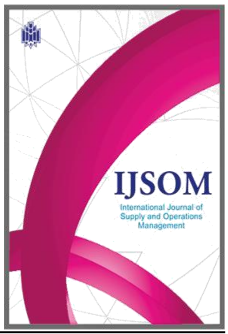
International Journal of Supply and Operations Management

IJSOM

August 2018, Volume 5, Issue 3, pp. 283-288
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



Analytical dimension to quality check in production process through control charts

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Abstract
Quality control is of paramount importance to any company in improving the product quality. Due to changing industry standards and competitive issues, embracing quality engineering techniques for strong operations support has become of prime importance to maintain and sustain competitive advantage. In this paper researcher intend to analyze the production line of a product, detect assignable variations in process and calculate the capability of the process using statistical Process Control. For plotting data points using control charts Sample size of 50 measurements with subgroup size 5 is considered. Since this is a variable data with subgroup size between 2 to 10, data is plotted with the help of X bar and R chart. Also to conclude on the capability of the process and check instability and level shift Process Capability and Process Capability Index is calculated. In this study it is found that process mean has shifted though there was a complete absence of assignable causes of variation.

Keywords: Quality control; Process capability; Process capability index; X bar and R chart.

1. Introduction

One of the key roles of operations managers is to develop and maintain the production processes that deliver quality products and services. Similarly production manager has to maintain the perfect balance in the process by selecting proper combination of man, machine, method, material and measurement to produce product with the production process that features smallest amount of variation. There are many factors which at any given point of time can induce variation in the process which ultimately impacts on the quality of the product. Hence once the production process is selected, it is important to monitor the process to ensure that it functions in the designed way as mentioned by Keller G. (2016) in his book Statistics for Management and Economics.

There are two approaches to manage quality of the product, Reactive and Proactive. In a Reactive approach, the products are checked if it is not as per specification either reject it or process it for rework. In a proactive approach or prevention approach, we monitor the production process to determine when the process starts producing non-conforming units. This allows correcting process before it creates a large number of defects. Sibalija T.V. and Majstorovic V.D. (2009) found that Control charts are quality engineering tools used separately or within SPC to measure and control process variation and detection of special causes of variation.

Control Charts have been in existence for nearly 70 years. Keller G. (2016) gave a very simple definition of a control chart: A control chart is a plot of statistics over time. Selection of Control charts is based on type of data. Data can be classified into two types – variable and attribute. Depending upon the type of data, different types of control charts are used. For a variable type of data we use I-MR (subgroup size 1), X- bar and R (subgroup size 2-10), X-bar and S (subgroup size > 10). For attribute data again the next level of classification is based on defects (C chart and U chart)

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(Document type: Technical note)

and defectives (NP chart and P chart). Zavvar, Mirzazadeh, Salehian and Weber (2014) identified some areas of application of Control charts. The following table gives a brief about their findings:

Table 1. Areas of application of Control Charts

Type of Control Chart	**Area of Application (Sample Case)**
X bar-R	Shear Carpet
P	Engine Piston Manufacturing Process
P	Textile Company
X bar-S	Biscuit Factory
X bar-R	Oil Field Centrifuge
P	LED Lighting
C	IC (Integrated Circuit)
X bar-R	Touch panels
X bar-R	Controlling piston Inner diameter compressors
X bar-R	Threading of the Natural Gas Valve by CNC Machine
X bar-R	Inside Diameter Measurement of Piston Ring
X bar-R	Electronic Company

In this research paper we will discuss about X bar and R chart. Black K. (2009), in his book Business Statistics for Contemporary Decision Making that X bar chart is a graph of sample means computed for a series of small random sample over a period of time. It measures whether the process is adjusted properly, comparing the calculated process average to nominal value. R chart is a plot of sample ranges and is used in conjunction with an X bar chart. R bar charts are used to plot variation of each sample as measured by sample range. If sample size is n ≤10, then X bar and R control chart is formed and control limit is calculated as:

For the average X bar chart

$$UCL = \overline{\overline{X}} + A_2 \overline{R}$$

$$LCL = \overline{\overline{X}} - A_2 \overline{R}$$

For the Range chart

$$UCL = D_4 \overline{R}$$

$$LCL = D_3 \overline{R}$$

Control charts helps us to determine whether the process is under control or not, but process capability helps us determine the capability of the process. The control limits in control charts are based on the sample data whereas while determining capability and capability index we take into consideration the specification limits as specified by the customer. Cp is the process capability which is simple and straightforward indicator of process capability. Cpk is the process capability index which is adjustment of Cp for non-centered distribution.

