Risk assessment of aging offshore jacket platform group: a case study on “B” Field platforms

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Abstract. Offshore jacket platforms are designed to fulfill their intended purpose in oil and gas exploitation at designated service life periods. During the operational development, a number of field operators extend their platform service life if the reserves are still available. This technical paper proposes the method to assess the structural integrity of several aging platforms in a field with a simplified approach. Taking the case of “B” Field platforms installed in the mid-1990s, the detailed procedure and example are discussed thoroughly. Five indicators furnished with quantification procedures are also presented to propose the ranking methodology. This paper also proposes the method of jacket platforms grouping based on several similarity criteria. The results of this approach can be used as a baseline for more detailed structural integrity assessment for each group representation.

1. Introduction

Offshore jacket platforms are designed to fulfill their intended purpose in oil and gas exploitation, should be cost-effective and have adequate structural integrity to cope with both environmental and operational loadings at certain service life periods [1]. During the operational development, a number of field operators prolong their platforms service life if the oil or gas reserves still available for further exploitation. Utilizing further the existing structures is the most economically rational moves to take, and it brings a lot of benefits [2]. The existing structures potentially exceed their intended design service life. Hence, field operators need to extend their jacket platforms’ service life.

Several studies describe that jacket platforms lifespan can be prolonged with regard to multiple details of the analysis. Risk evaluation that includes the hazard identification and failure modes and the possibility of preventive measures should be made to extend the service life of jacket platforms [3]. Information regarding the historical loading of the structures, characteristic data, and inspection results shall be made available in order to make a strong basis to decide a service life extension [4]. Not only for a single offshore platform, but also service life extension is relevant for a block of an offshore field that consists of several offshore platforms.

One of the examples of an offshore oilfield block is “B” Field in Eastern Borneo, Indonesia. This field consists of 13 platforms interconnected by pipelines and bridges support, built and installed in mid 1990s. This technical paper proposes the method to assess the structural integrity of several platforms in the field with a simplified approach, taking “B” Field as the case study. API RP 2SIM [5] is referred to as the primary recommended practice. Section 2 in this paper explains the assessment methodology of aging offshore jacket platforms. Section 3 explains the data review, especially with regards to the minimum required data for assessment and minimum inspections that need to be done to generate an
essential baseline for life extension decision making. Section 4 explains the structural integrity risk assessment, detailed procedures, and examples. The scoring method is introduced in this section to rank the jacket platforms’ worst physical condition. Section 5 gives the conclusions and the recommendation for further studies.

This technical paper is intended to propose the duplicable methodology of offshore platform group assessment for life extension. The proposed method can be utilized for a similar project with larger number of jacket platforms.

2. Methodology

Decision to extend the service life period of aging offshore jacket platforms is very dependent to a number of aspects. Long and thorough discussions from many stakeholders are done so to conclude that executing service life extension is the most beneficial strategy. However, as mentioned above, safety assessment is still the utmost priority. Existing aging offshore jacket platforms life extension requires no compromise.

State of the art in rules, codes and recommended practices are available and adopted in this technical paper. Based on various experiences, initial information should be made available in order for the decision makers. Table 1 below gives the general procedure of jacket platform life extension.

| Item       | General Procedure                                                                 |
|------------|-----------------------------------------------------------------------------------|
| A          | Gathering Historical Information                                                  |
| B          | Performing Inspection of Structural Aspects                                      |
| C          | Analysis of Existing Structure                                                   |
| D          | Decision Making                                                                  |

Table 1. Offshore jacket structure life extension decision list

A Gathering Historical Information

The historical information at least consists of the data below:
1. Design history (initial drawings, analysis reports, equipment and PFDs)
2. Fabrication history (anomalies and changes during fabrication)
3. Installation history (anomalies or accidents during installation)
4. Operational history (changes during operation, major accident, structural and equipment changes)

B Performing Inspection of Structural Aspects

Inspection of structural aspects at least consists of actions below:
1. Major damage due to accident(s)
2. Above water anomalies including lost and non-operational safety apparatus; corrosion of main, secondary, and tertiary members, unrecorded changes
3. Underwater anomalies including corrosion of tubular members, cathodic protection depletion, scouring, subsidence, marine growth thickness

