Master’s degree thesis

LOG950 Logistics

Virtual warehousing in offshore oil and gas platforms’ supply chain

Kiril Kukareko

Number of pages including this page: 76

Molde, 05 January, 2013

Molde University College

Mandatory statement

Each student is responsible for complying with rules and regulations that relate to examinations and to academic work in general. The purpose of the mandatory statement is to make students aware of their responsibility and the consequences of cheating. Failure to complete the statement does not excuse students from their responsibility.

<table>
<tr><td colspan="3">Please complete the mandatory statement by placing a mark <u>in each box</u> for statements 1-6 below.</td></tr>
<tr><td>1.</td><td>I/we herby declare that my/our paper/assignment is my/our own work, and that I/we have not used other sources or received other help than is mentioned in the paper/assignment.</td><td>☒</td></tr>
<tr><td>2.</td><td>I/we herby declare that this paper
1. Has not been used in any other exam at another department/university/university college
2. Is not referring to the work of others without acknowledgement
3. Is not referring to my/our previous work without acknowledgement
4. Has acknowledged all sources of literature in the text and in the list of references
5. Is not a copy, duplicate or transcript of other work</td><td>Mark each box:
1. ☒
2. ☒
3. ☒
4. ☒
5. ☒</td></tr>
<tr><td>3.</td><td>I am/we are aware that any breach of the above will be considered as cheating, and may result in annulment of the examinaion and exclusion from all universities and university colleges in Norway for up to one year, according to the <u>Act relating to Norwegian Universities and University Colleges, section 4-7 and 4-8</u> and <u>Examination regulations</u> section 14 and 15.</td><td>☒</td></tr>
<tr><td>4.</td><td>I am/we are aware that all papers/assignments may be checked for plagiarism by a software assisted plagiarism check</td><td>☒</td></tr>
<tr><td>5.</td><td>I am/we are aware that Molde University college will handle all cases of suspected cheating according to prevailing guidelines.</td><td>☒</td></tr>
<tr><td>6.</td><td>I/we are aware of the University College`s <u>rules and regulation for using sources</u></td><td>☒</td></tr>
</table>

Publication agreement

ECTS credits: 30

Supervisor: Nils Jacob Berland

Agreement on electronic publication of master thesis

Author(s) have copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).
All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).
Theses with a confidentiality agreement will not be published.

I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication: ☒**yes** ☐**no**

Is there an agreement of confidentiality? ☐**yes** ☒**no**
(A supplementary confidentiality agreement must be filled in)
- If yes: **Can the thesis be online published when the period of confidentiality is expired?** ☐**yes** ☐**no**

Date: 05 January 2013

Abstract

"*Gettin' good players is easy. Gettin' 'em to play together is the hard part.*" - Casey Stengel

Background. NorSea Group AS (NSG) is a leading Norwegian offshore and onshore logistics services and bases provider. Driven by its clients interest towards cuts in warehousing costs, the firm is looking for a new approach to manage its warehouse operations. This thesis explores possibilities for changing NSG's way of carrying out warehouse operations in order to prepare it for a new business opportunity and add more value for its customers.

Results. The proposed new approach is based on enabling material and data exchange which allows virtual spooling of regional warehouses stock in one virtual warehouse. This is aided by expanding NorSea's IT system with a special module for data exchange and item management coordination, based on ISO 15926 standard. In order to provide a basis for project group work, prerequisites and technical requirements for such system are provided and explained.

Acknowledgements

This thesis could not have been written without Nils Jacob Berland, who presented me this topic in the first place and, as my supervisor, guided me throughout the whole process. I am grateful to him for all that time he spent with us in Minsk, Molde and Bergen and for the effort he put in changing our mindset. I consider myself very lucky to know him as I haven't met anyone with such positive attitude, ability to make difficult things look simple.

I thank Ingrid Uthaug and Isabel Coderre for helping me with English and valuable comments.

I'd also like to thank administration of SBMT and Molde University College for giving **B**elarusian students a great opportunity to study logistics and supply chain management in such wonderful place as Molde.

I'm also grateful to my fellow groupmates who made my Molde semester an unforgettable experience and were already there for me when I needed them.

Last but not least, I'd like to thank my family, and especially my fiancee, who have been supporting and encouraging me during these years with all patience and love.

Table of contents

Chapter 1: Introduction

1.1 Oil and Gas in Norway

Norway holds the largest reserves of oil and natural gas in Europe. Since the original discovery these resources have been exploited intensively, making Norway one of the largest exporters of both oil and natural gas in Europe, second only to Russia. Oil production in Norway peaked in 2001 at 3.42 million barrels per day (bbl/d), steadily declining since then to 2.13 million bbl/d in 2010. At the same time, natural gas production levels have been increasing since 1993, and reached 3.76 trillion cubic feet (Tcf) in 2010. According to the Norwegian Petroleum Directorate, crude oil, natural gas, and associated pipeline transport services generated approximately 50 percent of the value of Norway's exports, 21 percent of GDP, and 25 percent of government revenues in 2010.

