POAC'17
Busan, Korea

Proceedings of the 25th International Conference on
Port and Ocean Engineering under Arctic Conditions
June 11-16, 2017
Busan, Korea

Systems Performance Measurement in the Arctic Using Internet of Things (IoT)

Zaki, R.[1], Ayele, Y. Z. [1], Barabadi, A. [1]

[1] Department of Engineering and Safety, UiT The Arctic University of Norway, NO-9037 Tromsø, Norway

ABSTRACT

The Arctic has unique and challenging operational conditions with strict regulations and requirement for safety and environment. A study of performance terminologies and standards revels that the performance elements measured such as reliability, maintainability, quality, though important, are not sufficient to describe the performance of a component for the Arctic. Some important elements like those that financial performance and sustainability are absent which, we mean are essential to reflect the performance of a system. This paper attempted to identify the shortcomings in the integrated performance frameworks for the Arctic. Hence, it begins with a review of the literature and evolution of performance measurement systems. Thereafter, the paper will illustrate how the concept of financial performance and sustainability should be integrated in performance measurement and suggest calculating process.

Moreover, due to the importance of availability and accuracy of data in calculation of the performance measurement, automated data-collection methods, quality of information being collected and processed are vital. Without available of accurate data, performance measuring can easily lead to a lack of credibility. Various indicators developed by processing raw data and other related information characterize such information. However, considering the high complexity of equipment and dynamicity of working environment collecting and analyzing of such data is a challenging task. It requires a platform to the generation of enormous amounts of data, which have to be stored, processed and presented in an efficient form. This paper will discuss the application of the concept of Internet of thing (IOT) to facilities such process.

KEY WORDS**:** Arctic, performance measurement, economic performance, IOT

INTRODUCTION

Performance measurement (PM) of the system, in general, is an essential tool that enables companies to achieve and control their desired objectives(Simons, 2013). The field of PM has been evolved over a long period of time; and, has been defined from different perspectives by different researchers. For instance,(Neely et al., 1995) defined, PM as the set of metrics used to quantify both the efficiency and effectiveness of actions. Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilized when providing a given level of customer satisfaction. Since 1880s different explanations and perspective used within the performance measuring concept including internal and external structure, financial, customer demand, effectiveness, efficiency, learning perspective, growth, stakeholder satisfaction, stakeholder contribution, productivity, Capacity, etc.

A study of the performance terminologies and standards reveals that the performance elements measured by them, though important, but not enough and still should be improve due to the unique and challenging Arctic operational conditions with strictly regulations and requirement for safety and environment. The operating environment of the Arctic, such as low temperatures, sea and atmospheric icing, polar low pressures, poor visibility and seasonal darkness, etc. has significant effects on the performance of system in various ways, including increasing failure rate and repair time; consequently, leads to production losses (Barabadi, 2014). Moreover, Arctic operational condition can increase the power losses, life cycle costs, and safety hazards. Furthermore, less developed infrastructure in the Arctic create several challenges such as limitations to the logistics of supplies, material and personnel required for the operation and maintenance activities (Barabadi et al., 2013). Hence, the Arctic region due to its peculiar operational conditions coupled with stringent environment regulation and safety requirement, requires new criteria for judging performance. However, most of the available literatures and methods lacks the ability to capture the effect of the dynamic nature of the Arctic on the performance of the system. Some of the measures has been used already to measuring performance in the Arctic but this paper will bring some new and important measures, such as sustainability and financial performance. Moreover, show how to calculate the suggest performance measure system.

The main purpose of this paper is, thus to modify the performance measurement system for Arctic conditions. Further, the concept of Internet of Things (IOT), for efficient ways of storing and processing data has been integrated in the modified PM concept. The rest of the paper is organized as follows: after a litreture review in section 2, the performability measurement concept for Arctic environment are discussed in Section 3. Section 4 presents formulations for quantifying the PM. The required data and information for PM estimation and the application of Internet of things (IOT) for this aim is described in Section 5. Finally, the concluding remarks is presented in Section 6.