C Analysis of Existing Structure

Thorough Finite Element Analysis (FEA) is performed at least consists of analysis below:
1. Existing vs design gap analysis, summary of anomalies
2. Static structural strength (design strength analysis)
3. Strength against seismic load analysis (if necessary)
4. Remaining fatigue life analysis

D Decision Making

The final decision divided into three categories:
1. Acceptable to be extended
2. Acceptable with several modification
3. Abandonment
However, based on further experiences, there are challenges faced by the team which should be considered in the process of life extension. Following list is the example of the challenges, especially for relatively old offshore platforms:

1. Incomplete technical drawings;
2. Unrecorded accidents, such as boat impact and dropped object;
3. Severe corrosion;
4. Discrepancy between technical drawings and actual conditions due to unrecorded modifications;
5. Depleted cathodic protection;
6. Excessive marine growth;
7. Excessive scouring and subsidence.

The complexity of challenges varies between one field to another. These challenges are meant to be tackled by strategic moves from the assessment team to obtain the best basis for decision making of aging jacket structure life extension. One of the strategic moves is the use of risk assessment. Risk assessment is introduced in this paper, supplied with comprehensive examples.

The jacket platforms assessment is based on practice recommended by API RP2SIM [5]. The recommended practice includes a risk-based approach to manage the structural integrity of existing offshore jacket structures. Risk is a probabilistic measure, calculated by multiplying the likelihood of some event occurred during designated time period and the negative consequences associated with the event, as in the following equation:

\[ \text{Risk} = \text{Likelihood} \times \text{Consequences} \]  

This method has major purpose to highlight the structures from HSE (Health, Safety and Environment) perspective as well as the economic standpoint in terms of future plan of inspection, maintenance and repair resources. The flowchart of assessment framework is described in Figure 1.

**Figure 1.** Flowchart risk assessment procedures

This methodology demonstrates the practical use of risk-based assessment on the historical information (item A in Table 1) and inspection of structural aspects (item B in Table 1) to generate the analysis (item C in Table 1) and subsequently support the decision making (item D in Table 1). The aforementioned documents are then studied, compared, and reviewed to conduct the actions as listed in Table 2.

**Table 2.** Risk assessment procedures

| Step | Action | Action Details |
|------|--------|----------------|
| 1.   | Data review: Historical Information and Inspection Results | Ensure the availability of data required at item A and B at Table 1. |
| 2.   | Evaluation: Platform Categorization | Categorizing platforms in one field according to the type, function, and configuration of the platforms to select most critical platforms |
| 3.   | Evaluation: Risk Categorization | Generate the rank of risk by product of exposure category and likelihood of failure |
| 4.   | Evaluation: Damage Evaluation | Damage evaluation is performed to the platform(s) with highest risk ranking. |
| 5.   | Evaluation: Fitness-for-purpose | The fitness-for-purpose assessment is performed by simplified method |
3. Data Review

This section gives the example of minimum data that should be made available by the owner/operator in order to make a proper risk assessment. Data shortage will lead to inaccurate analysis. This set of data is the minimum required information needed to get adequate result of assessment. Hence, the data availability is mandatory. Table 3 below shows the example of data checklist of 13 platforms in “B” Field.

| No | Data Category | Data Request | Data Availability per Platform Number* |
|----|---------------|--------------|----------------------------------------|
|    |               |              | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1. | A Design history | As-built drawings | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 2. |               | Design analysis reports | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 3. |               | Equipment list | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 4. |               | Metocean study | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 5. | B Fabrication history | Fabrication report | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 6. | C Installation history | Installation report | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 7. | D Operational history | Additional/removal of equipment(s) | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 8. |               | Accident report | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 9. |               | Major damage due to accident(s) | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 10. |               | Lost and non-operational safety apparatus | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 11. | E Above water inspection report | Corrosion of main, secondary and tertiary members | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 12. |               | Additional equipment and member | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 13. |               | Dented tubular member | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 14. |               | Uniformly corroded tubular member | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 15. |               | Locally corroded tubular member | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 16. | F Under water inspection report | Cracked tubular member | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 17. |               | Depletion of corrosion protection | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 18. |               | Scouring | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 19. |               | Subsidence | V | V | V | V | V | V | V | V | V | V | V | V | V |
| 20. |               | Marine growth thickness | V | V | V | V | V | V | V | V | V | V | V | V | V |

*Remarks: V = Data available; X = Data unavailable
3.1 Design, Fabrication, and Installation History

The main issue that is addressed in examining the historical aspects of the structure is the anomalies occurred during the fabrication and installation. The baseline to measure the anomalies is the initial design including as built drawings, design basis, and the analysis reports including the fabrication and installation procedures and analyses.

