Quality in the Greek Food Manufacturing Industry: implementation of diagnostic procedures in weight checking systems of an olive oil manufacturing company.

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Abstract

This paper investigates the usage of statistical process control (SPC) techniques, in specific production lines of a Greek olive oil company, as a diagnostic procedure in order to assess final product single net weight variation. Histogram analysis, normality tests, x-bar and r-chart and capability (for normal and between/within subgroup variation) analysis were performed in a total of twent- three products. The results of the statistical analysis revealed two types of process whose features depended on the relevance to specification and legal limits, as well as the variation levels that were revealed. Due to insufficient product behaviour the process of a specific production was closely examined. Interviews were conducted with the head of the quality department, the head of production, the maintenance mechanic and one of the chemists from the quality control laboratory in order to identify root causes that increase process variation. The results of the interviews are presented through cause-and- effect diagrams. It was concluded that maintenance problems, insufficient documentation of production results, input of rough calculations due to the indigence of the machine and the viscosity of the product are the common roots that lead the process to produce outputs with insufficient behaviour. After presenting the results of the analysis, the company exploited them, firstly by initializing a project of statistically analyzing production results, and secondly by focusing on the maintenance of the specific production line. By initiating these first "steps" the company clearly defines the way of introducing future course of action that can lead to improvement and control procedures. These actions also prove that the usage of SPC procedures is a flexible tool that fortifies fact-based decisions in an economic environment were quality is an option and not an imperative.

Keywords: diagnostic procedures; SPC techniques; weight control

Introduction

In a dynamic economic environment all changes can be presented as a result of various interactions. The most common cause of these reactions is competitors and demanding consumers. In order to enhance competitiveness and increase market share companies worldwide realized (1970's) that simple inspection techniques were no longer sufficient to protect their production scale. The offspring of the progression from reactive (inspection, quality control, quality assurance) to proactive approach is Total Quality Management (TQM) philosophy. TQM can be presented as a functional and flexible framework that encompasses key business processes and quality management principles, which aim at meeting, and hopefully exceeding, customer requirements and expectations. Deming (1982) along with Crosby (1979) and Juran (1988) have proposed quality schemes that involve specific guidelines from the application of which a company can take the "first step" at initializing a widespread quality culture.

The most common approach companies have to TQM philosophy is by pursuing a quality standard certification. ISO 9000, 14000 and HACCP are the most frequently of any acquired standards. An important factor for companies in understanding the function and usage of ISO 9000 is through the Plan-Do-Check-Act (PDCA) cycle, firstly introduced by W. Shewhart (1930's) and later adopted by Deming. W.E.Deming suggested that all business processes be approached through a continuous feedback loop (PDCA cycle) that will enable changes to be tracked and revised. This approach initiated the basis from which systems' information can be collected and transformed into qualitative and quantitative information, mostly with the aim of statistical process control (SPC) procedures (Shewhart, 1920's) as a means to enhance factual decision-making. Therefore, it is concluded that there is a strong relationship between TQM and pursuing ISO 9000 certification. Moreover, the revised version of the ISO 9001:2000 emphasizes on the "soft" elements of quality management, employee participation and human resources management.

A means to approach the current quality management level in Greece is through the published surveys from ISO organization and the Hellenic Organization for Standardization (ELOT). A survey carried out in 2001 by Gotzamani K. and Tsiotras G. revealed that the most significant motives behind ISO 9001:2000 certification are companies' overall quality policy, the quality improvement of final products and the quality improvement of internal operations. These results could verify the claim that standards can help initiate the "first step" towards quality especially for companies that want to become more quality aware and to improve their quality management system. One of the conclusions of a recent survey (2006) by Gotzamani K. and Theodorakioglou Y. on the contribution of ISO 9001 (1994) series towards TQM in the Greek industry was that although certification has improved significantly monitoring and usage of quality data, nevertheless all efforts focused on monitoring and keeping quality data rather than processing and evaluating them for decision-making purposes and for overall quality improvement. Furthermore, it was viewed that certified companies' performance was high in TQM elements directly related to final product quality like quality control processes and recording and availability of data. On the contrary, certified companies' performance was low in TQM elements less directly related to final product such as employee motivation, participation in quality improvement, training in quality improvement methods and statistical techniques and employee encouragement to decision making. Concluding, implementing the ISO 9000 series presuppose that the company has progressed in a culture shift that enables it to assess the eight quality management principles such as customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making and mutually beneficial supplier relationships, without constricting the ways the principles can be approached (tools or methodologies). Moreover, since quality standards, in general, manifest the necessity for record keeping and tangible measurement methods it is obvious that diagnostic procedures like statistical process control (SPC) are prerequisite in order to retrieve the information from the system and transform it into comprehensible data.

