CONFIGURATION SELECTION BASED ON LIFECYCLE COST OF SUBSEA PRODUCTION SYSTEM: CASE OF INDONESIAN DEEPWATER FIELD

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ABSTRACT

Subsea tie back systems are important parts of oil and gas production project. The decision to select a subsea tie-back configuration with the objective goal of lowest lifecycle cost can be configured in multiple ways based on the field specifications and operator's approach to operation. This paper presents an Analytic Hierarchy Process (AHP) method to determine economical levels of subsea tie-back wells configuration, based on lifecycle cost of subsea deepwater production systems with respect to wells number alternative. Field reservoir located in deepwater of eastern Indonesian with the depth of 1400 meters and field life 40 years is studied. From this study, it is identified that most economical configuration in subsea production systems; satellite tie-back configuration it is to develop the small field with 6 numbers of wells. For 12 numbers of wells, template subsea tie-back configuration is the highest ranking of economical

Keywords: Lifecycle Cost, Subsea Production System, Deepwater Field, Analytic Hierarchy Process

INTRODUCTION

When developing a field that contains oil or gas, a subsea production system is used to continuously transport oil or gas to a floating platform or an onshore platform by drilling more than one well and installing appropriate deepwater facilities. The economic analysis for field development is essentially lifecycle cost analysis, the minimum requirements are already suggested initially for the oil and gas industry by the Norwegian Standards (Mata, 2010)

Optimization of total lifecycle cost of deepwater production systems must include all of the cost components, that must be considered to determine the most effective cost of deepwater production systems for a particular site. The methodology of cost model development by Goldsmith to predict lifecycle cost for a field development is based on statistical and judgment reliability data, including the risk and the reliability costs associated with the field development options. The lifecycle cost elements of subsea production system included; CAPEX, OPEX, RISKEX and RAMEX (Goldsmith et al., 2000)

The various cost elements are defined as follows:

- CAPEX: Includes material cost and costs associated with installation of the wells and systems materials include subsea trees, pipelines, PLEMs, jumpers, umbilicals, and controls systems. Installation costs include vessel spread costs multiplied by the estimated installation time and for rental or purchase of installation tools and equipment.

CAPEX = (*well system materials*) + (*installation costs*)

- OPEX: Includes intervention costs associated with "planned" interventions, i.e.re-completions caused by depleted reservoir zones. OPEX for this planned re-completion is intervention rig spread cost multiplied by the estimated re-completion time for each zonal re-completion. The number and timing of planned re-completions are uniquely dependent on the site-specific reservoir characteristics and operator's field development plan.

  OPEX = (*intervention duration*) x (*rig spread cost*)

- RISKEX: Includes risk costs associated with blowouts

  RISKEX *P(BO during lifetime) = P(drilling) + P(initial completion) +*

  P(normal production) + ∑ *P (workover)+* ∑ *P (re-completion)*

- RAMEX: Includes lost revenues and intervention cost associated with "unplanned" intervention, i.e. interventions caused by component failures such as sand controls system failures, tubing leaks, and production tree valve failures.

  RAMEX = *(cost of repair vessel spread cost and the component*

  repair/change) x *(lost production cost)*

RAMEX calculation is performed through the following four steps:
Step (1) Identify components failures modes.
Step (2) Identify costs associated with each repair operation
Step (3) Determine the frequency of component failure
Step (4) Determine the cost of each subsea component failure.

OPEX, RISKEX and RAMEX are calculated by multiplying the yearly in field-life (N) and (r) is the discount rate. The lifecycle cost is the expressed;

Lifecycle cost = CAPEX + OPEX + RISKEX + RAMEX

$$LCC \equiv CAPEX + \sum_{k\in\{1,N\}} \frac{OPEX_k}{(1+r)^k} + \sum_{k\in\{1,N\}} \frac{RISKEX_k}{(1+r)^k} + \sum_{k\in\{1,N\}} \frac{RAMEX_k}{(1+r)^k} \quad (1)$$

The elements of the subsea production or injection system may be configured in numerous ways, as dictated by the specific field requirements and the operator strategy (API technical report, 2015). Subsea production system configuration (Yong Bai, 2010; Mudrak. C, 2016; Suyanto. A, 2008).

