CONTINUOUS IMPROVEMENT OF DRILLING ULTRA-SHALLOW HORIZONTAL WELL THROUGH LEAN SIX SIGMA METHODOLOGY

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Abstract Low oil price environment impacted to business of Oil and Gas Company including PT. SDEC. However, PT. SDEC was able securing limited and fixed capital budget to drill well and had committed to drill certain well number to Government of Indonesia. When the initial 12 wells were completed with longer cycle time (average 9.9 days/well) than business plan (7.5 days/well) and also higher cost, the problem became more complex because company needed to complete well as per commitment and in other hand no additional capital would be spent by parent company if actual expenditure exceeded the initial budget. Company assigned a team to solve the problem through Lean Six Sigma. Through strong collaboration among teams, the project execution performance was improved (the $CP$ of drilling cycle time was improved from 0.06 to 1.08). As the result of this project save cost around $ 2.8 million

Keywords: DMAIC, Drilling cycle time, Lean Six Sigma, Ultra-shallow Horizontal Well

1. Introduction

PT. Suwarnadwipa Energy Company (PT. SDEC\(^6\)) is a major Oil Company in Indonesia, which works under PSC term with Indonesia (represented by SKKMIGAS as representative of Government of Indonesia/GoI).

![Figure 1. PT. SDEC Area of Operation](image1)

PT. SDEC is one of subsidiaries of EC\(^8\) Inc., which is considered as one of the biggest energy Company in the world. PT. SDEC manages many fields which are all located in onshore area, one of them is called Uap Panas (UP)\(^9\) field. The size of UP field is about 18 km long by 8 km wide, this field composed of 14 areas. The main production formation are named sand 1, sand 2 and sand 3. The lithology of those formation is unconsolidated sandstone with 2,000 – 3,000 mD permeability. The depth of sand 1-formation is around 350 – 450 TVDSS, while sand 2-formation is around 450 – 550 ft TVDSS and sand 3-formation is around 550-650 TVDSS respectively.

![Figure 2. New Well Count Drilled by PT. SDEC for](image2)

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Historically, PT. SDEC had massive drilling activities, it was considered as company with the highest drilling activities in Indonesia. PT. SDEC drilled hundreds wells in many fields across company’s working area (concession) including drilling in UP field. During 2013 – 2015, team D&C of PT. SDEC drilled hundreds wells per year (see figure 2).

During low oil price environment, many project including drilling new wells became uneconomic and were dropped due to could not pass the economic hurdle. This situation created huge impact to all stakeholders. If all drilling new well projects were dropped, several impacts would be occurred such as:

- The production decline rate would be higher than original plan, it would impact to national oil production.
- Drilling rig contract would be terminated
- Supporting contract of drilling would be terminated as well
- Potential of employees lay off massively both for PT. SDEC itself and also for business partner
- Would impact to surrounding community

Consider those situation, project teams of drilling projects re-evaluated the project, including also project team of drilling Ultra Shallow Horizontal well projects in UP field.

After did several high effort, project team was able to develop very promising strategy. Therefore, management gave green light for this project to be executed. However, since the technical risk was higher compare to previous similar projects and in other hand the supporting data was very limited, even though it had been planned thoroughly, problem was still exist during execution and causing longer cycle time/CT (average 9.9 days/well) compare to Business Plan/BPlan (7.5 days/well).

This research is intended to find out the solutions to improve drilling cycle time (focusing on cost reduction). This research will identify the possible areas to be optimized and how to reduce the cost. This efforts are expected to give benefit around US$ 2.25 million at the end of control phase with calculation assumption:

- This project will be able to improve and achieve drilling cycle time as per target in BPlan
  Improvement = CT of baseline – CT in BPlan

2. Drilling Horizontal Well

An oil well is a hole into the earth which is drilled by using drilling rig and several supported equipment by rotating a drill string which is completed by a drill bit in front of that drill string. Once the hole is established, metal casings are inserted to the hole and usually cemented to give well integrity. The drilling project start from planning phase. Generally activities in planning phase (well design) for D&C cover completion design, casing design, cementing design, mud design, well trajectory (directional) design, BHA design, rig selection, cost estimation development & secure AFE, contracting and material purchasing, etc.

Execution phase will be initiated with well pad (platform) preparation. Once well pad is ready, rig will move in and rig up the rig. Spud in is terminology to describe the first drilling (bit make a hole). Operation team will execute the drilling process by follow the drilling program, step by step, well section by well section until new well is completed.