Statistical thinking, according to the Glossary of Terms for Statistical Quality Control (ASQ 1996), is a philosophy that is based on fundamental principles such as all work occurs in a system of interconnected processes, variation exists in all processes, and understanding and reducing variation is the key to success. As noted by Makrymichalos et al. (2005) among the possible reasons for lack of statistical thinking in today's businesses is shift in the organizations priorities; statistics have not been applied for managerial issues; managers view statistics as a tool for "fire-fighting actions"; changing the mindset of people in the enterprise; and fear of statistics by managers. There is also the identified inability of companies to process and evaluate effectively quality data, as well as the lack of employee training in quality improvement methods and statistical techniques. Therefore, companies that want to enhance their vitality should realize that quality improvement is not only about standardizing procedures, but also involves process improvement and problem solving strategies. The TQM philosophy, integrated in the quality standards, uses statistical (Pareto analysis, design of experiments, statistical quality control, multivariance analysis) and non-statistical (brainstorming, cause and effect diagrams) tools that are part of a problem-solving strategy, aims at distinguishing common and special cause variation, and establishes greater knowledge of any process.

Background

Control of final product single net weight is a major topic for many companies operating in the food-manufacturing sector. The company in question is one of Greece's major olive oil manufacturing companies. The site manufactures edible oils, cooking fats, margarines, olives, olive spreads and is also distributor of personal care products. The production capacity of the factory is 60,000 tons/year and distributes over thirty (30) brands across its global network of companies in Europe, Africa and Asia. Lately, concerns have been raised from the quality department of the company that there might be some products were final product single net weight is deviating from specifications and therefore they would like to investigate the special causes that lead to single net weight variation, in order to look after their customers and increase their credibility. As a result, the aim of this project is to collect data from the three production lines that are currently operating on full scale, analyze the behaviour of final product single net weight with statistical process control techniques and through the information derived, to help the company view its quality data with the aim of statistical thinking. In addition, propose the company of future corrective measures and actions to enhance process performance and optimize processes behaviour.

Methodology

During the first phase of data collection discussions were held with the head of the quality department in order to assign a proper plan for the attainment of final product single net weight data as well as legal and company's internal specification limits. It is noted that the company does not have a quality standard certification besides HACCP. All collected data refer to a five-month period (December 2004 to April 2005). The behavior of a total of twenty-three (23) products from production lines X, Y and Z was examined. Throughout the duration of the project no information was attainted on any procedure that might be used to assess quality data records. All quality data are documented in paper-kept records from employees operating the relevant production line. Therefore, the first stage of data preparation was to transform them in electronic format with the aim of the statistical software MINITAB® version 14.0. in order to be processed. For each product there are specific single net weight limits that have been adopted from the quality department relevant to legislation, tolerance of the relevant machine and internal procedures.

A preliminary view of paper kept records of final product single net weight revealed that the vast majority of final product net weight fluctuated near target value without major deviation from the company's internal specification limits. Therefore, it was assumed that most products could be presenting normal behavior. None of the three production lines has a system of recording rejected products, or exports rejection rate. As a result, construction of Pareto Chart was impossible in order to identify special causes for processes variation. Taking into consideration that it could not be feasible to obtain any information on prior history of processes behavior it was decided to proceed, as a second phase, in addressing undefined product characteristics through an initial study such as descriptive statistics, time series analysis, normal plots, R and X bar charts, capability analysis in order to identify time patterns or any other special causes that would aim the company to concentrate on the behavior of its products. All quality data were aggregated primarily into separate production dates and the sequence of statistical analysis steps depended on the behavior the product revealed from descriptive statistics and time series analysis. In the X-bar and R chart analysis tests for special causes of variation were performed. Data processing was divided into three categories relevant with the three production lines that were examined. Statistical results and charts are exported with the aim of the statistical package MINITAB® version 14.0. Taking into account the population of the available data (twenty-three products from three production lines) a representative example from the statistical analysis of the product X1 from production line X is demonstrated in table 1 and figures 1, 2 and 3 (appendix).

