	0.98	0.009	0.89	0.015	0.98	0.009	0.89	0.015	0.98	0.009
January-07	0.98	0.009	0.89	0.015	0.98	0.009	0.89	0.015	0.98	0.009
February-07	0.98	0.009	0.89	0.015	0.98	0.009	0.89	0.015	0.98	0.009
March-07	0.98 5	0.012	0.89	0.015	0.985	0.012	0.89	0.015	0.985	0.012
April-07	0.98 5	0.012	0.9	0.012	0.985	0.012	0.9	0.012	0.985	0.012
May-07	0.98 5	0.012	0.9	0.012	0.985	0.012	0.9	0.012	0.985	0.012
June-07	0.97 9	0.009	0.9	0.012	0.979	0.009	0.9	0.012	0.979	0.009
July-07	0.97 9	0.009	0.9	0.012	0.979	0.009	0.9	0.012	0.979	0.009
August-07	0.97 9	0.009	0.9	0.012	0.979	0.009	0.9	0.012	0.979	0.009
September-07	0.97 9	0.009	0.9	0.004	0.979	0.009	0.9	0.004	0.979	0.009

October-07	0.976	0.088	0.9	0.004	0.976	0.088	0.9	0.004	0.976	0.088
November-07	0.976	0.088	0.9	0.004	0.976	0.088	0.9	0.004	0.976	0.088
December-07	0.976	0.088	0.9	0.004	0.976	0.088	0.9	0.004	0.976	0.088
January-08	0.97	0.08	0.9	0.004	0.97	0.08	0.9	0.004	0.97	0.08
February-08	0.97	0.08	0.9	0.004	0.97	0.08	0.9	0.004	0.97	0.08
March-08	0.97	0.08	0.9	0.004	0.97	0.08	0.9	0.004	0.97	0.08
April-08	0.96	0.07	0.9	0.004	0.96	0.07	0.9	0.004	0.96	0.07
May-08	0.96	0.07	0.9	0.004	0.96	0.07	0.9	0.004	0.96	0.07
June-08	0.96	0.07	0.89	0.015	0.96	0.07	0.89	0.015	0.96	0.07
July-08	0.95	0.06	0.89	0.015	0.95	0.06	0.89	0.015	0.95	0.06
August-08	0.95	0.06	0.89	0.015	0.95	0.06	0.89	0.015	0.95	0.06
September-08	0.94	0.059	0.89	0.015	0.94	0.059	0.89	0.015	0.94	0.059
October-08	0.94	0.059	0.89	0.015	0.94	0.059	0.89	0.015	0.94	0.059
November-08	0.9	0.055	0.89	0.015	0.9	0.055	0.89	0.015	0.9	0.055
December-08	0.9	0.055	0.89	0.015	0.9	0.055	0.89	0.015	0.9	0.055
January-09	0.9	0.055	0.89	0.015	0.9	0.055	0.89	0.015	0.9	0.055
February-09	0.8	0.054	0.89	0.015	0.8	0.054	0.89	0.015	0.8	0.054
March-09	0.8	0.054	0.89	0.015	0.8	0.054	0.89	0.015	0.8	0.054
April-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
May-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
June-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
July-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
August-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
September-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
October-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
November-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
December-09	0.8	0.054	0.85	0.003	0.8	0.054	0.85	0.003	0.8	0.054
January-10	0.78	0.05	0.85	0.003	0.78	0.05	0.85	0.003	0.78	0.05
February-10	0.79	0.05	0.85	0.003	0.79	0.05	0.85	0.003	0.79	0.05
March-10	0.79	0.05	0.8	0.012	0.79	0.05	0.8	0.012	0.79	0.05
April-10	0.79	0.05	0.8	0.012	0.79	0.05	0.8	0.012	0.79	0.05
May-10	0.79	0.05	0.8	0.012	0.79	0.05	0.8	0.012	0.79	0.05
June-10	0.79	0.05	0.8	0.012	0.79	0.05	0.8	0.012	0.79	0.05
July-10	0.79	0.05	0.8	0.012	0.79	0.05	0.8	0.012	0.79	0.05
August-10	0.85	0.055	0.8	0.012	0.85	0.055	0.8	0.012	0.85	0.055
September-10	0.85	0.055	0.8	0.012	0.85	0.055	0.8	0.012	0.85	0.055
October-10	0.85	0.055	0.8	0.012	0.85	0.055	0.8	0.012	0.85	0.055
November-10	0.85	0.055	0.8	0.012	0.85	0.055	0.8	0.012	0.85	0.055

