



Quality-Cost Analysis of Gasoline Production Process

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ABSTRACT

Process capability provides a quantitative measure for gasoline production conformance to specifications. It was measured throughout four consecutive months of the last quarter of 2011. Results revealed high percentages (up to 44%) of non conforming gasoline blends to Iraqi marketing specifications for petroleum products (2000) by inspecting 122 different samples of Iraqi regular gasoline (RON 85). Quality cost analysis as an important financial control tool was carried out to evaluate Cost of Quality (COQ) which was large due to non conforming gasoline reached up to (722.8 M.ID) in October. In this research COQ was investigated in order to identify the opportunities of gasoline quality improvements through production process. Also customers' direct cost loss due to poor gasoline quality was verified and calculated, where amounted to its highest value (9.084960 M.ID) at November.

KEYWORDS: gasoline, RON, quality, Cp , CPI, CoQ.

تحليل النوعية- الكلفة لعملية إنتاج الكازولين

الخلاصة

توفر مقدرة العملية مقياس كمي لمطابقة عملية إنتاج الكازولين للمواصفات. تم احتسابها للاربع اشهر الاخيرة من عام 2011. بينت النتائج نسب عالية (الى 44%) من خلائط الكازولين العراقية الغير مطابق للمواصفات التسويقية العراقية للمنتجات النفطية لسنة (2000) عن طريق فحص 122 نموذج للكازولين العادي المنتج محلياً (الرقم الاوكتاني بطريقة البحث 85). في هذا البحث تم تحليل كلف النوعية (COQ) كونها أداة اقتصادية مهمة لذلك فقد تم احتسابها، حيث اظهرت النتائج خسائر كبيرة شهرية وصلت الى (722.8) مليون دينار عراقي في شهر تشرين الاول، ناتجة عن عدم مطابقة الكازولين للمواصفات. كذلك فان تحليل كلف النوعية يحدد من فرص تطوير مواصفات الكازولين خلال العملية التصنيعية. تم فيه ايضا احتساب الخسائر المباشرة للزبائن نتيجة النوعية الواطئة للكازولين حيث بلغت أعلى قيمة لها (9.084960) مليون دينار عراقي.

الكلمات الرئيسية: الكازولين، الرقم الاوكتاني بطريقة البحث، النوعية، مقدرة العملية، مقياس مقدرة العملية، كلفة النوعية

1.INTRODUCTION

Quality is the central customer value and it is considered as critical success factor for achieving competitiveness in highly competitive global environment. The Cost of Quality (COQ) is a useful tool in monitoring and achieving cost reductions. COQ analysis is the coupling of reduced costs and increased benefits for quality improvement. Therefore, a realistic estimate of COQ and improvement benefits, which is the tradeoff between quality conformance level and non-conformance costs, should be considered as an essential element of any quality initiative, and thus, a crucial issue for any manager. Any serious attempt to improve quality must take into account the costs associated with achieving quality since the objective of continuous improvement is to meet customer requirements at the lowest cost and the reduction of these costs is only possible if they are identified and measured [Schiffauerova 2006, and Rasamanie 2011].

Gasoline is the largest petroleum product produced in oil refineries and it is considered the largest consumed fuel among others. The quality of gasoline is subjected to compliance with dynamic global development standards. In general, gasoline production process done by crude oil first enters the desalter to remove any salts that may corrode the processing units. From there, the desalted crude enters the atmospheric distillation unit. The separated components are as follows: light straight run naphtha, kerosene, light gas oil (diesel), heavy

gas oil (fuel oils), and atmospheric residue. Light straight run naphtha is sent to the gasoline blending pool and the heavy straight run naphtha is hydrotreated and then sent to the reform unit to produce high octane gasoline.

Production process of gasoline is continuous process to surmount demand crisis of the product [Meyer R. A. 2004].

