Measurement challenges of supply chain performance in complex shipping environments

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Abstract

Purpose – Logistics service performance measurement (PM) is a fundamental activity pertaining to the achievement of logistics goals and the improvement of services. The choice of logistics PM criteria depends on stakeholder goals and expectations, including logistics service providers, customers and government and regulatory institutions. PM is especially challenging in areas where high values are at stake, several actors are involved and uncertainty about cause-and-effect relations is high. This paper aims to examine the measurement of performance in offshore oil and gas logistics, which has unique characteristics such as a supply chain (SC) exposed to a harsh environment, the presence of several independent carriers and a highly specialised and costly set of vessels involved in long-distance transport legs.

Design/methodology/approach – The study is designed as a multiple case study of two Norwegian shipping companies and two international oil and gas companies. Data were collected from several parts of the offshore service SC in several Arctic oil and gas fields.

Findings – This paper sheds light on the performance of the SC and presents key performance indicators for logistics operations. It concludes that the measurement of SC performance must be context-specific and emphasis needs to be placed on the degree of uncertainty and inter-dependency related to the SC in question.

Originality/value – The study suggests a list of context-specific key performance indicators for offshore logistics with a special emphasis on the peculiarities of a harsh operational environment.

Keywords Key performance indicators, Performance measurement, Offshore logistics

Paper type Case study

1. Introduction

Logistics performance measurement (PM) is especially challenging in areas where high-value goods are at stake, several actors are involved, and uncertainty is high. This is the case in the field of offshore support logistics servicing the oil and gas industry, where vessels must provide logistics value on a broad scale (Aas, Halskau and Wallace, 2009; Borch and Batalden, 2014). Field cargo vessels face challenging customer demands in terms of speed and punctuality, cost effectiveness and emission controls. The diverse and dynamic operational processes of an offshore field operation may stretch the resources required to fulfil contractual obligations and provide value-added services (Wong *et al.*, 2011).

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Customers of third-party logistics service providers are becoming increasingly demanding. A broad range of stakeholders influences logistics service and contributes to the need for clarification of the demands on ships and ship-owners regarding goal achievement within the supply chain (SC).

The efficient flow of goods and services throughout the value chain with a high degree of punctuality is vital in many industries. Assessment of logistics performance criteria must be a central part of contractual relations with carriers. The criteria development process depends on stakeholder goals and expectations, including those of logistics service providers, customers and government and regulatory institutions. Further, environmental issues have become an important parameter in international transport.

The Council of Supply Chain Management Professionals defines logistics management as "that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements". Supply chain management (SCM) is about integrating all key operational processes at any level between the final users and original suppliers to create added value for customers and other stakeholders (Lambert and Cooper, 2000). Mentzer *et al.* (2001) defined SCM as a systemic and strategic coordination of operational functions both within a given company and between partners working within a chain aimed at improvement of the long-term performance of each company within the chain (Mentzer *et al.*, 2001). In the context of this broader definition of SCM, smooth collaboration between logistics and other corporate functions is no longer sufficient to determine whether a company is actually performing well. When measuring the performance of logistics functions, a much broader range of areas come into play, which calls for a variety of additional perspectives. There is a need for a holistic and comprehensive performance assessment system and a valid list of logistics performance measures that is context-specific (Mishra *et al.*, 2018). This study aims at exploring logistics performance practices and metrics adopted in measuring strategic and operational performance in a context characterized by high complexity and volatility, specifically offshore logistics. To achieve this, the importance placed on specific upstream logistics performance metrics of the supplier in complex environments is assessed and the applicability and relevance of measures in specific environmental contexts are evaluated.

The paper is organized as follows. In Section 2, the theoretical framework for the measurement of performance in an SC context is presented. Section 3 considers the applicability of the Balanced Scorecard (BSc) framework for developing performance measures and metrics in offshore logistics systems. Section 4 presents the research methodology, namely, a case study approach. Section 5 presents an analysis of the results, and Section 6 discussion the implications before providing concluding remarks.

2. Theoretical framework

2.1 Logistics and supply chain performance

A central goal within SCM and logistics research is identifying and understanding the drivers and measures of SC and logistics performance. SCM is about managing the upstream and downstream relationships with suppliers and customers to deliver superior customer value at the least cost to the chain as a whole (Christopher, 1998). Hence, performance improvement is key to the fulfilment of the role of logistics and SCM. Two main approaches to defining SC performance are identified in the literature (Clivillé and Berrah, 2012). Logistics performance is studied in terms of company-level performance, with a focus on intra-organizational interaction and evaluation among companies, as well as the performance related to the whole SC.