Results

The end of processes' analysis revealed the presence of two types of process. There was the A type process that produced outputs inside specification limits and on target value but presented relatively high standard deviation. Bearing in mind that the company manufactures products from oil and margarine where the final receiver is the consumer, the difference of two or four grammars is not easily distinguished. In this case one could advocate that the company could find ways of ensuring that the A type process would perform much better. On the other hand, there is the B type process that is producing outputs outside specification limits, although within legal limits, presented very high standard deviation, but median and mean values were very close to target. It was observed that in the case where the process was producing oil range values were under ten grammars, a result which conforms with the ascertainment from type A process that a small deviation in final product net weight would not make any visual difference to the consumer.

The problem became more intense in the case of margarines. Both processes of production line Z are found to be in constant imbalance and since their variation level was significantly high it was decided to focus on the relevant production line and investigate the causes that lead to such inadequate process performance. A summary of the statistical analysis of products Z1 and Z2 is demonstrated in tables 2 and 3 (appendix). Interviews were conducted with the head of the quality department, the head of production, the maintenance mechanic and one of the chemists from the quality control laboratory, in order to identify root causes that increase process variation. The results of the interviews are presented through a cause-and- effect diagram (figure 4, appendix). It was concluded that maintenance problems, insufficient documentation of production results, input of rough calculations due to the indigence of the machine and the viscosity of the product are the common roots that lead the relevant process to produce outputs with insufficient behaviour.

Results from the statistical analysis were distributed to the head of the manufacturing plant, the Quality Assurance Lab and the head of the maintenance. A meeting was held with the Quality Assurance Lab in order to discuss the outcome of the processes' analysis. The company accepted the results of the analysis with positive comments. After a month from the presentation, the company launched in production line X an SPC project to monitor the existing procedures. Moreover, Z was stopped and a maintenance specialist from Germany was appointed to repair the relevant production line.

Discussions-Suggestions

Besides the two positive reactions the company launched to assess its processes' behavior, there are also other important aspects of the overall quality strategy that should be considered or perhaps revised. Lack of articulating quality needs and aspects was observed during the initiation of the project from the Quality Department to the employee appointed to collect the required data. This observation can be the result of both inappropriate record keeping and inadequate employee training in statistical thinking. By familiarizing statistical procedures and techniques to employees, translation of quality data into viewable information will be simpler. Training in statistical thinking should be provided in regular intervals, throughout the hierarchy levels of the company and as a means of self-assessment through which employees and managers will prove that knowledge of the process is not gained only by recording numbers, but by being capable to view and foresee process's behavior with simple means like standard deviation, control charts, normal plots and acceptance sampling.

Excessive amount of time was needed in order to obtain the correct information that would allow the current study to present accurate results on the behaviour of the products produced from production lines X, Y and Z. All final product single net weight checking is documented on paper from employees operating the relevant production line. Throughout the duration of the project no information was attainted on any procedure that might be used to assess these records. The inability of the company to assess in real time quality data behaviour advocates the fact that capability of process cannot rely merely on a hunch. Electronic transformation of single net weight data and review through a statistical process software will aim at fully utilizing work time, design models for predicting process behaviour, establish trail and error study on heavy production schedule and evaluate employee involvement in process behaviour.

From the statistical analysis of final product single net weight it was observed that there are some processes that were producing for a significant amount of time (two to four months) outputs with non-conforming characteristics. This prolonged process behaviour was further enhanced by the inability of the Quality Department to evaluate promptly processes' results. Greater emphasis was given to production line Z as it was proved to be producing products with high variation levels and low capability indices. In order to control a process like Z a sequence of steps should be followed in order to reassure that special causes of variation have been adequately identified and the remaining is only common-cause variation. It is of foremost importance to combine statistical process control techniques with employees with great work experience as SPC charts cannot improve process by themselves. Therefore, training of employees in basic statistical techniques is significant. Continuously, process should be thoroughly planned from start to finish. A detailed process flowchart of machines, materials, methods and employee resources should be available. Depending on the complexity of the process a team including key personnel should be appointed. The control team should be in the position to provide evidence of scrap, rework and excessive overtime in certain process areas. Workers operating the relevant process are usually the ones that are able to target specific problem areas.