A horizontal well basically is a directional well but have higher inclination, typically it will be more than 85 degree
inclination. In production section of horizontal well which has inclination around 90 degree (usually called lateral section), the hole drilled follow formation layer, the objective is to get longer exposure to interest zone (more pay zone), longer pay zone can increase the production of hydrocarbon. Recently, many oil company drill horizontal well to optimize their production and generally the well cost per barrel oil produced will be cheaper. Due to length of lateral section will have positive correlation with oil production, it trigger oil company to drill as long as possible of lateral section, they try to beat each other by achieving the longest lateral section.

3. Evolution Horizontal in UP Field

UP field is categorized as the busiest field from drilling activity in PT. SDEC. Horizontal oil wells in UP field was introduced in 1999, but that type well was not continued due economic reason (the well cost was very high, at the time it was considered not economic). So, the drilling development in UP field was dominated by vertical wells. Some directional wells project was initiated on 2010 due to surface limitation.

Refer to subsurface team review, that in several area, oil remaining in certain sub-sand layer was exist and consider also there was success similar project in other country, then horizontal oil well campaign in UP field was introduced again in 2009 (as trial project). From 4 trial wells, there was promising result both from executability and production. As the result, starting 2011, PT. SDEC had developed horizontal oil well in UP field, this well type was considered as extended reach well because the true vertical depth (TVD) well in this field was around 600 – 700 ft TVD and average total depth 2,200 ft MD (the ratio of MD to TVD was around 3). Due to the true vertical depth (TVD) value was very shallow, then this type well was called as shallow horizontal oil well. In this period, the well design used was big design (using big size of casing) and the average drilling cycle time of shallow horizontal well was around 14.5 days/well.

On 2013, there was trial to drill one well with shallower TVD using slim hole design. Starting 2014, opportunity to drill shallow horizontal well was decreasing and the available opportunity was to drill in shallower depth. The shallower TVD (this type well was called as Ultra Shallow Horizontal Well) would creating more complexity. Starting package 1 which drilled in 2011 until 2018, there was a lot of change done for horizontal well drilling project to improve the performance.

4. Improvement through Lean Six Sigma

In this paper, the root cause of the problem will be analyzed using Lean Six Sigma (LSS) methodology. Actually Lean Six Sigma is combination of Six Sigma and the lean manufacturing/lean initiatives. Lean initiatives are fantastic to improve the productivity, culture changing, et cetera within short time; however lean initiatives don’t have tool to fix unseen quality problem. Six sigma is data-driven approach which intended to produce consistent products/services (reducing or even eliminating defects). Six sigma is very powerful to uncover root causes, focused and effective; however six sigma usually take long time. A combination of both lean initiatives and six sigma will provide the tools to create business improvement (Smith, 2003, p.1, [7]). George (2002, p.6, [2]) described that Lean Six Sigma is a methodology that maximizes shareholder value by achieving customer satisfaction, quality, process speed, cost and invested capital in the fastest rate of improvement.

The concept and objective of Lean is to identify and eliminate things which do not have or give additional value (people call it as waste), as the result the cycle time will be accelerated. Usually people use acronym DOWNTIME (use the first letter of every waste), as the result the cycle time will be accelerated.

- Motion: unnecessary people movement
- Processing/Over Design: more materials and or products
- Defect/Rework: out of specification products/services which need resources to correct it
- Over Production: produce more than requirement or before is needed
- Waiting on/Delays: inefficient time due to waiting on some material, services, next step readiness
- Non-utilized talent: underutilizing people’s knowledge, talents and skills
- Transportation: unnecessary movement of materials and or products
- Inventory: over production and or excess unprocessed materials
- Motion: unnecessary people movement
- Extra-Processing/Over Design: more working done or higher quality than should
be (required by customer)

Erick C. Jones (2014, p.72, [4]) classified waste become 7 categories which are known as “Oh-no seven source of waste”, those seven categories as same above list, the only category not included is Motion.

Once company able to eliminate the waste or “non-value added” along entire value streams, company will operate efficiently and effectively. As the result, company will require less resources (less capital, less human efforts, less time).

