Chapter 37

Value Potential of Expert Systems for Offshore Oil and Gas Assets from a Maintenance Perspective: A Case from Norway With Respect to Integrated Operations

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Abstract Expert systems (ES) broaden the possibilities for solving complex practical challenges, providing quick decision support, particularly when operations become complicated and collaborative. Such systems can contribute to improve overall technical integrity of offshore asset, subsequently creating value for oil and gas (O&G) companies. Consequently, this paper summarizes the results of the data collected through multiple case studies to investigate how sophisticated tools and technologies, such as ES, can contribute to improve the technical integrity of assets and add value to the Norwegian continental shelf (NCS) under the new operating environment known as integrated operation (IO). The paper highlights the potential of ES to be effectively deployed for real-time decision-making, enhancing predictive/dynamic maintenance capabilities, improving equipment reliability and availability, and optimizing work planning and resource allocation. Given the practical complexities of IO, the paper also identifies potential challenges, obstacles, and factors in the use of such advanced applications.

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37.1 Introduction and Background

The Norwegian continental shelf (NCS) is advancing more and more into deeper sea operations with significant subsea developments. It is faced with the challenge of making the most of marginal profitability fields as well as mature fields that are in the production decline phase. It also has to deal with managing the risks associated with unmanned installations coupled with an aging workforce whose expertise is in danger of being lost completely. And ultimately, it has to battle with ensuring compliance with health, safety, and environmental (HSE) regulations and standards that are continuously being stiffened. All these, according to industry professionals, translate into a need for value creation through the efficient use of real-time data for enhanced decision-making. This in turn would require the efficient preservation, development, and management of valuably scarce expertise. These needs thus contributed to the conception and initiation of the new collaborative environment concept known on the NCS as integrated operations (IO).

IO is commonly described as the, "integration of people, work processes, and technology to make smarter decisions and better execution [1]." This initiative, introduced by the Norwegian Oil Industry Association (OLF) about a decade ago, emphasizes the need to use "ubiquitous real-time data, collaborative techniques and multiple expertise across disciplines, organizations and geographical locations [2]." Ultimately, therefore, value creation is the expected outcome of this initiative. Value creation is in terms of enhanced HSE and optimized production. Whether it is through HSE or production, improving the functional and technical integrity of offshore assets plays a key role in creating value. Subsequently, we can relate certain aspects of value to asset maintenance under IO.

Within the domain of operations and maintenance (O&M), IO's practical application has been interpreted to encompass the following [3]:

- Testing out and implementing new technological solutions to especially enable predictive maintenance capabilities
- Implementing more robust technical platforms for effective O&M data management
- Establishing new organizational forms as compensation for the lack and/or shortage of experienced O&M workforce
- Standardizing the technical language used by different stakeholders for communication and cooperation enhancement purposes
- Providing fast access to technical expertise in challenging and urgent scenarios
- Building a lively competence network to enhance decision-making and the execution of activities
- Making quick and effective decisions based on data (data value creation).

The above list, according to industry professionals, highlights the need to employ sophisticated tools/systems that have the capacity to efficiently utilize the large volume of data that is being made available through the IO scenario. The concept of *expert systems* (ES) is an example of the tools/systems that, if efficiently employed, have the potential to significantly improve the real-time decision-making ability of O&M engineers and managers.

ES are computer-based tools designed for problem solving. They are designed to execute specific tasks (domain specific) by approaching problem solving as a human expert would. Therefore, it is considered as a tool that equips the less skilled with some of the reasoning and decision-making abilities of experts [4–7]. They are also commonly referred to as a type of decision support system (DSS) or knowledge-based systems (KBS) [8].

Our own preliminary studies reveal an apparent lack of widespread adoption and use of ES technology for asset maintenance on the NCS. Subsequently, the purpose of this paper is to investigate how sophisticated tools and technologies, such as ES, can contribute to improve the technical integrity of assets and create value in the NCS under IO.

