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Reduction of bad records using Six Sigma Methodology in Geophysical Field Party of WON Basin, Gujarat, India

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Summary

The philosophy of Six Sigma is to apply a structured, systematic approach to provide defect free processes resulting from breakthrough improvement.

The Six Sigma Methodology was implemented in the Geophysical Services of WON Basin, ONGC, Gujarat. The two pilot projects namely "Reduction of Bad Records" and "Reduction of Bad Channels" were identified. These projects were implemented in Geophysical Party 85. This paper deals with the project "Reduction of Bad Records". The bad records vary in a range of 5% to 25% over a period from December 2004 to March 2006 (table 1). The average bad records were 10%. The Six Sigma methodology is applied mainly in five phases - Define phase, Measure phase, Analyse phase, Improve phase and Control phase (DMAIC).

In the Define phase the objective of the Six Sigma project was firmed up as reduction of bad records from 10% to 6.5% by April 2007, a modest 70% improvement from the average bad records (baseline value) of 10% to the best achieved result (entitlement) of 5% (table 1).

The statistical analysis was carried out in Measure, Analyse and Improve phases of Six Sigma, the results obtained were deliberated and the actions were taken on the key factors contributing to "Out of Optimum Depth (OD) Records". The adverse impact of significant factors such as lack of communication between various tractor operators moving in the field with the main supervisor, Less supply of water, Less number of tractors, hard formation contributing to out of OD shots were controlled by augmenting inputs, improving work practices and reducing time losses.

During the Control phase in the month of April '07, out of OD records deceased to 7.4%. It is 74.3% improvement over existing process capability as observed and measured in April, or in the language of Six Sigma, an increase in Sigma ratings from 1.3 to 1.45.

Introduction

In geophysical field parties of WON Basin the three successful and eventful years of Integrated QHSE Management System has boosted the data quality by adopting the technological developments like 'On-Line Quality Monitoring' using the SQC_Pro of the seismic instrument 408 - UL, Field Processing Units (Geocluster and Geoland software), Shallow Refraction instrument, DGPS survey equipment, Vibrators of NOMAD, Hand Held GPS instruments etc. These have greatly helped in meeting expectations of the client.

The bad records which constitute nearly 10% of the total records (table 1), was an area of concern. To get a breakthrough improvement in reduction of bad records ONGC management hired BMG India to impart theoretical training on "DMAIC" approach of Six Sigma to potential back belts of Geophysical Field Parties. The theoretical training was followed by a project on the topic "Reduction of bad records". The preliminary analysis of bad records revealed that these were due to transmission errors during recording, high level of noise and mainly due to improper depth of shot hole drilling widely termed as "out of OD" records (table 1). Therefore the project was fine tuned as "Reduction of out of OD records"

In Define phase of Six Sigma the Problem statement & Objective statement were firmed up. During the Measure phase the historical data was analysed (figs 1 & 2). Brainstorming discussions were held at camp to find the factors under different processes contributing to out of OD record. Detailed process map (PFD), I/O work sheet, Fish bone diagram, Cause and Effect matrix were prepared.

The factors thus identified were statistically tested to establish their significance under Analyse phase. During Improve phase a relationship between output i.e., out of OD records and the significant input factors was established in the form of $y = f(x)$.

During the Control phase the various sub-processes having significant factors were controlled to keep the out of OD records within the desired limit of 6.5%.

Table 1: Historical data

Month & Year	No of total records	Out of OD records	TE records	Bad records	%
Dec 2004	1032	254	0	254	25
Jan 2005	1914	338	0	338	18
Feb 2005	2569	324	0	324	13
Mar 2005	2789	253	0	253	9
Apr 2005	2509	138	0	138	6
May 2005	2827	135	0	135	5
Dec 2005	1099	204	3	207	19
Jan 2006	2835	230	8	238	8
Feb 2006	2717	198	17	215	7
Mar 2006	2586	279	11	290	11
	22877	2353		2392	10

TE: Transmission error

Phase Time frame	Define, Measure	Analyze	Improve	Control
Planned	Dec 01, 06 to Dec 20, 2007	Dec 21, 06 to Feb 14, 2007	Feb 15, 07 to March 31, 2007	Apr 1, 07 to Apr 26, 2007
Actual	Dec 01, 06 to Dec 22, 2007	Dec 23, 06 to Feb 15, 2007	Feb 16, 07 to March 31, 2007	Apr 1, 07 to Apr 26, 2007

Table 2: Time frame of DMAIC phases

The planned and actual time frame of DMAIC phases are shown in table 2.