LITRETURE REVIEW

Over the years, several methods, frameworks, and models have been developed, in order to quantify performance measurement (See e.g. (Nakajima, 1988), (Hayes and Abernathy, 2007) , (Kaplan, 1984), (Bourne et al., 2003), (Ghalayini and Noble, 1996), and (Khan and Shah, 2011)). Ghalayini and Noble (1996) categorized the performance measurement literatures into two phases: i) traditional phase, which is regarded as the first phase, was cost accounting orientation, and was started in the late 1880s; ii) the second phase, which is started after 1980, and attempted to present a balanced and integrated view of PM.

In general, the traditional phase literatures – cost accounting orientation approaches – have tried to quantify the system performance and, other improvement efforts in financial terms, by quantifying the return on investment (ROI), return on sales (ROS), etc. (Bourne et al., 2003), (Khan and Shah, 2011). There are several drawbacks of the traditional phase approaches. Most of the approaches, for instance, ignore clients and their needs (Ghalayini and Noble, 1996), are internal rather than externally focused (Hayes and Abernathy, 2007), (Kaplan, 1984), are backward looking and is historically focused therefore is not predictive measures and also criticized for not providing adequate information for a productivity measurement. To overcome these challenges, (Nakajima, 1988) introduced overall equipment effectiveness (OEE), by categorizing the major losses or reasons for poor performance, which is based on its availability, performance, and quality rate of the output. However, OEE and its measures, availability, performance speed, and quality rate only reflect the internal effectiveness of a system and financial performance and external effectiveness, which is characterized by customer satisfaction and measures that have long-term effect on company's profitability, was missing.

The end-1980 was a turning point in the performance measurement literatures, as it marked the beginning of the second phase (Hayes and Abernathy, 2007), As markets became competitive and customers became more demanding, due to globalization, companies attempts to find more balanced, multi-criteria, and integrated PM frameworks, by considering financial, non-financial, internal, and external performance perspectives. Consequently, several frameworks has been modified, suggested, and developed, see e.g. (Neely et al., 1995), (Keegan et al., 1989), (Kaplan and Norton, 2005), (Neely et al., 2002). Table 1 summarized the relative measures and/or criteria of various frameworks.

The applicability and suitability of second phase approaches vary from field to field, business-to-business, and even by time and location. Furthermore, these approaches are not well suited for operation and facilities with new and unique structures, functions, and business positions, such as the Arctic region.

Table 1. The relative measures and/or criteria of various frameworks

Framework	**Proposed in:**	**Measure/Criteria**	**Reference**
Performance measurement matrix	1989	Cost, non-cost, external, and internal factors	(Keegan et al., 1989)
SMART (performance) pyramid	1991	Quality, delivery, process time, cost, customer satisfaction, flexibility, productivity, marketing, and financial measures	(Lynch and Cross, 1995)
Results and determinants matrix	1991	Financial performance, competitiveness, quality, flexibility, resource utilization, and innovation	(Brignall et al., 1991)

Balanced Scorecard (BSC)	1992	Financial, customer, internal process, learning and growth	(Kaplan and Norton, 2005)
Integrated dynamic PM system	1997	Timeliness, finance, customer satisfaction, human factors, quality, and flexibility	(Ghalayini and Noble, 1996)
NORSOK Z-016	1998	Reliability, maintainability, and supportability	(Standard, 1998)
Performance prism	2001	Stakeholder satisfaction, strategies, processes, capabilities, stakeholders contribution	(Neely et al., 2002)
BSC of advanced information. Services Inc (AISBSC)	2003	Financial perspective, customer perspective, process, people, infrastructure and innovation	(Abran and Buglione, 2003)
System perfomability	2008	Survivability, dependability, and sustainability	(Misra, 2008a)
ISO 20815	2008	Item availability, production availability, and deliverability	(Standardization, 2008)
Production assurance performance	2010	Capacity, dependability, customer demand	(Barabady et al., 2010)
Production performance	2010	Economical, functional, and HSE	(Markeset, 2010)

PERFORMANCE MEASURMENT FOR THE ARCTIC

During the critical review of the available literatures, it can be concluded that for a comprehensive PM the following measurement should be considered:

- Financial performance
- HSE performance
- Overall Equipment Effectiveness,
- Sustainability performance

Figure 1 illustrates the concept of the performance measuring system and its related concepts. For instance, the Overall Equipment Effectiveness include functional and quality performance. The functional performance of a system basically, is expressed as a function of the availability and capacity of the system. Moreover, availability is expressed as a function of the system reliability, maintainability and supportability.