Satellite Well

A single subsea well that is tied in to a host facility with adequate infrastructure is called a satellite well. A satellite well is an individual subsea well Often the wells are widely separated and the production is delivered by a single flowline from each well to a centrally located subsea manifold or production platform

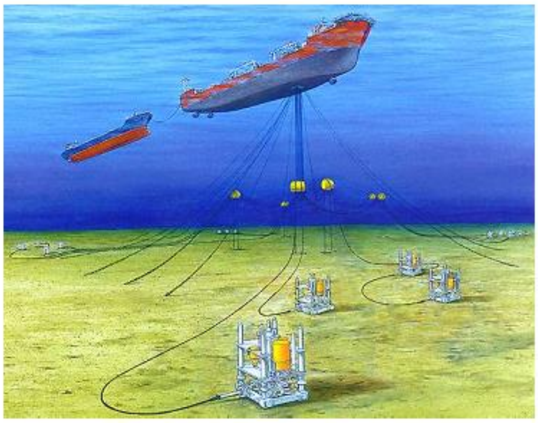

Figure 1. Satellite well (Suyanto. A, 2008)

Daisy Chain

A daisy chain configuration is a connection of various satellite wells in series, Each subsea tree may have a choke installed to avoid pressure imbalances in the flows, daisy-chained wells allows for the combined use of infield flowlines by more than one well, and may provide a continuous loop for round-trip pigging if needed.

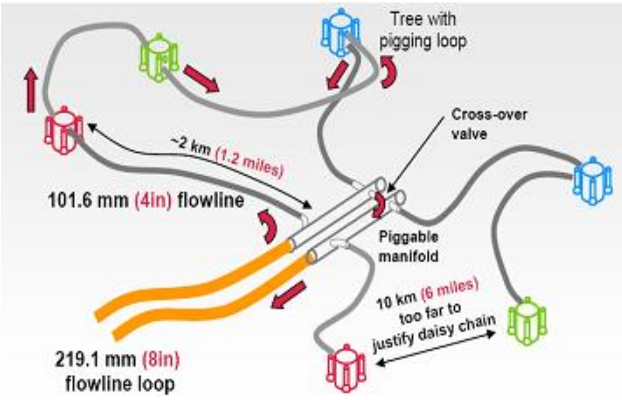

Figure 2. Well Daisy Chain (Suyanto. A, 2008)

Cluster

In a cluster arrangement, a number of single satellite wells are tied-in to a manifold. This device is used to gather and distribute fluids and is placed in proximity to the tied in wells preferably in a central location, several satellite wells are in proximity to one another, a separate production manifold may be placed near the wells to collect the production from all of the wells and deliver it in a single production flowline that is connected to the production facility.

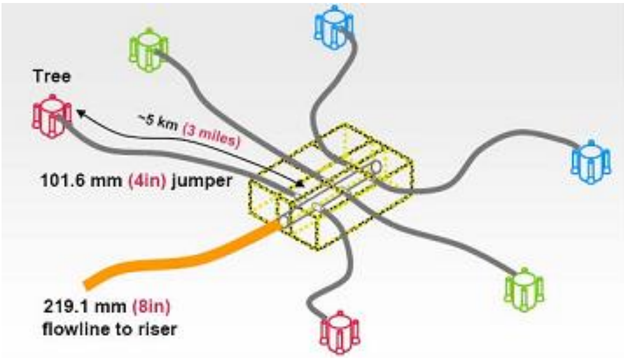

Figure 3. Well Clusters (Suyanto. A, 2008)

Templates

Well templates are structural weldments that are designed to closely position a group of well conductors. Well templates may support two wells or more than a dozen wells and manifold are situated on the same structure in a template configuration. Connections are therefore very short and are always made with rigid pipe. This allows for pre-fabrication and testing of equipment, hence reduced installation time. The template comprises of a foundation and a structural framework that provides support for seabed equipment. It may as well include protection against dropped objects and/or fishing gear.