Taking into consideration the statistical results of production line Z one way to assess process variation for e.g. product Z1 would be to set up initial study control charts. Process for Z1 has been set to perform on target value of 1000 gr. and specification limits of ± 3 gr. If the relevant process was capable to produce outputs with Cp =1.33 then standard deviation would have been:

$$Cp=1.33=\frac{USL-LSL}{6\sigma} \Rightarrow \sigma = 0.75.$$

For sample size of four (4) the control limits of the x-bar chart are:

$UCL\,\bar{x}=1000+3*0.75=1001$ and

$LCL\,\bar{x}=1000-3*0.75=998$

Additionally, the control limits of the R chart are:

$UCL\,\bar{R}=D4*0.75=2.282*0.75=1.71$ and

$LCL\,\bar{R}= D3*0.75=0$

R and X-bar charts with constructed control limits in comparison to a month's production of Z1 are demonstrated in figures 5&6 (appendix). Through this action the presence of extreme values is easily discerned. Moreover, the construction of control charts with specific target on capability and standard deviation will aim the company to effectively assess variation causes and focus on revising its control limits.

As mentioned previously, the analysis of behavioural patterns of production lines can be achieved through a preliminary study that includes statistical training of employees, formation of process team, descriptive statistics, and control charts. Before initiating a sampling scheme, which could aim to obtain a data set for the study of a process, gauge capability should also be assessed in order to determine the extent of gauge variation. An appointed repeatability and reproducibility study will aim at uncovering the variation caused from operator and measurement error. Considering the example of the company in question, it was observed that in many processes a time pattern occurred during the change of shifts. Moreover, variation in process's behaviour was revealed even on the same production shift. In a Gauge R&R study two to five operators are used to measure in random order up to five parts. The results of the measurements can be presented through a gauge study that is provided by most of statistical softwares. The repeatability of Gauge R&R studies depends mostly on the quality level of the company and the way it addresses the behavior of its processes.

Last but not least, employee training to understand the results of process's behaviour is part of an empowerment scheme that would aim the company at fully utilizing its workforce. Total quality management philosophy emphasizes people participation, which is one of the most difficult subjects due to the complexity and flexibility of human nature. A recent study (2006, reference 3) on the impact of human resources management (HRM) on TQM revealed that HRM practices on training and education, incentive competition and employee development produced the greatest influences on TQM. Through this study it was proved that a combination of HRM practices and TQM philosophy provide total quality and organization performance. In the case of the examined Greek olive oil company Dr Juran's assertion that "quality will improve only when there is proof of the need of it" is both necessary and sufficient. An environment of quality cannot be applied under any circumstance of market pressure and coercion. Total Quality Management philosophy should be received as an option and as not an imperative.

Conclusions

Control of final product net weight is an important topic for many Greek companies operating in the food-manufacturing sector. The aim of this project was to collect data from three production lines of a Greek olive oil company and apply statistical process control (SPC) techniques, as a diagnostic procedure in order to assess final product single net weight variation. Twenty-three products from production lines X, Y and Z through production dates 12/2004 to 04/2005 were statistically analyzed. All data were addressed in a preliminary way such as descriptive statistics, time series analysis, normal plots, R and X bar charts and capability analysis in order to identify time patterns or any other special causes that would aim the company to concentrate on the behavior of its products. In the case of production line Z both processes of products Z1 and Z2 were proved to be in constant imbalance and since the variation level was significantly high it was decided to focus on the relevant production line and investigate the causes that lead to such inadequate process performance. From interviews that were conducted with the head of the quality department, the head of production, the maintenance mechanic and one of the chemists from the quality control laboratory it was concluded that maintenance problems, insufficient documentation of production results, input of rough calculations due to the indigence of the machine and the viscosity of the product are the common roots that lead the relevant process to produce outputs with insufficient behaviour. Moreover, the results from the statistical analysis of all examined products were distributed to the head of the manufacturing plant, the Quality Assurance Lab and the head of the maintenance. A meeting was held with the Quality Assurance Lab in order to discuss the outcome of the processes' analysis. The company accepted the results of the analysis with positive comments. After a month from the presentation, the company launched in production line X an SPC project to monitor the existing procedures. Moreover, production line Z was stopped and a maintenance specialist from Germany was appointed to repair the relevant production line.

Taking into consideration that the company in question is in a primary level of addressing important quality issues a sequence of steps was proposed in order to begin addressing the variation that was identified in most of its processes. These steps included the need for initiating training and educational programs in order to familiarize statistical procedures and techniques to all hierarchical levels of the company. Moreover electronic transformation of single net weight data and review through a statistical software was proposed that will aim the company at fully utilizing work time, design models for predicting process behaviour, establish trail and error study on heavy production schedule and evaluate employee involvement in process behaviour. The combination of statistical process control techniques with employees with great work experience and construction of detailed process flowchart of machines, materials, methods and employee resources was also recommended. A positive action would be to appoint a control team that would include key personnel that will be in the position to provide evidence of scrap, rework and excessive overtime in certain process areas; construction of control charts with specific target on capability and standard deviation that will assist the company to effectively assess variation causes and focus on revising its control limits. Initiation of a repeatability and reproducibility study will help to uncover the variation caused from operator and measurement error. Last but not least, employee empowerment and involvement to decision making was underlined as TQM philosophy emphasizes people participation, which is one of the most difficult subjects due to the complexity and flexibility of human nature.