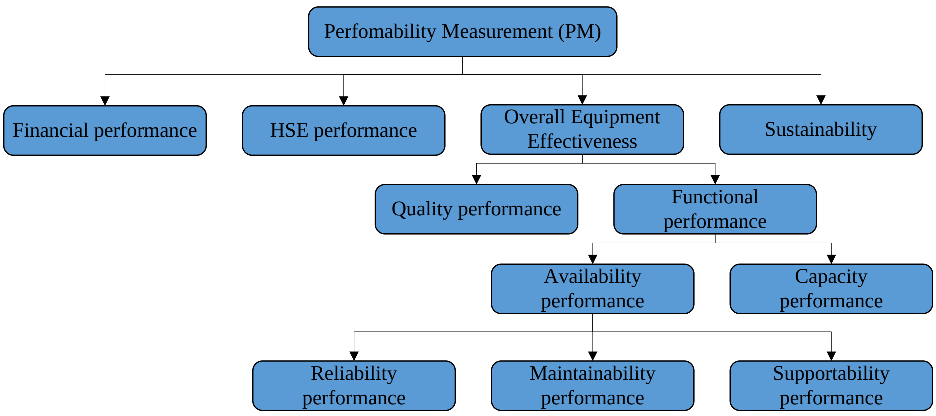

Figure 1. The concept of the performance measuring system

Sustainability Performance

Products and systems implied, especially in the Arctic should be on compliance with the principles of sustainable to increase the energy and material efficiencies, preserve ecosystem integrity, and promote human health, which in turn result in minimum life-cycle costs (Hallstedt et al., 2010). Without sustainable analysis, which include economic, environment and social aspects (Figure 2) an overall performance evaluation cannot be comprehensive particularly in the Arctic with strictly regulations and requirement for safety and environment.

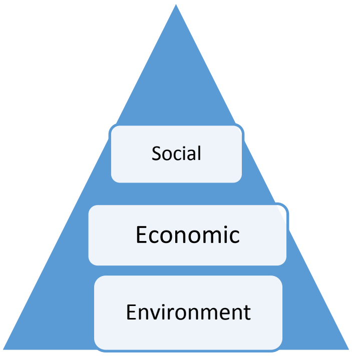

Figure 2. Sustainability aspects

For environment impact assessment, indicators such as air pollution, generated waste, waste recycling rates, use of non-hazardous materials, etc. should be included. In response, a vast range of methods, tools and concepts have been developed, each focusing on certain part of environment aspects of sustainability concept. These include Environmental Management Systems (EMSs), cleaner production and eco-design and various kinds of ecological indicators, such as ecological foot printing and Factor (Markeset and Kumar, 2000).

Social impact assessment should be included how company contributes to better health, education and safety of employees and the impact the company have on the local community. Economic impact assessment also need to be evaluated, economic activity can reduce the environmental and social capital. A company need environmental and social capital - alongside economic capital to create value in the future (Jan and Petra, 2016). A sustainable company can improve company reputation, brand value and can increase shareholder value or cost savings due to minimize use of material and energy. Moreover, sales may increase or strengthen of customer loyalty due to there is growing number of people who prioritize environmentally friendly product and services (Jan and Petra, 2016).