Pyzdek and Keller (2010, p.148, [6]) stated that five steps of Lean Six Sigma Project:

- Define: establish the goals or targets of the improvement activities, incorporate into a project contract.
- Measure: activity to know the existing system, determine reliable and valid variable (metrics) to support monitoring progress of target, determine the baseline performance.
- Analyze: analyze the system to find out the potential root causes, close the gaps between existing performances of current system with the goals. In this step, statistical tools commonly used to help the analysis.
- Improve: After understand the root causes and have solution from analyze phase, in this phase we will improve the system by implementing the solution. The quality and creativity of project team during analyze phase will directly impact to the quality of offered solution. The user of lean six sigma including PT.SDEC, usually expect safer, better, faster and cheaper result. The improvement can be validated use statistical method.
- Control: in this phase we talk about how to sustain the improved one. To sustain the improvement, usually project team will develop clear guideline about what to do, the PIC, how to measure to ensure that the improvement will be sustained. 

Jones (2014, p.65, [4]) explained about six sigma approach which known as The Juran Six Sigma approach, the component is DMAIC (like mentioned above) + replicate which using know-how, knowledge, skill acquired by team to improve other problem.

PT.SDEC’s Lean Six Sigma DMAIC Framework depicts in figure 3:

![Figure 3. DMAIC Framework of PT. SDEC](Source: Internal Data PT. SDEC)

4.1 Define Phase
The objective of this phase is to express the encountered problem which is extracted from business issue and to establish a team to solve the problem. Define phase cover:

- **Project Team forming.** Align with PT. SDEC’s guideline about Lean Six Sigma, this project was composed of project sponsor, project champion, project facilitator, project team members and project resources.
- **Identify the opportunity.** The opportunity was improving drilling cycle time and reducing drilling cost so PT. SDEC could complete all proposed wells as per business plan. As described in section 1 about business issue, during low oil price environment, only limited capital spent in Oil & Gas Company including in PT. SDEC. Even though PT. SDEC had been successfully secured certain amount of capital from parent company to drill new well, but the amount was fix. When 12 wells which drilled in second semester of 2017 completed with longer cycle time which was causing higher cost than business plan, project team was requested to overcome the problem soon, otherwise with same amount, PT. SDEC would be able to drill less well number. In other hand, when PT. SDEC had proposed certain number of wells to SKKMIGAS through WP&B, SKKMIGAS would keep asking to drill same number of wells as per WP&B (SKKMIGAS will more focus on number of wells to support production instead of focus on budget limitation).
- **Voice of Customer.** The customer of this project were Business plan team, Asset team and D&C team. The voice of customer summarized in Appendix 1
• **Project Scope.** Described in table 1

| Parameter          | In Scope                      | Out of Scope                                                                 |
|--------------------|-------------------------------|------------------------------------------------------------------------------|
| Area               | UP Field                      | Other field in PT.SDEC                                                        |
| Well type          | Horizontal Oil Well (HOW)    | Other type well (vertical & directional)                                      |
| Task sequence      | Drilling activity only        | Before and after drilling activity (such as well pad preparation, POP, etc.) |
| Discussion boundary| • Discussion focus on drilling cycle time improvement & cost reduction | • Detail technical (engineering part)                                        |
|                    | • Completed Ultra-Shallow HOW | • In-completed well (for example due to significant problem well A was not completed as Ultra Shallow HOW) |

• **Project Contract.** To formalize and as documentation, this project documented in project contract.

4.2 Measure Phase

The objective of this phase is to know and to understand parameters that affect on performance. Measure phase cover:

• **Determine Measurement Parameters.** The metrics would be measured for this project were Health, Environment and Safety (HES), drilling cycle time and drilling well cost.

• **Determine Measurement System.** Project team will use data from daily drilling report to get those three data.

• **Data Collection & Determine Baseline.** Data was collected from 12 wells which were executed during 2nd semester of 2017. The record system of HES metric was well established, therefor the writer would not discuss in detail about this metric. Drilling cycle time would be expressed both in day/well and hour/footage drilled. Upper spec limit (USL) was set 7.5 refer to cycle time as per business plan, even though the faster would be better for company, but the lower limit was determined 5.3 days as the fastest drilling cycle time achieved (even though with less complexity and less drilling depth). The Cpk analysis of drilling cycle time was shown in figure 4 and figure 5. Novaes et. al., (2016, p.4, [5]) stated that Cp value < 0.67 indicate poor process. The Cpk of current process was less than 0.1, it was concluded that current process was poor.