Methodology

The application of Six Sigma DMAIC (Define phase, Measure phase, Improve phase, Analyse phase & Control phase) methodology to solve the problem of bad records is given below.

2.1) Define Phase

The historical data was analysed in Define phase (figs 1 & 2). For a good record the Drilled Depth should be plus or minus 2 m of the optimum depth (fig 1). The records beyond this range were considered as bad records.

Fig 2 depicts that out of OD holes are minimum in within a range of 28 to 35 m and these increase substantially in the ranges of 24 to 26 m and 36 to 41 m.

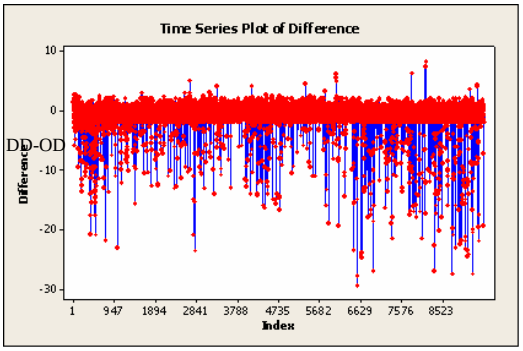

Fig 1: Time series plot of out of OD records

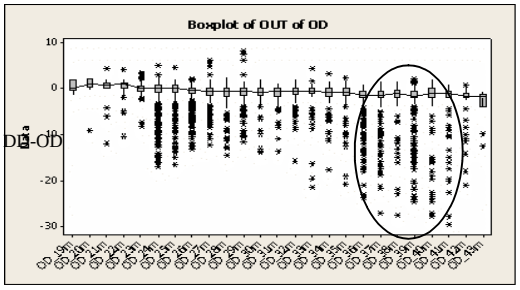

Fig 2: Out of OD records at different drilled depth

2.1.1) Problem Statement:

An average of 10% Bad records in Seismic Data Acquisition in WON Basin from Dec. 2004 to March 2006 against limit of 5%.

2.1.2) Objective Statement:

Reduction of out of OD shot holes from 10% to 6.5% i.e., to increase the Sigma level from 1.3 to 1.5 by April 2007.

A macro map of seismic data recording was prepared to know the process generating bad records (fig 3).

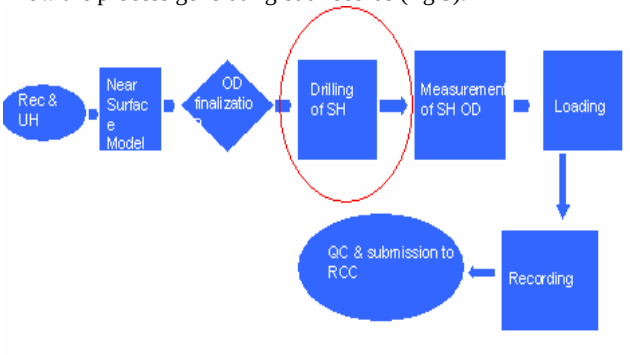

Fig 3: Macro Process Map of Seismic data recording

The drilling of shot hole is the main process. The desired result in Six Sigma methodology can be achieved by controlling the significant input factors of the sub processes of shot hole drilling. The main process of shot hole drilling was divided into sub processes. The activities which were not defined by the management are shown in red in fig 4.

2.2) Measure Phase

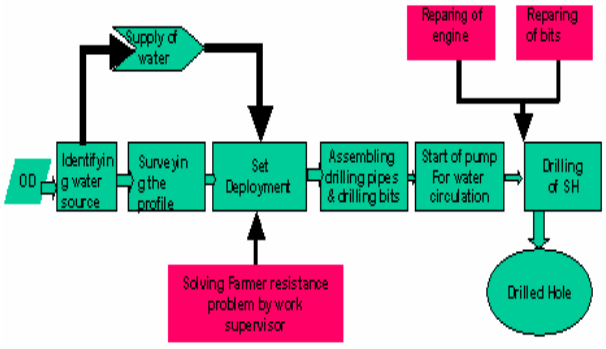

Fig 4: Detailed Process Map of Shot Hole Drilling

In Measure phase brainstorming sessions of process experts along with black belt and facilitator were held to list out the factors causing out of OD records. The Input/Output sheet consisting of Process Out put details and process input details was prepared (Unpublished report on "Reduction of bad records). The Cause and Effect (Fish bone diagram) was prepared and all the factors which might have lead to bad records were listed under the six heads ie, man, machine, material, method, measurement and environment (fig 5).