Fig.1. North Sea Oil and Gas fields location scheme (taken from [link1])

As oil and gas resources in this region are located offshore, the joint production requires international agreements on maritime boundaries and on the development of fields that straddle those. In the 20th century the production of such fields was governed by separate 'ad-hoc' treaties and negotiations. To simplify the process, in April 2005, Norway and the UK signed a bilateral treaty detailing the handling of such resources in the North Sea. This agreement helped to build a general framework for inter-boundary oil projects. In 2011 a similar agreement has resolved a 40-year old dispute between Norway and Russia regarding their maritime boundaries in the Barents and Arctic seas and related development of fossils deposits. The agreement implies joint development for the oil and gas deposits in question, which are located in a 176,000 square kilometer maritime area and cross boundaries. This agreement was fully ratified by both governments in early 2011 and went into effect in July 2011.

When it became obvious that Norway possessed significant oil and gas resources, it required serious state-level managerial decisions concerning the control of Norwegian petroleum reserves. That included establishing a ministry to work on oil policies, and eventually oil legislation was formulated in the national assembly. In addition, a national oil company was built up and the Petroleum Directorate was established. At the time, there was a severe lack of competence in the country's oil and gas sector, which required enormous amounts of capital investments and close collaboration with people from the petroleum industry who had the necessary knowledge. As a former Director of Information in the Norwegian Petroleum Directorate, Jan Hagland notes in his *The Norwegian Oil and Gas Adventure* [1]:

> "The world's biggest oil companies operate today on the Norwegian shelf. In this way, Norway procures the widest possible professional basis for the extraction of its oil reserves. It can therefore be said that the development of Norway's oil and gas fields has consisted of a grand- scale 'clubbing together' between the owner country and the world's biggest oil companies."

Let us consider some details on the current state of the oil and gas industry in Norway. Information has been taken from the 2011 U.S. Energy Information Administration (EIA) report. (It can be found at their website [link2]; the latest version is dated August 2012.)

1.1.1 Oil

According to EIA [link2], as of January 1, 2011, Norwegian proven oil reserves were estimated as 5.67 billion barrels, which are the largest oil reserves in Western Europe. These are located offshore on the Norwegian Continental Shelf (NCS), which consists of three geographical sections: the North Sea, the Norwegian Sea and the Barents Sea. Norway's oil production mostly takes place in the North Sea, with smaller amounts produced in the Norwegian Sea. Several recently discovered fields in the Barents Sea are currently at the pre-development stage with plans of moving to the production stage in 2015.

The largest of the well-developed oil fields in Norway is the Troll complex. Other important fields include Ecofisk, Snorre, Oseberg and Draugen. Most of the older fields have already peaked and have a flat or declining production rate, so the Norwegian government puts emphasis on increasing production from existing projects, including the incorporation of smaller satellite fields and further exploration of new fields. Among newer fields, the most promising are Skruger and Goliat in the Barents Sea.

The largest company in the Norwegian oil and gas market is Statoil ASA, which controls 80 percent of oil and gas production in the country. Having interests in more than thirty countries, Statoil ASA is an international company, but 67 percent of it belongs to the Norwegian government. It was created in 2007 as a result of the merger of Statoil and Norsk Hydro. Other international operators who take an active part in Norway's petroleum production are ExxonMobil, Total, Shell, ConocoPhillips and Eni, working in partnership with Statoil. In order to attract additional international investment in the Norwegian oil and gas sector, since 2005 the government has reduced taxes from oil activities and has introduced Norway's state subsidy of oil and gas exploration, which refunds 78 percent of the exploration costs to involved operators. The “State's direct financial interest” (SDFI) in Norwegian petroleum operations are managed by state-owned company Petoro, which serves as a licensee for such activities.

It was reported that in 2010, Norway exported approximately 1.6 million bbl/d of crude oil with the UK, the Netherlands, France, Germany and the USA being among the top five importers.

For efficient crude oil transportation, operators have built an extensive network of subsea oil pipelines. Eight major domestic oil pipelines connect offshore oilfields with onshore processing terminals and provide a total capacity of more than 2.2 million barrels per day. Numerous smaller pipelines connect the North Sea fields to either the Oseberg Transport System or the Troll I and II pipeline systems. A fraction of offshore production is being transported ashore via shuttle tanker. Finally, an international subsea pipeline called Norpipe connects Norwegian oil fields in the Ekofisk system and associated fields near the Norwegian-UK maritime border to the oil terminal and refinery at Teesside, England. The Norpipe has a capacity of 900,000-bbl/d, and is a 50-50 joint venture between ConocoPhillips and Statoil.