As earlier indicated, the enhanced technical integrity of offshore assets can be related to effective asset maintenance. Technical integrity management, as we know it, is simply ensuring that facilities are in a sound condition (structurally and mechanically) such that they are able to perform and produce the outcomes they are designed for. These maintenance activities must therefore ensure that the assets are available and can be relied upon to deliver the expected outcome. Through the collaboration of people, technological systems, and processes/procedures, these maintenance activities can actually ensure asset availability and reliability, translating into enhanced technical integrity. It is the technological systems used to support maintenance decision-making and actions (e.g., sophisticated technology such as ES) that our attention is directed at here. IO is to realize a complex interactive environment of equipment, personnel, systems, processes, and organizations on the back of information and communication technology (ICT). Subsequently, the use of ES can only serve to foster the realization of a collaborative operating environment and improve the overall technical integrity of offshore assets. But for these systems to improve technical integrity, they must have a structure that is suitable for the task at hand. This means that they must possess (or have the capability to possess) functionalities relevant to the activities aiding the decision-making process.

37.2 Methodology

This study was conducted through multiple case studies using information obtained via two methods: interviews and questionnaires. The study was, however, limited to existing maintenance DSS within the field of asset maintenance. Four maintenance professionals from four O&G companies took part in the survey. Three of them were from large operating companies, and the other one was from a major maintenance service provider. The results and deductions are therefore limited by the data obtained from only these companies operating on the NCS.

Interview sessions were scheduled with highly experienced asset management professionals. Their expert insight was sought into “what,” “why,” and “how” ES/DSS are acquired in industry and also the identification of factors/challenges that affect their implementation. The availability/scarcity of expertise within maintenance and how this affected maintenance activities was also explored. The interviews also focused on IO’s impact on the need for innovative technology and the acceptance of such technologies by employees within the O&G industry. The interviewees also expressed their professional views on the expertise requirement under IO, and the part ES/DSS plays (or can/will play) in the attainment of the O&M goals under IO.

The aim of the questionnaire administration was to assess the efficiency/effectiveness and impact of sophisticated technology (ES/DSS) for decision-making in maintenance. It covered three main system areas: *structure*, *functionality,* and *value impact*. Under system structure, the questionnaire respondents graded the domain specificity and knowledge base of a chosen maintenance system on a three-point scale. User friendliness, interoperability, reporting facility, large-volume data handling capacity, data uncertainty handling, response time, explanation facility, 24/7 online availability, knowledge acquisition capacity, symbolic processing capacity, and conflict resolution ability were graded on a five-point scale for system functionality. These functional areas were considered necessary for decision support within an IO environment. Finally, the respondents assessed the current and potential system impacts. Impact on productivity within maintenance, equipment availability and reliability, value-added gains, HSE activities, work planning and resource allocation, competence buildings, preventive/predictive/dynamic maintenance capacity, decision support, and expert task execution were graded on a five-point scale. These impact areas were considered relevant for value creation.

37.3 The Expert Systems Structure

Various researches (e.g., [4]) believe that the power of an ES lies in its ability to receive and combine factual and heuristic knowledge for complex problem solving. They therefore suggest that the knowledge setup within an ES be organized in a manner that fosters easy retrieval and in a format that can distinguish between data, control structures (parameters), and heuristics. Consequently, developers organize ES’s around three main structures:

1. *Knowledge base*—this is the nucleus of all ES. It consists of a combination of the organized knowledge (a specific set of rules and procedures within the application domain for problem solving that have been captured by a knowledge engineer using knowledge representation techniques such as frames, semantic networks, and IF-Then rules) and the database (data and facts that may or may not be directly related to the application domain).

2. *Working memory*—this is where all the initial data about the problem are input/received, and the intermediate and final results/recommendations are displayed/retrieved.
3. *Inference engine*—this is the physical link between problem and possible solution. It is the control mechanism that organizes and matches knowledge in the knowledge base with the problem-specific data so that conclusions can be drawn and solutions can be found. It employs AI technologies such as ANN, GA, fuzzy logics, etc., that may be used singly or in combination.