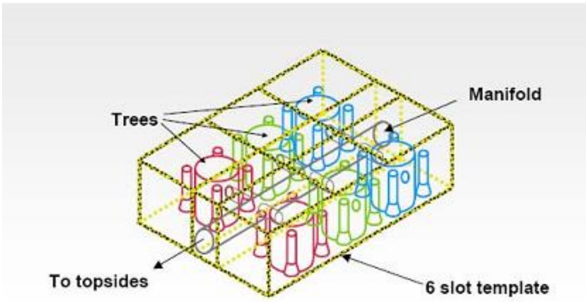

Figure 4. Well templates (Suyanto. A, 2008)

METHODOLOGY

A Field of deepwater of 1400 meters, in eastern Indonesian with field life 40 years is studied. This area is much more complicated than in others area and filled with many uncertainties since it is less explored. Thus it still has many large untested features and still has higher exploration cost and risk (Liana, 2014).

This study is to determine economical levels of subsea tie-back wells configuration, based on lifecycle cost of subsea deepwater production systems with respect to wells number alternative by using Analytic Hierarchy Process (AHP) Method. AHP one of the most popular multi-criteria decision-making methods for determining the best level, this methodology developed by Saaty (1980) considers a set of chosen criteria and set of alternatives among which the best solution is to be found regarding the weights of criteria and alternatives. The methodology of the AHP can be explained in following steps. We used the steps of the method in accordance with Bhusan & Rai (2004). :

Step (1) The problem is decomposed into a hierarchy of goal, criteria, sub-criteria, and alternatives. shows figure 5 hierarchical structure at the root of the hierarchy is the goal or objective of the problem being studied and analyzed.

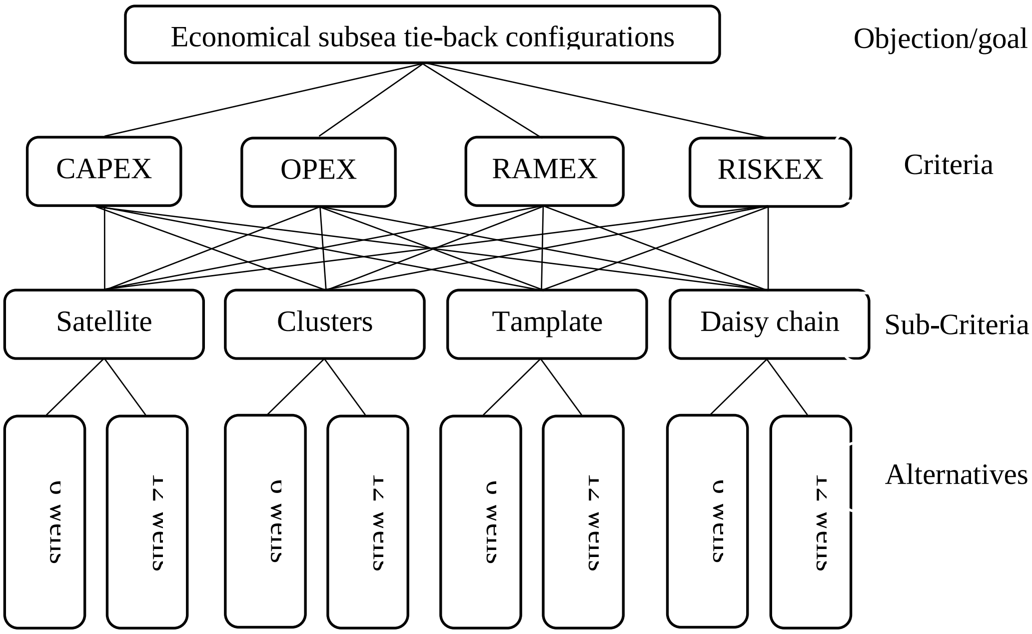

Figure 5. Hierarchical structure

Step (2) Data are collected from experts or decision-makers corresponding to the hierarchic structure, in this study base on calculated each criterion CAPEX, OPEX, RISKEX and RAMEX, the pairwise comparison of alternatives on a qualitative scale as described Table 1.