• **Determine COPQ.** COPQ is the impact on financial or cost if no improvement done to existing problem (or sometime people call it as financial benefit). In this case, COPQ was calculated as Capital Avoidance – LPO due to process improvement = (Average baseline drilling well cost – actual drilling well cost) – (Total oil loss due to increase distance criteria for shut in producer well).

![Figure 4. Cpk Analysis of Drilling Cycle Time](image1)

![Figure 5. Cpk Analysis of Drilling Cycle Time per Footage Drilled](image2)

Similar with drilling cycle time, drilling well cost would be expressed in $/well and $/footage drilled (see figure 6 and figure 7). Upper spec limit (UCL) was kept at USS 750K refer to well cost budget as per business plan, the lower limit was determined at USS 530K (even though the cheaper the cost, would be...
better for company but in this project assumed LCL = US$530K refer to P10 of cost estimation). The run chart is available in Appendix 2.

![Figure 6. Cpk Analysis of Drilling Well Cost](image)

![Figure 7. Cpk Analysis of Drilling Well Cost per Footage Drilled](image)

### 4.3 Analyze Phase

The objective of this phase is to find problem’s root causes. Project team performed Forum Group Discussion (FGD). This FGD involved the Subject Matter Expert (SME) from D&C team, Asset team (Geologist and Petroleum Engineer), business partner representative refer to their expertise. This activity was started with narrow down the possible root causes refer to historical data, performed brainstorming and developed the why tree.

In determining the process variance or defect source, the project team used Pareto principle. As mentioned by Fryman (2002, p.189, [1]) “around 80% of the problem in a product or process lie in 20% of factors”. Refer to that principle, FGD started with reviewing historical data. Refer to historical data which was presented by Pareto chart in figure 8, team found that the source of variance mostly came from NPT. Beside about NPT, there was additional time for logging which done separately (not during drilling), this issue came from D&C team (explained in section voice of customer). Consider the portion of NPT and also the complexity, team decided by focus to reduce the additional time for logging and to reduce (or even eliminate) the NPT instead of trying to reduce the normal cycle time. If around 2.5 days of NPT could be eliminated, the drilling cycle time would achieve the target.

![Figure 8. Pareto Chart of Drilling Cycle Time in 2nd Semester of 2017](image)

Refer to figure 9, the 3 biggest hitter were well problem (among factors contribute to well problem were 51% due loss circulation and 39% due to tight hole), waiting on something and rig equipment problem. Therefore, team was only focus to those 3 category and focus to reduce additional logging time as raised up by D&C team (normal operation but considered as “waste”) while found out the root causes.

![Figure 9. Pareto Chart of Contributor Factor to NPT during Drilling in 2nd Semester of 2017](image)

The why tree is available in Appendix 3, the result is summarized in Table 2.

### 4.4 Improve Phase

Improve phase will discuss possible solutions of root causes which were found in
### Analyze Phase

Project team collected the possible solutions, evaluated them including communicated to respective team to get support from them. The recommendation solutions were summarized as below:

a. Project team would re-arrange the well execution sequence to give ample time for project team to re-evaluate the design, while rig kept drilling other well candidate
b. D&C team would assign qualified mud engineer only to this project.

c. D&C team would improve the drilling practice by using 400 GPM during drilling and they would do reaming after stand down. While bit had reached casing point, D&C operation team would increase the flow rate to 520 GPM to ensure hole cleaning.

d. Production team would shut in respective surrounding producer wells within 50 m radius prior drilling in respective formation section and turned on the producer wells again once casing of new well was in place and cemented.

e. D&C Operation team would prepare high concentration mud in separated tank, it would be transferred to active tank and diluted as per requirement when any loss circulation.

f. Rig Company would do preventive maintenance during moving (prior spud in) in every well.

g. Asset team would provide detail and accurate data about fault.

h. Asset team would provide accurate formation pressure prediction.

i. Drilling engineer and asset team would work together during design well trajectory especially about well direction with objective as long as possible would avoid E – W direction and or parallel to second largest stress direction.

j. D&C Operation team would put preventive Loss Circulation Material (LCM) on active tank.

k. Production team would maximize proximity to injection well.

l. D&C Operation team would arrange composite matting board and provide additional dozer from D&C Services (support team).