From fabrication and installation aspects, it is important to study the designed procedure and the actual executed steps. For instances, comprehensive elevation and levelness for each jacket elevation after installation are very essential for subsidence assessment. Figure 2 below explains the importance of actual jacket and deck elevation after the installation. This information is extremely important to acquire within the initial data recording, as it is used to assess the likelihood of subsidence and the foundation performance.

![Figure 2. Example of an actual elevation of the existing structure](image)

3.2 Inspection Report

During the service life, inspection of offshore jacket platforms is performed both annual (minor) and major inspection. These inspection data are the critical information that need to be gathered to provide information on the actual up to date structural condition. Minimum data that should be made available is defined at Table 3 in category E and F. These inspection data must be arranged in such way as to facilitate the risk assessment process. Table 4 below gives the example of inspection report data arrangement for individual offshore jacket platform.
Table 4. Example of data summary for individual platform

| No | Description                                      | Anomalies (Y/N/NA\(^{[a]}\)) | Status (C/NC\(^{[b]}\)) | Photo (V/X\(^{[c]}\)) |
|----|--------------------------------------------------|-------------------------------|--------------------------|----------------------|
| 1  | Above water inspection                           | Y                             | C                         | V                    |
| 2  | Splash zone inspection                           | Y                             | C                         | V                    |
| 3  | Anode survey (percentage of depletion)           | Y                             | C                         | V                    |
| 4  | Scour survey (measurement of scour below the lowest jacket elevation) | Y                             | C                         | X                    |
| 5  | Debris survey                                    | Y                             | C                         | V                    |
| 6  | Marine growth survey                             | Y                             | C                         | V                    |
| 7  | Wall thickness survey                             | Y                             | C                         | X                    |
| 8  | Damaged member                                    | Y                             | C                         | X                    |
| 9  | Caisson survey (if any)                          | NA                            | C                         | X                    |

Remarks:

\(^{[a]}\) Y = anomalies found / N = no anomalies found / NA = Not applicable

\(^{[b]}\) C = Completed / NC = Not completed

\(^{[c]}\) V = photos available / X = no photos available

4. Results and Discussions

This section discusses structural integrity risk assessment of aging offshore jacket platforms, taking the case study of the jacket platforms in “B” Field. Review of the structural configuration, detail construction, and equipment that represent the latest condition including new modifications is performed. Design criteria including environmental and operation criteria and inspection reports are also reviewed. The comparison analysis is performed for each typical platform according to the type, function, and configuration of the platforms to select most critical platforms. The selected platforms are then further analysed using Finite Element Analysis (FEA) software, especially SACS for the current study.

4.1 Codes Related to Structural Integrity Risk Assessment

Comprehensive study that discusses the codes related to integrity assessment is presented in [3]. Table 5 below presents the most essential chapters to be considered for structural integrity assessment of aging offshore jacket platform.

Table 5. Codes standard and recommended practices related to structural integrity assessment of existing structures

| Codes, Standards or Recommended Practices | Chapter or Section |
|------------------------------------------|--------------------|
| API RP2SIM [5]                           | Section 07: Structural assessment process |
| API RP 2A WSD 2000 21\(^{st}\) edition 2007 [6] | Section 17: Assessment of existing platforms |
| ISO 199002 – 2007 [7]                    | Section 24: Assessment of existing structures |
| NORSOK Standard N-006 [8]               | Section 06: Assessment principles for existing structures |

API RP 2A WSD 22\(^{nd}\) edition 2014 [9] erases the section related to the assessment of existing platform and generate specific recommended practice which is API RP2SIM that discusses the details of structural integrity management. Based on codes, standards and recommended practices summarized above, this paper proposes the simplified method to assess the structural integrity assessment for life extension of aging offshore platform. The proposed method has been agreed by the owner, operator and the inspection contractor. This simplified method can be an instructive standard practice for similar project, not only in Indonesia but also in South East Asia where the climate, humidity and sea characteristics are relatively similar.
4.2 Simplified Method to Assess Structural Integrity of Offshore Jacket Platforms

The simplified method of structural integrity assessment is divided into several steps. This section presents the steps followed by the case study to provide assessment example.