Step (3) The pairwise comparisons of various criteria generated at step 2 are organized into a square matrix.

Step (4) The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared.

Table 1. Scale of pairwise comparisons (modified. Saaty, 2008)

Intensity of Value	Interpretation
1	Requirements i and j are of equal value.
3	Requirements i has a slightly lower cost value then j.
5	Requirements i has a strongly lower cost value then j.
7	Requirements i has a very strongly lower cost value then j.
9	Requirements i has an absolutely lower cost value then j.
2,4,6,8	These are intermediate scales between two adjacent

	judgments.
Reciprocals	If requirement i has a lower value then j

Step (5) The consistency of the matrix of order n is evaluated. The consistency index, CI, is calculated as

$$CI \equiv \frac{(\lambda \max - n)}{(n-1)} \qquad (2)$$

where λ max is the maximum eigenvalue of the judgment matrix.
Step 6: The rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion.

RESULTS AND DISCUSSION

Table 2 shows a matrix pairwise comparison of the criteria in this study. The highest priority factor is given to CAPEX, with 51 % relative priorities (weights) with respect to criteria RAMEX, OPEX, and RISKEX. The consistency ratio (CR) indicates an acceptable level of inconsistency and largest eigenvalue of matrix λmax 4.1687.

Table 2. Pairwise comparison matrix for the first level.

Criteria	CAPEX	OPEX	RAMEX	RISKEX	Priority factor
CAPEX	1	5.00	2.00	9.00	0.51
OPEX	0.20	1	0.25	5.00	0.13
RAMEX	0.50	4.00	1	7.00	0.32
RISKEX	0.11	0.20	0.14	1	0.04

λ max = 4.1687
CI = 0.0562
CR = 0.0568

Pairwise comparison of criteria, sub-criteria, and alternative (6 number of wells) with respect to each other are represented in Tables 3,4,5 and 6.

Table 3. 6 wells pairwise comparisons with CAPEX criteria

CAPEX 6 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	7.00	5.00	3.00	0.566
Clusters	0.14	1	0.20	0.33	0.060
Template	0.20	5.00	1	0.50	0.164
Daisy Chain	0.33	3.00	2.00	1	0.209

λ max = 4.2115
CI = 0.0705
CR = 0.0712

Table 4. 6 wells pairwise comparisons with OPEX criteria.

OPEX 6 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	0.33	0.20	0.14	0.057
Clusters	3.00	1	0.33	0.20	0.122
Template	5.00	3.00	1	0.33	0.263
Daisy Chain	7.00	5.00	3.00	1	0.558

λ max = 4.1185
CI = 0.0395
CR = 0.0399

Table 5. 6 wells pairwise comparisons with RAMEX criteria.

RAMEX 6 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	0.33	5.00	3.00	0.263
Clusters	3.00	1	7.00	5.00	0.558
Template	0.20	0.14	1	0.33	0.057
Daisy Chain	0.33	0.20	3.00	1	0.122

λ max = 4.1185
CI = 0.0395
CR = 0.0399

Table 6. 6 wells pairwise comparisons with RISKEX criteria.

RISKEX 6 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	0.50	5.00	3.00	0.308
Clusters	2.00	1	7.00	3.00	0.469
Template	0.20	0.14	1	0.20	0.053
Daisy Chain	0.33	0.33	0.33	1	0.170

λ max = 3.7907
CI = -0.0698
CR = -0.0705

The data of cost calculated, shows priority factor of CAPEX criteria with respect to 6 wells, have the highest priority to satellite and daisy chain (Tables 3); OPEX priority factor it is can be seen that daisy chain and template (Table 4); RAMEX with clusters and satellite (Table 5) and RISKEX present clusters and satellite (Table 6).

