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CONSTRUCTION OF DOUBLE SAMPLING PLANS INTEGRATED WITH THEORY OF CONSTRAINTS FOR I-TYPE PRODUCTION PLANTS THROUGHSIMULATION MODELLING

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Abstract

In this paper, an attempt is made to design the Double SamplingPlansfor I-type production plants through Theory of Constraints (TOC) using simulation models designed with the help of a simulation software, called Goldsim 14.0, by fixing the lot size. Using the simulation models designed for I-type of plants, the Double Sampling Plans are constructed. These constructed plans are used in two different points to inspect the quality of the raw-material and the finished products. The constructed Double Sampling Plans are presented in tables along with Return on Investment for various values of the proportion defective.

Keywords: Theory of Constraints, Simulation Modelling, I-type production plants,Double Sampling Plans.

1. Introduction

Acceptance sampling is a statisticaltechnique used in quality assurance to make decision about incoming or receiving inspection of products. It involves inspecting a sample form batch or lot of products to determine if it meets the pre-determining quality criteria. The sampling plan specifies the sample size, the acceptance-rejection criteria for the lot. By testing a smaller sample instead of inspecting the entire lot, acceptance sampling allows for efficient decision-making while still maintain a high level of confidence in the quality of lot. In acceptance sampling, a sample is taken from a lot of products or raw-materials used in the production process. The sample is inspected to evaluate certain quality characteristics. Based on the information from the sample, a decision is made about whether to accept or reject the entire lot. The decision is based on predetermined acceptance criteria that define the acceptable level of quality of the lot. If the sample meets the criteria, the lot is accepted indicating that it can processed to the next stage of the manufacturing process. If the sample does not meet the criteria the lot is rejected and appropriate actions are taken, such as returning the lot to the suppler or taking corrective measures to improve quality.

Hald and Keiding (1969) developed the Double Sampling Plans by attributes assumes the sample size and acceptance number of the second sample to be independent of the outcome of the first sample. Hence, a Double Sampling Plan is determined by four parameters-two sample sizes and two acceptance numbers. This analysis is based on direct minimization of the risk function which depends on these four parameters.

Hamaker (1955) has also shown that the differences between the two methods of matching, namely matching of the OC curves for the double sampling plan and the single sampling plans using p_0 and $h_0$and that using $p_{0.10}$and $p_{0.95}$are slight and they amount to not more than 5 percent of the sample size. Craig (1981) has given a method of constructing double sampling plans with 100% inspection of rejected lots with given rejection numbers, incoming quality level, lot size and probability of acceptance of a lot of quality. Soundararajan and Arumainayagam (1990) have presented a table for double sampling plan which is mainly based on Schilling (1981) table. Their tables can be used to select double sampling plan indexed through AQL, AOQL and LQL and double sampling scheme indexed by AQL.Govindaraju and Subramani (1992) have designed double sampling plans in such a way as to obtain a plan having minimum sum of producer’s and consumer’s risks.

Mahesh Gupta et al. (2010) developed Theory of constraints to improve a production process, to reduce operating expenses, to optimize inventorylevels, to increase the profit values, and the development of new products in the markets.Tulasi and Rao (2012) developed the TOC and it has been beneficial in many areas such as services, marketing, projects, process industries etc.,Alvarez, Alda and John (2017) have applied TOC along with lean management which resulted in reduction in non-value-added activities and inventory. Katherine Helper et.al. (2022) used the simulation approach to Logistics of IWATERs gaining timeline for decontamination operators and characterize an alternative to reduce the influence of the limited resources on operational progress logistics and operational variables.

The notations and abbreviations used in this study are:

TOC: Theory of Constraints

DSP: Double Sampling Plan

ROI: Return on Investment

CCR: Capacity Constraint Resource

n_{1A} : First Sample size for the firstinspection before CCR batch

n_{2A}: Second Sample size for the first inspection before CCR batch

c_{1A} : First Acceptance number for the first inspection before CCR batch

c_{2A} : Second acceptance number for the first inspection before CCR batch

n_{1B} : First Sample size for the second inspection before shipment

n_{2B}: Second Sample size for the second inspection before shipment

c_{1B} : First Acceptance number for the second inspection before shipment

c_{2B} : SecondAcceptance number for the secondinspection before shipment

DSP($n_{1A,}n_{2A}$, c_{1A}, c_{2A}): Double Sampling plans for the inspection before CCR

DSP($n_{1B,}n_{2B}$, c_{1B}, c_{2B}):Double Sampling plans for the inspection before shipment.