Figge and Hahn (2008) have developed a value-oriented methodology to calculate the sustainability performance of companies, called Sustainable Value. Sustainable Value allows assessing sustainable performance in a value-orientated way. Sustainable Value can have calculated by:

$$SV = \frac{\sum_1^n VC_n}{n} \quad (1)$$

VC = Return value – OC (2)

where:

- VC is Value Contribution for all environmental, economic and social resources for the company.
- OC is Opportunity Cost; is how much return would be created, if the resources in the company were used by the benchmark, and
- Return value is how much return the company creates with its resources.
- Finally, *n* is number of indicators for economic, environment and social aspects.

Financial Performance

In general, LCC analysis combined with a LCA (Life Cycle Assessment) analysis can be used for financial performance (Misra, 2008b). Several LCC tools have been developed, for cost benefit evaluation of a system, which describes the costs of system from the early planning stages to the end of use and, gives the decision makers information to find the correct balance or best solution considering cost and benefit. For instance, Norwegian Standard NS3454 provides a standardized methodology for carrying out the LCC. Design for the harsh climate condition, increases the LCC of the systems, and consequently, increases business risk. This is due to the lack of infrastructure in the Arctic, limitations to the logistics of supplies, material, and personnel required for the operation and maintenance activities, etc.

In general, the financial performance of a system FP_S, is a measure of efficiency of an investment and, can be used to express the measure of relative effect the operating environment of the Arctic has compared to that of an 'ideal' or designed operating environment. It is the ratio of the rate of investment (ROI) of a system under the Arctic condition and the ideal' operating environment. This ratio shows how the FP_S will be changed (increased or decreased) based on the effect of the operating environment.

Suppose our system is installed or is planned to be install in the Arctic region, and we wish to estimate the financial performance of the system under Arctic and 'ideal'-operating conditions. For the two operating environments with ROIs, ROI_{AR} and ROI_{ID}, the financial performance of a given system FP_S, can be expressed as follows:

$$FP_S = \frac{ROI_{AR}}{ROI_{ID}} = \frac{\frac{IG_{AR}-CI_{AR}}{CI_{AR}}}{\frac{IG_{ID}-CI_{ID}}{CI_{ID}}} \qquad (3)$$

where:

- IG_{AR} and IG_{ID} are the gain from the system investment under Arctic and 'ideal' operating environment, respectively.
- CI_{AR} and CI_{ID} are the cost of the system investment under Arctic and 'ideal' operating environment, respectively.

The FP_S are useful to describe the multiplication of the cost that occurs due to the peculiar Arctic operating environment. For instance, an FP_S of 1.5 for a particular system implies that the operating environment of the Arctic increases the cost of investment by $100 \times (FP_S - 1)\% = 50\%$. In similar manner, an FP_S of 0.5 is interpreted as the financial performance of the system installed in the Arctic region being more than half of that in the 'ideal' operating environment. The numerical value of the estimated FP_S must always be between zero and $\frac{1}{ROI_{ID}}$.

Health, Safety, and Environment (HSE) Performance

Engineering products and systems can cause hazards during operation or maintenance. Hence, performable system must seek to minimize the possibility of hazards (Misra, 2008b). The Arctic has great resources of different fish species, planktonic organisms, and bird habitats, which makes the area vulnerable and in the public perception Arctic is an icon for undisturbed nature, and the ''last'' wilderness (Paulsen et al., 2005). Hence, hazard reduction measures should be implemented to improve the HSE performance of the system. In addition, at very low temperature, electrical insulation can be cracked and, eventually exposed the conductors to the environment, and this can lead to a serious hazard for personnel. Further, salt water ice on antennas can bridge the insulators, then causing arcing and loss of communication. Moreover, low temperature generates static electricity, which destroys computer and can cause loss of data. Icing on stairs, deck and other surfaces can further cause slippery hazards that can result in accidents. Further, icing can damage structures and equipment, can hinder access to equipment and prevents work (Ryerson, 2011). There are several tools for consequence evaluation as well as quantifying probabilities of failure, such as failure mode and event analysis (FMECA), event tree analysis (ETA), cause consequence analysis (CCA) and fault tree analysis (FTA).