In the SCM perspective, performance assessment involves both internal processes and performance expectations of other member firms throughout the whole SC (Lai *et al.*, 2002). Successful performance of an SC requires clear and transparent coordination and measurement mechanisms (Frohlich and Westbrook, 2001). Efficient measurement of an SC provides partners with a number of benefits, such as alignment of the partners' goals, updated status of the activities within the SC, sophisticated control mechanisms (Laihonen and Pekkola, 2016), continuous performance improvement and enhancement of the competitiveness of the whole chain (Varma *et al.*, 2008). At the same time, managers often struggle with multiple, seemingly conflicting objectives (Laihonen and Pekkola, 2016). Efficiency and effectiveness targets may be regarded as mutually exclusive (Fugate *et al.*, 2010). A lack of agreement on goals and SC performance measures between SC partners makes it difficult for firms to evaluate the performance of their activities on an SC-wide basis, and hence they focus on improving areas strictly in their own interest (Cooper *et al.*, 1997).

Conflicting interests of partners within the chain, along with the need for agreement and coordination of operations, imply a holistic approach towards SCM (Akyuz and Erkan, 2010; Chia *et al.*, 2009; Bigliardi and Bottani, 2010; Laihonen and Pekkola, 2016). Elaboration and adoption of an integrated performance management system presumes systemic and explicit representation of data on both individual and network levels that initiate a dialogue between the partners within the SC. Establishment of communication between the partners should promote increased awareness of activities and understanding that lead to improved transparency, a consolidated network strategy, inter-organizational learning and improved absorptive capacity from SC partners (Laihonen and Pekkola, 2016).

Interest in logistics and SCM research has contributed to the development of a number of measures purported to capture the performance of logistics and SCM activities. The development of such measures has propagated their use in operations management research, particularly in measuring the impact of various strategies or characteristics on performance. However, the complexity of SCs makes this a challenging task.

2.2 Supply chain performance measurement

Despite the existence of the numerous approaches and models for SC PM, there remain many challenges to overcome. These include huge amounts of data to be analysed for evaluation, lack of alignment between tactic, strategic and operational measures, lack of defined of metrics, the absence of a balanced approach (Katiyar *et al.*, 2017; Bai and Sarkis, 2012; Adel El-Baz, 2011; Bhagwat and Sharma, 2007; Akyuz and Erkan, 2010). Overall, these difficulties in developing standards for PM can be traced to various measurement taxonomies: which management level to measure; tangible versus intangible measures; variations in collection and reporting; organizations' location along the SC; and functional differentiation within organizations (Hervani *et al.*, 2005). The variety and level of performance measures depend on the goals of an organization or an individual strategic business unit's characteristics (Hervani *et al.*, 2005). Several authors have analysed SC PM with the aim of classifying performance areas, performance goals and performance measures (Chan, 2003; Gunasekaran *et al.*, 2001; Forslund and Jonsson, 2007).

Some studies have focused on quantitative metrics for SC PM. For instance, Martin and Patterson (2009) assessed the extent to which firms involved in specific agreements associated with SCM practice perceived their performance in terms of inventory, cycle times and financial performance. Forslund and Jonsson (2010) assumed that for successful performance assessment, companies must understand the importance of using validated, measurable and sufficiently detailed definitions of metrics, with clearly formulated targets.

Dissanayake and Cross (2018) introduced a mechanism for the development of an SC PM model that indicates the relationship between the performance of a single organization and the whole SC.

Otherwise, researchers increasingly understand importance of including non-financial qualitative indicators in assessments. In particular, Chan (2003) identified seven categories of PM, namely, cost, resource utilization, quality, flexibility, visibility, trust and innovativeness. Gunasekaran *et al.* (2001) discussed a range of performance metrics and classified them into strategic, tactical and operational levels of management as well as financial and non-financial. Han *et al.* (2018) developed a framework for SC PM in cross-cultural SCs, where the main emphasis was on the importance of mutual understanding and overcoming cultural differences.

With regard to identifying what should be measured, reference must be made to models describing SC functions. The Supply Chain Council has developed the Supply Chain Operations Reference (SCOR) model, which considers the performance requirements of partner firms in an SC (Stewart, 1995). This model views SC processes as comprising four components linked together to make up an integrated SC, namely plan, source, make and deliver. This theoretical framework has been used extensively to study SC processes to determine related performance measures.

Considering the SCOR model, Gunasekaran *et al.* (2001) designed a framework for performance metrics of an SC. Studying SCOR model application within the footwear SC, Sellitto *et al.* (2015) concluded that the model provides only an overview of the status of goal achievement. However, the model lacks a clear connection between measures, operations and strategic objectives and focuses purely on financially based quantitative indicators. To overcome the shortfalls of the SCOR model, Chorfi *et al.* (2018) suggested a framework that integrates the BSc approach and the SCOR model. However, the framework focuses on the alignment of SC strategy and core business processes and was developed for a particular context, namely SCM in healthcare organizations.