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Appendix

Table 1: Summary of statistical analysis results for X1 through production dates 07/12/2004-22/04/2005

Date	**07/12/2004**	**08/12/2004**	**15&16/12/2004**	**05/01/2005**	**10/01/2005**	**11/01/2005**
Mean	915,08	915,7	915,04	915,75	915,69	915,04
Max	916	916	916	916	917	917
Min	914	915	913	915	914	913
Range	2	1	3	1	3	4
StDev	0,669	0,47	0,969	0,463	0,896	0,92
Cp	1,03	2,13	1,03	2,16	1,12	1,04
Cpk	1,29	1,61	0,82	1,77	1,03	0,71

Date	**20/01/2005**	**21/01/2005**	**09/03/2005**	**28/03/2005**	**29/03/2005**	**22/04/2005**	**Average Values**
Mean	916,04	916,25	915,86	915,39	915,75	915,59	*915,60*
Max	917	917	917	917	917	917	*917*
Min	915	915	914	914	914	914	*914*
Range	2	2	3	3	3	3	*2,50*
StDev	0,624	0,577	0,632	0,737	0,866	0,844	*0,72*
Cp	1,34	1,73	1,58	1,36	1,15	1,18	*1,31*
Cpk	1,42	1,58	1,11	1,08	1,06	1,02	*1,11*

Figure 1: Time Series plot and Histogram analysis of product X1 through production dates 07/12/2004-22/04/2005

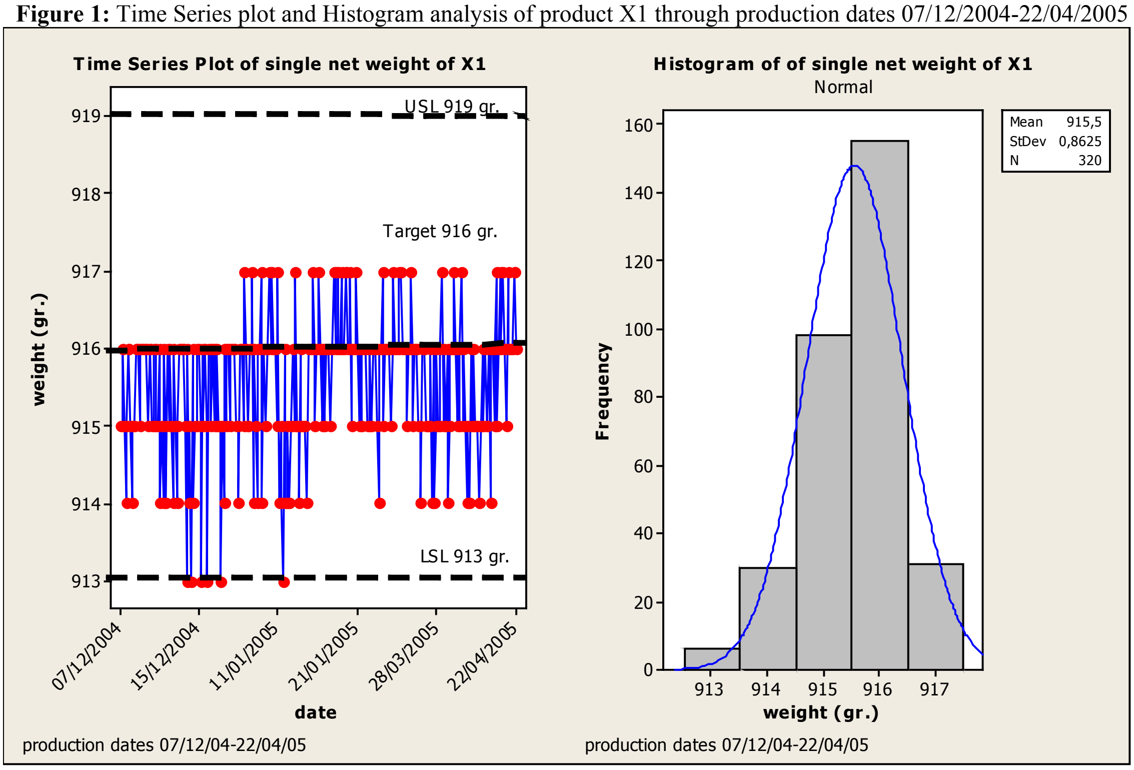

Figure 2: X-bar and R chart of product X1 through production dates 07/12/2004-22/04/2005

