The Safety 4.0 challenge: The Asset Integrity Management for Safety Critical Element risk management.

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1 - Introduction

The Asset Integrity Management (AIM) is also part of Asset Management (AM), but the main objective is to achieve physical asset high performance concerning safety and environmental aspects. In fact, in the last decades, the risk management has been applied for all Oil and Gas, Nuclear, Chemical, Pharmaceutical, Mining, Metallurgy, Aerospace, Automotive and Railway industries all over the world. However, in most of such industries, despite of the major accident reduction along time by mitigating the risk, such events have been not been completely avoided.
Therefore,
The beginning of AIM started in July 2008 that marked the 20th Anniversary of the Piper Alpha Disaster. Because of the risk posed in the Oil and Gas aged physical assets, a very important discussion in 2004 arose about the residual risk mitigation of such physical assets. The UK Secretary of State for Work and Pensions afterwards a Parliamentary debate which triggers a request of the ″Key Program Asset Management (KP3).
The main program objective focused on offshore installations on the United Kingdom Continental Shelf and revealed significant issues regarding the maintenance of safety critical systems used in major accident concerning the period between 2004 and 2007.
The Asset integrity is defined by the HSE (UK) as:
"The ability of an asset to perform its required function effectively and efficiently while protecting health, safety and the environment."
Based on such definition the HSE's Offshore Division undertook the review, with input and cooperation from key oil and gas industry´s stakeholders, including trade unions and industry trade associations. The Asset integrity program was comprised of the following aspects:

- Asset integrity/process safety management;
- Physical state of plant;
- Safety-critical systems;
- Leadership;
- The engineering function;
- Corporate and cross-industry learning and communication;
- Human resources and competence;
- Safety culture;
- Workforce involvement in controlling major accident hazards;
- Existing mechanisms for workforce involvement.

Based on this case, the first effort of the AIM had the objective to find evidence of awareness of the need for effective process safety management and major hazard risk controls, in other words, risk management.
In order to verify compliance with such elements, it was necessary to establish an audit process. That required:

- To define the auditors qualified to check the asset compliance on such criterion defined above;
- To define the asset to be audit based on safety criticality;

- To define the evidence required in the audit process to assure the compliance with those asset integrity elements as well as how to get such evidence.

In order to precede such audit, process some templates were defined by KP3 as shown the figure 1.

Offshore D	**Maintenance of safety critical elements (SCE)**		
1. Does the maintenance work order for a SCE contain a statement of or reference to the relevant SCE performance standard? 2. Does the work order describe any tests to be conducted prior to re-commissioning, to demonstrate that the relevant performance standards has been met? 3. How is the result of this test recorded (e.g. pass / fail / remedied) 4. What do you do if the test doesn't meet the acceptance criteria?			
RELEVANT LEGISLATION PFEER 5 Assessment - establish appropriate performance standards SCR 2 (5) SCEs remain in good repair and condition PFEER 19 Suitability and condition of plant PUWER 5 Maintenance			
NON COMPLIANCE / MAJOR FAILING	ISOLATED FAILURE / INCOMPLETE SYSTEM	IN COMPLIANCE / OK	NOT TESTED / NO EVIDENCE

Figure 1 KP3 Audit guide. Source: HSE, 2014

The first step in direction to verify the compliance of critical factors for AIM was successfully achieved. However, the addition and important steps were to implement the asset integrity management in Oil and Gas company's day based operational routine.
Since the first effort to improve the asset integrity performance, different discussions have been taking place in different Oil and Gas companies as well as different models have been implemented.
However, no international standard such as ISO 55000 have been applied to asset integrity management in Oil and Gas and other industries.

2 – Asset Integrity Management Program Elements

The Asset Integrity Program can apply the same aspect of the AM defined in ISO 55000 such as context of the organization, leadership, planning, support, operation and performance evaluation but need to focus on the critical safety elements risk management.
The safety critical elements are the ones, which in case of failure may lead to a major accident such as jet fire, toxic cloud release, explosion, fire, toxic product spill, aircraft crash, trains collision or derailment. In fact, the safety critical element can be a result of a software, hardware or human error combination as shows the figure 2.