December-10	0.85	0.055	0.8	0.012	0.85	0.055	0.8	0.012	0.85	0.055
January-11	0.85	0.055	0.8	0.012	0.85	0.055	0.8	0.012	0.85	0.055
February-11	0.8	0.054	0.8	0.012	0.8	0.054	0.8	0.012	0.8	0.054
March-11	0.8	0.054	0.8	0.012	0.8	0.054	0.8	0.012	0.8	0.054
April-11	0.8	0.054	0.6	0.008	0.8	0.054	0.89	0.015	0.8	0.054
May-11	0.8	0.054	0.6	0.008	0.8	0.054	0.89	0.015	0.8	0.054
June-11	0.79	0.05	0.6	0.008	0.79	0.05	0.89	0.015	0.79	0.05
July-11	0.79	0.05	0.6	0.008	0.79	0.05	0.89	0.015	0.79	0.05
August-11	0.79	0.05	0.6	0.008	0.79	0.05	0.89	0.015	0.79	0.05
September-11	0.79	0.05	0.6	0.008	0.79	0.05	0.9	0.012	0.79	0.05
October-11	0.79	0.05	0.6	0.008	0.79	0.05	0.9	0.012	0.79	0.05
November-11	0.7	0.04	0.6	0.008	0.7	0.04	0.9	0.012	0.7	0.04
December-11	0.7	0.04	0.6	0.008	0.7	0.04	0.9	0.012	0.7	0.04
January-12	0.6	0.015	0.6	0.008	0.6	0.015	0.9	0.012	0.5	0.013
February-12	0.6	0.015	0.6	0.008	0.6	0.015	0.9	0.004	0.5	0.013
March-12	0.6	0.015	0.6	0.008	0.6	0.015	0.9	0.004	0.5	0.013
April-12	0.6	0.015	0.6	0.008	0.6	0.015	0.9	0.004	0.5	0.013
May-12	0.6	0.015	0.6	0.008	0.6	0.015	0.9	0.004	0.5	0.013
June-12	0.85	0.055	0.6	0.008	0.85	0.055	0.9	0.004	0.85	0.055
July-12	0.85	0.055	0.6	0.008	0.85	0.055	0.9	0.004	0.85	0.055
August-12	0.85	0.055	0.6	0.008	0.85	0.055	0.9	0.004	0.85	0.055
September-12	0.8	0.054	0.6	0.008	0.8	0.054	0.9	0.004	0.8	0.054
October-12	0.8	0.054	0.6	0.008	0.8	0.054	0.9	0.004	0.8	0.054
November-12	0.8	0.054	0.6	0.008	0.8	0.054	0.7	0.008	0.8	0.054
December-12	0.8	0.054	0.65	0.004	0.8	0.054	0.65	0.004	0.8	0.054
January-13	0.8	0.054	0.65	0.004	0.8	0.054	0.65	0.004	0.8	0.054
February-13	0.79	0.05	0.65	0.004	0.79	0.05	0.65	0.004	0.79	0.05
March-13	0.79	0.05	0.65	0.004	0.79	0.05	0.65	0.004	0.79	0.05
April-13	0.79	0.05	0.65	0.004	0.79	0.05	0.65	0.004	0.79	0.05
May-13	0.79	0.05	0.65	0.004	0.79	0.05	0.65	0.004	0.79	0.05
June-13	0.79	0.05	0.65	0.004	0.79	0.05	0.65	0.004	0.79	0.05
July-13	0.7	0.04	0.65	0.004	0.7	0.04	0.65	0.004	0.7	0.04
August-13	0.7	0.04	0.7	0.008	0.7	0.04	0.71	0.018	0.7	0.04
September-13	0.6	0.015	0.7	0.008	0.6	0.015	0.71	0.018	0.5	0.013
October-13	0.6	0.015	0.7	0.008	0.6	0.015	0.71	0.018	0.5	0.013
November-13	0.6	0.015	0.7	0.008	0.6	0.015	0.71	0.018	0.5	0.013
December-13	0.6	0.015	0.7	0.008	0.6	0.015	0.71	0.018	0.5	0.013

Table 4: Evaluating Quality Of Defective Production During Corrective Maintenance 2012