Developing a comprehensive SC PM system, Chelariu *et al.* (2014) suggested four categories of measures, namely, relationship, operational, strategic and economic measures. Addressing similar issues, Lam and Song (2013) developed a three-level framework within the context of a port. However, this PM system does not suggest any factual performance indicators and focuses on port performance for port stakeholders instead of the whole SC. Finally, Lin and Li (2010) suggested a systematic problem-solving approach, namely, Six Sigma, and focused on the evaluation of team structure management, processes and outcomes. However, this approach addresses the customer's perspective and may not be applicable for other actors. This seems to be a key problem in various approaches adopted for SC PM.

2.3 The Balanced Scorecard approach

To develop a comprehensive PM system, BSc is a relevant approach that can be implemented in the offshore logistics context. The BSc is a PM method that considers financial and non-financial measures of performance based on the organization's critical success factors, which are driven by its business strategy. The BSc concept was developed by Kaplan and Norton (1996) as an alternative to conventional financial PM systems. Its main purpose is to overcome shortcomings of other approaches by introducing a mix of financial and non-financial indicators that represents a company's activities and provides a basis for the implementation and further improvement of the organizational strategy (Atkinson, 2006).

The BSc approach develops measures from four important perspectives: financial, customer, the internal process (value chain) and learning and growth. Each perspective is described by goals that are linked by cause-and-effect relations. For each goal, multiple measures are developed to improve reliability of the measurement system.

The measures of the BSc approach are referred to as key performance indicators (KPIs). For each KPI, a specific performance target must be calibrated in accordance with pre-determined criteria such as historical performance or another reference. By setting targets first, the proper measures can be chosen and adopted; this supports the meaningful assessment of desired outcomes. Akyuz and Erkan (2010) indicated that the BSc approach provides an opportunity to look at performance from both short- and long-term perspectives and incorporates the interests of all SC stakeholders. The main advantages of the BSc are assistance in clarification and operationalization of the strategy of the whole chain, as well as alignment between the overall strategy and individual operations of partners (Bhagwat and Sharma, 2007). Further, its special focus on the value-adding processes contributes to an understanding of the mismatch between predefined targets and inputs and outcomes (Varma *et al.*, 2008). Some of the benefits include rationalization of cost and functions, improvement in operations, upgrading of procedures and systems and development of a realistic policy of performance-based remuneration.

The literature lacks an analysis of the BSc approach in the context of SC analysis (Chia *et al.*, 2009; Balfaqih *et al.*, 2016). Most examples are from the manufacturing industry (Bhagwat and Sharma, 2007; Varma *et al.*, 2008; Chia *et al.*, 2009; Bigliardi and Bottani, 2010), and examples from the service industry are needed (Gawankar *et al.*, 2016; Liang, 2015). Moreover, the concept is still widely criticized in the literature. For instance, Otley (1999) stated that lack of experience and analytical skills can lead to the mistaken creation of cause-and-effect relations and not context-related indicators. Moreover, Norreklit (2000) argued that relations between the four main perspectives of the BSc are not causal, but logical due to the lack of a time-related connection between the objectives, which is the main criterion of causality. BSc does not consider the external environment, only the interests of shareholders and customers, and ignores important interest groups such as competitors and suppliers (Rillo, 2004). The deployment of measures by actors of the same SC in different contexts can result in contradictory perspectives (Mooraj *et al.*, 1999). Thus, there is a need to look closer into performance measures and their indicators throughout the value chain, taking into consideration the context of each actor, and adapt the measures accordingly.

3. Research methodology

3.1 Research strategy

To study the relevance and context adaptability of SC PM, an inductive multiple case study approach based on Yin (2009) was chosen. The benefits of case studies for this purpose has been illustrated in prior research. These benefits, stem primarily from their information richness and ability to answer *how* and *why* questions (Eisenhardt, 1989a; Yin, 2009). In addition, the topic of study is in an exploratory stage, and little is known about performance-related measures and metrics of logistics service providers in complex environments. Second, case study research is also well-suited for the investigation of complex phenomena with many reciprocal links due to information-rich cases, which would be too complex for surveys (Yin, 2009; Borch and Arthur, 1995). Third, case study research also enables the possibility to check for the validity of responses due to the nature of personal communication and experienced interviewers.