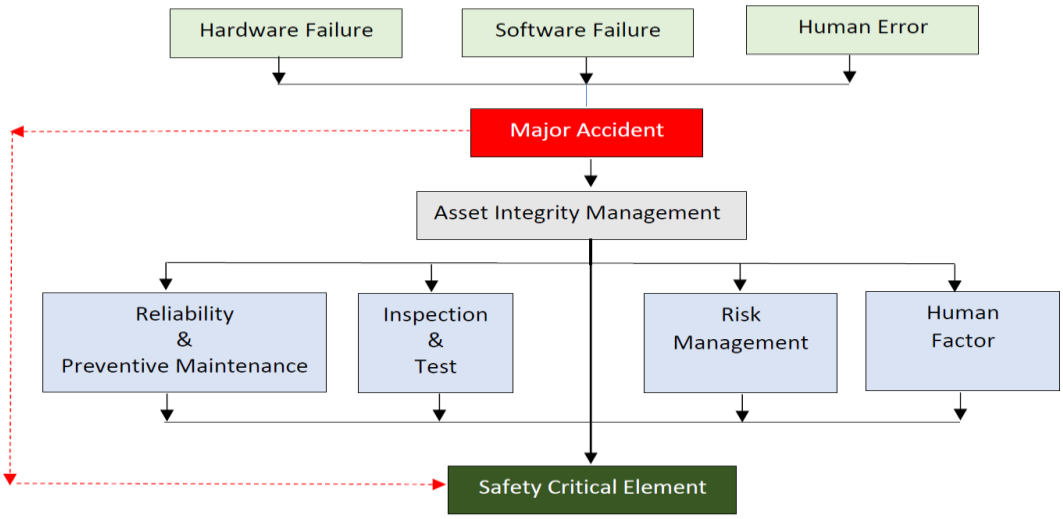

Figure 2 Safety Critical Element
Source: Calixto. E et al 2018

Nowadays, the current AIM programs, mostly are based only on RBI analysis without considering the human factor assessment, which is a vulnerability that can be reduced based on proposal integrated Asset integrity management.
In addition, it´s also important to integrate reliability and preventative maintenance into asset integrity management since the very beginning life cycle phase as a way to achieve and maintain the asset integrity. Therefore, the AIM pillars are “Risk Management”, “Reliability & Maintenance” and “Human factor” as shows figure 3.
The Risk Management means to define a risk target, hazard identification, incident and accident investigation, risk assessment, risk evaluation and risk mitigation, communicate the risk and prepare an emergency response plan. In order to identify hazards and assess the risk different qualitative and quantitative methods can be applied. Such analysis will not be discussed here in this paper.
The Reliability & Maintenance methods are implemented in order to enable the risk mitigation based on preventive maintenance at the proper time as well as to define reliability and safety performance index. Such methods are defined and implemented since the concept and design phase to be verified and validated during operational phase.
The Human factors that may influence or trigger a major accident are identified by human reliability analysis, which concerns all human performance factors related to all critical activities that can lead in an accident or environmental impact.

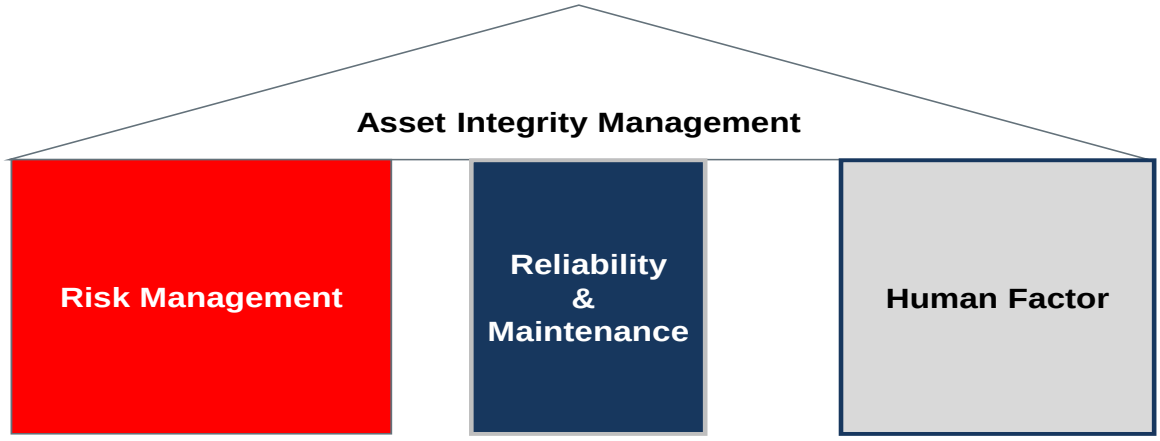

Figure 3: House of AIM.
Source: Calixto. E et al 2018

3 – Asset Integrity Management into Industry 4.0 contexts

Since 2010, the new era of Industry 4.0 becomes to be reality for many industries across the globe. In the last five years new IOT technology development has been applied to AM based on different topics such as Big Data, Prognostic Health Maintenance and Machine Learning, being part of the so-called Maintenance 4.0.