When it comes to exports, Norway is not only shipping crude oil, but also produces fuel both for domestic international markets. There are two major oil refining facilities in Norway: Slagen plant (operated by ExxonMobil) and Mongstad plant (operated by Statoil). Mongstad facility complies with strict EU environmental regulations related to diesel and gasoline fuel production, and is used by Statoil for European refined oil products’ market expansion.

1.1.2 Natural gas

EIA states [link2], that as of January 1, 2011, Norwegian proven natural gas reserves were estimated to be 72 trillion cubic feet (Tcf). Nowadays Norway is the second largest exporter of natural gas next to Russia, and holds the fifth rank among world’s natural gas producing countries. Even though most of Norway’s gas fields in the North Sea have matured, there has been a sustainable annual increase in natural gas production levels due to exploration and development in new fields. Be it direct gas shipments via pipe or liquefied natural gas LNG, long-term commitment is what characterises Norway as a gas supplier to Europe. The 21st century has been dubbed ‘the gas century’, and it is expected that by 2020 gas will outstrip oil as the major money-maker in the Norwegian oil and gas industry.

Similar to the oil sector, natural gas production in Norway is dominated by Statoil among a sizable international presence. The Norwegian domestic natural gas pipeline network is administered by state-owned Gassco, which also manages the international natural gas pipeline network Gassled, co-owned by companies involved in regional petroleum activities.

In 2010 Norway exported 94 percent of produced natural gas. This was mainly consumed in the Europe Union, and covered 18 percent of the EU’s natural gas demand. The three largest importers of Norwegian natural gas were Germany, the United Kingdom and France. Most of the transportation was provided via Gassled pipes, either directly to the receiving country or via onshore pipelines. A smaller fraction was shipped as liquefied natural gas in tankers. As for LNG, Norway started to export it in 2007 when Statoil launched commercial production at its liquefaction facility Melkoya. This facility has a pipeline connection with Snohvit, which is the first Norwegian natural gas field in the Barents Sea. Statoil runs the Melkoya facility at full capacity. It is considering further enhancement projects involving increased liquefaction capacities by adding a second train fed from another Barents Sea gas field Askeladd. The main consumer of Norwegian LNG in 2010 was Spain, which received more than 35 percent of the 138 Bcf shipped that year.

1.2 NorSea Group - role and modus operandi.

The oil and gas industry deals with an extremely complex supply chain and thus creates a constant strong demand for a full spectrum of logistics services. When we are considering production tasks, apart from means to transport extracted materials further down the supply chain, there is another very important set of activities. In order to avoid downtimes and accidents which are both extremely costly and could have significant negative impact on environment, oil production operations require constant support activity, known as “IRM” which is an abbreviation for “Inspection, repair and maintenance”. While these activities are usually taking place on production facilities by means of special staff, they demand consistent and reliable logistic services onshore, including efficient warehousing and quick delivery of the spare parts. This is where the offshore logistics services providers come into play.

NorSea Group AS is a leading Norwegian offshore and onshore logistics services and bases provider. The company owns and operates most supply bases in Norway. There are ten strategically located Supply and Support Bases along the Norwegian Continental Shelf. As stated on the NorSea website [link3], "*A contract with NorSea Group can cover the entire Norwegian Continental Shelf*". Each of those bases is operated as a separate business unit, which allows to run a pilot project on one base to test new business approaches and services. In addition, NorSea Group is involved in supply base operations abroad, which adds more challenge for operations re-think process because of various policies and different demands to such operations around the globe.

Supplies for installations on the Norwegian Continental Shelf are normally distributed through one of several supply bases. One operator may run several installations from one supply base, and each operator will usually handle all installations from one or more separate warehouses and with people dedicated for these installations. In practice this means that e.g. Statoil will handle all their installations in the region served from a specific base with a dedicated infrastructure including storage facilities and personnel, which is usually not owned but sourced from the base owning company.

Dedicated storage facilities and personnel are of course an advantage as they can easily locate supplies and spare parts for a given operator. However, this current approach is not always cost efficient, and doesn’t allow direct communication or transfer of spare parts between different operators’ warehouses. There is also a possibility that to cut their costs, operators could choose to outsource their warehouse operations and maintenance to NSG; several operators outsource their base/warehouse logistics to NorSea Group already. Therefore NorSea Group are looking into restructuring the way warehouses and personnel are handled in a more joint manner..