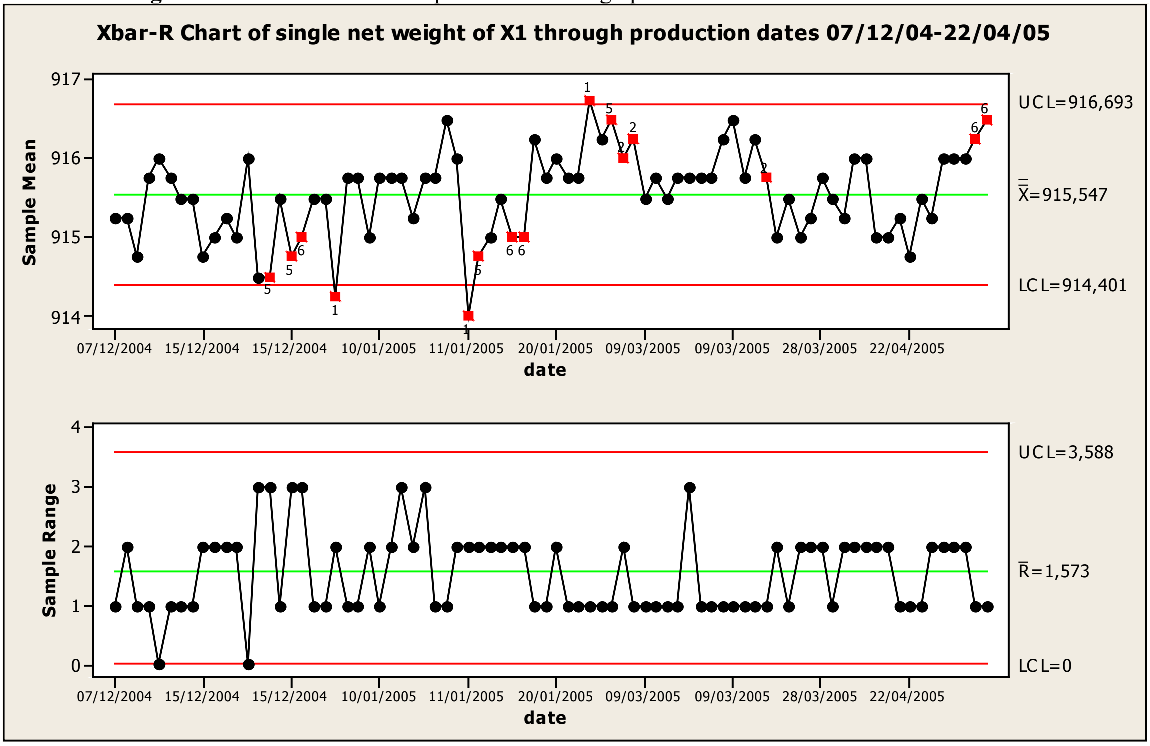

Figure 3: Capability analysis of product X1 through production dates 07/12/2004-22/04/2005