SAMPLE NO	1	2	3	4	5	X	x/n = X	Max Min = R	X-x= D	$(X-x)^2$ D^2=S
JAN	43	42	46	49	43	223	44.6	7	178.4	31826.56
FEB	44	43	46	42	45	220	44.0	4	176	30976
MAR	46	47	47	44	45	229	45.8	3	183.2	33562.24
APR	42	43	40	45	43	213	42.6	5	170.4	29036.16
MAY	43	42	45	46	44	220	44.0	4	176.0	30976
JUNE	45	44	43	44	45	221	44.2	2	176.8	31187
JULY	42	43	45	46	42	218	43.6	4	114.4	30415.36
AUG	43	40	41	43	40	207	41.4	3	165.6	27423.36
SEPT	44	44	42	41	46	217	43.4	5	173.6	30136.96
OCT	42	42	44	41	44	213	42.6	3	170.4	29036.2
NOV	45	45	43	40	46	219	43.8	6	175.2	30695.0
DEC	45	45	41	44	42	217	43.4	4	173.2	299982
							523.4	50		
							12	12		336263

Table 5: Evaluating Quality Of Defective Production In Preventive Maintenance 2014

Sample No	1	2	3	4	5	x	x/n=X	R	D	S
Jan	5	4	8	11	5	33	6.6	7	26.4	697.96
Feb	6	5	8	4	7	30	6.0	4	24	576
Mar	8	9	9	6	7	39	7.8	3	31.2	973.44
Apl	2	1	2	3	2	10	2.0	2	8	64
May	5	4	7	8	1	25	5.0	6	20	400
Jun	7	6	5	6	7	31	6.2	2	24.8	615.04
Jul	4	5	7	8	4	28	5.6	4	22.4	501.76
Aug	5	2	1	5	2	15	3.0	4	12	144
Sep	5	6	4	3	8	26	5.2	5	20.8	432.64
Oct	6	4	6	3	1	20	4.0	5	16	256
Nov	1	1	1	1	2	6	1.2	1	4.8	23.04
Dec	5	7	3	6	4	25	5.0	4	20	400