37.4 Results and Discussion

In total, five maintenance tools/systems were studied and of these five systems (and based on an analysis of collected data), only one was considered to possess ES characteristics. To a certain degree, this is an indication of the alleged lack of widespread deployment of ES for asset maintenance on the NCS. This apparent lack of widespread ES adoption and use was perceived to be a direct consequence of a lack of knowledge and thorough understanding about the concept of ES by maintenance professionals. Proper product branding (or the lack of it for that matter) was highlighted as an underlying cause of the limited understanding of ES by maintenance professionals. A high-level approach involving the collaborative efforts of regulatory institutions and notable research and product development firms in ensuring that ES is appropriately branded was suggested as the first step in addressing this challenge. Other issues, such as the lack of confidence in unproven technology, embedded difficulties of the ES development process, lack of interest from service companies, and some perceived misconceptions about the implementation of IO, were also identified in this study as possible hindrances to the widespread adoption and application of ES and, in general, other sophisticated technologies.

The results of the study seem to suggest that, collectively, the maintenance systems may not be having their desire-valued impact on the NCS. Figure 37.1 below is an overall graphical representation of the estimated valued impact of maintenance systems on the NCS. It is derived from our five case studies by plotting the average rating given to each of the 9 impact areas. The impact assessment is lowest in the center with a rating of 0.0 (undeterminable impact/no expectation) and increases progressively toward the highest rating of 5.0 (significant impact/way above expectation). A rating of three is the minimum desirable and acceptable impact level. Thus, the further away a rating is from the center, the more desirable and valued the impact it has on maintenance activities on the NCS.

The consistency and quality of work output, together with productivity, seem to be highest valued impact areas. This we consider complementary of the systems. However, in an IO environment, lack of the desired impact on real-time decision-making, preventive/predictive/dynamic maintenance capabilities, and work

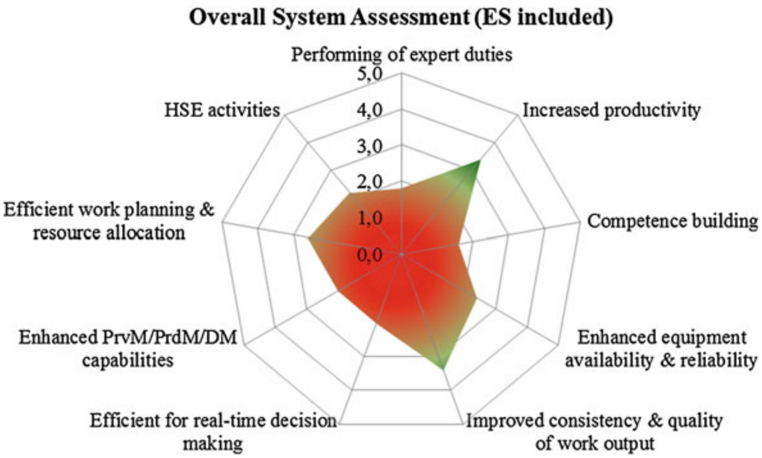

Fig. 37.1 Graphical representation of the overall impact of maintenance systems on the NCS (including ES)

planning and resource allocation is a conspicuous deficiency that would need attention. These deficiencies coupled with little or no impact on enhancing competence building and the performing of expert duties give the indication of lack “expertness”/sophistication in the maintenance systems on the NCS.

In this study, we employed an ES (sophisticated DSS technology) accept criteria of at least three. This is the least grade we expect any system considered to be an ES to have. Our argument for this acceptance criterion was that, since we rely on our human experts to assist us in enhancing our value creation process, we expect nothing less than quality work. Consequently, if we are to employ ES in our operations, the least-valued impact we can tolerate/expect is exactly what a human expert would have been expected to deliver (i.e., the system should meet and/or exceed or expectation). Any delivery/impact that is *below* our expectation is *not* considered value for money. Subsequently, we deduced from Fig. 37.1 that the overall impact assessment of the systems were below expectation (average of about 2.4). Hence, this adds to the perceived lack of widespread “expertness”/sophistication in the maintenance systems on the NCS.

The results also seem to suggest a positive relationship between ES application and the value impact of maintenance systems/software on the NCS. When the ES’s ratings were omitted from the analysis, the overall value impact assessment dropped by about 17 % (from 2.4 to 2.0), whereas the omission of the other non-ES resulted in less than a ±4 % difference in the overall assessment. The omissions were performed to investigate the impact each system had on the overall analysis. The impact of ES on the overall assessment can be seen in Fig. 37.2 where, in comparison with Fig. 37.1, the shaded area has diminished quite significantly.