4.2.1 Determining exposure category based on the platform functions

Exposure category determines how severe the consequences are when failure occurred at specific platform. This paper adapts the platform exposure category based on API RP2A WSD 2014. The levels of failure consequences consider the life-safety, that is the maximum anticipated environmental event that would be expected to occur while personnel are on the platform [9,10]. The exposure category are described in Table 6 below.

| Function       | Life Safety                  | Consequences of Failure | Exposure Category |
|----------------|------------------------------|------------------------|-------------------|
| Wellhead       | Manned-nonevacuated          | (C-1) High             | L-1               |
| Processing     | Manned-nonevacuated          | (C-1) High             | L-1               |
| Living Quarter | Manned-nonevacuated          | (C-1) High             | L-1               |
| Bridge Structure| Unmanned                     | (C-2) Medium           | L-2               |

4.2.2 Determining the integrity status to define likelihood of failure

The integrity status is summarized based on the data provided. The information on the general condition of the platform is divided into three category, namely good, fair, and poor. The integrity status is stated as good if the structure satisfies all the following requirements [5]:

1. The global structural integrity is ascertained;
2. The integrity of safety critical elements is assured so that the structure is safe for people to live or work on and around it;
3. Good functioning cathodic protection system that is capable of providing protection against corrosion to underwater structures;
4. There is no scouring occurred;
5. There is no subsidence occurred.

The integrity status is stated as fair if the structure satisfies at least one of the requirements. The integrity status is stated as poor if the structure does not satisfy all the requirements.

4.2.3 Categorizing the anomalies

The anomalies found in inspection is categorized in 5 types based on the integrity status requirements. The examples below give the overview on how to assess the anomalies in relation with the structural integrity.

1. Global structural state. Global structural state category includes the corrosion or damage of primary structures, i.e. leg, pile, main & secondary beam, that affect directly to the structural integrity. Global structural state also includes the history of accidents occurred during the service life, especially that affect the integrity of primary structures. Changes in global structural state potentially affect the integrity of structure to withstand in-situ loads, including its capacity to withstand environmental loads. The structural stiffness is also affected due to the changes of the structural state. It will further modify the natural frequency, overall structural dynamic behaviour and reduce the ultimate capacity of the jacket structure [11,12].

As stated in Table 7, the inspection report is in descriptive and qualitative form, the scoring methods shall be provided to present the objective and quantitative assessment. The scoring method is based on generic database or company’s internal database [13]. Alternatively, the scoring can be established using expert judgement. For the current case study, the scoring method for global structural state is established by expert judgement and presented in Table 7. Table 8 below gives the example of anomaly in global structural state.
For instance, if the inspection premise stated, “Moderate corrosion on leg A1”, then the score can be given as:

$$\textit{Moderate corrosion} \times \text{leg A1 (main structure = 3)} = 6$$

Each premises are then summarized to obtain the final structural state score.

| Condition          | Score | Location               | Score |
|--------------------|-------|------------------------|-------|
| Slight Corrosion   | 1     | Tertiary and Auxiliary Structure | 1     |
| Moderate Corrosion | 2     | Secondary Structure    | 2     |
| Heavy Corrosion    | 3     | Main Structure         | 3     |
| Dent               | 2     |                        |       |
| Damage             | 3     |                        |       |
| Broken             | 3     |                        |       |
| Hole               | 3     |                        |       |

Table 8. Example of anomalies in global structural state

| Example of Global Structural State Anomalies | Example Inspection Pictures |
|---------------------------------------------|----------------------------|
| Moderate corrosion of deck leg A2 to deck truss from deck leg A2 to row 2 | ![Image](example-1.png) |
| Moderate corrosion on leg A1 | ![Image](example-2.png) |

2. \textit{Damaged/lost or malfunction of safety element}. Safety elements include damages on boat landing and safety elements installed. This category also includes the lost or malfunction of safety apparatus such as the fire extinguisher, handrail, or emergency life raft that affect the personnel safety on the platform.
The scoring method is again used at this category to provide objective assessment. Table 9 below shows the scoring method for assessing the safety element. Further, Table 10 below explains the example of anomalies in safety item. For example, if the inspection premise stated, “Heavy corrosion on boat landing”, then the score is counted as:

\[
\text{Heavy corrosion (3)} \times \text{boatlanding (3)} = 9
\]

Similar with previously discussed category, each premises are then summarized to obtain the final safety element score.