3.2 Case selection

Using the framework developed above, theoretical sampling was applied to select the cases (Closs *et al.*, 2008; Eisenhardt, 1989a). The companies were purposefully selected to provide a wide range of perspectives. Four firms related to the provision of logistics services in turbulent environments were chosen. Of the four companies that agreed to participate, two are from the oil and gas sector and two are shipping companies that supply offshore support services. An overview of the selected companies is presented in Table I.

The oil and gas companies are responsible for the whole SC, from inbound logistics to the supply base to delivery at the offshore drilling rig or installation. The shipping companies represent the most challenging part of sea transport operations, from the supply base to the rig.

3.3 Data collection

For the purpose of the study, semi-structured in-depth interviews with top and middle managers responsible for logistics were conducted and transcribed. The use of interviews provides a number of advantages, including the opportunity to clarify obtained information, to control the flow of an interview and to observe the behaviour of interviewees during interviews (Frankfort-Nachmias and Nachmias, 1996; Rugg and Petre, 2007). Moreover, the semi-structured interview technique, which was based on predefined interview guides (Appendix), gave interviewees the opportunity to answer in their own way and avoid misunderstandings (Saunders *et al.*, 2009).

In addition, secondary information sources such as industry reports and internal documents and information about the value chain with a special focus on designers, yards and oil companies were included in the analysis. In the complex environment of the High North, there is a high level of interaction both with the oil rig as well as with the operating SC coordinator and the supply base contributing to incoming logistics. Third-party material was thus important (Yin, 2009).

	Energy companies		Shipping companies	
Companies	Energy Company 1	Energy Company 2	Shipping Company 1	Shipping Company 2
Type of company	Energy company, part of an integrated energy group	Independent energy company	Shipping company	Shipping company, part of an international group of offshore supply service providers
Main product(s)	Crude oil, natural gas	Crude oil, natural gas, processed products, renewable power	Offshore support services	Offshore support services
Area of operations	Norway	International	Norway	International
Number of employees (2014)	450	19,670	680	243 (2012)
Total revenues (2014)	NOK 17,200m	NOK622.7bn	NOK 965.1m	NOK 276.1m (2012)
Operational expenses (2014)	NOK 8,900m	NOK 80.2bn	NOK 719.5m	NOK 269.1m (2012)

Table I.
Information about the companies

The key informants who were interviewed were personnel that were knowledgeable and experienced regarding the aspects investigated in this study and reflected a broad domain of job descriptions. The informants included master mariner/captain, chief officer, deck officers, HSEQ manager, former managing director from shipping companies, logistics expert from Norwegian Polar Research Institute and oil spill adviser, personnel manager and principal logistics consultant of oil and gas company. During the interviews, the respondents were encouraged and probed to talk about what they perceived as barriers to achieving higher performance in the specific context. This was followed by a discussion of critical success areas and possible measures and metrics that one can use to monitor and control performance.

3.4 Data analysis

The data were coded to allow them to be linked to different parts of the value chain, specific processes and customer relations. The objective was to identify both critical success factors for SC operations in the Arctic oil and gas context as well as KPIs that may be used to measure performance. The case data were examined by experienced researchers before cross-case analysis was performed to detect commonalities and differences in patterns of SCM, as suggested in Eisenhardt and Graebner (2007) and Yin (2009).

4. Empirical findings

4.1 Context of the downstream offshore supply chain

In offshore logistics, the downstream offshore SC consists broadly of three nodes, namely, the supply base, offshore support vessels (OSVs) and the offshore oil and gas installations (oil rigs). The supply base stores and provides equipment, consumables, spare parts and personnel. It is responsible for warehousing, loading and unloading and transportation of all materials and personnel. The OSV fleet, which may be chartered and operated from an OSV owner and operator, consists of OSVs, anchor handling vessels, crew boars, oil spill response vessels and other specialised vessels.

At the offshore oil and gas installation, the OSVs will offload equipment, supplies and personnel and load waste, returned equipment and personnel to transport back to the supply base. Support and rescue vessels may also be on call.

4.2 Case study analysis

By interviewing key personnel and studying secondary sources and company documents, it was possible to reveal a number of critical success factors for operations. In addition, further probing during the interviews resulted in the precipitation of relevant KPIs that may be used to measure and evaluate performance in the context of offshore logistics in the High North.

The analysis of the cases, which was performed by means of the BSc framework, revealed a particular pattern in the areas that personnel deemed critical for the success of offshore oil and gas logistics operations in harsh environments. Table II indicates the areas that were identified as barriers to the effective performance of offshore oil and gas logistics operations. The critical areas were classified into the four perspectives of the BSc. The financial perspective includes capital costs and expenditure; the customer perspective includes the undertaking of offshore SC operations; the internal process perspective encompasses health, safety and environment issues; and the learning and growth perspective includes human resources and technology and information management.