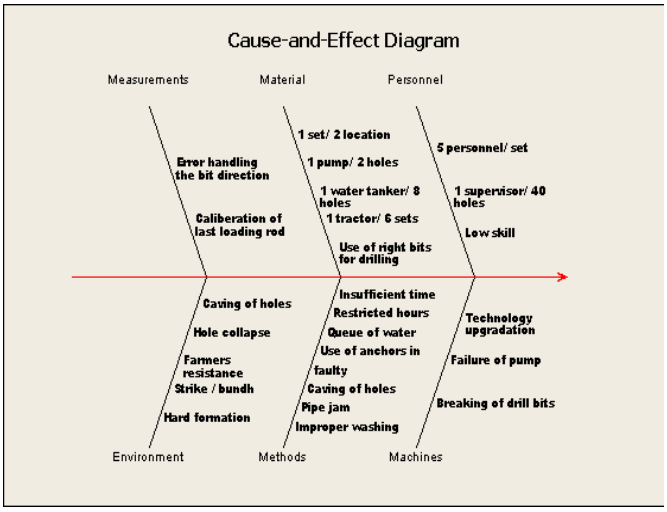

Fig 5: Cause and Effect (Fish Bone) diagram

From Input Output sheet and Fish Bone diagram Cause and Effect matrix was prepared listing out all of the input factors of various sub processes. Each factor was given weightage on the basis of its effect in generating a bad record. The factors with high score of 90 and above on a scale of 100 were taken out for further studies. This exercise has filtered out the 7 non significant factors from a total list of 18 factors (Unpublished report on "Reduction of bad records).

Based on the study in Measure phase, the 11 factors causing out of OD records were:

1. Lack of communication amongst drilling crew
2. Less supply of water
3. Hard formation
4. Low skill
5. Water loss
6. Less drilling time
7. Less supply of diesel
8. Less number of tractors
9. Less number of drilling sets
10. Queue of water tanker
11. Restricted working hours

2.3) Analyse Phase

2.3.1) Hypothesis Tests

The significant factors identified were statistically tested to see that whether they really affect the drilling of optimum depth or they have been listed merely on the basis of brainstorming. The statistical tool applied was Mean test on the data collected for the above 11 factors. The detail of Mean Teat for the factor of lack of communication is given below:

2.3.1.1) Mean Test (T – Test)

The lack of communication between various tractor operators moving in the field with the main supervisor was causing delays. Farmers on account of fear of losses to crops stopped the tractors. Due to lack of communication the tractor has to wait for hours together. The set supervisors were also not able to communicate the problems of drilling bit, delay in water supply etc to the main supervisor causing in delayed release of holes. In order to solve this problem the communication sets were provided to drilling crew and **Two-sample T Test** was run to see the effect of improved communication amongst drilling crew. The details are:

	N	Mean	St Dev	SE Mean
Before provision	10	8.10	6.33	2.0
After provision	10	0.80	1.03	0.33

Difference = mu (Before use of communication sets) - mu (After use of communication sets)

Estimate for difference: 7.30000
95% CI for difference: (2.71018, 11.88982)

T-Test of difference = 0 (vs not =): T-Value = 3.60 P-Value = 0.006 DF = 9

H0 = No difference in out of OD holes before and after uses of communication sets i.e., $\mu_0 = \mu_1$

H1 = Out of OD holes reduced after uses of communication sets i.e., $\mu_0 > \mu_1$

The value of P as calculated above is < 0.05 there for the null hypotheses (H = 0) is rejected. That is Out of OD holes reduced after provision of Walkie talkie and mobile phones. Use of communication sets (Walkie talkie and mobile phones) was a significant factor (fig 6).