### 4.5 Control Phase

Control Phase will cover about implementation of solution plans which have been discussed in Improve phase. This section is the last step of DMAIC methodology.

After spent a lot of effort, finally this project was moved to control phase. To be able implemented the proposed solution, project team spent around 5 days to do Forum Group Discussion (FGD). In this FGD, project team collected the data, found out the root causes and proposed solutions. Consider the business nature in D&C of PT. SDEC which was PT. SDEC still need to pay cost (rig cost and some other rental cost) even though if rig was not operated, the implementation of solutions were applied directly to next candidate well (let’s call as well improved#1). To be able implementing the solutions directly, during that FGD, project team performed well by well assessment to determine the risk rank and the improvement requirement, and after that the project team re-

### Table 2. Root Causes Category

| No | Root Cause                              | Controllability | Related to          |
|----|-----------------------------------------|-----------------|---------------------|
| 1  | Improper well direction                 | Controllable    | Design              |
| 2  | Weather                                 | Un-controllable | Nature              |
| 3  | No allocation time for rig maintenance  | Controllable    | Procedure           |
| 4  | No economic comparison between shut in surrounding producer wells vs cost of problem | Controllable    | Procedure           |
| 5  | Flow rate while drilling is too high    | Controllable    | Design              |
| 6  | New mud engineer to this kind of project| Controllable    | People              |
| 7  | In-accurate formation pressure prediction| Controllable    | Design              |
| 8  | No clear information about fault        | Controllable    | Design              |
| 9  | Long time for mixing mud                | Controllable    | Procedure           |
| 10 | High permeability formation             | Un-controllable | Nature              |
| 11 | Depleted zone                           | Un-controllable | Nature              |
arranged well execution sequence. Wells which need a lot of improvement, the well execution was delayed to last schedule and vice versa for wells which not require many improvement, the execution schedule was accelerated. As part of implementation strategy, team would applying trial on 3 wells and team would evaluate the result of those trial. If the result was showing significant improvement, the proposed solution would be applied to all remaining wells.

While rig was drilling baseline well#12, team directly performed socialization and did further follow up action to ensure that the proposed solutions could be applied directly in first 3 wells of 30 remaining wells. The proposed solutions would be discussed in detail well by well basis during pre-spud meeting. The implementation of proposed solutions were explained below:

a. 2 proposed solutions (re-design well trajectory to avoid E – W direction and study to provide formation pressure prediction) were not applied yet in trial due to the well direction of 3 wells were not pointed to E – W and study for formation pressure prediction would need long time.

b. Respective D&C Engineers engaged Mud Company and assessed mud engineer Drilling engineer informed Mud Company on 4 January 2018 and worked together with Mud Company to satisfy the requirement related to mud area. Drilling engineering team spent around a half working day to perform assessment to all mud engineer candidate on 5 January 2018.

c. Respective D&C Engineers engaged Rig Company and secured approval from them to perform rig maintenance prior spud in. After project team showed the comparison calculation between perform preventive maintenance maximum 16 hour per month as per allowed in contract and no preventive maintenance as per current practice but get NPT around 3.1%, Rig Company had agreed with the proposal. They did several maintenance especially for critical equipment such as mud pump, top drive system, etc. prior spud in well improved#1 and on every well.

d. Asset team (sub-surface) provided information about fault for first 3 wells. The information about remaining wells would be provided later (the information of remaining wells were provided during rig was executing trial wells).

e. Respective drilling engineer communicated to and secured additional tank from D&C support team (DCS) to store high concentration mud. 2 tanks from DCS had been secured and dedicated to this project to store high concentration mud. DCS also provided more vacuum truck to transfer the mud to next location if no loss circulation event on well being drilled.

g. Respective Petroleum Engineer communicated to asset team (production team) and got approval to shut in surrounding producer well. The meeting was performed directly and as result project team successfully secured the approval to shut in surrounding producer wells within 50 m radius during drilling execution. Shut in scenario itself was performed while rig drilled in same sand formation only and once casing was in place and cemented, surrounding producer wells were put back on production mode.

g. Respective drilling engineer run again the simulation to get more suitable drilling parameters. Starting well improved#1, flow rate was reduced during drilling to minimize loss circulation, but flow rate increased again while performed circulation hole clean.