2. Research Methodology

In this study, theGoldSimsoftware is used to design simulation model for double sampling plansintegrated with I-type production plants and hence to find out the ROI.By Simulating the designed model two Double Sampling Plansare simulated along with ROI.

This I-type of implementation is effective in the process having a single raw-material, five different work stations and a single product. A simulation model is developed using Goldsim software, for the I-type production process, to construct Double Sampling Plans to apply at two different stages. First,one is to checkthe quality of the raw-material (after processing through WC-1, WC-2)just before CCR.Second one,is to check the quality (after processing throughWC-4, WC-5) justbefore shipment for improving the quality of the finished product.

Using thedesigned simulation model, by fixing the lot size N, and by giving various proportiondefective(p)values as input, two double sampling plans, DSP($n_{1A,}n_{2A}$, c_{1A}, c_{2A}) , and DSP($n_{1B,}n_{2B}$, c_{1B}, c_{2B})areconstructed.Inthe I-type production process, the quality of raw-material is checked before CCR using DSP($n_{1A,}n_{2A}$, c_{1A}, c_{2A}) andthe quality of the final product is checked using the DSP($n_{1B,}n_{2B}$, c_{1B}, c_{2B}) just before the shipment. The ROI are also simulated.

The procedure for DSP(n_1,n_2,c_1,c_2) consists of the following steps:

i) Select a random sample of size $n_1$from the lot received from the producer.

ii) Count the number of defectives (d_1) in the first sample.

iii) If $d_1 \leq c_1$, the acceptance number for the first sample, accept the lot.

iv) If $d_1 > c_2$, reject the lot and replace the defective items with good items using 100% inspection.

v) If $c_1 < d_1 \leq c_2$, select the second random sample of size $n_2$from the lot.

vi) Count the number of defectives (d_2) in the second sample.

vii) If $d_1+d_2 \leq c_2$, accept the lot; otherwise reject the lot and replace the defective items with good items using 100% inspection.

The parameters n_1, n_2, c_1 *and* c_2 are the parameters of the Double Sampling Plan. The probability of acceptance for DSP is calculated using the Poisson function given in equation(1).

$$P_a(\mathrm{p}) = \sum_{i=0}^{c_1} \frac{e^{-n_1 p}(n_1 p)^{x_i}}{x_i!} + \left[\sum_{j=c_1+1}^{c_2} \frac{e^{-n_1 p}(n_1 p)^{x_j}}{x_j!} \left\{\sum_{i=0}^{c_2-j} \frac{e^{-n_2 p}(n_2 p)^{x_i}}{x_i!}\right\}\right] \ldots\ldots.(1)$$