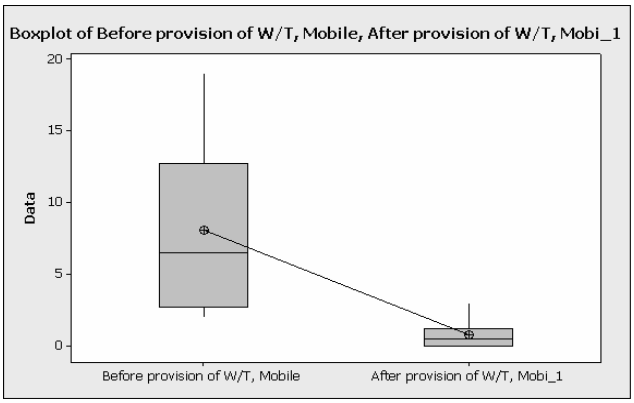

Fig 6: Box plot before and after provision of W/T, Mobiles

Means test was carried out on other 10 factors also and it was found that only 7 factors (numbered 1 to 5 and 7, 8) were significant (fig 7).

The problems of less number of tractors and less supply of diesel were discussed with the contractors' representative. It was agreed by him that the tractors would be increased from 10 to 12 for shifting man and material and supply of diesel would be augmented.

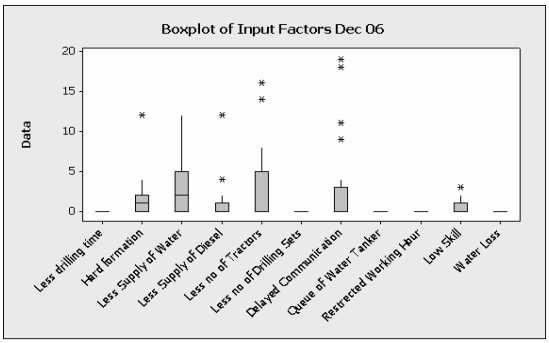

Fig 7: Box plot of Input factors of Dec 06

The measures mentioned above have solved the problems of less number of tractors, less supply of diesel and lack of communication. The insignificant factors are also reflected in fig 8. The remaining 4 significant factors need to be controlled. Out of these hard formation and water loss are noise factors (the factors which are difficult to control). Less supply of water and low skill are controllable factors.

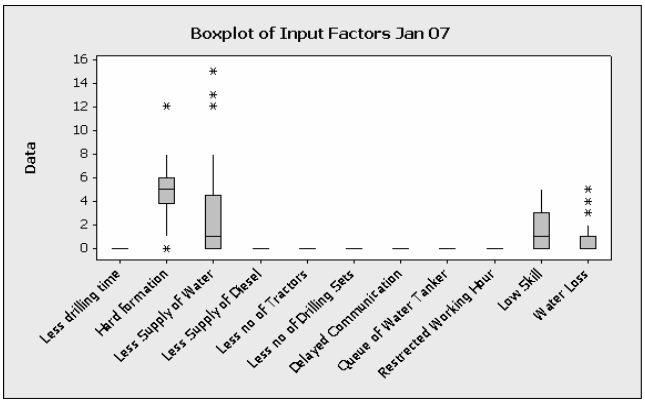

Fig 8: Box plot of Input factors of Jan 07

2.4) Improve Phase

Under Improve phase the equation y=f(x) was derived using Binary Logistic Regression.

The various abbreviations used in arriving at the equations are : OOD (Out of OD), HF (Hard formation), Sk (Skill), WL (Water loss), WS (Water supply (less)).
The equation derived using the data is

Y (Out of OD) = 1.866 + 0.297 Sk + 0.853 WL – 0.861 WS
Odds = Ratio of success to failure
The probability of Out of OD due to Skill ; Sk = 1, WL = 0, WS = 0
Y = 1.866 + 0.297 = 2.163
Y = ln[p/(1-p)]
$e^{Y =}$ p/(1-p) = [.897/(1-.897)] = 8.7
eY = $e^{2.163}$ = 8.7

Table 3: The statistical parameters of the equation

Factors	Coefficient	Odds	Probability	Odds Ratio
HF (Hard formation)	1.866	6.5	0.866	
Sk (Skill)	0.297	8.7	0.897	1.35
WL (Water loss)	0.853	15.1	0.938	2.35
WS (Water supply)	-0.861	2.7	0.732	0.42

The factors of Hard formation and Water loss have 73% and 89% probability affecting a hole for falling in out of OD range. These factors can not be eliminated, only their effect in causing out of OD hole can be reduced . Water Supply and Skill have 73% and 89% probability affecting a hole for falling in out of OD range.