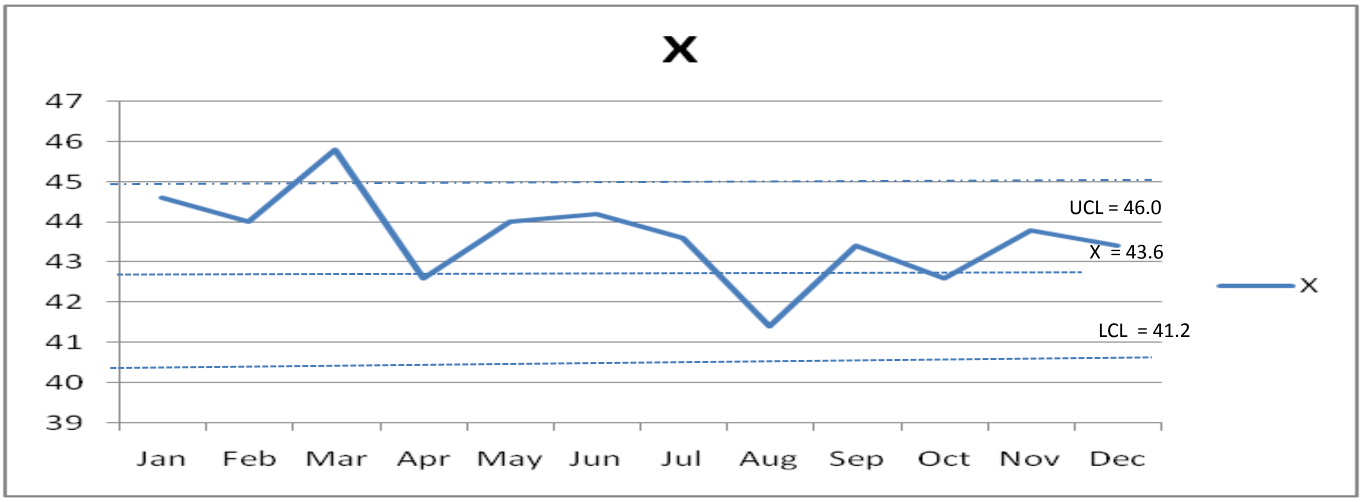

Figure 2: Statistical Control Charts For Defective Production In 2012 X-Chart

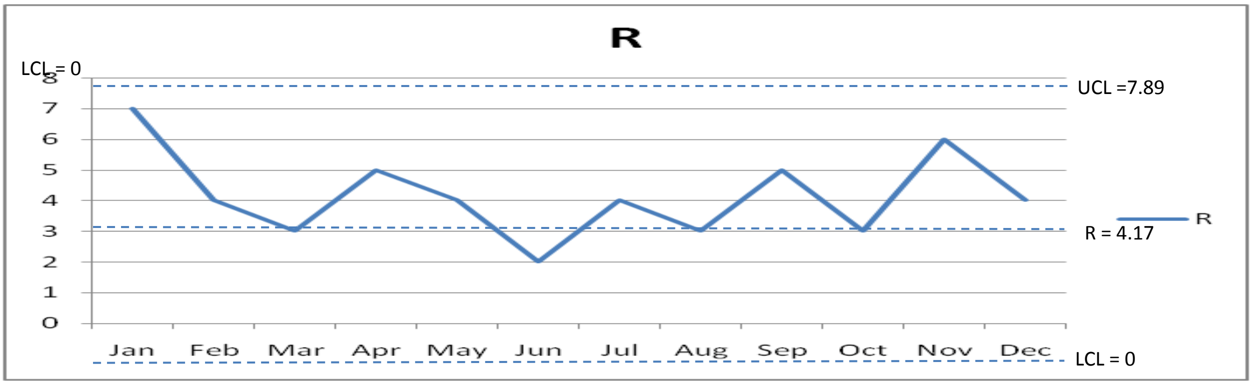

Figure 3: Statistical Control Charts For Defective Production In 2012 R-Chart

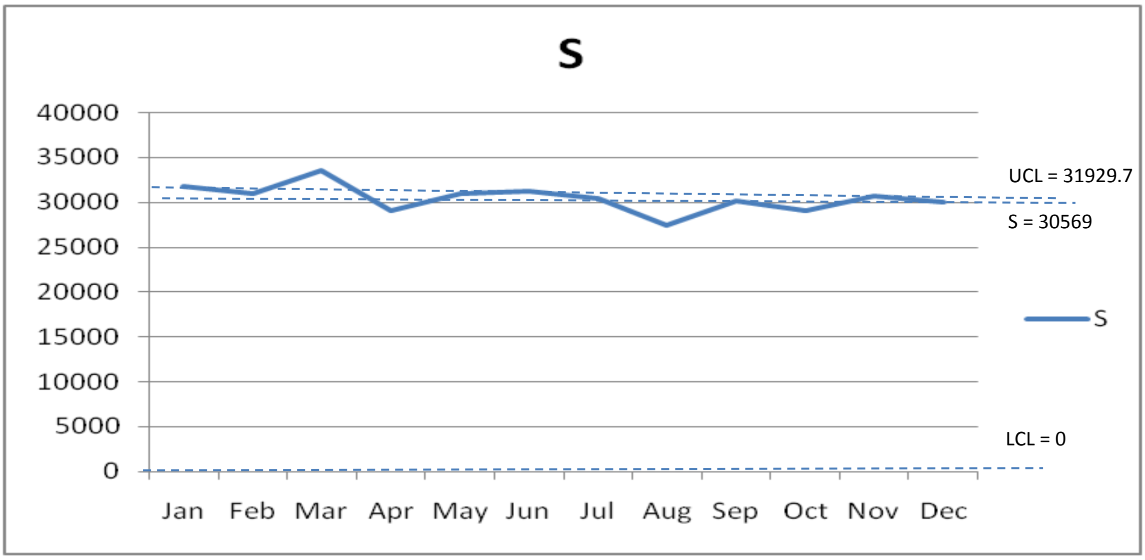

Figure4: Statistical Control Charts For Defective Production In 2012 S-Chart