The updating of gasoline specification is the majority concern of automotive industries, petroleum refining industry, and the governmental regulations [Matijošius 2009, and (WFC) 2012]. Gasoline is multi-component blends obtained by mixing several refinery streams at predetermined concentrations which have properties that satisfy some but not all of the relevant standards, also production units' type at the refinery affect directly the quality of produced gasoline. Modern gasoline blends contain various components, added to improve its performance, meet demands of today's advanced engines' technology, and stringent environmental regulations. The price of gasoline is generally derived by the quality as the process of producing quality gasoline requires the employment of the most advanced and hence rather costly technologies [Matijošius 2009, Xu Xiaohong 2011, and Babazadeh 2012]. Whereas the gasoline production retail price accounts approximately 55% of the major refineries raw material (crude oil) price [Rowe 2007].

Cost minimization dictates that gasoline must be blended to meet rather than exceed



specifications to certain possible extent. So the aim of this research analyzes gasoline process performance also to quantify the cost of poor gasoline quality produced at al-Dura refinery for both customer and refiners.

2. LITERATURE SURVEY

Improving quality is considered to be one of the best ways to enhance customer satisfaction. Quality costs integrate all the separate quality activities into a total quality system. They force the entire organization to examine the performance of each quality activity in terms of cost. Many companies have developed quality cost reporting systems to assist them in identifying, controlling and minimizing these costs [Hwang 1996]. Costs of quality are costs of poor quality that may exist or actually does exist. These costs are divided into; cost due poor quality and cost associated with improving quality. More specifically, are the total of the costs incurred by (i) investing in the prevention of non conformances to requirements(costs of all activities specifically designed to prevent poor quality in products or services) (ii) appraisal costs associated with measuring, evaluating, or auditing products or services to assure conformance to quality standards and performance requirements(include costs of incoming and source inspection/test of purchased material, and the costs of associated supplies and materials), and (iii) failure to meet requirements. These costs are divided into internal and external failure cost categories. Internal failure costs occurring prior to delivery

or shipment of the product, or the furnishing of a service, to the customer such as the costs of scrap, rework, re-inspection, retesting, material review, and downgrading. These costs are identified as huge amount and may range (20-40) % of sales of manufacturing companies, but are (30%) of sales for service industries. It is difficult to get accurate information on the costs incurred with respect to each of these categories. Therefore, measuring and reporting these costs is a crucial issue for managers since cost reduction will result from attacking few problems that are responsible for the majority of quality costs [Anta 2008, Schiffauerova 2006 , Gryna 1998, and Montgomery 2011].

COQ generally represent the costs associated with conformance to specification, as these costs represent the resulted costs from not making a product as standards. An important issue that must be often considered in assessing process performance is the degree to which products fit specifications where process capability (C_p) indices provide a quantitative measure of this conformance [Gryna 1998, and Montgomery 2011]. But the process should be in control before its capability measured [Pearn 2004, Jeang 2009, and Sun 2010].

C_p index focuses on the dispersion of the process, C_p measures only potential of a process to provide an acceptable product. The Process Capability Index (PCI) is a value which reflects quality status, thus enabling process controllers to acquire a better grasp of the quality of their on-site processes [Pearn 2004], and it is used for

measuring their ability to carry out tasks or achieve production-related goals.

A process that is just meeting specification limits (specification range = $\pm 3\sigma$) has C_p value of (1.0). The deviation between process mean and design target can be reduced by having the process mean as close as to the design target without extra production costs being incurred. The process variance can be lowered by tightening the process tolerance, albeit with extra costs incurred. The criticality of many applications and the reality that the process average will not remain at the midpoint of the specification range suggest that C_p should be at least (1.33), Process Capability (C_p) is calculated by [Jeang 2009, Sun 2010, Rezain 2006, and Rao 1998]:

$$C_p = \frac{UCL - LCL}{6\sigma} \quad (1)$$

Where USL and LSL = Upper and Lower Specification Limits.

σ = Standard deviation of the process.