Despite of all development, that enable an integrated AM concerning performance index measurement, maintenance routine management and prognostic health maintenance, too much focus has been given for maintenance and a lack of effort for safety concerning the safety critical element management.

However, based on the last IOT technology development, it's possible to integrate the AIM as part of AM based on the field data collected automatically in the FRACAS (Failure Report And Corrective Actions System) that is part of AM system and enable to collect all information related to safety critical elements as shows figure 4.

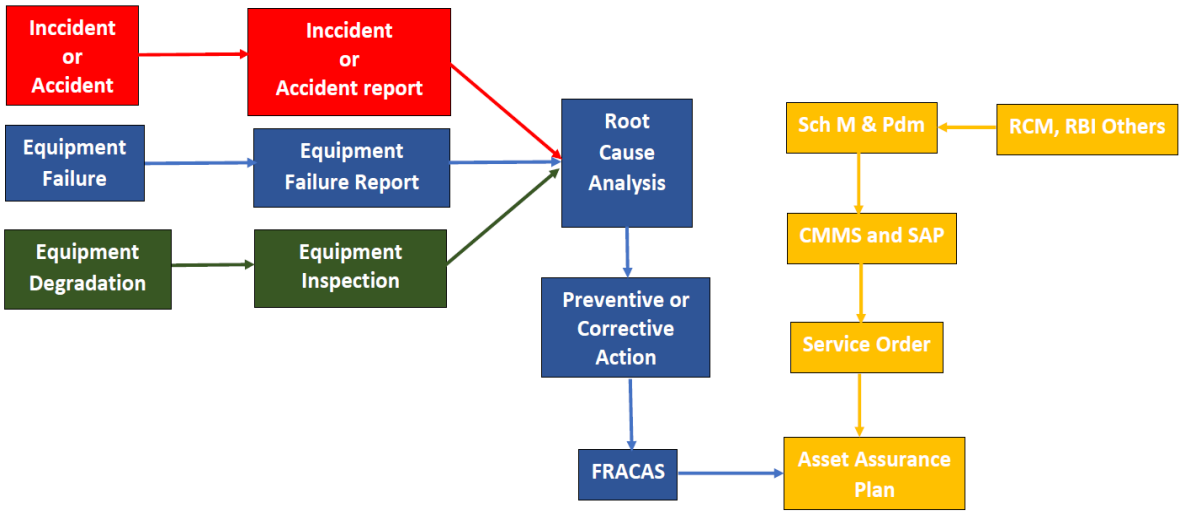

Figure 4: FRACAS Flow.
Source: Calixto. E et al 2018

Indeed, the FRACAS is part of the AM Flow, which enable to collect not only equipment failure information, but also incident and safety critical element conditions based on predictive maintenance and inspection that deploy preventive actions such as schedule maintenance in the assurance plan to mitigate the risk. However, it´s very important to establish a process to enable an effective AIM flow into the AM process as shows figure 5.