Risk matrix can be used to estimate the HSE performance. After calculating the associate risk for Health, Safety, and Environment the highest associate risk with these elements can be considered as the HSE performance of the production facilities. For example, if the risk of specific activity is high regarding the Health, medium regarding the safety and low with respect to the Environment the HSE performance will be High in this case.

Capacity Performance and Availability Performance

Functional performance of a system can be expressed as a function of availability and capacity. Capacity performance can be defined as an item's ability to deliver according to design capacity and/or current demands (requirements/needs). Capacity can calculate as:

Capacity = (Ideal Cycle Time × Total Count) / Run Time (4)

where, Ideal cycle time is minimum time to produce one part and run time is calculated by subtracting down time from production time and includes time when the process could be experiencing small stope, reduced speed and making reject part. The availability performance is also expressed, as dependability, which is a function of reliability, maintainability, and maintenance supportability, for details see (Barabady et al., 2010).

Quality is another important term to measure the performance of a system. The quality of an equipment is a measure of its degree of conformance to applicable design specifications and workmanship standards. It can realize that the degree of perfection is inversely proportional to the variability present in the equipment. Production facilities are made up of complex subsystems and components and they employ materials and machines. Hence, variation of parameters and dimensions of components leads to weakening, component mismatch, incorrect fits, vibration, etc. These issues can increase the failure (Misra, 2008b). Quality can calculate by dividing produced part that meet the quality standard by total of produced part including defect parts.

Quality = Acceptable count / Total count (5)

ESTIMATION OF PERFORMABILITY MEASURING INDEX

To quantify the PM, firstly the concept of performance measuring index (PMI) needs to be developed. In general, quantifying the PMI is a bottom–to–top process, which starts by quantifying the Availability Performance (AP). This constitutes an analysis of the reliability, maintainability and supportability performance of the system. Different form of the availability have been developed for example in the form of the Steady State Availability when the reliability, maintainability ad supportability is model by the Exponential Distributions it can be express as:

$$AP = \frac{MTTF}{MTTF+MTTR+MTTS} \quad (6)$$

where, MTTF represent the men time to failure, MTTR is the mean time to repair and MTTS is the men time which need to bring the spare parts and logistic support to the failure location.

Having the AP, the quality performance (QP) and the capacity performance (CP) of the production facility the OEE can be calculated by:

$$OEE = AP \times QP \times CP \quad (7)$$

Finally, by considering the value of the OEE, the Performability Measuring Index (PMI) can expressed as:

$$PMI = Fi^{\alpha_{Fi}} \times HSE^{\alpha_{HSE}} \times OEE^{\alpha_{OEEI}} \times Sus^{\alpha_{Sus}} \quad (8)$$

where,

- Fi, HSE and Sus are financial, HSE, and sustainability performance measures of the equipment, respectively
- α_{Fi} , α_{HSE} , α_{OEEI}, and α_{Sus} are weight vectors for financial, HSE, OEE and sustainability performance measures, respectively
- $\alpha_{Fi} \geq 0$, $\alpha_{HSE} \geq 0$, $\alpha_{OEEI} \geq 0$ and $\alpha_{Sus} \geq 0$ and $\alpha_{Fi} + \alpha_{HSE} + \alpha_{OEEI} + \alpha_{Sus} = 1$.

The basic assumption embedded in the estimation of AMI is that the performability measures, i.e. the financial, HSE, and sustainability performance have a different importance or weight on the overall performability of the system. Hence, when estimating the AMI, the weight of each of the performability measures needs to be quantified. Typically, the criticality of the selcted will decide the weight of each of the performability measures. For instance, for a critical component, which needs to be repaired as soon as it fails, maintainability is an important factor that has a significant impact on its availability; and, consequently on its overall performability. Hence, its maintainability has a high weight compared to a system, which has several redundancies, and it can be repaired later.