Other type represents in measuring capability with unilateral tolerance. It is measured for actual capability of process which requires upper C_{pu} or lower specification C_{pl} . The Index C_{pu} measures of capability of a "smaller-the-better". While the C_{pl} index measures of capability of a "larger-the better, as shown in equations (2, 3) respectively [Sun 2010, Rezain 2006, Rao 1998 and Aufy 2012]:

$$C_{pu} = \frac{UCL - \mu}{\mu - LCL} \quad (2)$$

$$C_{pl} = \frac{\mu - LCL}{3\sigma} \quad (3)$$

Where μ = process mean

While C_{pk} describes how well the process fits within the specification limits, and calculated [Rezain 2006, Aufy 2012] where:

$$C_{pk} = \frac{\text{Min.}(C_{pu}, C_{pl})}{3\sigma} \quad (4)$$

Gasoline quality is ensured throughout the establishment of technical specifications since gasoline must follow the quality standards set at local markets, meeting car engines requirements, and with minimum possible damage to the environment. The quality of gasoline used in our engines affects engine performance, life expectancy and emissions. It is defined in terms of a range of quality properties such as Research Octane Number (RON), Motor Octane Number (MON), Reid Vapor Pressure (RVP), and Sulfur content etc. Although these properties are essential quality parameters, but gasoline is classified and consequently sold according to its Octane Number (ON) ratings. Generally three common grades of gasoline are specified; Regular, Moderate, and Premium [Jones 2006, Nelson



2010, and Phuong 2007]. High ON values reflect high resistance of the fuel against knocking where two types of octane numbers should be considered; Research Octane Number (RON) and Motor Octane Number (MON). RON provides an indication of how gasoline will perform on mild driving conditions, while MON represents the performance of gasoline at more severe conditions. Each year, as the new automobiles are introduced, to the market both the automobile and petroleum industries are concerned in determining the appropriate ON value of the gasoline needed to satisfy the requirements of the various new models [Phuong 2007, Singh 2000, Ministry of Economic Development 2001, Brinegar 1960, and Kaiser 2010].

Other properties are; the pressure exerted by gasoline vapors in a confined space (measured at 37.8 °C) is Reid Vapor Pressure (RVP) as an important indicator of both volatility and emissions because of the relation of the existing volatile organic compounds and RVP value in fuels. It also indicates the evaporation hazard of the fuel. Sulfur is naturally present in crude oil, Sulfur compounds also contribute to corrosion of refinery equipments and poisoning of catalysts. Also many catalysts are sensitive to Sulfur contamination. Therefore, it should be decreased /removed to balance with the modern regulation in some countries. Hence, additional units should be added to treated gases emission, and waste water according to the changing requirements of environmental regulations [Pandey 2004].

3. EXPERIMENTAL PROCEDURE

To quantify the process performance related to the primary characteristic is RON, the production process should be basically in control. In earlier studies gasoline production process was investigated where analytical study is performed according to data collected from Research and Quality Control Department at al-Daura refinery for period (2010 - 2011). It was recorded that the process is in control for RON parameter during research study period (September–December)/2011, and no assignable variation causes were found [Ismayyir 2012, and Ismayyir and Dawood 2012], **Fig. 1** indicate process performance for RON parameter of gasoline in November / 2011. But in order to investigate the conformance of Iraqi gasoline, evaluate production process and check the degree to which gasoline meets standards. Iraqi standards (2000) were employed to set the USL and LSL for RON parameter, where it is for regular gasoline is (90-85) respectively. **Table 1** shows Iraqi standards of gasoline product [www.mrc.oil.gov.iq].

122 samples of different Iraqi gasoline blends were collected from al-Daura Refinery in Midland Refineries Company (MRC) during four consecutive months (September–December) / 2011. Sample size at al-Daura refinery is determined according to different blending tanks (three tanks) of one litter for each specimen.