**Table 9. Safety element score**

| Condition Level       | Score | Safety Element     | Score |
|-----------------------|-------|--------------------|-------|
| Partially functional  | 1     | Safety apparatus   | 3     |
| Slight Corrosion      | 1     | Boat landing       | 3     |
| Moderate Corrosion    | 2     |                    |       |
| Heavy Corrosion       | 3     |                    |       |
| Damage/Unfunctional   | 3     |                    |       |
| Lost                  | 3     |                    |       |

**Table 10. Example of anomalies in safety item**

| Example of Safety Item Anomalies | Example Inspection Pictures |
|----------------------------------|----------------------------|
| Heavy corrosion on vertical fender of lower boat landing | ![Example Inspection Pictures](image1) |
| Heavy corrosion on grating, kick plate and handrail of jacket pump operating deck | ![Example Inspection Pictures](image2) |

3. Under/over-protection of cathodic protection due to missing/depleted anodes. Corrosion Protection (CP) is an electrochemical protection performed by decreasing the corrosion potential to a level at which the corrosion rate of the metal is significantly reduced [14]. The CP readings of anodes
should vary between -1150 mV to -900 mV [15]. The values more negative than -1150 mV is considered as over-protection that will cause the damage to structural members. The value less negative than -900 mV is considered as under-protection that causes corrosion. In occasion where the CP reading is not applicable, survey still need to be performed to estimate the depletion of the CP, if more than 75% anodes depleted, it must be noted as anomaly. Table 11 below gives the example of anomaly in CP checking.

Table 11. The example of anomalies in CP checking

| Example of Anode Depletion | Example Inspection Pictures (sketch not to scale) |
|-----------------------------|--------------------------------------------------|
| Anomalies                   |                                                  |
| % of Depletion              |                                                  |
| No  | Depleted % | No  | Depleted % | No  | Depleted % | No  | Depleted % |
|-----|------------|-----|------------|-----|------------|-----|------------|
| 001 | 10         | 009 | 5          |
| 002 | 5          | 010 | 100        |
| 003 | 5          | 011 | 5          |
| 004 | 100        | 012 | 100        |
| 005 | 5          | 013 | 5          |
| 006 | 5          | 014 | 5          |
| 007 | 100        | 015 | 5          |
| 008 | 10         |     |            |

The proposed quantification of this category is presented by equation below:

\[
\text{Anode depletion score} = \frac{\sum \text{depleted anode}}{\sum \text{anode}} \times 9
\]

4. Scouring. Scouring is the transference of seafloor soils due to environmental condition, namely currents and waves [9]. The scouring occurred at the bottom of seabed could be measured. However, the exact prediction of scour depth and pattern cannot be exactly calculated. Scour is categorized into
local and global or general [16]. Local scour is portrayed as pitting in local area around single pile or one pile group, while global scour is in the form of shallow basin around the pile or pile groups caused by the interference of multiple piles, as shown in Figure 3.

![Figure 3. Definition of general and local scour [16]](image)

Scour potentially creates negative effect to overall structural stability due to the loss of soil axial or lateral support. This will further cause the slip settlement of mudmat or overstressing of foundation system. There is no exact measure of allowable scouring in offshore jacket structure. The maximum allowable scouring is usually determined at the design stage. Based on aforementioned statement, due to the lack of data gathered related to the allowable scouring depth, this study uses maximum depth of scouring to 100 cm underside the lowest bracing. The stated measurement comes from the agreement of the jacket owner/operator with the consultant. To further project extended beyond this example, maximum allowable scouring depth must be determined from the design history gathered at data review step. Table 12 below gives the example of scouring occurred at one specific platform.