Mathematical representation of Cp and Cpk:

$$\hat{\sigma} = \frac{\overline{R}}{d_2} \quad Cp = \frac{USL - LSL}{6\hat{\sigma}} \quad Cpk = \frac{Z_{\min}}{3}$$

$$Z_{upper} = \frac{USL - \overline{\overline{X}}}{\hat{\sigma}} \quad Z_{lower} = \frac{\overline{\overline{X}} - LSL}{\hat{\sigma}}$$

A2, D4, D3 and d2 are the standard coefficients which are selected depending on the sample size. It is desirable to have Cp and Cpk value to be greater than 1.33 and for 6 sigma Cp and Cpk minimal required value is 2.

Four issues are considered while designing the control charts: the basis for sampling, the sample size, frequency of sampling and the location of the control limits. A good sampling method should have the property that, if assignable causes are present, the chance of observing differences between samples is high, while the chance of observing differences within a sample is low. Samples that satisfy these criteria are called rational subgroups.

If we are not able to get sample subgroup size greater than 1 then we use the Moving Range control chart. Moving range is defined as the absolute difference between two successive observations = $MR_i = |x_i - x_{i-1}|$. This will indicate the possible shifts in the process from one observation to the next. P and NP chart uses proportion defectives in a sample while C and U chart uses the number of defects in an item. Variable control charts offer more information, more sensitive to changes and are more accurate as compared to attributes control charts.

2. Literature Review

The early adopters of SPC were the automobile industries of Japan and USA. However the application of SPC ranges from Hospitals, Grocery stores, Airlines, Fast food restaurants, Catalogue-order companies, Insurance companies, etc. Many research papers in the wide application of SPC has been done from past. The brief Literature Review is based on a survey of 15 journal articles on SPC. The articles suggest steps of implementation of SPC, challenges in implementation, new modifications in conventional charts, application of multivariate analysis, challenges in application SPC, use of technology and sensors in application of SPC to get real time data, etc. The focus area of research paper is to analyse the process based on the findings and interpretations of application of SPC in various case studies and research papers to find out the usefulness of X-bar and R chart, process capability and process capability index.

Research paper by Oberoi, Parmar, Kaur and Mehra (2016), “A Quality Control Technique for Confirmation to Ability of process” explained the use of SPC to be one of the important and widely used tool for improving performance of the process. The power of SPC lies in the ability to examine a process and the sources of variation in that process, using tools that give weight age to objective analysis over subjective opinions and that allow the strength of each source to be determined numerically. Cp is called process potential as a high Cp value doesn’t mean that process will fall under specification limits. Thus we need Cpk to measure the ability of the process to create product within specification limits. A higher standard deviation means a decrease in Cpk which further results in increase in ability of process to produce products beyond specification limit.

Lee Ho and Quinino (2013), in the paper “An attribute control chart for monitoring the variability of a process”, taking reference from the studies of Wu (2009), authors here have studied and proposed possibility to monitor a process mean by attribute control chart as an alternative to X bar chart. Traditional np charts require more sample size(60) to detect same mean shift which X bar can detect in less sample size(50). This has reduced popularity of attribute control charts in measuring mean shifts.

In the case study by Skulj, Vrabic, Butala and Sluga (2013) “Statistical Process Control as a Service: An Industrial Case Study”, authors have proposed the use of eSPC as a replacement of paper SPC for small businesses. Big companies don’t encounter the problem of acquiring or training the required statistical expertise for carrying out the SPC, but small businesses on the other hand struggle in the same area. Control charts can be prepared in real time basis and can serve as documentation for customers and also can give warning signals to operator when the process is going out of control.