Regular gasoline production rate is 2700 m³/day, with production percent(20%) of (RON 85)

value usually from different types of Iraqi crude oils {of different American Petroleum Institute (API) values of density and constituents}. Different components are added throughout off-line blending process, these components are; Light Straight Run Naphtha (LSRN) (RON 63), Reformate (RON 88.5) in a mixture of 30% LSRN, 70 %.{ Heavy Straight Run Naphtha (HSRN) (RON 88.5), and Power Formate (RON87). The production units (catalytic reformate, power former, hydrotreating) provide the component tanks with these intermediate products. Two types of Iraqi crude oils used throughout the study period were al-Basrah and Kirkuk crude oils [www.mrc.oil.gov.iq]. Minitab 16 software was employed to generate process capability values and process capability indexes of gasoline throughout the tested period {last quarter of 2011(September-December)}.**Fig. 2** shows data entry form for RON at September. Employing equations from eq. (1) to eq. (4) the process capability values were evaluated, **Fig. 3 - Fig. 6** shows the variations of gasoline production process performance of the four consecutive months. It could be noticed that higher value of Cp is revealed on October. The percentage of samples that are out of specification (non-conforming) were evaluated and tabulated in **Table 2** within these four months, reaching up to higher value (44.42 %) at November. These results indicates that despite of the improvements at the refinery towards high values of RON throughout blending process, but still crude oil(s) nature play the major role in determining the quality of

gasoline (RON value). API values at September _November were high resulting a decrease RON value therefore, high percentage of non conforming (out of specification) gasoline produced blends. Moreover, at al-Daura refinery there is no down grading in gasoline product since there is only on type produced that is regular gasoline.

4. RESULTS AND DISCUSSION

Although, Iraqi gasoline specification is far behind worldwide developing specification these specification still cannot be met throughout production process. As noticed in **Table 2** the out of specification samples are escalating up to 44.4% and the average for last quarter is about 22% ,which indicate that about 25% of the daily production of gasoline is non-conforming to Iraqi specifications(2000). The impact of gasoline non- conforming to the quality of engines is great, it is not apparent to common users as there is a high demand for this gasoline in the local market, and these users cannot predict the impact of low (out of) quality gasoline. Moreover technically results do not emerge immediately but becomes visible and detectable on the later stage, therefore they don't mind using less quality gasoline.

As any quality issue it is multi facet and requests the collaboration of different activities towards the development of gasoline production process such as using on-line blending where the control, boosting of RON values and other quality parameters so as to improve engine, environmental, and operational effects. Also

additional efforts in quality control activities at al-Daura refinery are required to estimate monthly gasoline production process performance, as well as process control variables that are already estimated there.

COQ is financial control tool therefore it is determined as shown in **Table 3** at the second column of this Table. It could be noticed that the total quantities out of specification during the studied period are equal about one month period of production (about 80000 lit). Consequently, money loss is huge through this period, where as the rough cut of gasoline production process accounts is evaluated (almost 55% of crude oil price [www.oil.gov.iq]) at that period as shown in **Table 3**.

The out of specification gasoline affect common customers' cars/engines performance. This non- conforming gasoline product costs an indirect cost loss due to deterioration of vehicles and engines. Direct loss to common customers that is imparted on buying non conforming gasoline product as it is not downgraded(since only one type of gasoline is sold in the local market to common users at price 500ID/lit). The common customers direct cost loss on buying out of specification gasoline fuel is shown in **Table 4** (in this table it assumed that non-conforming gasoline may be sold at lower price 300 ID/lit.). In the last columns of both **Table 3** and **Table 4**, it could be noticed that Millions of Iraqi Dinars (M.ID) are spent and wasted for both customers and refineries on non-conforming gasoline product. Therefore, Al-Daura refinery must quantify the loss of poor

produced gasoline quality, also they ought to monitor quality costs, and the causes of formation quality costs. Furthermore, it is essential for al-Daura refinery to quantify the elements of the quality costs throughout the production process and classify them according to man, machine, material, method technology and the environment as first step towards decrease/ eliminate the causes of poor gasoline quality.

5. CONCLUSIONS

- i. Gasoline quality is multifaceted; improving the quality requires the intervention of production, quality control activities of the refineries.
- ii. Controlling the quality of gasoline is not enough; the process performance should be monitored to assure that gasoline produced is within Iraqi marketing specification.
- iii. Iraqi gasoline specification should be revised annually to catch up the worldwide specifications, and guarantee the continuous of improvement of the gasoline product that match new cars' introduction technologies, and ever changing environmental regulations.
- iv. COQ is very powerful tool to force the entire refinery to examine the performance of each quality activity in terms of cost. Quality cost analysis should be reported regularly to assist refiners in identifying, controlling and minimizing poor quality costs.