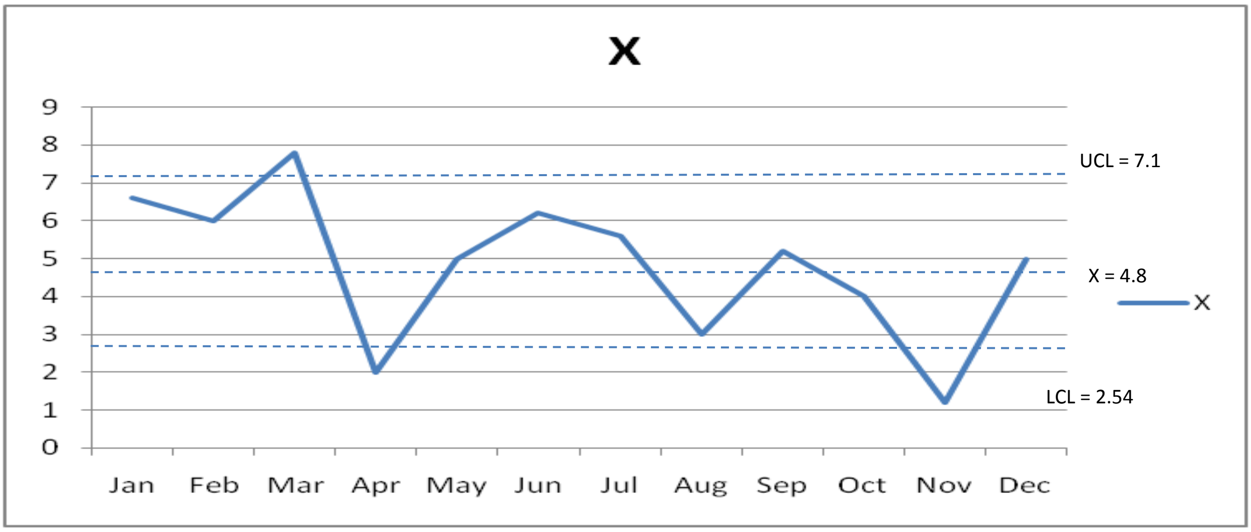

Figure 5: Statistical Control Charts During Preventive Maintenance In 2014, X-Chart

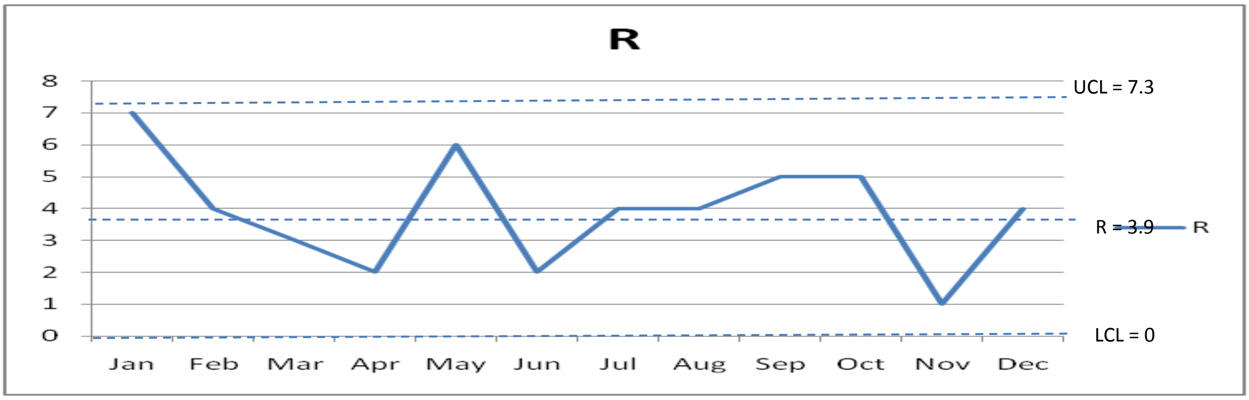

Figure 6: Statistical Control Charts During Preventive Maintenance In2014, R-Chart

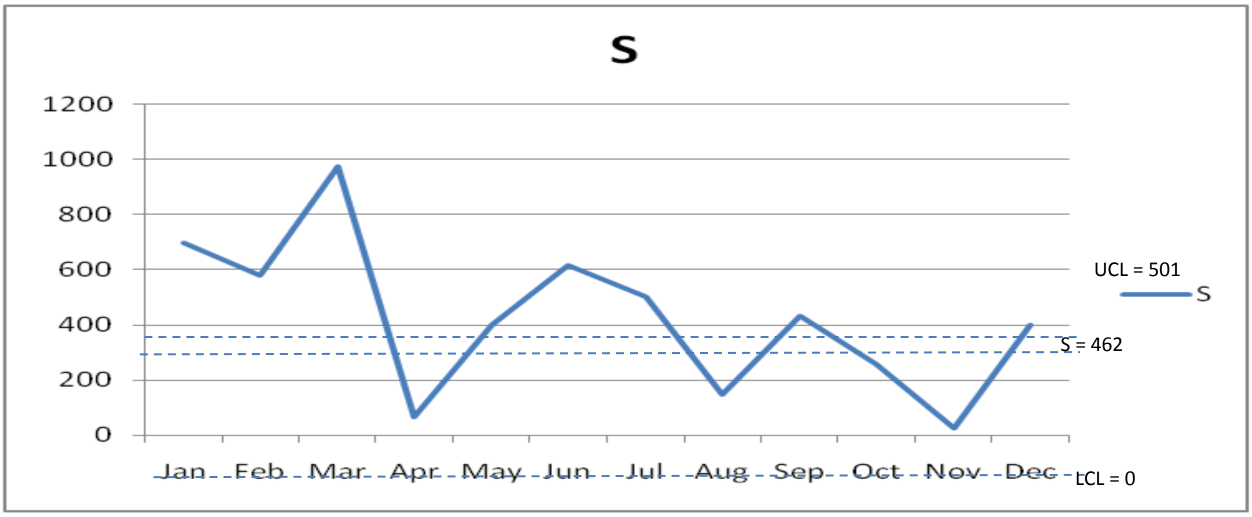

Figure 7: Statistical Control Charts During Preventive Maintenance In 2014, S-Chart