4.2.1 Capital costs and expenditure. One of the most challenging parts of transport logistics in this specialised chain is transportation between the shore supply base and

Perspective	Critical performance area	Barrier description
Financial	Capital costs and expenditure	Comparably lower capital expenditure due to higher cost of investment in specialised equipment and vessels Higher OPEX for performing complex operations
Customer	Offshore supply chain operations	Attaining a high level of quality and environmental standards is more challenging in a harsh environment Achieving supply chain goals (optimization, economies of scale, timeliness, routing, reliability, frequency, planning, satisfaction)
Internal processes	Health safety and environment	Physical risks and dangers in the Arctic offshore oil and gas environment Impact of physical and environmental risks on operations
Learning and growth	Human resources	Skilled staff that is knowledgeable of the Arctic oil and gas environment and specialised operations Physical risks and danger to staff
	Technology and information management	Specialised equipment sourcing and investment Diffusion of innovation on specialised systems and equipment

Table II.
Barriers to effective arctic oil and gas supply chains

platforms. In this context, OSVs play an important role in value creation. Depending on the nature and characteristics of the sea region, investments may vary in terms of functionality and technology level.

Ship transportation capacity is relatively standard and includes large tank capacities in the hull and a large deck area of up to 1,100 m^2. Added functionality may include different types of emergency preparedness capacity, such as fire-fighting, search and rescue resources and oil spill recovery equipment.

These resources and their functional performance are related to investments and capital expenditures (CAPEX) as well as the costs of running the assets (OPEX). These increase with increased size, functionality, and operational area, such as high ice class and winterization. There is continuous innovation in design, building and equipment, with customers participating and often taking the lead.

Because the cost of hiring a vessel is high, optimal routing is important. Vessel costs may reach US$30,000 per day, and fuel costs may be US$10,000-15,000 per visit. On some occasions, deliveries is needed promptly, and the vessel may run at maximum speed, increasing fuel costs significantly. Fuel costs are normally paid by the oil company in the role of caretaker of the whole SC. A platform may need supplies every second day depending on activity type, size and storage capacity. A vessel may operate as a single vessel-single platform concept or may be a part of a pool, where several vessels work together.

Context and available infrastructure influence the need for investment in vessels and basic competence. Vessels are very much tailor-made, and personnel have experience for the sea area in question. Going from one sea area context to another may create additional investment costs. One example of this is moving from the Norwegian North Sea with significant infrastructure to an even harsher environment with very limited infrastructure in the High North.

For example, the former *Managing Director* of Shipping Company 2 shared the experience of the company moving to West Greenland:

> The first vessel that was chartered to the company, it was a multi-functional OSV [. . .] We discovered that this vessel had a pretty large accommodation area, so we used it as a hub, but we had to put a crane onboard because they had no contingencies on cargo handling. They did not

> have a crane in that harbour. We put the crane onboard and, of course, these were the costs. For the installation of the crane, the daily rate went up. Then we asked them if they have a medical team and diving support. What if you need a diver for West Greenland? Because if you are in Aberdeen, then there is no problem. You can make a call, and you will have a diver within an hour, they have services there.

Critical success factors (CSFs) include monitoring capital expenditure, return on capital, return on investment, operating costs, large capacity and size, optimal routing and pooling to optimize operating costs.

4.2.2 Offshore supply chain operations. There are many factors influencing offshore SC operations, especially in a harsh environment with specific idiosyncratic characteristics.

The tender offered and the charter party contracts between the ship owner and the oil company set the framework for the platform supply vessel service. In addition, there may be additional oil company procedures in general and for the specific field, such as industry standards like the GOM-O guidelines for marine operations in the North Atlantic. The customer may demand or recommend ISO certification such as ISO 9001 for quality and ISO 14001 for environmental procedures. Finally, there are international and national rules and regulations such as safety management systems that relate to the vessel and the ship owner. In total, there is a large set of standards, operating procedures, and objectives that must be met. These are controlled through vetting from oil company consultants, flag and port state authorities, and classification societies.

In SC operations, time is of the essence, so timeliness in delivery, reliability and frequency of SC operations to the offshore location is critical. This entails considerable planning as the same vessel may visit several platforms on one tour. Day-to-day coordination is handled through emails and telephone meetings between the inbound and outbound logistics coordinator and material coordinator at the supply base, the drilling or production coordinator, the platform manager and the store keeper at the platform or installation, with directions from the drilling superintendent and marine base superintendent, who are normally located at the oil company's regional headquarters.