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[\[www.mrc.oil.gov.iq\]](http://www.mrc.oil.gov.iq)

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Nomenclature

API: American Petroleum Institute Value
 COQ: Cost of Quality
 CP: Process Capability
 CPI: Process Capability Index
 CPu: Process Capability upper specification limit
 Cpl: Process Capability lower specification limit

HSRN: Heavy Straight Run Naphtha
 LSRN: Light Straight Run Naphtha
 MON: Motor Octane Number
 MRC: Midland Refineries Company
 ON: Octane Number
 RON: Research Octane Number
 RVP: Reid Vapor Pressure
 σ = Standard deviation of the process
 μ = process mean

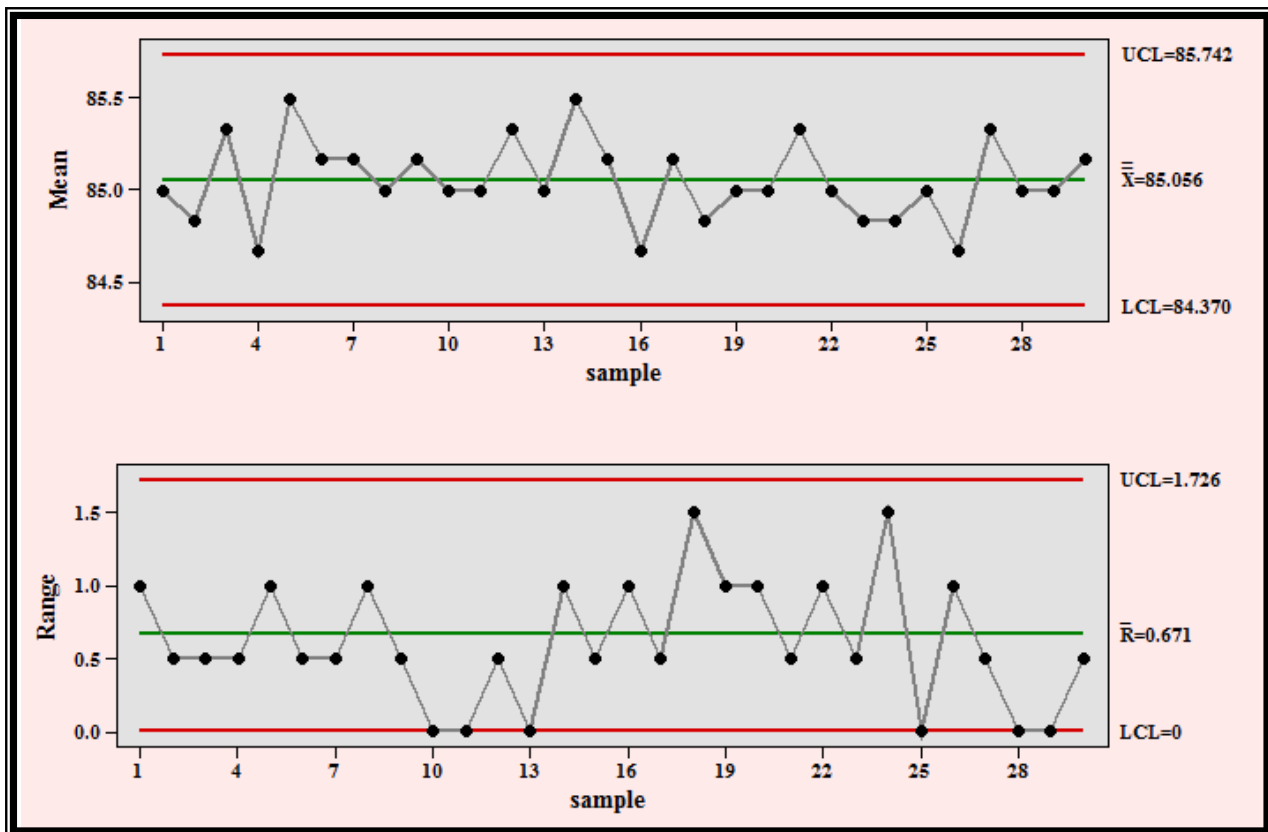


Figure 1. X bar and R control charts for RON of Gasoline at November / 2011 [Ismayyir 2012]