The likelihood of out of OD record due to water loss was 15.1 whereas for less supply of water it was 2.7.

2.5) Control Phase

Statistical Process Control (SPC) method was applied. Run charts were made for the data generated on input factors namely less supply of water, low skill etc. The run chart is simply time series plot. They show cycles, trends, sense of stability and provide some predictability.

If the out of OD holes cross the specified limit on any day, drilling contractor was asked to apply remedial measures and if the problem persisted on the second consecutive day drilling was stopped. The input factors causing out of OD records was corrected and thereafter the work was resumed.

The purpose of "Out of OD records" project was to empower the contractor's workers through their management to act to prevent the problems at first sight of an issue. An action may be taken without the permission of supervisor in accordance with the Standard Operating Procedures (SOP). Any deviation from the SOP will require the permission of the supervisor

The run charts for two factors Hard formation and Supply of water show that values are falling within range (figs 9 & 10). Similarly the run chart for low skill and water loss were also made.

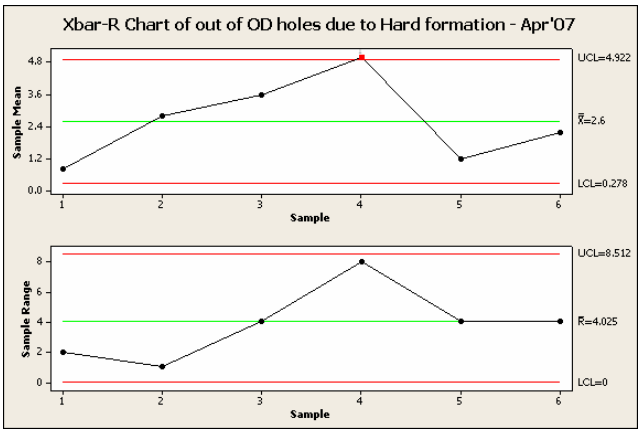

Fig 9: Xbar-R chart of out of OD holes for Hard Formation

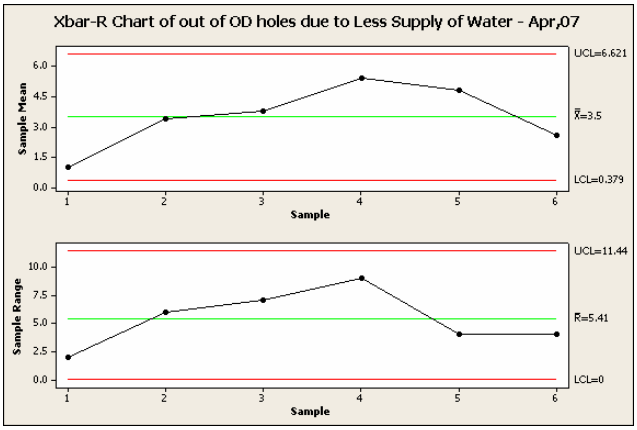

Fig 10: Xbar-R chart of out of OD holes for Less Supply of Water

2.6) Realise Phase

During the realize phase the gains obtained from Six Sigma methodology will be recorded upto April 2008

3. Benefits accrued

Two major benefits accrued are defect reduction and improved customer satisfaction. Better quality seismic data acquired has increased the confidence of mapping subsurface.

Other intangible benefits were:

- Employee awareness of loss of seismic data due to out of OD hole,
- Understanding of the concepts and application of the various tools utilized within this project,
- Employee's accountability and ownership of the processes.

4. Conclusion

The out of OD records were reduced to 7.4% during the period 1st April 07 to 26th April 07. It further reduced to 4.6 % in next 10 days. The best achieved practice i.e., entitlement of 5% is achievable by controlling the supply of water to the shot points. The following points should be adhered to

- Water storage point to be 4 to 5.
- 1 water tankers per 5 drilling sets is required.
- Water supply is to be monitored and controlled by contractor supervisors.
- For Hard formation 5 carbonised drilling bits for 3 drilling sets has given excellent results.
- To reduce water loss, casing of hole, Cow dunk or bentonite is to be continuously used.
- The skill of the set supervisors is to be ascertained before handing over the job.
- Use of mobile phones to communicate amongst the drilling, shifting crews and supervisors.

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