Table 6: Statistical Reliability Evaluation

Determine Distribution for each component based historical data		
Reliability Distribution - lowest & highest		
HYDRAULIC SYSTEM R1	0.60	0.99
INJECTION SYSTEMR2	0.6	0.9
CONTROL SYSTEMR3	0.6	0.994
MOLD SYSTEMR4	0.65	0.9
CLAMPING SYSTEMR5	0.5	0.994
Failure Rate Distribution - lowest & highest		
HYDRAULIC SYSTEM λ1	0.009	0.088
INJECTION SYSTEMλ2	0.003	0.015
CONTROL SYSTEMλ3	0.009	0.088
MOLD SYSTEMλ4	0.003	0.018
CLAMPING SYSTEMλ5	0.009	0.088

Table 7: Forecast For Injection Mould System

Forecast:	***Injection Moulding Machine Series System is reliable 27.59% of the time and the System will be down72.41% of the time.***				
	Average	**MIN**	**MAX**	**STD Dev**	**Reliability**
	0.7739	0.5006	0.9939	0.1103	0.2771
	0.7752	0.5004	0.9940	0.1121	0.2795
	0.7743	0.5004	0.9938	0.1101	0.2778
	0.7738	0.5007	0.9940	0.1103	0.2770
	0.7745	0.5010	0.9934	0.1104	0.2782
	0.7728	0.5006	0.9938	0.1119	0.2750
	0.7714	0.5001	0.9939	0.1101	0.2726
	0.7740	0.5010	0.9939	0.1118	0.2774
	0.7748	0.5004	0.9938	0.1094	0.2786
	0.7715	0.5006	0.9938	0.1108	0.2728
	0.7715	0.5001	0.9937	0.1112	0.2726
	0.7753	0.5011	0.9940	0.1114	0.2795
	0.7727	0.5022	0.9940	0.1104	0.2750
	0.7746	0.5003	0.9939	0.1126	0.2783
	0.7727	0.5010	0.9940	0.1106	0.2750
	0.7722	0.5001	0.9938	0.1104	0.2741

	0.7705	0.5002	0.9938	0.1119	0.2708
	0.7721	0.5004	0.9938	0.1100	0.2738
	0.7745	0.5000	0.9939	0.1102	0.2782
	0.7724	0.5003	0.9940	0.1117	0.2745

Table 8: Run Simulation of The Components Rate 1000 times

Ʀ1	ƛ1	Ʀ2	ƛ2	Ʀ3	ƛ3	Ʀ4	ƛ4	Ʀ5	ƛ5
0.840	0.010	0.758	0.006	0.712	0.088	0.805	0.005	0.659	0.042
0.738	0.063	0.786	0.012	0.891	0.051	0.692	0.005	0.835	0.063
0.864	0.034	0.635	0.007	0.854	0.084	0.725	0.017	0.597	0.075
0.710	0.084	0.871	0.006	0.758	0.080	0.772	0.014	0.799	0.034
0.705	0.064	0.611	0.003	0.967	0.013	0.678	0.009	0.715	0.037
0.791	0.022	0.824	0.010	0.734	0.020	0.828	0.013	0.918	0.081
0.871	0.013	0.844	0.012	0.733	0.087	0.847	0.014	0.754	0.058
0.967	0.077	0.856	0.013	0.665	0.023	0.807	0.004	0.593	0.061
0.720	0.057	0.730	0.008	0.950	0.028	0.806	0.016	0.796	0.036
0.602	0.074	0.848	0.004	0.781	0.073	0.765	0.006	0.800	0.070
0.894	0.077	0.634	0.006	0.632	0.062	0.876	0.004	0.716	0.082
0.878	0.057	0.841	0.007	0.882	0.038	0.684	0.005	0.748	0.076
0.976	0.025	0.865	0.005	0.839	0.033	0.837	0.010	0.552	0.036
0.679	0.062	0.738	0.015	0.990	0.022	0.779	0.017	0.762	0.037
0.975	0.037	0.859	0.012	0.645	0.029	0.817	0.009	0.638	0.051
0.932	0.047	0.614	0.007	0.635	0.049	0.834	0.010	0.678	0.078
0.691	0.056	0.647	0.013	0.702	0.066	0.802	0.005	0.546	0.035
0.843	0.038	0.636	0.010	0.816	0.077	0.775	0.008	0.565	0.023
0.813	0.068	0.799	0.008	0.764	0.012	0.759	0.017	0.877	0.015
0.648	0.054	0.726	0.007	0.805	0.073	0.809	0.009	0.521	0.031
0.804	0.026	0.622	0.013	0.796	0.048	0.855	0.007	0.669	0.058
0.931	0.085	0.745	0.013	0.932	0.024	0.876	0.016	0.627	0.039
0.702	0.015	0.763	0.011	0.739	0.053	0.898	0.011	0.601	0.044
0.799	0.020	0.822	0.007	0.675	0.059	0.836	0.008	0.979	0.088
0.832	0.016	0.847	0.009	0.827	0.079	0.714	0.004	0.928	0.047
0.788	0.031	0.891	0.014	0.799	0.049	0.769	0.008	0.872	0.014
0.911	0.029	0.838	0.006	0.771	0.015	0.825	0.014	0.646	0.023
0.713	0.049	0.628	0.014	0.791	0.062	0.656	0.016	0.657	0.032
0.977	0.083	0.771	0.014	0.852	0.061	0.749	0.008	0.537	0.038
0.830	0.044	0.621	0.008	0.770	0.081	0.657	0.011	0.690	0.061