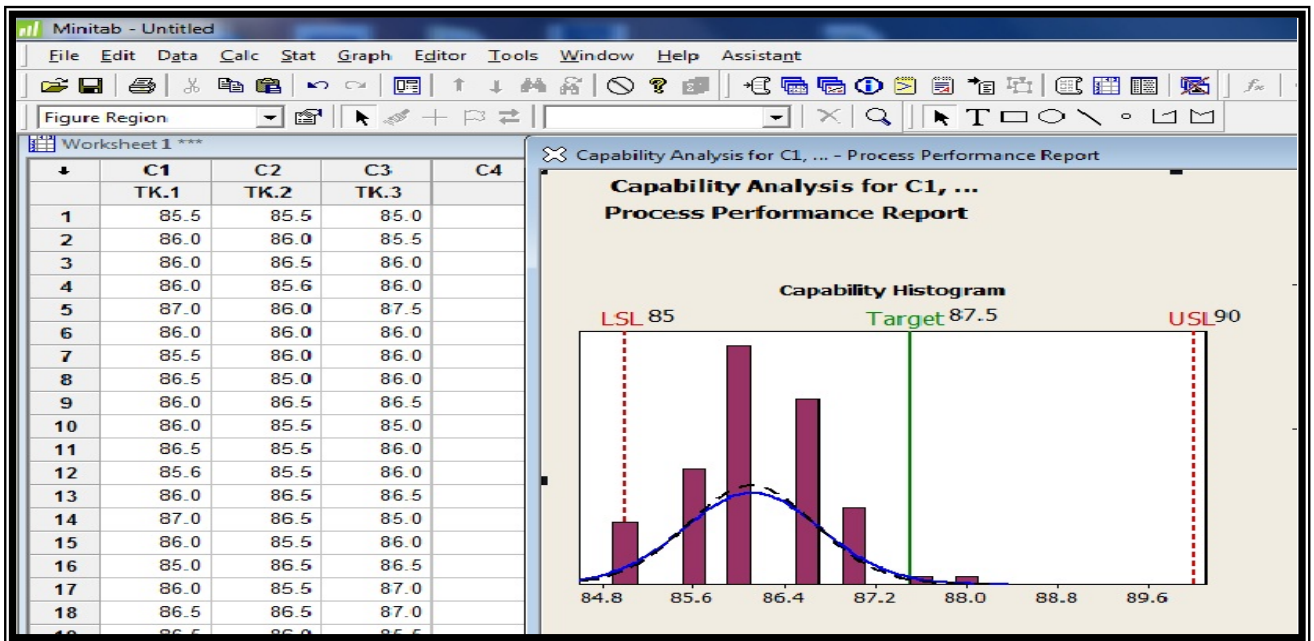


Figure 2. Data Entry Window of RON at September / 2011

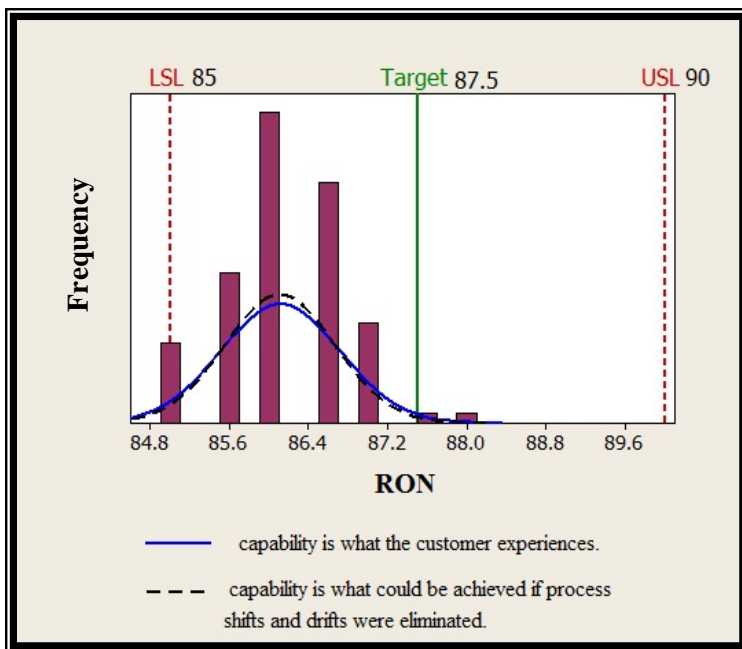


Figure 3. Capability Analysis for RON Parameter in September/2011

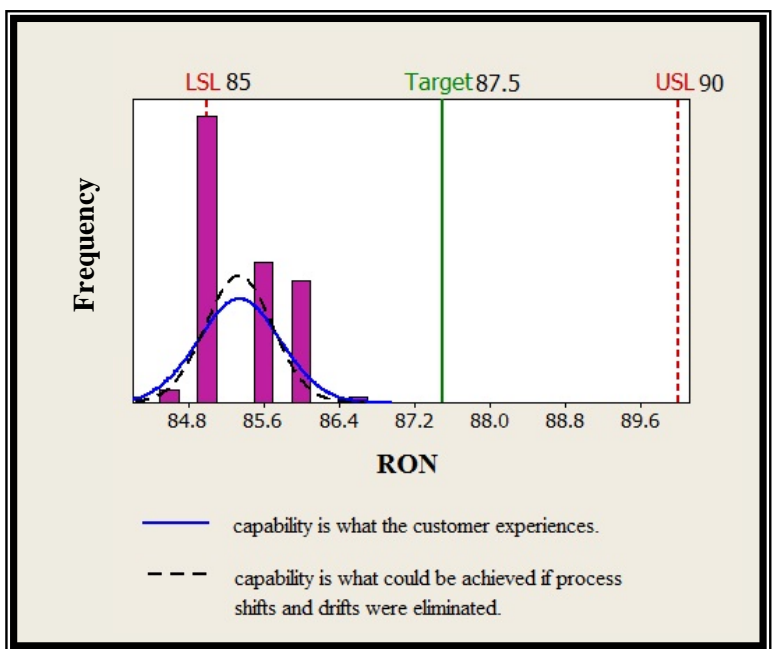


Figure 4. Capability Analysis for RON Parameter in October/2011

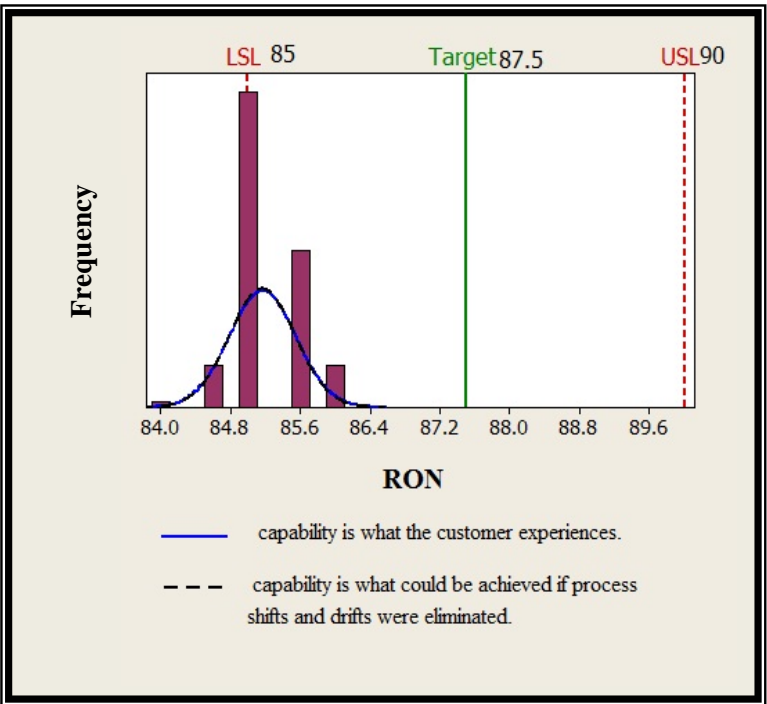
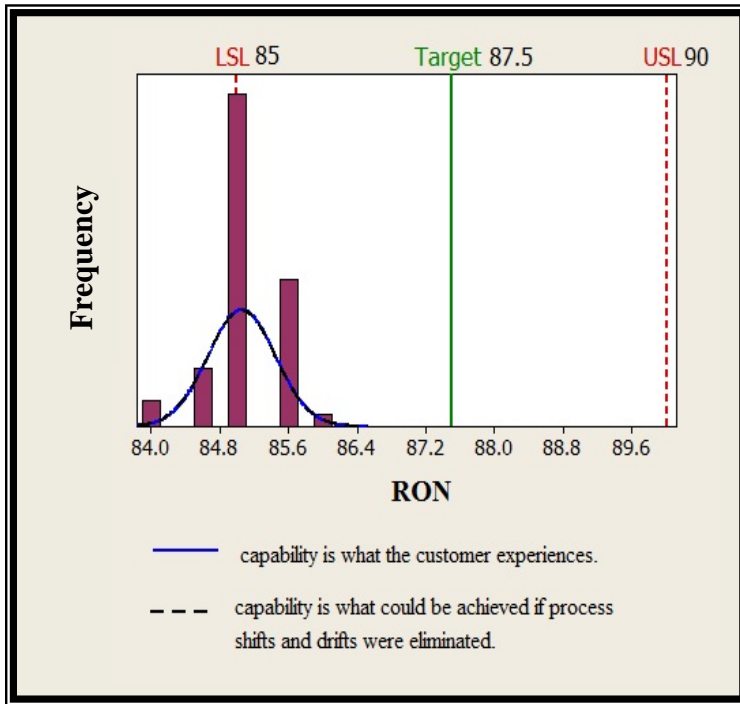


Figure 5. Capability Analysis for RON Parameter in November/2011

Figure 6. Capability Analysis for RON Parameter in December/2011

Table 1. Iraqi Marketing Specifications of Gasoline (2000) / Ministry of Oil [www.mrc.oil.gov.iq]