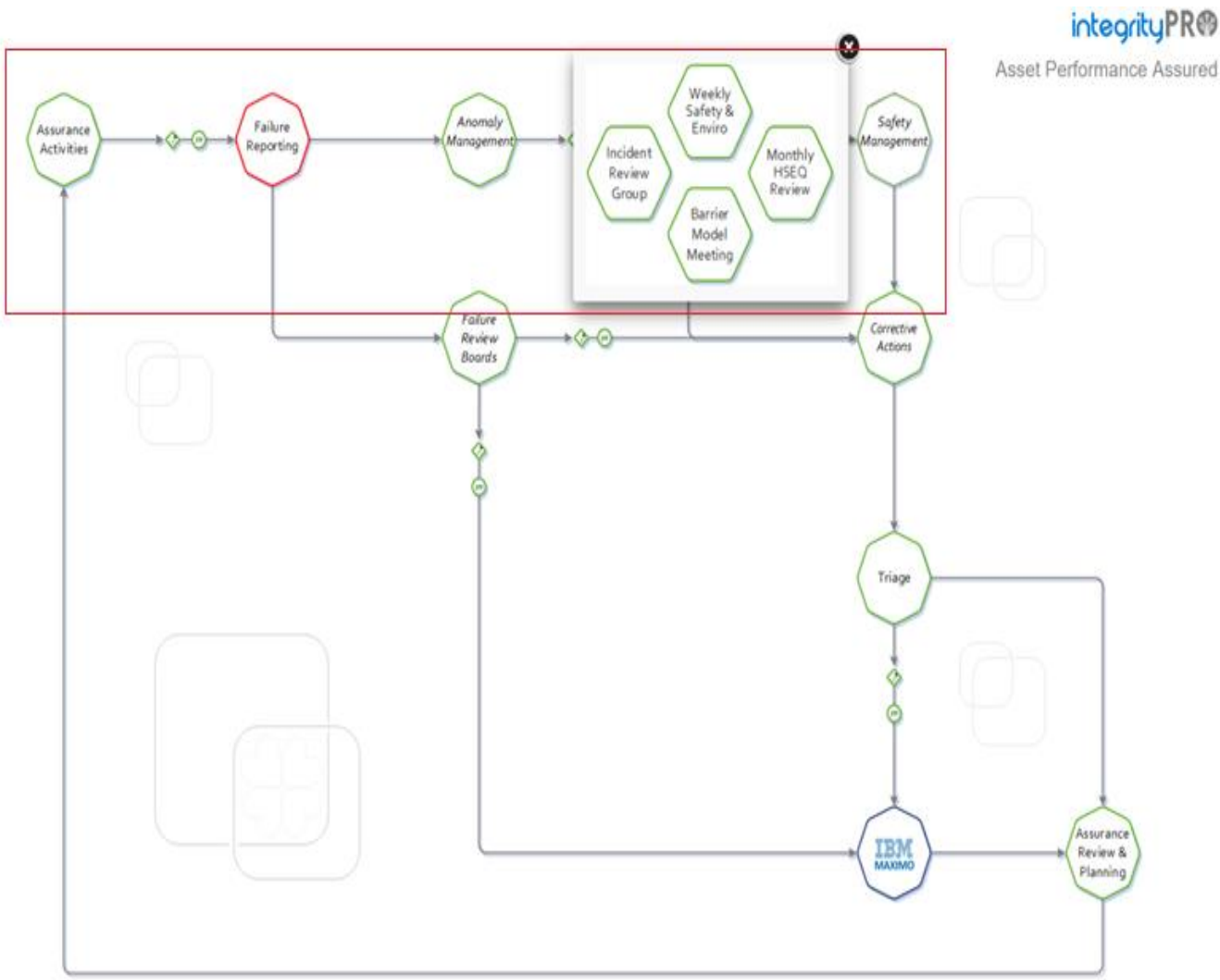

Figure 5: AIM flow into AM Process.
Source: Integrity PRO, Enkelt,2018

The figure 5 describes the AIM flow, highlighted in red, as part of the AM flow described. Therefore, the first step is the assurance activities, that enable to collect information based on online monitoring and inspection about all types of assets, include the safety critical elements. The second step is the failure report where the FRACAS system is implemented considered all information as described in figure 4. The third step is the anomaly management, which enable the managers to prioritize the asset based on the risk classification. In case of AIM, the safety management takes place in the fourth step, which encompasses all safety meeting and incident reports as well as the barrier model as described in figure 6.