The following Table shows all the research papers referred, including few mentioned above, and the main extract from those research papers:

Table 2. Methods/Remarks and extract of referred Research Papers

Sr.No.	Author	Year	Journal	Methods/Remarks
1	Linda Lee Ho, Francisco Aparisi	2016	Int.J. Production Economics 182 (2016) 472-483	Use of a mixture of X-bar and Attribute control chart (ATTRIVAR Charts) to monitor process mean with less operational cost
2	Harpreet Oberoi, Mamta Parmar, Harpreet Kaur, Rahul Mehra	2016	IRJET Vol 03 Issue:06 e-ISSN 2395-0056	Step by step procedure of plotting X-bar and R chart and also steps for calculating process capability and process capability index
3	Radu Godina, Joao C.O. Matias, Susana G. Azevedo	2016	IJIEM, Vol 7 No 1, 2016, 1-8 ISSN 2217-2661	Application of Control charts in Automotive industry to suggest systematic approach to use SPC
4	Radu Godina, Joao C.O. Matias, Susana G. Azevedo	2015	IJISR, vol 14, 2015, 154-158 ISSN 2351-8014	Application of P chart to identify assignable cause of variation in health care delivery time- case study

Table 2. Continued

Sr.No.	Author	Year	Journal	Methods/Remarks
5	A. Mystica and J.Mary Suganthi Bai	2015	IJRCM, Vol 6, No. 1 ISSN 0976-2183	7 Quality Control tools and their application
6	Mohammad Hossein Zavvar Sabegh, Abolfazzl Mirzazadeh, Saber Salehian, Gerhard-Wilhelm Weber	2014	Int.J. Supply and Operations Management	A Literature Review on Fuzzy Control charts, classification and analysis
7	Linda Lee Ho, Roberto Costa Quinino	2013	Int.J. Production Economics 145 (2013) 263-267	use of npx control chart as an alternative to R chart to monitor a process mean by attribute inspection
8	Gasper Skulj, Rok Vrabic, Peter Butala, Alojzij Sluga	2013	Forty Sixth CIRP Conference on Manufacturing Systems Procedia CIRP 7 (2013) 401-406	Real time online graphical epresentation of Control charts. This Case study illustrates the use of service in a small company
9	Shichang Du, Jun Lv and Lifeng Xi	2012	Int.J. Production Research, vol 50, No. 22, 5288-6310	Use of Multivariate analysis to detect out of control points and determine process mean shifts using SVM and PS-SVME
10	Mei Yang, Zhang Wu, Ka Man Lee, Michael B.C. Khoo	2012	Int.J. Production Research, vol 50, No. 3, 893-907	Comparison between application of X-bar and CUSUM chart
11	Zhang Wu, Mei Yang, Michael B.C. Khoo, Philippe Castagliola	2011	Int.J. Production Economics 131 (2011) 650-662	Best Sample sizes for X-bar charts & the effect of sampling cost on chart performance
12	Tatjana V. SIBALIJA, Vidosav D. MAJSTOROVIC	2009	Int.J. TQM & Excellence, Vol. 37, No. 1-2, 2009	SPC and Process capability analysis- case study
13	S. Bersimis, J. Panaretos and S. Psarakis	2005	MPRA paper no 6397,2007,	Simultaneous monitoring and control of two or more related quality process characteristics using multivariate statistical process control
14	William H. Woodall, Douglas C. Montgomery	1999	Journal of Quality Technology, Vol 31,No. 4, 1999	Issues, general trends and research ideas in the field of Statistical Process Control
15	Andrea C. Palm, Robert N. Rodriguez, Fred A. Sipring, Donald J. Wheeler	1997	Journal of Quality Technology, Apr 199, 122	Challenges and new frontiers for control charts application

3. Methodology and Findings

While analyzing the process, researcher has collected 50 sample data of a product and classified it under 5 subgroups with each subgroup containing 10 sample data points. The values in the table are in centimeters. The values in the table are the measurement of distance of hole from the heel of Steel Angles which are referred to as Back Mark.