At the same time, many difficulties threaten the smooth running of operations:

> It must be remembered that in extreme temperatures, many systems and components will be operating at or near their design limits. This is also true for crew members, who may also quickly reach their physical limits. Performance may degrade rapidly with a comparably rapid increase in risks to personnel, equipment, and the ship itself. *Logistics Expert*

In addition to the above, interviewees mentioned the stressful situations created by weather conditions such as fog, floating ice growlers and ice that cannot be detected on radar and causes reductions in transit speed.

The interviewees indicated that linking up business processes both internally and externally to subcontractors and customers was difficult due to long distances and communication challenges. The necessity of knowing in real time the arrival of packages with critical tools and equipment is an issue involving communication effectiveness and technology advances in offshore logistics operations. This limits delays both at the rig and supply base.

The interviewees pointed to the importance of having adequate supply base capacity and planning for capacity changes. They indicated it was frustrating for the crew to wait for a long time in port for new orders, creating ripple effects and hampering the crew's arrival to the rig on time, and thus delaying rig operations. Hence, it is important to ensure that there is adequate coordinative capacity as well as loading and discharging capacity to make shore-sea operations run smoothly. This is also important for dangerous goods and waste disposal.

CSFs include compliance to industry and customer quality and environmental standards, compliance to national and flag state regulations, adequate inbound logistics warehouses, loading/discharging capacity, personnel capacity for planning, coordination and control, measuring performance against delivery on time and reliability and frequency of service for the end user.

4.2.3 Health, safety and environment considerations. Safety in the work environment is imperative, especially in the maritime industry, as it entails additional physical dangers. Safe and effective cargo handling and storage as well as an effective information system are mandatory following the first "Greenland experience". The following quotes are indicative of the key issues pertaining to safety in the work environment:

> What I think is the most important is winterization, so you have safe access for the crew and personnel. It could snow, so you have these tents; ice and ice blocks or snow can fall on containers or equipment, and we want no falling objects. It could be dangerous when we are lifting the containers. *Principal Consultant Logistics*

> We did not plan for extreme weather during transit in spring time. This was even worse than the North Sea in winter time. Out of the storm, the vessel faced a large belt of potentially dangerous ice growlers in the operation area. *HSEQ Manager*

Delivering critical cargo on time is crucial in an industry where "time is money". The presence of floating ice and fog creates additional challenges to the punctuality of a delivery. In this context, it is vital to include in the health and safety dimension an indicator measuring the ability to detect sea impediments such as floating ice and fog.

The transport of goods must be performed safely and without risk to health, life and environment. The competence of the crew must match the challenges of the environment. Vessels moving towards the High North have to adapt competences in regard to personnel for both personal and vessel safety. There is also a capacity aspect as there is a need for additional crew on duty to avoid negative fatigue situations.

Obviously, it is critical to measure operational performance against extreme conditions, which leads to the adoption of relevant KPIs on winterization and a weather detection system. Responsiveness is also key to SC operations in this context. Further, there must also be a safety index to report and measure performance against accidents, incidents and near, as well as environmental impacts such as emissions, discharge and violations of international regulations.

4.2.4 Human resources. Creativity and innovation are important to make a company ready for changes towards new markets and operational areas. Having the right competences for meeting challenging contexts and having the ability to improvise and find new solutions are critical as uncertainty increases, as the consequences of wrong decisions could be dramatic.

According to the interviewees, it is important for people to be engaged in surveillance for the detection of ice and other weather conditions. People engaged in this task need to have good knowledge of the Arctic region and, of course, be competent in reading satellite data:

> Today, we see that the crew may need extra training for ice-covered waters. We are emphasizing extra courses for this type of operations. *Personnel Manager*

> Luckily, we had persons with broad experience with navigational instruments gained from service with the Coast Guard. We managed repositioning of our bridge resources and, through R&D activity, found out about the satellite navigation equipment we needed. *Master Mariner*

It is also important to hold workshops at regular intervals to ensure that relevant skills are constantly honed and updated. Training for working in such conditions is essential.

It is crucial that personnel are well experienced in working in conditions that require specialised training. It is of the essence that relevant KPIs are inserted in the performance management system of operators to reflect the effectiveness of recruitment of specialised personnel, training of personnel, personnel satisfaction and personnel turnover.

4.2.5 Technology and information management. In the context of offshore logistics in the High North, the interviewees indicated the importance of information and communication technologies as means of supporting daily ship operations. In particular, they mentioned that onboard and shore systems are necessary. A *Logistics Consultant* indicated that it is important to have an ice detection and communication system onboard that can provide information while navigating in icy waters. Both an ice detection system and an ice prediction system were deemed necessary.