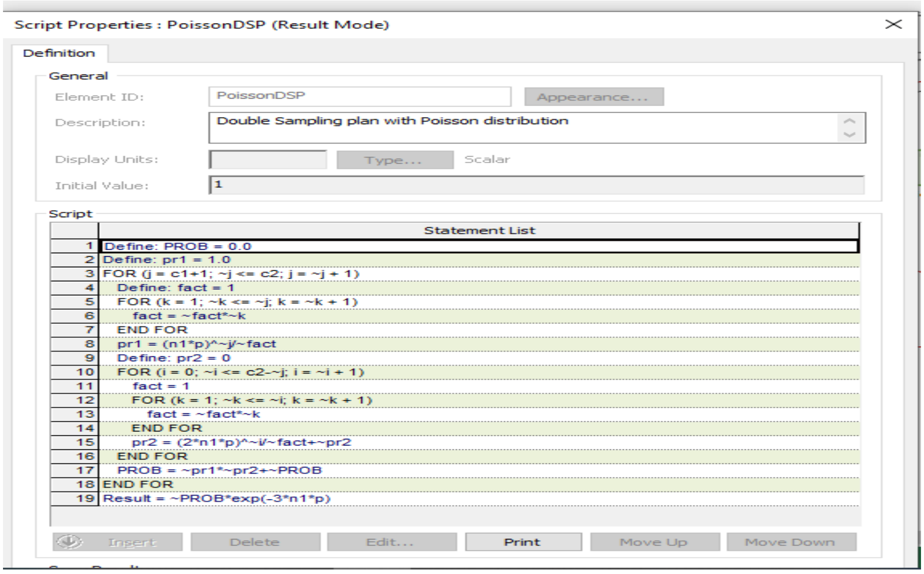

Figure 2.1: Script used in GoldSim for DSP

The script used in the GoldSim software to calculate probability of acceptance $P_a(p)$ given in the equation (1), for various 'p' values, is presented in Figure 2.1. In the script, it is assumed that the second sample size is twice that of first sample size,ie., $n_2 = 2n_1$.

A simulation model for DSP is developed using the GoldSim Software and is presented in Figure 2.2.

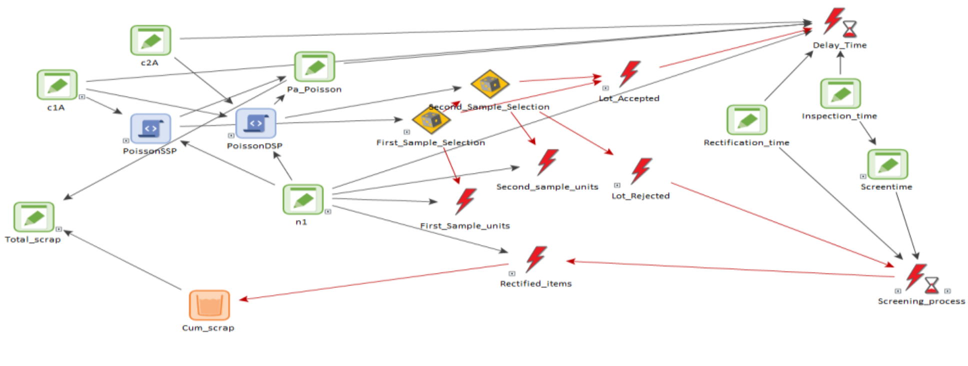

Figure 2.2:Simulation Model for DSP

3. DesigningSimulation Model for DSP with I-type Production plants ($n_{1A} = n_{2A}$)

In this section, a simulation model for DSP($n_{1A} = n_{2A}$)is developed using the GoldSim Software and is presented in Figure 3.1.

It is assumed that the simulation model has five work stations viz., WC-1, WC-2, WC-3, WC4, WC-5with various capacities. Also, this model involves drum buffers, drum beats and drum ropes. In this simulation model, after purchasing, the raw-material is processed through WC-1, WC-2, WC-3, WC4, WC-5 and the final product moves to the shipment.Finally, the finished product goes to shipment and thenmoves to throughput values.