| Jacket Row | Location | Scouring Measurement (m) |
|------------|----------|--------------------------|
| A          |          | 2.5                      |
| B          |          | 2.5                      |
| C          |          | 2.5                      |
| A          |          | 2.5                      |
| B          |          | 2.5                      |
| C          |          | 2.5                      |
| A          |          | 2.5                      |
| B          |          | 2.5                      |
| C          |          | 2.5                      |

The quantification process is based on its depth and scored at deepest scour on every platform side. The scoring is described at Table 13 below.

| Scouring Depth (m) | Score |
|--------------------|-------|
| No scouring found  | 0     |
| 0.1 – 1            | 1     |
| 1 – 2              | 3     |
| 2 – 5              | 6     |
| > 5                | 9     |
5. Subsidence. This category consists of indication of platform subsidence found during the inspection. Platform subsidence can be measured by comparing deck actual elevation at installation historical report with the latest deck actual elevation survey. The effect of subsidence to the global jacket integrity are as follow [17]:

a) movement of pile groups towards each other;
b) high compressive forces within the lowermost jacket framing;
c) rotations of the lowermost sections of the jacket legs, and consequential rotations of the pile sleeve cluster and the top of the piles;
d) higher bending stresses in the piles due to the effects of pile top rotation;
e) a more unequal distribution of pile axial loads within each pile group (a push-pull effect within the pile group, resulting in increased pile axial design loads);
f) a higher axial pile capacity and higher pile axial stiffness, due to the higher soil friction generated between the pile surface and the surrounding soil;
g) relative upward vertical soil displacements and strains along the length of each pile (equivalent to a Poisson’s effect) of around 60 mm.

The presented study case shows that there is no subsidence found within the structures. However, it should be borne in mind, the effects will potentially be catastrophic if the subsidence occurred. Hence, in the future similar project using this method, the subsidence anomaly shall be accounted in the risk assessment.

4.2.4 Jacket platform grouping

To assess the structural integrity status of each platform, simplified method can be used to choose the most severe platform based on the risk assessment. The fitness for purpose criteria for simplified method is limited to the static strength analysis of existing structural condition. However, not all of these platforms in this field is analysed. The platforms can be grouped based on similarities in framing, steel material, foundation properties, structural condition, loading condition, water depth and operational history. The representation of the selected group is the structure with highest assessment score. The structure is then analysed for structural fitness-for-purpose. Table 14 below shows the platform grouping based on the aforementioned criteria.

| No. | Group    | Platform Type       | Number of Leg | Number of Platforms Represented | Platform names |
|-----|----------|---------------------|---------------|---------------------------------|----------------|
| 1   | Group 1  | Well with 3 legs    | 3             | 3                               | W1; W2; W3     |
| 2   | Group 2  | Well with 4 legs    | 4             | 6                               | W4; W5; W6; W7; W8; W9 |
| 3   | Group 3  | Living Quarter      | 4             | 1                               | LQ             |
| 4   | Group 4  | Support Structure   | 3             | 2                               | FS; BS         |
| 5   | Group 5  | Processing          | 4             | 1                               | PP             |

4.2.5 Assessing risk based on exposure category

The risk assessed based on the exposure category and the integrity status. Exposure category is determined as in section 4.2.1 above, and the integrity status is determined based on the 5 categories as stated at section 4.2.2. Initial step of the integrity status assessment is to categorize the anomaly for each platform, then the anomalies are assessed based on the scoring method to provide objective quantitative likelihood of failure score. Table 15 below explains the example to summarize the anomalies occurred on a single jacket platform, taking one case of LQ (Living Quarter Platform).
### Table 15. Example on results of anomaly assessment (case of LQ)

| Anomaly Category | Inspection Finding Premise | Score | Total Score |
|------------------|----------------------------|-------|-------------|
| Global Structural State | Slight corrosion on barge bumper and flange connection to jacket leg B2 | 1 × 2 = 2 | |
| | Heavy corrosion on weld joint of deck leg B2 to deck truss from leg B2 to row 2 | 3 × 3 = 9 | |
| | Heavy corrosion on frame and plate of roof shelter at south face EL (+) 60° | 3 × 1 = 3 | |
| | Dent on ladder support at v shape jetty area | 2 × 1 = 2 | |
| | Hole on column at extension deck at row 1 with Approx. size 100 mm x 40 mm | 3 × 3 = 9 | 25 |
| Safety Element | Moderate corrosion on ladder support to boat landing framing connection | 2 × 3 = 6 | |
| | Broken line indication due to heavy corrosion on boat landing shim connection at view A2 | 3 × 3 = 9 | |
| | Non-functional fire extinguisher | 3 × 3 = 9 | 25 |
| Cathodic Protection | Sum of anode potential reading above -900 mV = 9 unit | 9/30 × 9 = 2.7 | 2.7 |
| | Sum of total anode = 30 unit | | |
| Scouring | Side A-1 = 1.5 m | 3 | |
| | Side A-2 = 2.5 m | 6 | |
| | Side B-1 = 3 m | 6 | |
| | Side B-2 = 1.5 m | 3 | 18 |
| Subsidence | No Subsidence found | 0 | 0 |
| **TOTAL SCORE** | | **70.7** | |