Tables 7, 8, 9 and 10 present the matrices of comparisons of the criteria CAPEX, OPEX, RAMEX and RISKEX with respect to the sub-criteria and their alternatives (12 number of wells)

Table 7. 12 wells pairwise comparisons with CAPEX criteria.

CAPEX 12 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	0.50	5.00	3.00	0.128
Clusters	2.00	1	7.00	3.00	0.067
Template	0.20	0.14	1	0.20	0.533
Daisy Chain	0.33	0.33	0.33	1	0.273

λ max = 4.2013
CI = 0.0671
CR = 0.0678

Table 8. 12 wells pairwise comparisons with OPEX criteria.

OPEX 12 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	0.33	0.20	0.14	0.057
Clusters	3.00	1	0.33	0.20	0.122
Template	5.00	3.00	1	0.33	0.263
Daisy Chain	7.00	5.00	3.00	1	0.558

λ max = 4.1185
CI = 0.0395
CR = 0.0399

Table 9. 12 wells pairwise comparisons with RAMEX criteria.

RAMEX 12 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	0.33	5.00	3.00	0.263
Clusters	3.00	1	7.00	5.00	0.558
Template	0.20	0.14	1	0.33	0.057
Daisy Chain	0.33	0.20	3.00	1	0.122

λ max = 4.1185
CI = 0.0395
CR = 0.0399

Table 10. 12 wells pairwise comparisons with RISKEX criteria.

RISKEX 12 well	Satellite	Clusters	Template	Daisy Chain	Priority factor
Satellite	1	3.00	7.00	5.00	0.558
Clusters	0.33	1	5.00	3.00	0.263
Template	0.14	0.20	1	0.33	0.057
Daisy Chain	0.20	0.33	0.33	1	0.122

λ max = 3.8073
CI = -0.0642
CR = -0.0649

The matrix pairwise comparisons of 12 wells numbers are obtained: for CAPEX the highest priority to clusters and satellite (Table 7); OPEX with daisy chain and template (Table 8); RAMEX to clusters and satellite (Table 9), and RISKEX present satellite and clusters (Table 10).

Through AHP method to determine the ranking of subsea production operating systems configuration. The problem selection based on lifecycle cost of deepwater oil and gas field cases in Indonesia, some results can be shown below.

Table 11. Economical level of subsea tie-back configurations with respect to 6 wells.

Subsea tie-back wells configuration	6 Wells	Rank
Satellite	0.39	1
Clusters	0.24	2
Daisy Chain	0.22	3
Template	0.14	4

These results have taught that thorough cost components must be considered. Evaluation of lifecycle operation is required to determine the most economical wells configuration systems. Satellite is the highest ranking for solution smaller fields development with limit wells shown Table 11. This configuration is a new approach for decision making of investment the subsea field development, which will help reduce both capital investment (CAPEX) and intervention cost of the reliability, availability, and maintainability (RAMEX) factor from wells production to host facility, especially in development of remote marginal fields with a limit of the reserves.

Table 12. Economical level of subsea tie-back configurations with respect to 12 wells.

Subsea tie-back wells configuration	12 Wells	Rank
Template	0.33	1
Daisy Chain	0.25	2
Clusters	0.24	3
Satellite	0.18	4

It is clear from Table 12, that subsea tie-back wells template configuration is economical. The groupings wells layout of template configuration is the most effective balancing, between the cost of materials and the installation cost (CAPEX). The well spacing is closely controlled by the template structure on one control and produce into a single flowline from wells to host facility (OPEX).

CONCLUSION

According to the study, the number of wells and the subsea tie-back wells productions systems configuration is sensitive in optimation of lifecycle cost of deepwater field development. 6 wells using satellite configuration is a solution more economical than others; and groupings of 12 wells template is the most economical configuration.

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