1.3 Goal of Thesis

This thesis will explore possibilities for improving NSG's way of carrying out warehouse operations in order to prepare it for an expansion in advanced outsourcing. This may involve:

- Multipurpose warehouses
- Alternative supply chain configurations
- More joint shipping of goods
- New system to manage goods for many customers

As it will be shown later, all these activities could be incorporated in one new approach aided by additional services, enabling inter-operators' material and data exchange. As a goal for this thesis we have chosen to:

- Analyse the current situation with stock handling
- Suggest more optimal processes where possible
- Based on process analysis and existing technology, offer requirements for a new IT system enhancement module that could be used by a project team as a basis.

1.4 Literature overview

This review will cover the following areas:

- Issues and trends in Oil and Gas SCM
- IT-aided Collaborative practices and SCM software engineering
- ISO 15926 related publications

When dealing with newer concepts, it is sometimes hard to come a long some proper publications and books dedicated to subject.

Issues and trends in Oil and Gas SCM

There are many publications related to most common issues and trends in contemporary Oil and Gas Supply chain management. Among the most frequently noted problems are the ones related to lack of collaboration, interoperability and visibility across the supply chain [2], [3], [4].

In his article [3] John K. M emphasizes the increasing role of technology and collaboration and states that modern information systems require more transparency and visibility in order to provide deeper process controllability and real-time operations, which is dictated by todays state of the industry. Collaborative approach to data standards, information exchange, total process tracking and automation are considered as the pre-requisites for more efficient seamless operations and considered to be keys for addressing contemporary logistical challenges.

In their research [link30] Michael P. Gallaher et al. draw a conclusion that "*Inadequate interoperability increases the cost burden of construction industry stakeholders and results in missed opportunities that could create significant benefits for the construction industry and the public at large"*

Software vendors also understand these problems and are working on their own solutions aimed to address them [link4], [link5], [link29].
Among other trends which are worth mentioning it is focusing on core competencies while outsourcing other activities [2], [3], [4] and more close integration of smaller supply chain members with key supply chain players.

IT-aided Collaborative practices and SCM software engineering principles

In this paper we are not only trying to build a feasible approach to IT-aided collaboration in a given node of petroleum upstream supply chain, but also are focusing on how existing collaboration frameworks may be used for our needs. For example, Dr. C. John Langley Jr's. "7 immutable laws of collaborative logistics" [**link**6] describes a common approach to organization and evaluation of collaborative practices and "Stairway model for collaborative commerce" [link7] suggested by AT Kerney consulting is used as an example for IT collaboration prerequisite steps.

Some of the broader concepts, like *transparency* or *visibility* have very significant role in collaboration and are well covered in published papers which consider prerequisites for implementation and common concepts [2], [5], [6], [7].
To see more strict approach to IT-aided collaboration organization we consider a well developed and widely used in retail CPFR (Collaborative, Planning, Forecast and Replenishment) framework. This approach has become an acknowledged standard, therefore in addition to publications [8], [9] there is a documentation and official standard owner overview [link8] available at VICS website online [link9]. CPFR implementation were not always successful, but works have lead to development of popular Vendor Management Inventory (VMI) concept [10], improved forecasting and new forms of collaborations in retail supply chains [link9].

For principles of warehousing management systems planning and software engineering, recommendations from [11] and [12] were used as well as modern trends in industrial programing from numerous web sources and author's personal IT experience.

Virtual warehousing concept is aimed to facilitate communication between the seller and the manufacturer. It became popular with rise of major online retailers because of especially broad selection of various goods, which because of different storage requirements and limitations was economically unreasonable or physically impossible to stock in one place. Under the hood, it hides a distributed network of warehouses [link31] and efficient means of transportation as well as information system to coordinate the flow of f goods [link31], [link32], [link33].

As it is mentioned in publications related to Virtual warehousing [link32], "*It no longer matters where the merchandise is stored, as long as it can be delivered to the customer on time.*" This means that for a customer there is only one big "Virtual Warehouse", as she does not know about hidden internal logistics. Started as a tool for e-commerce, nowadays virtual warehousing became one of standard practices for major logistics service providers.

ISO 15926 related publications

Implementation of ISO 15926 principles is one of the key elements of the approach suggested in this paper. The standard has not been finalized yet and changes rapidly. However, there are not much publications on paper, but a lot of information is available through various wikis and slides from ongoing presentations. Therefore this section contains only links to various information on the Web.

The only published book about ISO 15926 is Gord Rachar's "An Introduction to ISO 15926" [13], which has been released by Fiatech in collaboration with POSC Caesar as an online e-book [link10] in the end of 2011 and contains all the necessary information to understand what is ISO 15926 and how it can be used.