### Table 16. Results of assessment scoring

| Group | Type       | Platform Name | Anomaly Category | Global Structural State | Safety Elements | Low CP Reading | Scouring | Subsidence | Total Score | Integrity Status |
|-------|------------|---------------|------------------|-------------------------|-----------------|----------------|----------|------------|-------------|------------------|
| 1     | Well 3 legs | W2            |                  | 25                      | 27              | 8.1            | 17       | 0          | 77.1        | FAIR             |
| 1     | Well       | W3            |                  | 34                      | 24              | 3              | 16       | 0          | 77           | FAIR             |
| 1     | Well       | W1            |                  | 22                      | 24              | 5.4            | 21       | 0          | 72.4        | FAIR             |
| 2     | Well       | W7            |                  | 21                      | 29              | 6.3            | 23       | 0          | 79.3        | FAIR             |
| 2     | Well       | W8            |                  | 19                      | 25              | 2.7            | 29       | 0          | 75.7        | FAIR             |
| 2     | Well       | W6            |                  | 19                      | 24              | 7.2            | 25       | 0          | 75.2        | FAIR             |
| 2     | Well       | W9            |                  | 17                      | 25              | 4.5            | 27       | 0          | 73.5        | FAIR             |
| 2     | Well       | W5            |                  | 14                      | 18              | 6.3            | 22       | 0          | 60.3        | FAIR             |
| 2     | Well       | W4            |                  | 18                      | 19              | 6.3            | 0        | 0          | 43.3        | FAIR             |
| 3     | Living Quarter | LQ       |                  | 25                      | 25              | 2.7            | 18       | 0          | 70.7        | POOR             |
| 4     | Bridge     | BS            |                  | 17                      | 22              | 2.7            | 0        | 0          | 41.7        | FAIR             |
| 4     | Flare Structure | FS        |                  | 0                       | 0               | 3.6            | 0        | 0          | 3.6         | GOOD             |
| 5     | Processing | PP            |                  | 28                      | 28              | 7.2            | 28       | 0          | 91.2        | POOR             |
In the current study, there are 13 platforms that are assessed based on the methodology stated above. Table 16 summarize the scoring results based on the assessment that has been conducted.

5. Conclusions
In this paper, the methodology of risk assessment is proposed to assess the structural integrity of the aging offshore platform group. Some conclusions are drawn as follows:

- Five indicators are introduced to determine the integrity status of each platform. Several platforms are grouped by considering the similarity in framing, steel material, foundation properties, structural condition, loading condition, water depth, and operational history.
- The simplified risk assessment method enables to select the most severe platform from each group to be assessed further for finite element analysis. In this case of study, there are 13 platforms that divided into 5 groups. First group consists of 3 wellhead platforms with 3 legs, the severest platform is W2. Second group consist of 6 wellhead platforms with 4 legs, with W7 as the severest platform.
- Living Quarter platform is only member of group 3, which automatically selected into further analysis. The same principle applies for group 5, where Processing Platform is the only member and automatically selected into further analysis. Group 4 consists of 2 platforms, with BS as the severest platform. In addition, from all the platforms assessed based on five indicators to determine the integrity status, two platforms namely PP (Processing Platform) and LQ (Living Quarter) are categorized as poor, as this two platforms do not satisfy all five indicators.
- For future works, finite element analysis will be conducted to evaluate in place, seismic and fatigue performances by modelling the members in accordance with the results of survey and inspection. In parallel, the scoring method will be prepared to perform the quantitative assessment.

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