Parameters	Regular	Premium	Super
Distilled @ 100° C Vol % (min)	30	30	30
Distilled @ 145° C Vol % (min)	70	70	70
Final Boiling Point °C (max)	200	200	200
Color	Yellow	Red	Red
RON (min)	85	91	96
Sulphur Content (wt %) (max)	0.05	0.05	0.05
Exist Gum (mg/ 100ml) (max)	4	4	4
Corrosion (copper strip)	1	1	1
Lead Content (gm/l) (max)	0.1	0.3	0.4
RVP (KPa/ cm ²) @ 37.8 °C	0.45-0.84	0.45-0.84	0.45-0.84
Specific Gravity @ 15.6 °C	0.775	0.770	0.770

**Table 2. Analysis of Gasoline production Conformance (September 2011 – December 2011)**

Month	Cpk	Cp	Out of Specification
September	0.66	0.89	2.4%
October	0.32	1.4	16.75%
November	0.05	1.26	44.42%
December	0.16	1.32	33%

Table 3. Quality-Costs Analysis of Gasoline Production Process

Month	Quantity loss due to lack quality (lit.)	COQ/ M. ID
September	1944	77.29
October	14019.75	722.8
November	35980.2	185
December	27621	142.4

Table 4. Cost/Quality Loss Imparted to the Common Iraqi Customer

Month	Production Quantity/month (lit.)	Monthly Out of Specification Quantity (lit.)	Cost loss by customer(M. ID)
September	81000	1944	0.388800
October	83700	14019.75	6.583950
November	81000	35980.2	9.084960
December	83700	27621	5.524200