Table 9: Forecast of Injection System

Forecast:	*Injection System is reliable 74.95% of the time. Injection System will be down 25.05% of the time.*				
	Average	**MIN**	**MAX**	**STD Dev**	**Reliability**
	0.7496	0.6000	0.8997	0.0878	0.7496
	0.7534	0.6002	0.8993	0.0886	0.7534
	0.7514	0.6004	0.8994	0.0848	0.7514
	0.7498	0.6006	0.8997	0.0849	0.7498
	0.7473	0.6002	0.8996	0.0855	0.7473
	0.7462	0.6003	0.9000	0.0879	0.7462
	0.7502	0.6012	0.8998	0.0856	0.7502
	0.7447	0.6005	0.8985	0.0868	0.7447
	0.7490	0.6007	0.8989	0.0859	0.7490
	0.7457	0.6010	0.9000	0.0869	0.7457
	0.7511	0.6002	0.8999	0.0882	0.7511
	0.7547	0.6001	0.9000	0.0856	0.7547
	0.7459	0.6002	0.9000	0.0870	0.7459
	0.7500	0.6004	0.8996	0.0872	0.7500
	0.7489	0.6016	0.8999	0.0870	0.7489
	0.7522	0.6001	0.8997	0.0878	0.7522
	0.7531	0.6002	0.8999	0.0857	0.7531
	0.7465	0.6001	0.8995	0.0865	0.7465
	0.7539	0.6004	0.9000	0.0839	0.7539
	0.7460	0.6002	0.8998	0.0869	0.7460

Table 10: Forecast of Control System Reliability

Forecast:	*Control System is reliable 75.66% of the time. Control System will be down 24.34% of the time.*				
	Average	**MIN**	**MAX**	**STD Dev**	**Reliability**
	0.7948	0.6001	0.9931	0.1125	0.7948
	0.7945	0.6000	0.9938	0.1146	0.7945
	0.8000	0.6000	0.9940	0.1138	0.8000
	0.8004	0.6003	0.9939	0.1130	0.8004
	0.7882	0.6000	0.9939	0.1141	0.7882
	0.7974	0.6001	0.9939	0.1164	0.7974
	0.7967	0.6009	0.9936	0.1129	0.7967
	0.7932	0.6007	0.9931	0.1114	0.7932
	0.7949	0.6002	0.9940	0.1154	0.7949
	0.7935	0.6002	0.9939	0.1161	0.7935
	0.7982	0.6006	0.9930	0.1126	0.7982
	0.7969	0.6003	0.9937	0.1166	0.7969
	0.7910	0.6000	0.9937	0.1116	0.7910
	0.7946	0.6002	0.9936	0.1134	0.7946
	0.7999	0.6004	0.9939	0.1121	0.7999

	0.7984	0.6001	0.9938	0.1130	0.7984
	0.8020	0.6003	0.9940	0.1126	0.8020
	0.7991	0.6001	0.9930	0.1137	0.7991
	0.7975	0.6008	0.9928	0.1116	0.7975
	0.7979	0.6001	0.9936	0.1131	0.7979