PM DATA COLELCTION AND SHARING UISNG IOT

Performance measurement is an information system and a reporting process through which the employees are given feedback on the outcome of their actions (Bititci et al., 1997). To obtain such feedback, availability, accuracy and quality of relevant data is a key factor. To have an effective PM analysis both currently reported data as well as historical data available in corporate databases should be used. Different type of the data should be collect and used in PM analysis including: data from manufacturing, experts, local information about climate, life cycle data of equipment , event and accident data, reliability data, financial data and products life cycle costs etc. Moreover, information about the behavior equipment under a given operational setting, their functional characteristics, and the technical faults and failures need to be collected precisely.

However, considering the high complexity of equipment and dynamicity of working environment in the Arctic, generation of enormous amounts of data, which have to be stored, processed and presented in an efficient form to calculate PM is a challenging task. Moreover, considering this fact that there is no sufficient data, information regarding the industrial activity in this area and conventional O&M practices may not be suffocation, thus some new technical solution should be developed. More specifically the proposed practice should enable differ department and even different industries in the region to achieve the timely critical PM data. The growth of implementation of advanced information and communication technology ICT solutions have generated new opportunities to data management of the complex, high-risk assets and capital-intensive industrial plants and facilities such as oil and gas industry in the Arctic.

Internet of Things (IOT) is a novel paradigm, which makes a data exchange and communication platforms for Business-to-Business (B2B) communication and technical solutions where data acquisition, processing and interpretation, and decision support components are integrated (Stojkoska and Trivodaliev, 2017), (Sundmaeker et al., 2010), (Gubbi et al., 2013). The connection of physical things to the Internet makes it possible to access remote sensor data and to control the physical world from a distance. A thing can be any real/physical object like simple autonomous sensor nodes, actuators, a virtual/ digital entity, or machines (Mihailovic, 2017).

IOT can brought unique capabilities to share information, knowledge, and experience to optimize decisions and actions. In the industry, integrated e-operation and e-maintenance are some example of IOT. In Norway from 2004 the term Integrated e-Operation is used in offshore industry. The Norwegian Oil and Energy Department support the Oljeindustriens Landsforening initiative and OLF is now coordinator for Norwegian efforts to improve and implement e-Operation at the NCS. There are examples of implementation of IO in relation to the O&G activity on the NCS. An example of integrated e-Operation framework modeling is the 'Secure Oil Information Link' (so-called SOIL) network available in the North Sea for oil & gas exploration and production industry, operated and administrated by the network service provider Oil Camp. SOIL was introduced to the Norwegian E&P industry in 1998, which consists of a number of application services actively connecting almost all the business sectors of the Norwegian O&G industry. This network, through the use of fiber-optic cables and wireless communications helps establishing the connectivity and interactivity between different parties, for instance, offshore O&M teams, operator's onshore O&M support groups, third- party CBM experts, logistic contractors, etc. Real-time equipment data can be acquired, jointly analysed and results can be exchanged online between these parties, enhancing the ability for shared interpretation and decision-making (Liyanage and Langeland, 2009). Another example is the onshore support center OSC in SKF-Norway, a CBM expert center that has remote diagnostic and prognostic capabilities and serves various operators in the Norwegian and Danish O&G sectors. Over the past, few years provide expert assistance, in logistics, and it has carried out online remote vibration monitoring of critical machinery of offshore production platforms in its OSC (Liyanage, 2008). Moreover, ConocoPhillips also as the operator of the Ekofisk asset has two such onshore centers OSC onshore support center. One of them is called onshore operational center (OOC) and has built-in integrated solutions for O&M planning, logistics, and other production and operation related activities.

Industry activities in the Arctic is not limited to oil and gas exploration. Mining operations, hydropower development, power lines, windmill parks, military activities, shipping activities and tourist traffic, particularly around Svalbard and Greenland have also been arisen across the past decades. These industries have varies experience and data about operation and maintenance in the Arctic. Connectivity and interactivity enhancing decisions and work processes regardless of the geographical location. This helps industries for manage the challenges due to less developed infrastructure in the Arctic. Limitations to the logistics of supplies, material and personnel required for the operation and maintenance activities in the Arctic create several challenges. Thus, IOT can be contributing to implement new business solutions between these industries by sharing the expertise between different industries in the Arctic, particularly between shipping and O&G industry. The connectivity and the interactivity between offshore and onshore, as well as between different onshore-based competence groups and other sectors of the industry (e.g. engineering contractors, equipment suppliers, technical expert centers, spare-part vendors, logistics, etc.), allows more effective PM analysis and consequently more effective decision loops as well as more coordinated planning and execution of O&M.