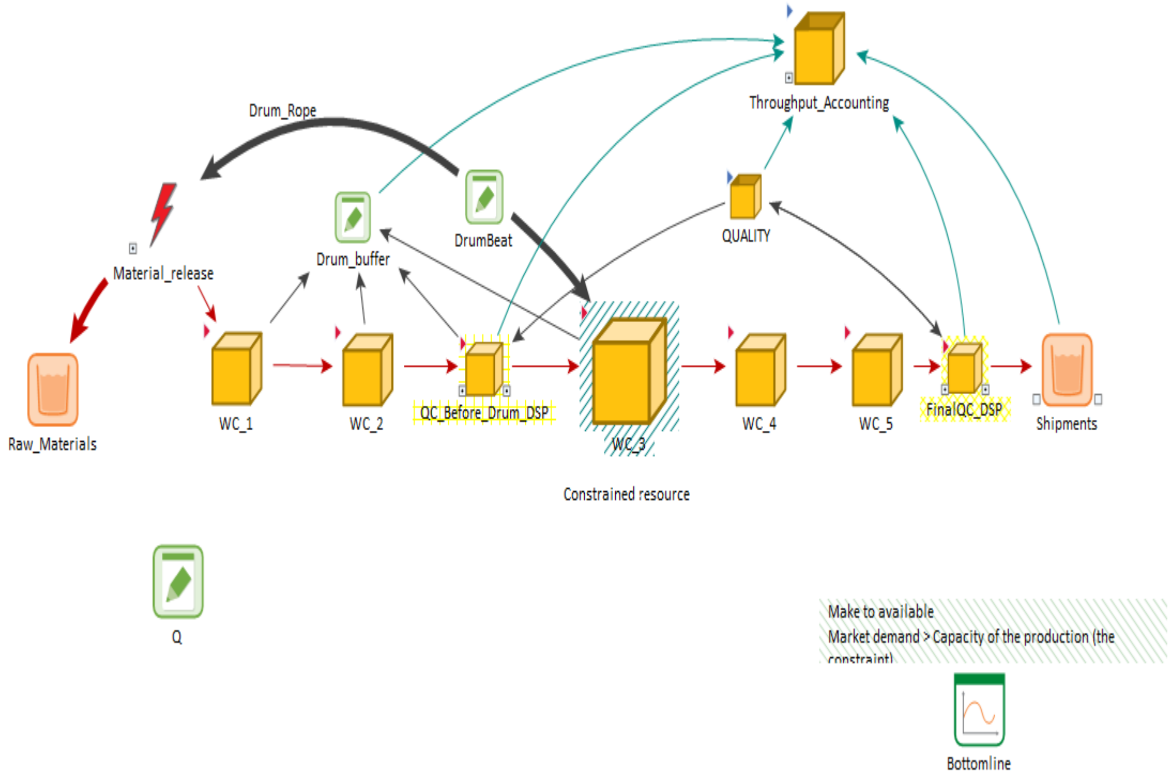

Figure 3.1: Simulation Model for DSP withI-type Production Plant

Once the Raw-material is processed through WC-1,WC-2,using the DSP$(n_{1A,}n_{2A}\,,c_{1A},c_{2A})$, the raw-material is inspectedbefore reaching WC-3(CCR), the main constraint resource. The quality of the product is inspected using DSP$(n_{1B,}n_{2B}\,,c_{1B},c_{2B})$before the shipment.

4. Construction of DSPs and Calculationof ROI for I-type plants (n_{1A}= n_{2A})

Using the model presented in the figure 3.1, two double sampling plans,DSP$(n_{1A,}n_{2A}\,,c_{1A},c_{2A})$ and DSP$(n_{1B,}n_{2B}\,,c_{1B},c_{2B})$ have been simulated and hencethe ROI % values have been calculated, for various proportion defective values (p) by fixing the lot size N as 500,1000,1200 and 1500. Theses DSP plans are presented in the Table4.1,Table-4.2, respectively.

Table 4.1: ROI% using DSP with $(n_{1A},n_{2A}\,,c_{1A},c_{2A})$ $(n_{1B},n_{2B}\,,c_{1B},c_{2B})$ lot size of (500 ,1000)

	500							1000						
p	n_{1A}	c_{1A}	c_{2A}	n_{1B}	c_{1B}	c_{2B}	ROI	n_{1A}	c_{1A}	c_{2A}	n_{1B}	c_{1B}	c_{2B}	ROI
0.01	33	11	9	35	19	4	911.268	51	3	2	81	12	3	863.264
0.02	42	13	12	47	13	10	909.972	58	12	4	75	8	2	862.472
0.03	100	19	7	104	12	4	908.624	54	13	7	61	12	4	861.571
0.04	96	18	8	22	11	4	907.423	46	2	0	47	11	4	858.330
0.05	71	32	2	42	12	9	906.177	35	5	1	39	11	6	854.332
0.06	63	20	8	41	13	7	904.899	77	1	0	78	10	1	854.210
0.07	43	17	2	37	12	2	903.615	47	12	5	49	12	3	853.742
0.08	74	23	3	74	10	2	902.347	32	14	4	41	13	4	852.362
0.09	71	12	3	74	5	2	898.513	48	13	4	55	7	4	851.324