As for infrastructure on land, there are additional contextual challenges. In this context, it is extremely important to invest in equipment that enhances the land-sea interface. Relevant performance measures must be identified and implemented. According to the interviewees, it is important to have satellite communication capabilities and thus the necessary satellite communication infrastructure to facilitate full workability of the positioning system because precision is of utmost importance in reaching drilling rigs for supplies. The oil company should follow the logistics operations in real time and have an accurate view of the position of the vessel. Base operations should have continuous communication with vessels on a 24/7 basis.

For the shipping company, the integration of all objectives and performance indicators in an SCM system is important to map the totality and make coordination and control as smooth and efficient as possible. The range of objectives and indicators and the reporting needed takes considerable effort, especially from the captains.

5. Discussion

The above findings illuminate several areas where uncertainty and barriers to effective operations are present in the context of the offshore oil and gas logistics operations. The findings call for adjustment and further development of a comprehensive set of KPIs.

Vessels need to be designed, constructed and equipped in a way that they can operate in harsh environments. Inbound logistics to the onshore supply base require efficient transportation by sea or air using different transport platforms (Kaiser, 2010; Milaković *et al.*, 2014). The shore supply base for cargo handling should be located in an appropriate port/terminal with maritime infrastructure and warehouses, tanks for drinking water, fuel and drilling mud and construction, repair and inspection facilities (Kaiser, 2010; Berlin, 2013). All the above require capital investments and entail high operating expenses. It is thus of the essence that performance in these two areas must be measured and tracked through the development of appropriate KPIs.

The challenges to achieving SC goals as well as attaining high levels of relevant quality and environmental standards are even more relevant in this environmental context. Customers expect higher levels of performance that must be attained in the context of potential physical risk and uncertainty. Relevant KPIs must thus be developed and used.

The physical and environmental risks and dangers in the Arctic offshore oil and gas context and the consequent impact on operational performance present areas of concern that must be closely monitored through a system of measuring and managing performance. The context, where people are required to perform operational tasks, presents a number of physical risks that requires particular vigilance, skills and knowledge. At the same time, to complete offshore logistics tasks successfully, there is a need to be at the forefront of relevant technological developments to be able to source and invest quickly in specialised equipment. Several studies have supported the positive link between information technology capability and firm performance, including Bharadwaj *et al.* (1999) and Kohli and Devaraj (2003). A significant body of research has attempted to link firms' investments in information technology (IT) with overall competitive advantage in the pursuit of superior performance (Melville *et al.*, 2004; Piccoli and Ives, 2005). IT matters to business success because it directly affects the mechanisms through which they create and capture value to earn a profit (Drnevich and Croson, 2013*)*. It has been shown that IT positively affects the logistics industry (Choy *et al.*, 2014). These are key areas for developing and adopting relevant KPIs.

Table III indicates areas of critical importance and presents tentative KPIs based on the BSc.

In terms of KPIs for the critical performance area "Capital costs and expenditure", it is important to monitor financial measures, which include capital expenditure, profitability ratios and return on investment ratios. In addition, it is important to monitor operational expenditure with relevant KPIs that measure operating costs, costs to budget and change in fuel costs in relation to distance and speed.

Customers are mostly interested in the delivery of goods and personnel on time, at the right quantity and in an optimal way. Large capacity ensures the ability to deliver large quantities and achieve scale economies. Relevant KPIs include the delivery in full on time (DIFOT) rate, transit time metrics, required arrival date (RAD) compliance, inbound and outbound volume activities and throughput and order fulfilment metrics.

In terms of internal processes, safety and risk analysis are critical areas for developing relevant KPIs. Several KPIs are identified and proposed, including monitoring accidents and incidents over time, HSE auditing and observation and measurement of process interruptions.

From a learning and growth perspective, CSF areas include having an effective information system (KPIs include investments made in technology, information exchange failures and attendance of operator training courses); the ability to invest in suitable systems and vessels (investments in satellite systems, winterization and ice detection and failures in regard to detection and prediction of vessel positioning); and staff effectiveness (experience in the Arctic, staff turnover, satisfaction and training expenditure to name but a few KPIs). A full set of identified KPIs and the perspectives discussed appear in Table III.

6. Conclusions

The downstream segment of the oil and gas value chain, especially towards the production site, is more complex than other areas and chain activities. In the High North, the number of stakeholders is large, and there is added uncertainty due to weather and climatic conditions. The SC plays a very important role due to the investments and operating costs of offshore oil and gas activities, with every delay costing several millions of dollars per day (Aas *et al.*, 2007; Aas *et al.*, 2009; Rowbotham, 2014). Supply operations are strongly interlinked, which requires a high level of efficiency and the optimal utilization of supply vessels (Milaković *et al.*, 2014; Berlin, 2013; Rowbotham, 2014).