Table 11: Forecast ForMold System

Forecast:	***Mold System is reliable 73.64% of the time. Mold System will be down 26.36% of the time.***				
	Average	**MIN**	**MAX**	**STD Dev**	**Reliability**
	0.7754	0.6500	0.8999	0.0728	0.7754
	0.7708	0.6503	0.9000	0.0705	0.7708
	0.7736	0.6500	0.8997	0.0735	0.7736
	0.7769	0.6500	0.8990	0.0702	0.7769
	0.7725	0.6500	0.8998	0.0733	0.7725
	0.7740	0.6501	0.8999	0.0730	0.7740
	0.7754	0.6504	0.8997	0.0731	0.7754
	0.7768	0.6508	0.8999	0.0724	0.7768
	0.7724	0.6506	0.9000	0.0703	0.7724
	0.7785	0.6501	0.8998	0.0710	0.7785
	0.7783	0.6500	0.8999	0.0724	0.7783
	0.7779	0.6501	0.8996	0.0710	0.7779
	0.7755	0.6506	0.8997	0.0717	0.7755
	0.7720	0.6504	0.8996	0.0731	0.7720
	0.7756	0.6511	0.8996	0.0730	0.7756
	0.7738	0.6501	0.9000	0.0705	0.7738
	0.7744	0.6505	0.8998	0.0718	0.7744
	0.7774	0.6507	0.8997	0.0738	0.7774
	0.7762	0.6501	0.8997	0.0737	0.7762
	0.7761	0.6503	0.8997	0.0726	0.7761

Table 12 : Forecast For Clamping System

Forecast:	***Clamping System is reliable 74.87% of the time. Clamping System will be down 25.13% of the time.***				
	Average	**MIN**	**MAX**	**STD Dev**	**Reliability**
	0.7529	0.5006	0.9939	0.1429	0.7529
	0.7529	0.5006	0.9927	0.1459	0.7529
	0.7538	0.5004	0.9937	0.1436	0.7538
	0.7485	0.5000	0.9939	0.1415	0.7485

	0.7504	0.5004	0.9930	0.1398	0.7504
	0.7472	0.5006	0.9924	0.1424	0.7472
	0.7463	0.5001	0.9932	0.1444	0.7463
	0.7444	0.5004	0.9927	0.1433	0.7444
	0.7455	0.5001	0.9933	0.1423	0.7455
	0.7494	0.5004	0.9921	0.1408	0.7494
	0.7514	0.5006	0.9940	0.1434	0.7514
	0.7481	0.5012	0.9939	0.1472	0.7481
	0.7418	0.5003	0.9937	0.1414	0.7418
	0.7451	0.5001	0.9938	0.1423	0.7451
	0.7500	0.5006	0.9937	0.1436	0.7500
	0.7491	0.5000	0.9936	0.1404	0.7491
	0.7514	0.5002	0.9937	0.1421	0.7514
	0.7485	0.5004	0.9933	0.1407	0.7485
	0.7474	0.5005	0.9934	0.1417	0.7474
	0.7494	0.5020	0.9939	0.1411	0.7494

Table 13: Forecast of Hydraulic System

Forecast:	***Hydraulic System is reliable 71.78% of the time. Hydraulic System will be down 28.22% of the time.***				
	Average	**MIN**	**MAX**	**STD Dev**	**Reliability**
	0.7967	0.6003	0.9938	0.1133	0.7967
	0.7988	0.6001	0.9935	0.1118	0.7988
	0.7961	0.6003	0.9925	0.1108	0.7961
	0.8016	0.6009	0.9939	0.1149	0.8016
	0.8005	0.6003	0.9940	0.1141	0.8005
	0.7991	0.6006	0.9931	0.1143	0.7991
	0.7968	0.6002	0.9938	0.1172	0.7968
	0.8014	0.6013	0.9939	0.1122	0.8014
	0.7873	0.6007	0.9938	0.1143	0.7873
	0.7966	0.6005	0.9939	0.1137	0.7966
	0.7990	0.6007	0.9937	0.1103	0.7990
	0.7933	0.6000	0.9934	0.1144	0.7933
	0.7961	0.6005	0.9934	0.1145	0.7961
	0.7975	0.6003	0.9939	0.1155	0.7975
	0.8000	0.6002	0.9937	0.1144	0.8000
	0.7981	0.6006	0.9930	0.1123	0.7981
	0.7949	0.6003	0.9940	0.1163	0.7949
	0.8056	0.6002	0.9940	0.1116	0.8056
	0.7987	0.6002	0.9938	0.1130	0.7987
	0.7943	0.6005	0.9923	0.1132	0.7943