Other links we with useful ISO 15926-related information are including published parts ([link11] through [link16]), POSC Caesar ISO 15926 wiki [link17] and Bentley [link18], where various related resources are collected, W3C (the World Wide Web consortium) RDF wiki [link19]. iRING-related resources cover JORD [link20], iRINGTools [link21] and Project Proteus [link22]. Gellish language is going to be an important part of ISO 15926 when part 11 is finalized [link23].

There are no complete guides or best practices available for ISO 15926 implementation, however, some information may be deducted from project slide like [link24] and from pilot ISO 15926 projects, such as IOHN [link25] and related whitepapers [link26]. Another source of information is presentations and guides for exisiting ISO 15926-based software, like the following EqHub slides [link27].

Chapter 2: Interoperability, collaboration and information sharing in SCM.

The petroleum industry is characterized by an enormously wide supply network. What is there in common between a rocket launch on the cape Canaveral, a small Korean boy brushing his teeth somewhere in the Busan suburbs and an electric kettle whistling in the Novosibirsk mayor's office? All these events are connected through one of the biggest supply chains, which spans from a drilling platform in the middle of nowhere to refineries, plastics manufacturers and power plants all across the world, fueling our civilization, powering it and providing it with materials.

2.1 Supply chain management in Oil and Gas industry

As Peter J Metz defines it in his article "Demystifying Supply Chain Management" [14]:

> *"Integrated Supply Chain Management (ISCM) is a process-oriented, integrated approach to procuring, producing, and delivering products and services to customers. ISCM has a broad scope that includes sub-suppliers, suppliers, internal operations, trade customers, retail customers, and end users. ISCM covers the management of material, information, and funds flows."*

Traditionally, supply chain management activities in Oil and Gas are divided in three broad parts: upstream (production), midstream (gathering and transportation of crude resources to process plants) and downstream (final product distribution). Each area has its own specifics to consider. In this paper we will be dealing with upstream supply chain.

As professor Christopher M. Chima states in his publication [2], the main tasks for SCM practitioners may be divided in the following three groups: *"Supply- chain management (SCM) can be defined as the configuration, coordination and continuous improvement of a sequentially organized set of operations."* Let us interpret what hides behind those activities:

Configuration of Supply Chain Management involves the following questions (as per [2]):

- What product-service bundle to produce
- What portions of the bundle to produce in-house and what portion to purchase from others
- Facility capacity
- Location of facilities
- Type of technology to adopt
- Handling communications between suppliers and customers
- Standards expected of customers and suppliers

Supply-chain management requires an oil and gas company to integrate its decisions with those made within its chain of customers and suppliers; this can be described in terms of **coordination**, which, from the perspective of each company, involves the following issues [2]:

- Ensuring supplier effectiveness in cost, timeframes and quality
- Setting appropriate targets for inventory, capacity, and lead times
- Monitoring demand and supply conditions
- Communicating market and performance results to customers and suppliers

Today, there are more opportunities for coordinating activities across a supply chain even in such complex sectors as oil and gas, because of the growing role of constantly improving information systems and communication technologies. The oil and gas industry is involved in a global supply chain that includes domestic and international transportation, ordering, inventory visibility and control, materials handling, import/export facilitation and information technology. The famous "7 R's" of logistics are becoming very dependant on similar R's but related to information. This means that right information is required in the right form in the right place at the right time for the right person.

Of course, once set up, configuration and coordination should not be considered an unquestionable way of doing things because in order to stay on the market and be competitive, those should not be rigid. It is quite the opposite -- configuration and coordination should be revised and **improved** continuously.

It is obvious that the supply network in the oil and gas sector is exceptionally vast and clumsy with numerous connections between its key players, their partners and affiliates. In this paper we will focus on a small fraction of this monstrous structure: a supply chain for offshore extraction platforms.

Offshore production platforms (for instance, drilling platforms and oil rigs) are isolated complex structures dedicated to oil production. These are equipped with advanced heavy machinery and operated by people who are living on them and therefore require beds, catering, medicine supply. In size and demands, oil rigs are sometimes compared to small cities [link28] as they require a constant supply of various items and spare parts for platform maintenance, machinery repairs and human needs. This supply is handled by means of platform-supporting vehicles from onshore supply bases nearby. Let us formulate what configuration, coordination and improvement tasks we are dealing with here.

In regards to **configuration**, there might be different angles to view it from. First, in terms of **product**, in the exploration and production sectors of the oil industry, there is not much to variate. The product is almost exactly the same for all competing firms, it is crude oil and natural gas with very narrow product differentiation. Consequently, it is virtually impossible for many of these firms to differentiate themselves from one another by introducing an exciting new product.