| Well Name | NPT (hour) | Normal CT | Total CT |
|-----------|------------|-----------|----------|
| Well Name | Problem | Waiting On | Reliability Equipment | Others NPT | Total NPT |          |          |
| Baseline  | 67.6     | 20.5      | 16.4     | 6.8       | 99.3      | 152.1    | 247.8    |
| Well Imp.#1 | 0        | 1         | 1        | 0         | 2         | 156      | 158      |
| Well Imp.#2 | 13.5    | 2         | 4        | 0         | 19.5      | 151      | 170.5    |
| Well Imp.#3 | 1       | 1         | 0        | 2         | 4         | 153      | 157      |
| Av. Well Improved | 4.8 | 1.3 | 1.7 | 0.7 | 8.5 | 153.3 | 161.8 |
The result of trial on first 3 wells were displayed in table 3 and figure 10, the result indicated significant improvement.

Refer to promising result, team agreed to apply the recommendations to remaining wells (27 wells more) and the practices would be adopted for upcoming other similar projects. The detail information related to well design, information about fault, surrounding producer wells need to be shut in, etc. were available and those information would be discussed during pre-spud meeting. To ensure the consistency of this improvement, control plan document was developed.

Toll gate meeting is required for every Lean Six Sigma project which formally will enter “control phase”. Toll gate meeting is a meeting among LSS advisor, Champion and project facilitator to discuss about project status. The facilitator presented about the project since Define phase until the end of Improve phase including trial process which showing the result of improvement, and if all involved person (especially LSS advisor) agree that the project has make progress and able to show improvement result, the project will be declared enter “control phase”. Toll gate meeting for this project was conducted on April 2019, and this project had been declared in control phase, then project team was requested to monitor the actual financial benefit (AFB) for 12 months period and to update the result in online database of lean six sigma. Consider concession issue, unfortunately similar drilling project for Q4 of 2018 and 2019 were postpone until undecided time yet. The results of improvement applied in 30 wells, which had been agreed in WP&B, were as per below:

1. HES

No recordable safety incident during execution this project, so project team was able to achieve safety metrics target which were 0 fatality, 0 day away from work, 0 serious + catastrophic Motor Vehicle Crash (MVC), 0 spill.

2. Drilling Cycle Time

The average drilling cycle time of improved wells was 7.39 day/well and after normalized by taken out non-controllable NPT, the average cycle time was 6.91 day/well. From average cycle time perspective, project team met or even exceeded the customer expectation. As per shown in figure 11, the mean of drilling cycle time after improvement was 6.91 day/well. Even any significant improvement was observed (Cp improved from 0.0749 to 0.5941 and Cpk improved from -0.1082 to 0.3211), however the Cp and Cpk value were less than 1, it indicated incapable process. This condition was happened mainly due to different well depth from well to well (even though there were several other factors, such as well direction, length of tangent section, et cetera, also triggered result variance). By considering depth of well as the main contributor of variance, the writer made comparison in hour/ft to get better explanation. Refer to Cpk analysis of drilling cycle time which was stated in hour/ft unit in figure 12, the Cp value had improved from 0.06 to 1.08 and Cpk value had improved from -0.07 to 1.03. This result indicated that solutions applied successfully improved drilling cycle time.
3. Drilling Well Cost

The average drilling well cost of improved wells was US$639,795/well. If we refer to total cost for 30 wells which actual cost was US$ 19,193,840, the actual cost was less than target cost (target for 30 remaining wells = $22.430 million). In this metric, the project team also met or even exceeded customer expectation. As displayed in figure 13, the mean of well cost after improvement was US$639,795/well, even there was tremendous improvement compared to baseline, however the Cp and Cpk value were still less than 1 (it indicated incapable process). Similar with drilling cycle time, the different well depth from well to well was the main contributor to that condition. By considering depth of well as the main contributor of variance, the writer made comparison in US$/ft to get better explanation. Refer to Cpk analysis of well cost which stated in US$/ft in figure 14, the Cp value improve from 0.11 to 1.12 and the Cpk value improved from -0.02 to 1.01. This result indicated that solutions applied successfully improve the well cost.

The run chart of this project is available in Appendix 2.