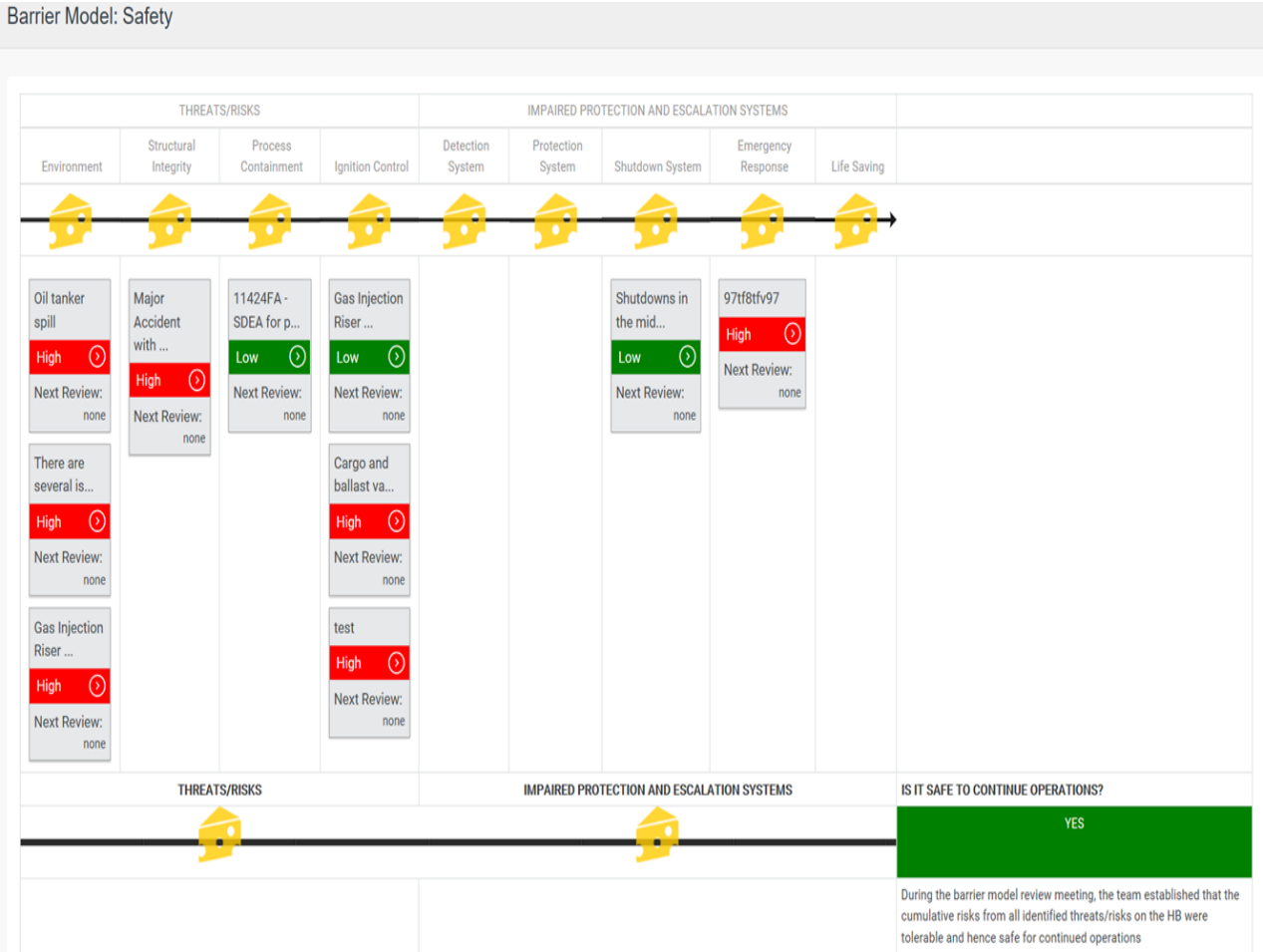

Figure 6: Barriers Model to Safety Critical Element Management.
Source: Integrity PRO, Enkelt, 2018

Since the Critical Safet Element are defined in the FRACAS system and the risk is classified in the Anomaly system (steps 2 and 3), the Barrier Model is automatically updated and enable the Asset Integrity and Safety managers to manage the risk of the safety critical elements.

4 – Conclusion

The paper achieves its objective that was to demonstrate how to manage the safety critical element risk under the context of Industry 4.0, the main pillars that support the AIM program and how to integrate the asset integrity into an asset management program. Therefore, the main recommendations are:

- The necessity of an international standard for asset integrity management is very necessary to establish a common understanding about the AIM concepts and principles;
- It´s very important to consider the Reliability & Maintenance, Risk Management and Human factors as the main pillars of the AIM;
- The asset management elements can be also considered in the AIM, but the main focus needs to be the safety Critical element;
- The AIM can be part of the AM, but it´s necessary to define clearly the process steps as well as the resources and organizational structure;

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