But in regards to **capacities and location of facilities**, it is a different story, as this is dictated by geographical field location and available technology. And that's where much more complex configuration differentiation rises. Offshore oil fields are located various parts of the ocean, which may vary significantly in properties, such as bottom terrain, depth of oil field, its dimensions and configuration, resources quality and even weather conditions on the surface. So each oil field production facility demands a specific customized approach, tailored to fit those properties so that production would be as efficient as it possible. This means that each facility is somehow unique and uses the most advanced technology available at the time of construction and subsequent moving it to production. Oil companies invest heavily in research and development and this leads to rapid advancements in drilling and extraction technology as well as dedicated machinery and infrastructure. In fact, oil production technologies are advancing so fast that two oil rigs which belong to one Operator and are not very distant from one another may have very significant differences.

Thus, in terms of configuration, companies working in exploration and production areas can only differentiate themselves based on the ability to find and produce oil and gas more efficiently than their competitors. Excluding the research and development from the equation and looking at this from supply chain management point of view, there are, basically, two possible fields for advancement. The first is reliability which equals service quality for fossils extractors and as low downtime as possible. The second is how well organized is the communication among tiers in the supply chain. And this is exactly where potent modern IT systems come in handy. But let us leave it here for now and proceed to the next point.

When considering **coordination and improvement**, nowadays this is all about right technology, information availability, and properly set up inter-tier visibility. Speaking of ‘right’ technology, it should be mentioned that this sphere is rapidly changing which means that processes and tools would require continuous evaluation and improvement. This could also result in a necessity to change the supply chain configuration and/or the approach to coordination itself, and such changes could enhance the performance of the overall chain. This is what actually happens in the industry. For example, in response to these challenges, many forward-thinking oil companies are moving away from being just oil drilling companies to seeing themselves as reservoir development and resource management companies.

It is worth mentioning, that major software vendors are also looking for possible solutions. In their presentation whitepaper [link5] , authors present SAP vision of common problems in Oil and Gas supply chain:

Table 1: Key Issues in Oil and Gas supply Chain Management (M. McBroom, D.Williams, 2005)

Key Issues	Observations
Rationalizing Supply Chain network	Lack of visibility and lack of integration of supply chain
Lack of global industry wide standards	„Lack of central source of mission critical data
Lack of ability to rapidly respond to real world scenarios	Need for real time data visibility and ability to perform “what if” scenarios to quickly adjust operating plans
Lack of collaboration between supply chain partners	Creates imbalances and inefficiencies along supply chain
High occurrence of M&A (Mergers and Acquisitions)	„Creates disruptions to company operations and management
Lack of Risk Management	Creates possibility of distress spot contracts

Another IT giant, IBM is also working on problems of integration and collaboration in Oil and Gas sphere. In their whitepaper named “The value of smarter oil and gas fields” [link29] Lewis S. Edison, state that *“The complexity and cost of integration has greatly declined over the last decade. Major IT advances now make it not only possible but also potentially profitable to share information throughout the field to bring people, processes and petroleum technologies together in powerful new ways”.* They also make a conclusion that well-planned investments in data integration projects repay in increased production and recovery rates and cut expenses. Time-to-value of such projects can be short and paybacks well worth it.
Authors are also referencing a research, which included interviews of more than 100 top managers from Oil and Gas industry which states that for them *“integration is vital to delivering “the right information on demand to the right people at the right time for better decision making.”*

2.2 Detailed problem description and analysis

As it was previously mentioned, in terms of warehouse management, currently NorSea already provides onshore buildings and workforce to operators. Actual processing of inventory is managed by the operators themselves. Yet lately some of NorSea's clients have shown interest in greater collaboration in the form outsourcing their onshore warehouse logistics to NSG. It is also described in publications that with maturing larger oil fields in the North Sea, oil production passed its peak in 2001. And major operators in the region are gradually changing their policies since towards more cost-efficient approaches. One of the ways to cut costs is to focus on core competencies while outsourcing other activities. [2].