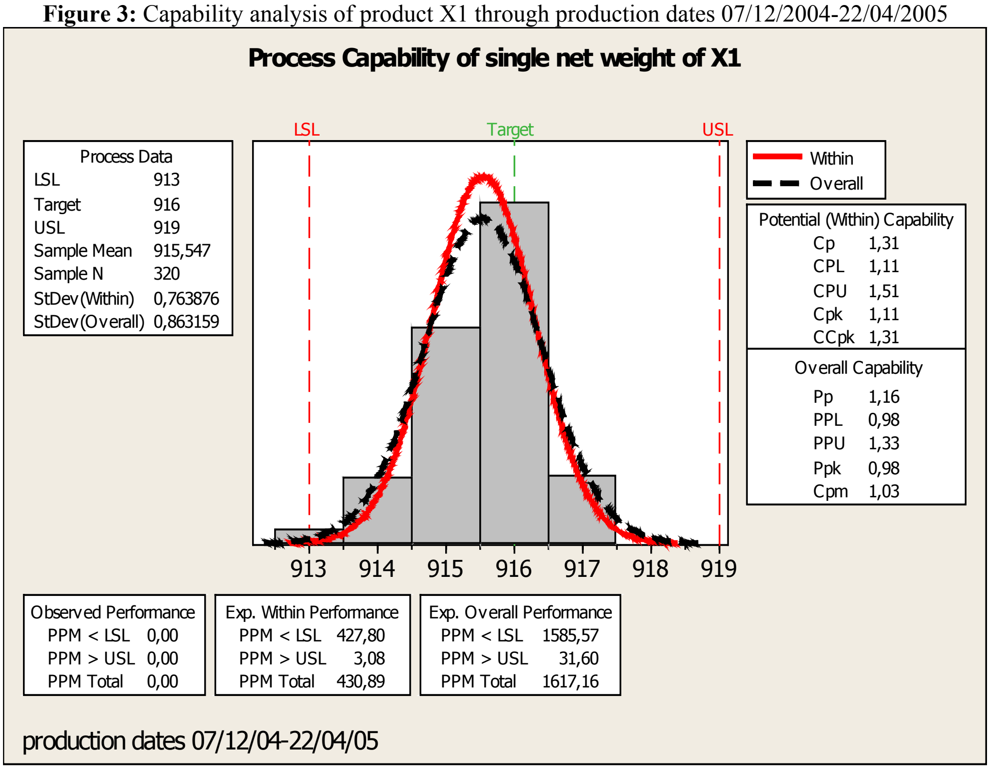

Table 2: Summary of statistical analysis results for product Z1 on the examined production dates of 01/12/2004-12/04/2005

Date	01/12/2004	14/12/2004	15/12/2004	25/01/2005	14/02/2005	08/03/2005	22/03/2005	12/04/2005	Average Values
Mean	999,84	1000,3	1000,7	990,02	997,99	1000	1000,6	1000	998,68
Max	1002	1003	1002	1005	1005	1005	1005	1005	*1004*
Min	995	998	1000	995	955	995	995	995	*991*
Median	1000	1000	1000,5	1000	1000	1000	1000	1000	
R	7	5	2	10	50	10	10	10	13,00
Stdev	1,18	1,15	0,794	3	8,66	2,2	2,75	2,45	2,77
Cp	*0,85*	*0,87*	*1,26*	*0,33*	*0,11*	*0,45*	*0,36*	*0,41*	*0,58*
Cpk	*0,8*	*0,78*	*0,96*	*0,22*	*0,04*	*0,45*	*0,29*	*0,41*	*0,49*

Table 3: Summary of statistical analysis results for product Z2 through production dates 02/12/2004-13/04/2005

Date	02/12/2004	13/12/2004	14/12/2004	26/01/2005	15/02/2005
Mean	1999.5	2000.2	2001.3	1996.7	1998.7
Median	2000	2000	2002.5	1995	1995
Max	2004	2005	2006	2005	2005
Min	1995	1995	1995	1990	1990
StDev	2.92	3.69	4.28	4.63	3.59
Range	9	10	11	15	10
Cp	0.34	0.27	0.23	0.25	0.23
Cpk	0.28	0.25	0.13	0.02	0.13

Date	16/02/2005	09/03/2005	22/03/2005	12/04/2005	13/04/2005	Average values
Mean	1999.5	1999.6	2000	2000.5	2000	2000
Median	2000	2000	2000	2000	2000	
Max	2005	2005	2005	2002	2005	2005
Min	1995	1995	1995	2000	1995	1995
StDev	4.75	4.75	3.78	0.811	2.58	3.58
Range	10	10	10	2	10	9.70
Cp	0.28	0.21	0.26	1.23	0.39	0.37
Cpk	0.23	0.18	0.26	1.03	0.39	0.29