CONCLUSION

This work has introduced a modified performance measurement (PM) analysis of a given system, by considering the impact of the arduous Arctic operating environment. The proposed PM formulations comprises the estimation of the financial performance (to measure of efficiency of an investment), HSE performance (to measure the risk profile of the system), Overall Equipment Effectiveness (to measures the availability and quality rate of the system), and sustainability performance (to measure the material and energies used to build, run and dispose a specific system).

The proposed concept of performance measuring index (PMI) is particularly important in the Arctic operating environment since it expresses the measure of relative effect the operating environment of the Arctic has compared to that of an 'ideal' or designed operating environment. Moreover, the paper introduced the concept of measuring the sustainability and financial performance and, integrate it with the overall PM estimation process. Further, the paper illustrates the application of the concept of Internet of Thing (IOT) for measuring the performance of a given system. Incorporating IOT with PM analysis will be especially vital in the Arctic, due to the dynamicity of working environment as well as high complexity of equipment in the region. Our conclusion is that the use of a modified PM estimation technique has a vital role for ensuring that a system has high-level performance index, when operating in cold Arctic environment.

REFERENCES

ABRAN, A. & BUGLIONE, L. 2003. A multidimensional performance model for consolidating balanced scorecards. *Advances in Engineering Software,* 34**,** 339-349.

BARABADI, A. 2014. Reliability analysis of offshore production facilities under arctic conditions using reliability data from other areas. *Journal of Offshore Mechanics and Arctic Engineering,* 136**,** 021601.

BARABADI, A., NASERI, M. & RATNAYAKE, R. C. Design for Arctic Conditions: Safety and Performance Issues. ASME 2013 32nd International Conference on Ocean, Offshore and Arctic Engineering, 2013. American Society of Mechanical Engineers, V02AT02A024-V02AT02A024.

BARABADY, J., MARKESET, T. & KUMAR, U. 2010. Review and discussion of production assurance program. *International Journal of Quality & Reliability Management,* 27**,** 702-720.

BITITCI, U. S., CARRIE, A. S. & MCDEVITT, L. 1997. Integrated performance measurement systems: a development guide. *International journal of operations & production management,* 17**,** 522-534.

BOURNE, M., NEELY, A., MILLS, J. & PLATTS, K. 2003. Implementing performance measurement systems: a literature review. *International Journal of Business Performance Management,* 5**,** 1-24.

BRIGNALL, T., FITZGERALD, L., JOHNSTON, R. & SILVESTRO, R. 1991. Performance measurement in service businesses. *Management Accounting,* 69**,** 34.

FIGGE, F. & HAHN, T. 2008. Sustainable investment analysis with the sustainable value approach? a plea and a methodology to overcome the instrumental bias in socially responsible investment research. *Progress in Industrial Ecology, An International Journal,* 5**,** 255-272.

GHALAYINI, A. M. & NOBLE, J. S. 1996. The changing basis of performance measurement. *International Journal of Operations & Production Management,* 16**,** 63-80.

GUBBI, J., BUYYA, R., MARUSIC, S. & PALANISWAMI, M. 2013. Internet of Things (IoT): A vision, architectural elements, and future directions. *Future generation computer systems,* 29**,** 1645-1660.

HALLSTEDT, S., NY, H., ROBÈRT, K.-H. & BROMAN, G. 2010. An approach to assessing sustainability integration in strategic decision systems for product development. *Journal of Cleaner Production,* 18**,** 703-712.

HAYES, R. H. & ABERNATHY, W. J. 2007. Managing our way to economic decline. *Harvard business review,* 85.