Table 3. Sample collection for Back Mark

SNO.	1	2	3	4	5	6	7	8	9	10
1	37.13	36.77	37.11	37.11	37.12	37.02	37.09	37.06	37.16	36.70
2	36.43	36.72	36.91	36.75	36.79	37.06	36.88	36.71	36.79	37.29
3	37.11	36.15	37.24	37.02	36.90	36.92	36.89	37.49	37.07	37.38
4	37.15	37.37	36.53	36.94	37.34	37.03	36.86	37.20	37.28	37.02
5	37.55	36.68	37.23	37.01	36.84	36.86	37.00	37.36	37.33	37.26

Further the subgroup wise range and X bar values are calculated and then the X bar and R bar charts are plotted as shown below:

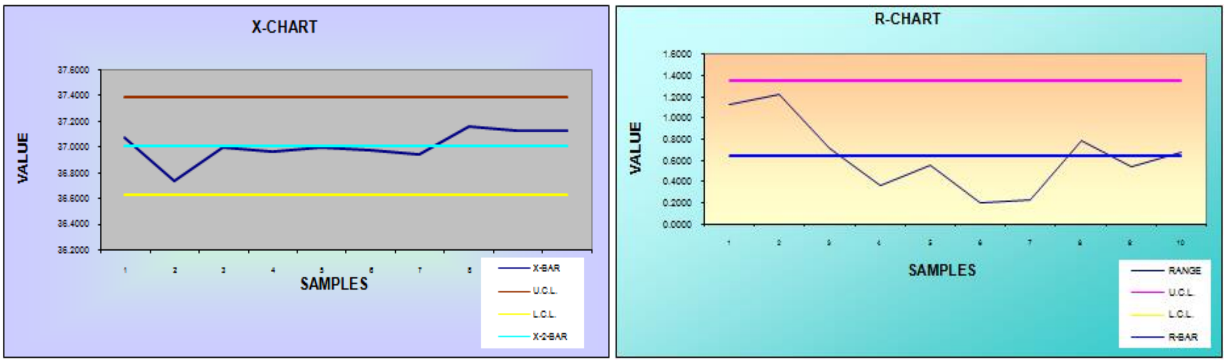

Figure 1.X-bar and R-bar control charts of the collected sample data

Table 4. Specification limits for product and table of standard constant used in calculation

U.S.L.	**37.25**	**SAMPLE**	**D2**	**A2**	**D4**
		1	1.12	2.56	3.27
		2	1.13	1.88	3.27
L.S.L.	**35.25**	3	1.69	1.02	2.57
		4	2.06	0.73	2.23
		5	2.33	0.59	2.11

Based on the specification limits and value of $\overline{\overline{X}}$ and standard deviation Cp and Cpk were calculated with Cp being 1.22 and Cpk being at 0.2910, which is far less than standard value of 1.33.

4. Conclusion

1) Control charts helps to detect special causes of variation. Corrective action taken on time helps in eliminating these special causes of process variation before generating defects. As seen in the above scenario from sample analysis, there exists no such special cause of variation which are above UCL or below LCL, in X bar chart. Similar is the case in R chart.
2) Process Capability compares the performance of a process against specifications. For six sigma process the value of Cp and Cpk required is 2. Cp value 1 means that the process is just within the specification limits. Here our Cp value is 1.22 and Cpk is 0.2910. The minimum requirement for Cp and Cpk value is 1.33. From the value of Cp we can conclude that although the value is greater than 1 still there is need to control the variations to avoid future rejections. The value of Cpk is very low which indicates that the process mean has shifted to a greater extent. The process is not capable.
3) X bar and R chart did not show the special cause of variation but on the calculation of process capability and process capability index indicates that the process needs immediate attention in order to achieve process improvements.

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