So the trend to outsource non-primary activities and existing contracts is expected to develop a new business opportunity for service providers. Therefore there is a new strategic goal for NorSea, which is to offer their clients a new service, providing a complete set of warehousing operations. This requires aligning and rethinking existing practices into a new centralized approach to incorporate various clients' requirements. Obviously, such an approach should help NorSea to achieve more efficient handling of parts on behalf of the operating companies than they are able to do themselves, so that the outsourcing endeavour would be mutually profitable for involved parties. These improvements would ideally lead to:

- Better planning
- Better cost and operations control through more flexible IT systems
- Possibility to locate parts across all supply bases in case of an emergency
- Allowing more alternatives in parts manufacturers and in interchangeable parts
- Better integration with suppliers, base operations, etc.
- Faster and more reliable warehouse operations at bases
- More efficient inspections

There are several prerequisites that should be met to achieve that goal, like providing a way to keep track of various items in stock and automatically process customers' needs, which is an absolute 'must have' for operating with large quantities of items and related complex data. Another aspect with any new approach to processes handling is to keep related operating costs at current level or ideally decrease them. In the information age an obvious solution for that would be switching to a centralized approach in warehousing, which would also imply close integration with customers' IT systems. To make sure that the whole system is responsive enough, it should be enabled with means for real-time data and processes monitoring. All these significant improvements in warehouse operations would require NorSea Group to adopt an advanced IT system in order to keep track of all items on storage and coordinate interactions with the operators of the offshore fields.

As such, we will closely examine modern approaches to collaborative data management and various requirements for the implementation of collaborative systems. This will allow us to set a roadmap for a project team. It should also be considered that each operator has their own ERP-class (Enterprise Resource Planning) systems in place (SAP is among the most frequently used), which means a new centralized system must possess the necessary interfaces for various ERP systems to data flow.

Despite the fact that NSG is the biggest player in this market, or possibly even due to that fact, the current situation with information flow both in-house and between NSG and their clients is far from perfect. The oil and gas sector was established before modern resourceful IT systems came into play. With sufficient funding it was able to hire a tremendous workforce of people to cover all the necessary transactions, checks and paperwork. This work has been mostly conducted by human-to-human communication in form of phone call, e-mail, and fax, thereby a largely paper-based document flow, so currently information is unstructured, is often duplicated, or gets lost and is difficult to process. Of course to be competitive now, this old approach should be reconsidered, as in terms of warehousing, this results in unwanted delays, increased holding costs and sunk capital, which is a waste that should be eliminated. Moreover, improvements in this area would also lead to increased efficiency in other aspects, such as better planning, controlling and improved overall business processes' visibility. As it is expected that even more operators will outsource warehousing tasks to logistics providers, such as NorSea Group, improvements in this area would also lead to competitive advantage in this growing market and better services for all involved parties.

One of the main things we will be addressing is the computer-to-computer interconnectivity within the whole supply chain. By implementing this we would help to decrease the amount of slow paced and error-prone partly-manual human-to-human communication, thereby saving time, paper and postage. It also enables quick decision making based on up-to-date, reliable information. Real-time line of sight into market conditions and demands helps cut down the need to hold extra, just-in-case products—which are frequently the mark of outmoded warehouse systems that are not synchronized with other supply chain activities.

To implement ideas of collaboration and inter-connectivity across the oil and gas supply chain sphere may be not the easiest task, as operators usually do not like the idea of information sharing. However, as Bradley S. Fordham defines it in his whitepaper titled "Sharing Secrets: Online Insight's Golden Nugget Breakthrough for Relationship Management" [7], *"Collaboration represents a full two-way dialogue and value-exchange between parties where each can learn and adapt their next response based on the information expressed by the other side*." So correctly implemented collaborative practices could be a win-win solution for the whole industry. To cope with operators' concerns regarding information sharing, we will discuss ways to ensure that only necessary information is shared and access to business-sensitive data is restricted.

Another significant problem is that currently warehousing data is operator-specific, which is why an IT system designed to manage different warehouse operations for various clients would need to have numerous interfaces for data flow, so that there would be no difficulties in checking the needed stock data for any operator. But to achieve best results in collaboration, the whole supply chain should be moving to a strategic goal of 'different systems, one common language' which ultimately means common standards implementation. And what makes it easier, such set of standards exists in the form of ISO 15926, which will be described later on.

2.3 Collaboration and Transparency in the supply chain

One of the most challenging issues in regards to collaboration is not how developed the technology is or how well trained the staff is, but is rather the development of collaborative culture and a clear understanding of the mutual benefits to be gained by all involved partners in a collaborative business model. And all this starts with trust. This should be set straight: mutual trust and collaboration is by no means achievable in a matter of months, nor it is something achievable by only one company's efforts. To succeed at it, it should be considered as a long-term strategic goal for all involved parties, both upstream and downstream. Efficient collaborative business requires mutual trust and significant investment in tools for planning, forecasting and IT. But, it is the next natural step in supply chain evolution that will allow for significant increases in business efficiency.

Collaboration and transparency in the supply chain are closely intertwined, as the former is impossible without the latter.