In brief, the total efforts done for this project consisted of 5 days FGD involving 10 persons SME (equivalent to 5 x 8 x 10 = 400 man hour) and spent another 96 man hour to revisit design and further meeting with team outside project team. However, no cost was charged to this project related to 496 man hour spent to do this project improvement due to employee salary and benefits had been included as company G&A cost and also no additional cost charged to this project related to software/application utilization (company had spent cost to rent software in annual basis) or services cost from Business Partner. The cost component counted for this effort was cost related to Lost Production Opportunity (LPO) due to asset need to shut in more producer wells which causing loss production. Total cost related to this LPO was US$623,867.

By spending US$ 623,867 additional cost, project team was able to save drilling cost US$ 3,480,523. By subtracting the additional cost from cost saving, we got the actual financial benefit which was around US$ 2,85 million as result of improvement.

5. Conclusion and Recommendation

After the implementation of improvement plan from this project, several points taken from this paper:

a. Lean Six Sigma with DMAIC (Define – Measure – Analyze – Improve – Control) methodology is a powerful methodology to improve the performance, it is scalable (fit for purpose), and it is applicable to improve simple process until complicated process. This project “Continuous Improvement of Drilling Ultra-Shallow Horizontal in UP
Field” is an example of success story of LSS implementation in D&C department of PT. SDEC.

b. Even in low oil cost environment, PT. SDEC was able to deliver the target in term of well count drilled of Ultra-Shallow Horizontal Well as per agreed in WP&B with SKKMIGAS by performed proper process, utilized fit for purpose strategy and got support from all team.

c. Complexity (such as loose formation, high permeability, steam flooded, high DLS requirement, etc.) and other limitations (such as limited technology availability in respective area, limited partner choices, limited budget, etc.) always create challenges, but like two side of coins, there are always opportunities behind those challenges. In this case, PT. SDEC was able to optimize the opportunity to deliver tremendous result within very challenging environment.

Some recommendations and the next opportunities are:

a. Apply this project improvement in other project (align with “replicate” as 6 phase of “the Juran approach”), the replication can be started from similar project in different area.

b. The writer recommend to include this improvement in standardized book of Drilling Ultra-Shallow Horizontal Well in UP field to ensure the continuity. This step is to anticipate if all involved personnel (person who knows this project) move from D&C team or even from PT. SDEC, the process still be applied consistently.

c. Consider the nature of drilling activities are contains many variable (mostly the design from well to well is always different), recommend to use cluster/range approach as comparison during analysis or perform the analysis in detail and normalized un-controlled (out scope variable).

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### APPENDIX 1. Voice of Customer

| NO | Voice of Customer | Customer | Clarification | Customer Critical Requirement |
|----|------------------|----------|---------------|-------------------------------|
| 1  | Drilling cycle time was longer than business plan | Business plan team and Asset Team | Refer to 12 well which drilled in second semester of 2017, total cycle time was 119.9 days (average drilling cycle time was 9.99 days/well) compare to business plan was 90 days (7.5 days/well) | • Improving drilling cycle time, total drilling cycle time for 30 remaining well max was 225 days as per BP (average 7.5 days/well) with cost $31.5 million for 42 wells (for 30 remaining wells = $22.430 million) and no delay on well deliverability (no delay on oil production) |
| 2  | Well cost higher than business plan | Business plan team and Asset Team | Total cost US $9,069,745 compare to US $9,000,000 | |
| 3  | Late deliver wells | Well deliverability was late around 2.5 days/well | |
| 4  | Keep safe drilling execution | General Manager D&C | No improvement allowed if sacrifice safety | Execute project with incident free |
| 5  | Need to elaborate more detail about well hazards | D&C | Risk assessment done in project level not well by well | Need to know more detail about the well hazards within well by well |
| 6  | Reduce run Casandra survey | D&C | Casandra survey need longer time | Need to review well direction to avoid run Cassandra survey |
| 7  | Reduce controllable factors which contribute to loss circulation | D&C | D&C team believe that there was several controllable factors contribute to loss circulation such as wells penetrating fault, surrounding producer, etc. | Minimize factors contribute to loss circulation |
APPENDIX 2. Run Chart

Run Chart of Drilling Cycle Time of Improved Wells Expressed in Day

Run Chart of Well Cost of Improved Wells

Run Chart of Drilling Cycle Time of Improved Wells Expressed in Hour/Ft

Run Chart of Well Cost Expressed in US$/Ft of Improved Wells
APPENDIX 3. Why Tree

Why Tree of Longer Drilling Cycle Time and Higher Well Cost of Ultra-Shallow Horizontal Well in UP Field