Figure 4: Cause and effect diagram for production line Z process variation

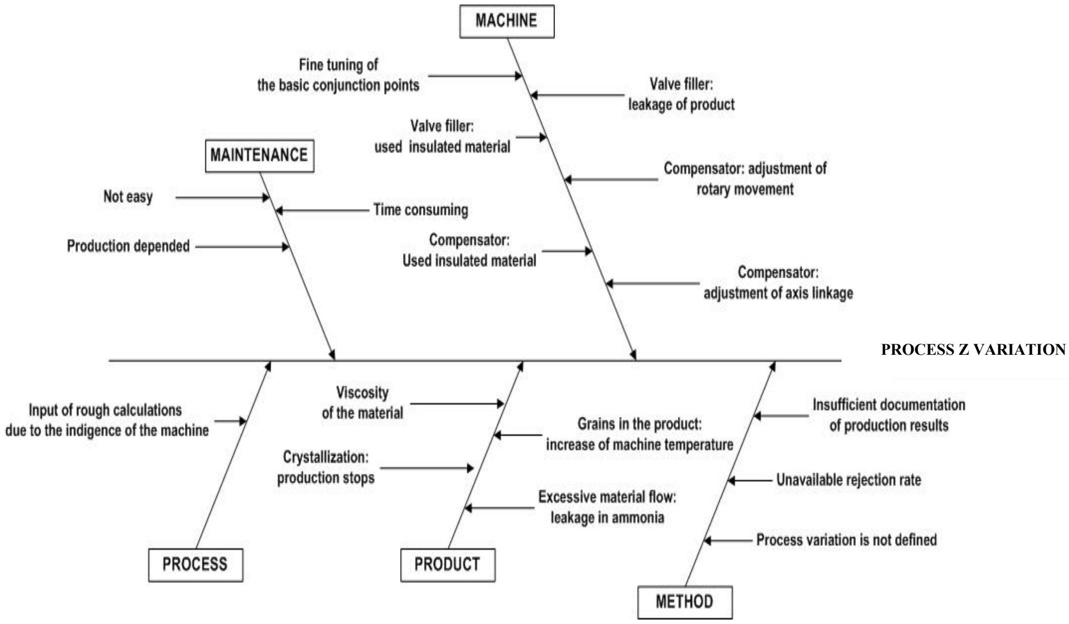

Figure 5 : Comparison of R charts of Z1 with actual measurements and with Cp=1.33, s=0.75

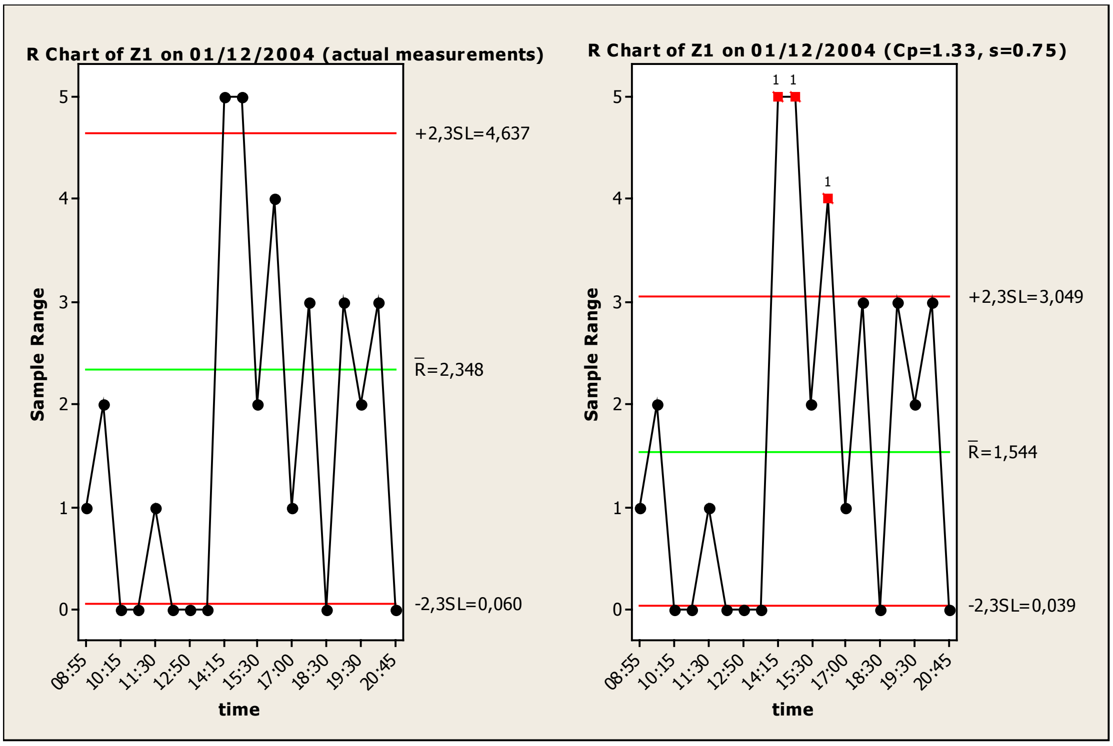

Figure 6: Comparison of X-bar charts of Z1 with actual measurements and with Cp=1.33, s=0.75