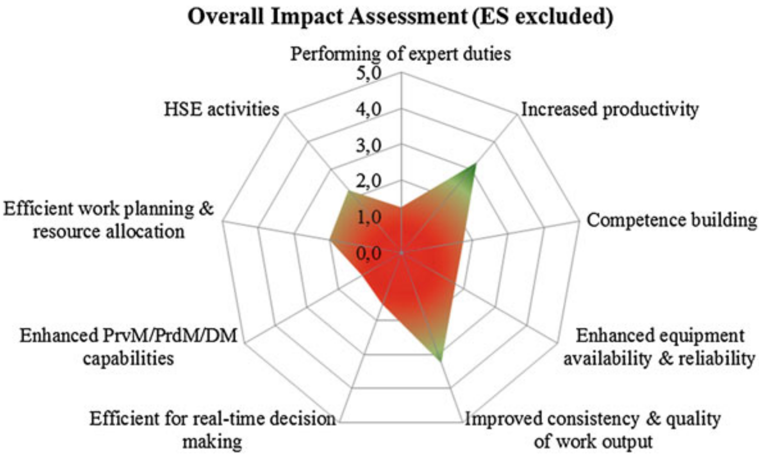

Fig. 37.2 Graphical representation of the overall impact of maintenance systems on the NCS (excluding ES)

The most affected value areas due to the omission of ES ratings were real-time decision-making, preventive/predictive/dynamic maintenance capabilities, equipment reliability and availability, performing of expert duties, and work planning and resource allocation. On the basis of this analysis, we could sufficiently infer that ES fosters the realization of the maintenance goals within an IO environment, i.e., value creation within maintenance as described in the introduction section of this paper.

Also, the study generally confirmed the notion that knowledge is more valuable than data and/or information. Subsequently, KBS's are most valuable to O&M managers and engineers. The system structural assessment part of this study indicated that for a system to effectively utilize a knowledge base, an interactive user interface, heuristics programming, and an inference engine should be present in the system structure. Anything short of this would require considerable human expertise to effectively link this knowledge to the problem at hand.

Figure 37.3 is a combination of 2 value pyramids: intelligence/wisdom is at the top of the decision (bigger) pyramid, and knowledge bases are at the top of the technology (smaller) pyramid. Since technological systems are currently not yet established in the intelligence/wisdom section, the height of the technology pyramid only reaches the knowledge section of the decision pyramid. Hence, Fig. 37.3 simply suggests that if the selection of maintenance tools/DSS is based on highest value creation potential, then ES should be one of the first to be selected. Since an ES is a KBS, it therefore possesses significant value creation potential.

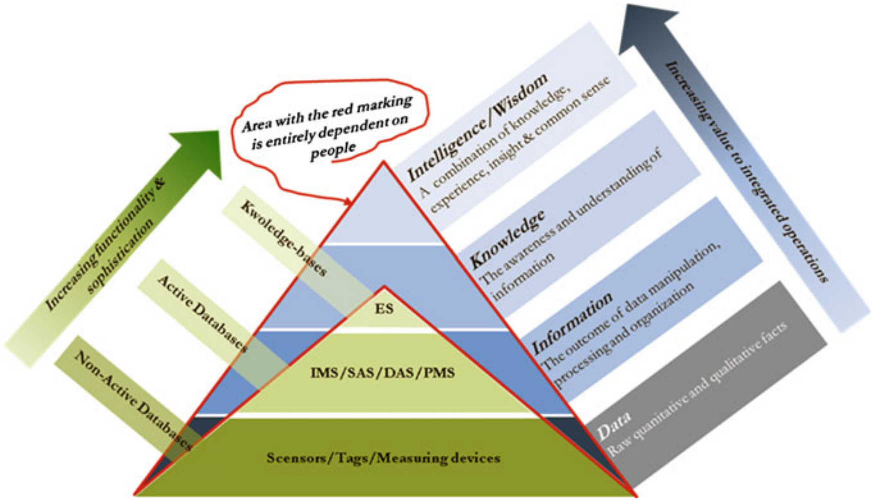

Fig. 37.3 Value assessment from data to intelligence (The initial figure was adopted from reference [9])