JAN, F. & PETRA, L. 2016. Sustainable Value as a Tool for Corporate Performance Management within New Public Management Framework. *WSEAS Transactions on Environment and Development, volume 12, issue: 12, 2016*.

KAPLAN, R. S. 1984. Yesterdays accounting undermines production. *Harvard business review,* 62**,** 95-101.

KAPLAN, R. S. & NORTON, D. P. 2005. The balanced scorecard: measures that drive performance. *Harvard business review,* 83**,** 172.

KEEGAN, D. P., EILER, R. G. & JONES, C. R. 1989. Are your performance measures obsolete? *Strategic Finance,* 70**,** 45.

KHAN, K. & SHAH, A. 2011. Understanding performance measurement through the literature.

LIYANAGE, J. P. 2008. Integrated e-operations-e-maintenance: Applications in north sea offshore assets. *Complex system maintenance handbook.* Springer.

LIYANAGE, J. P. & LANGELAND, T. 2009. Smart assets through digital capabilities. *Encyclopedia of Information Science and Technology, Second Edition.* IGI Global.

LYNCH, R. L. & CROSS, K. F. 1995. Measure up!: Yardsticks for continuous improvement.

MARKESET, T. 2010. Design for performance: review of current research in Norway. *The Proceedings of Condition Monitoring and Diagnostic Engineering Management (COMADEM2010). June*.

MARKESET, T. & KUMAR, U. Application of LCC techniques in selection of mining equipment and technology. Mine planning and equipment selection 2000: Proceedings of the Ninth International Symposium on Mine Planning and Equipment Selection/Athens/Greece/6-9 November, 2000. 635-640.

MIHAILOVIC, A. 2017. Liberalising Deployment of Internet of Things Devices and Services in Large Scale Environments. *Wireless Personal Communications,* 92**,** 33-49.

MISRA, K. B. 2008a. Maintenance engineering and maintainability: An introduction. *Handbook of performability engineering.* Springer.

MISRA, K. B. 2008b. Performability Engineering: An Essential Concept in the 21st Century. *Handbook of Performability Engineering.* Springer.

NAKAJIMA, S. 1988. Introduction to TPM: Total Productive Maintenance.(Translation). *Productivity Press, Inc., 1988***,** 129.

NEELY, A., GREGORY, M. & PLATTS, K. 1995. Performance measurement system design: a literature review and research agenda. *International journal of operations & production management,* 15**,** 80-116.

NEELY, A. D., ADAMS, C. & KENNERLEY, M. 2002. *The performance prism: The scorecard for measuring and managing business success,* Prentice Hall Financial Times London.

PAULSEN, J. E., HOSET, H., RØRHUUS, T., LARSEN, V., ALM, D., BIRKELAND, O. & MARKER, R. Exploration Drilling In The Barents Sea; Prevailing Zero Discharge Regime, Challenges And Learning From Two Recent Exploration Wells. SPE Asia Pacific Health, Safety and Environment Conference and Exhibition, 2005. Society of Petroleum Engineers.

RYERSON, C. C. 2011. Ice protection of offshore platforms. *Cold Regions Science and Technology,* 65**,** 97-110.

SIMONS, R. 2013. *Performance Measurement and Control Systems for Implementing Strategy Text and Cases: Pearson New International Edition*, Pearson Higher Ed.

STANDARD, N. 1998. Regularity management & reliability technology. *Norwegian Technology Standards Institution, Oslo, Norway*.

STANDARDIZATION, I. O. F. 2008. Petroleum, Petrochemical and Natural Gas Industries–Production Assurance and Reliability Management. International Organization for Standardization Geneva.

STOJKOSKA, B. L. R. & TRIVODALIEV, K. V. 2017. A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, 140**,** 1454-1464.

SUNDMAEKER, H., GUILLEMIN, P., FRIESS, P. & WOELFFLÉ, S. 2010. Vision and challenges for realising the Internet of Things. *Cluster of European Research Projects on the Internet of Things, European Commision*.