0.10	78	19	7	79	12	6	895.995	50	11	4	56	9	5	850.223
0.11	65	15	3	69	12	7	893.465	45	14	3	48	13	4	847.546
0.12	54	12	0	57	17	10	890.942	78	11	5	87	14	2	844.732
0.13	75	38	5	79	14	5	888.425	44	9	1	49	11	3	843.66
0.14	78	23	16	85	12	7	885.903	30	15	7	65	13	2	842.110
0.15	60	36	2	65	11	8	883.407	44	12	5	84	13	7	840.223
0.16	88	23	2	29	17	6	880.913	80	13	1	110	15	1	838.963
0.17	24	12	5	28	15	3	878.416	20	4	1	55	21	1	834.251
0.18	68	14	8	69	21	11	875.937	37	12	7	75	13	1	833.143
0.19	35	3	2	36	28	8	863.264	128	14	3	140	6	3	832.328
0.20	48	6	10	54	15	2	851.426	20	2	1	45	3	1	831.438

Suppose, for a given lot of sizeequal to 500, and for the desired proportion defective p = 0.16, it is found from the tables 4.1, that the DSP (88,23,2) is to be used before CCR, the DSP (29,17,6) is to be used before shipment in order to achieve the ROI is 880.913.

Table 4.2: ROI% using DSP with $(n_{1A}, n_{2A}, c_{1A}, c_{2A})$ $(n_{1B}, n_{2B}, c_{1B}, c_{2B})$ lot size of (1200 ,1500)

	1200							1500						
p	n_{1A}	c_{1A}	c_{2A}	n_{1B}	c_{1B}	c_{2B}	ROI	n_{1A}	c_{1A}	c_{2A}	n_{1B}	c_{1B}	c_{2B}	ROI
0.01	43	3	0	66	12	4	892.74	74	14	5	101	5	3	941.32
0.02	47	21	11	52	13	10	890.54	56	20	7	65	14	2	935.32
0.03	54	14	7	21	2	0	888.21	45	15	11	98	11	7	931.55
0.04	37	12	9	19	7	2	885.32	42	7	5	45	17	9	930.22
0.05	79	15	6	17	11	9	841.32	57	7	2	33	8	7	877.78
0.06	25	11	9	29	1	2	835.31	54	7	3	58	6	2	875.32
0.07	19	2	11	54	4	2	833.41	56	16	0	36	4	0	874.35
0.08	98	24	2	56	3	1	832.45	55	15	2	54	15	2	873.69
0.09	91	23	9	124	1	0	830.78	89	19	5	98	14	3	870.25
0.10	36	11	8	88	2	1	828.74	120	12	7	141	11	2	869.32
0.11	28	4	2	45	3	0	824.23	110	20	11	98	15	2	864.35
0.12	25	11	2	50	10	7	821.25	101	11	9	97	22	3	862.32
0.13	23	19	17	44	15	2	814.23	109	19	7	108	17	3	861.35
0.14	11	5	2	87	11	6	812.36	147	17	1	124	19	4	857.21
0.15	36	12	12	64	10	7	808.32	104	14	7	132	22	8	856.69
0.16	54	13	11	98	7	3	807.56	55	15	6	87	9	2	847.32

0.17	59	14	13	63	6	4	805.37	69	19	10	78	7	2	844.71
0.18	89	2	2	97	0	2	804.99	96	16	8	125	15	3	842.66
0.19	54	17	14	88	9	7	802.31	36	14	2	54	19	4	841.33
0.20	21	2	1	29	3	2	800.34	59	13	3	96	10	2	840.96

Suppose, for a given lot of sizeequal to500, and for the desired proportion defective p = 0.20, it is foundfrom the tables 4.2, that the DSP (21,2,1)is to be used before CCR, the DSP (29,3,2) is to be used before shipment in order to achieve the ROIis 800.34.

Example:

Let us consider thecoffee production unit as an example of the I-type production processs.The coffee seeds are processed in five different work sations WC-1, WC-2, WC-3, WC-4, WC-5. In the WC-1 raw-material of the coffee seeds, undergoes a series of cleaning proceess.Coffee seeds go through the blending processin the work station WC-2. The quality of the coffee seeds are checked and then moved to the work station WC-3 forbrewing process. In the WC-4 the seeds undergo the roasting process and grinding in WC-5. Finallythe quality is checked, shipped and sent to the throughput.

Figure 4.1: Coffee production for I-type plants

5. Conclusion

In this study, double sampling plans($n_{1A} = n_{2A}$) for I-type production plants using the developed simulation modelare constructedalong with the ROI values. The constructed doublesampling plans along with the ROI values for various proportion defective values are listed as tables. These tables may be used to check the quality of the products at the two different stages of the I-type production plants.

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