37.4.1 Potential for Expert Systems Utilization and Value Creation

With reference to the complementary research paper entitled, "*The Use of Expert Systems in Offshore Oil and Gas Assets: A Status Review With Respect to Emerging Needs for Innovative Solutions,*" it is therefore envisaged that the time and cost saving potential of ES within maintenance of offshore assets on the NCS is quite significant. Figure 37.2 from that paper was thus revised to illustrate the significant value creation potential being suggested in this study.

This (Fig. 37.4) thus indicates that the NCS seems to be utilizing ES applications (sophisticated technologies) for a comparatively small portion of its maintenance activities. Potentially large time and cost savings could be achieved in real-time decision-making if ES utilization can be extended to encompass the design, determine, and deploy phases of problems solving. There may also be the potential to develop an integrated ES (essentially domain specific) for maintenance problem solving that would incorporate all these phases in one application.

Essentially, the outcome of this study points to the need for more ES for value creation through enhanced asset maintenance:

1. IO is directed at transforming data/information into knowledge for decision-making → ES are technological systems that use knowledge bases efficiently/effectively.
2. IO is directed at dynamic operating regimes → ES fosters and enhances the quality of real-time decision-making, improves predictive and dynamic maintenance capabilities, and has the functional capacity to handle uncertainties.

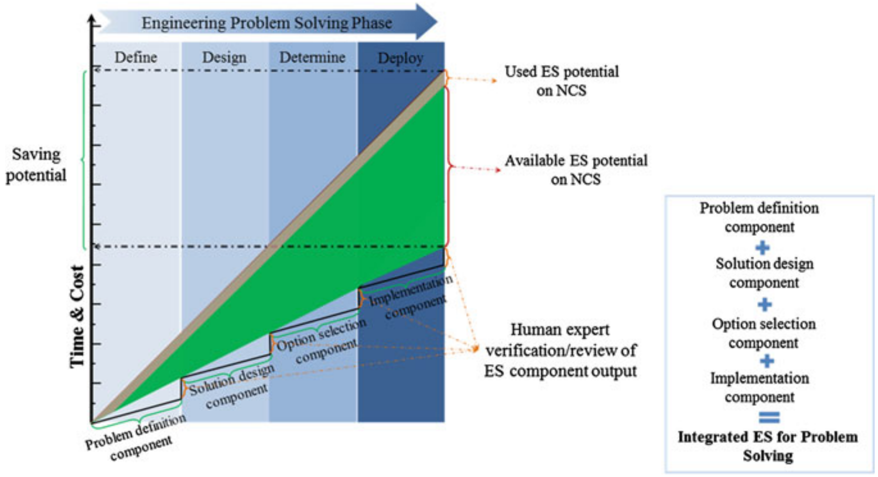

Fig. 37.4 Available asset problem-solving time and cost-reducing potential on the NCS

3. IO is directed at enhancing HSE → ES has functionalities that foster asset availability and reliability, which in turn influences the technical integrity of offshore assets.
4. Ultimately, IO is directed at enhancing value creation → ES is perceived to have the highest value creation potential.

37.5 Conclusion

The NCS has the potential to benefit immensely from more ES applications for asset maintenance. The study suggests that effectively deploying ES could assist in optimizing the technical integrity of O&G assets. This paper thus infers that significant maintenance time and cost savings stemming from widespread adoption and use of ES technologies are possible on the NCS. Areas such as real-time decision-making, enhancing predictive/dynamic maintenance capabilities, improving equipment reliability and availability, and optimizing work planning and resource allocation are prime ES impact areas that would be of worth in the IO environment. The study thus concludes that IO has created a conductive environment for the application of sophisticated technologies (such as ES) for value creation, especially within the maintenance discipline. Whether through enhanced HSE standards or through improved productivity of offshore installations, the optimization of the technical integrity of assets on the NCS can be achieved with the aid of ES.

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