The ultimate purpose of KPIs and PM is not to develop and provide more information but to provide the right information to the right decision maker at the right time and in the right place, using the correct communication medium in an effective and cost-efficient manner. Insufficient or ineffective KPIs prevent decision-makers from understanding the real underlying issues that are driving their decisions.

Table III. Key performance indicators for offshore logistics

Perspective	Parameters for performance measures	Tentative key performance indicators
Financial perspective	Capital costs and expenditure	% change in value of CAPEX per period
	Monitoring of capital expenditure	Return on investment (ROI):
	Return on capital	Gross profit
	Return on investment	OPEX per time period (absolute value):
	Operating costs	% change in OPEX per time period:
	Fuel costs	Monthly operating costs
	Productivity measures	Results versus operational budget
	Pooling to optimize operating costs	Fuel expenditure per time period:
		Labour cost per man hour versus throughput
		% change in fuel costs per miles and speed recorded:
		No. of ships pooled per time period
Customer perspective	Large capacity and size	DIFOT:
	Optimal routing	Transit time metrics
	Timely supply	Weight capacity utilization
	Reliability in supply	On-time performance on fulfilment orders
	Frequency of supply	RAD compliance
	Customer satisfaction	Shipping and receiving turnaround times
		Orders shipped complete
		Shipped fill rate on fulfilment orders
		Inbound/outbound volume activity and throughput
		24/7 visibility
		Claims ratio
Customer (Effective storage)	Storage capacity	Inventory stock turns in days
	Safe storage	Facility space utilization
	Storage procedures	Inventory accuracy
	Compliance with procedures	Order accuracy
	Storage planning	
	Stock management	
	Needs assessment	
Internal processes (safety)	Safety index	Emissions (Sox, NOx, CO_2):
	Compliance with international operations quality standards	No. of ISO certifications
	Compliance with environmental standards	Change in safety index measure:
		No. of international regulation violations
		No. of accidents, incidents, and near misses
Internal processes (risk analysis)	Risk analysis	No. of incidents per time period
	Prevention	No. of accidents per time period
	Incidents and accidents	HSE audit observations
	Injuries	Lost time due to injury frequency
	Process interruption	No. of process glitches
Learning and growth (IT)	Real-time information exchange	Investment in technology
	Procedures for information exchange	No. of reports for real-time information exchange failure
		No. of operator training courses attended
Learning and growth (Staff effectiveness)	Staff experience	Total years of Arctic experience per worker
	Recruitment effectiveness	No. of workers with Arctic experience
	Staff satisfaction	Staff turnover
	Empowered staff	Staff satisfaction rating
		No. of training courses attended
		Expenditure on staff training

In this paper, the challenges of developing measurement tools for PM in a complex SC were introduced. The study is built upon BSc categorization as a tool, which also emphasizes relationships within and between companies. The study shows that actors within the SC need to feel that the criteria match their contextual challenges. This study shows that there is a need for an integration of standards and tailor-made KPIs in turbulent and complex environments. The KPIs may serve as a service net for more advanced cooperation, as they make clear the basic obligations and balance the interests of each partner in terms of the bottom line. Further, it may be necessary to fulfil demands from more formal systems, including standards such as ISM and classifications such as ISO certificates. Third, KPIs may play a role in the vetting and bridging process for specific operations. Accordingly, a broader range of KPIs may be needed. Owing to lack of predictability, there is a need for both lead and lag indicators and the inclusion of KPIs at the department level to emphasize root cause analysis. There is a challenge of finding KPIs that have the necessary precision for evaluating target objectives of different stakeholders and avoid being creating conflict or placing too much emphasis on the wrong questions. A balance between a structure with a formalized control regime, and openness and freedom from a rigid system, is also needed to find creative solutions.

Further research in this field could analyse a broader area of performance and consider a wider array of KPIs. The sample in this study was limited and included mostly personnel at the operational level. The study was cross-sectional and did not consider the different phases of operating and servicing an oil field. Further studies could go deeper into the processes at the operational level and link it to other management levels. The list of indicators should include a broader range of issues on strategic levels, including financial issues and capital investment needs, to adapt to a more turbulent SC.

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Further reading

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Appendix. – Interview questionnaire

Please state the goals that you want to achieve in your business.

Please state any goals that are very important for:

- Shareholders;
- Customers;
- Business processes;
- Employees; and
- Other.

Please state performance measures that you use in your logistics operations.

Please state performance measures that you use in your business in general:

- Company information;
- Principal area of business;
- No. of employees;
- Years in operation;
- Headquarters;
- Services provided;
- Assets (no. of ships owned/operated);
- Annual turnover;
- Respondent;
- Total years of work experience;
- Total years in a management position; and
- Years in company.

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