2.3.1 Collaboration in the supply chain

In the late 90s and early 00s, pioneers of the rapidly growing e-business segment were conventionally using the Internet as a mere additional advertising channel, considering it as an e-brochure of sorts. The first subsequent Internet-enabled business systems were aimed at e-commerce business-to-customers (B2C) and e-procurement business-to-business (B2B) transactional approaches and had very narrow practical usage. But as it usually happens, new tools give birth to new approaches, and in the case of the Internet and supply chain management the new approach was the collaborative business model. Let us see how Dr. C. John Langley Jr. described this in his white paper, "7 Immutable Laws of Collaborative Logistics" [**link**6] published in 2000:

> "When two or more organizations agree to work together, synergy is a common outcome. This is readily apparent, for instance, when buyers and sellers agree to share point-of-sale product information, so as to better understand demand in the marketplace. Taking this phenomenon one major step further, the essence of collaboration suggests that competencies are created when collaborative activity actually takes place."

It is clear that in more sophisticated scenarios, such as oil and gas exploration and production sector levels of interdependency can be much higher, allowing more efficient approach to common tasks and resources exploitation, so organizations may gain much more from collaboration. However, there might be a reluctance towards collaborative practices as organizations tend to see other market players as their rivals only allowing some rare ad-hoc joint programs and hesitating to share information. This lack of understanding of possible collaboration benefits is not uncommon -- as Dr Langley continues:

> "The idea of collaboration is not one that always comes naturally to organizations, especially between companies offering the same or similar

> products or services. While most competition occurs in the marketplace itself, the lack of certain types of collaboration among competing firms sometimes creates inefficiencies which are experienced by all...When organizations refuse to collaborate, real losses may easily outweigh perceived gains."

It might be difficult to see, considering the market as a battlefield of sorts, but many businesses are considering collaboration as a way to further improve their relationship with partners and add more value for their customers. This is possible due to the fact that collaboration can help to build a "*synergistic environment in which the sum of the parts is greater than the whole*":

> "The need to work closely with other organizations is rapidly gaining acceptance. Although some organizations may find it challenging to meaningfully buy into the idea of collaborating with customers, suppliers, and even competitors, many are quickly adopting changes to accomplish this objective. Considering the imperative on creating value for the end-user customer or consumer, the need for collaborative relationships cannot be overstated."

If collaboration is recognized as a long-term strategic goal, it should lead to a development of more efficient cross-organizational structure operating on jointly established rules and regulations. This set of rules would take into consideration what information could be shared and to which extent, making it easier to join forces in effort to solve common issues. This is how Dr. Langley describes it:

> "Collaboration goes beyond vague expressions of partnership and aligned interest. It means that companies leverage each other on an operational basis so that together they perform better than they did separately...
> It's a business practice that encourages individual organizations to share information and resources for the benefit of all... Cooperative in nature, Collaborative Logistics is supported through a robust network that allows members to pool resources for greater efficiencies."

In his paper, Dr. Langley also formulates the following recommended rules, which he calls "Seven immutable laws of collaborative logistics":

1. **Must result in real and recognized benefits for all members.** Pretty self-explanatory, this means that special "rules of engagement" must be set so that all participants would gain more profit or incur less loss in a result of collaborative practices comparing to non-collaborative approach.
2. **Must allow members to dynamically create, measure and evolve collaborative partnerships.** Collaborative business structures are not rigid, they should change and evolve, allowing different members to choose how deep they want to be involved and continuously evaluate collaboration costs and benefits. Collaborative process is often an recurring exercise of trial-and-error, and involved organizations should be ready for it.

3. **Must support co-buyer and co-seller relationships.** Collaborative approach adds buyer-to-buyer and seller-to-seller models to traditional buyer-to-seller one, thus encouraging collaboration between competitors.
4. **Must provide a flexible security model.** Members should be allowed to create public transparent relationships as well as private ones with variable level of transparency. Business sensitive data must be intact, while operational data is required to be publicly available.
5. **Must support collaboration across all stages of business integration.** Original paper proposed four stages of business collaboration (shared individual transactions, shared data, shared process, shared results) but we will be using modern CFPR model to describe various stages of collaboration implementation (Chapter 3).
6. **Must support open integration with other services.** Collaboration in supply chain might be limited to only some specific tasks, e.g. procurement. In the meantime, connecting (or co-developing) it to system for joint transportation or warehousing could add even more business opportunities and - ultimately - value for involved organizations.
7. **Must support collaboration around all five of the essential logistics flows.** Information, product, assets, document and capital flows of various members of a collaborative network -- all these flows should be made visible where required and aligned where necessary in regards with common rules of engagement, so that collaborative processes could work seamlessly.

To sum up, applying ideas of a collaborative supply chain, as well as applying joint data and material processing could aid finding more efficient solution of the eternal logistical problem of the ‘Right Product in the Right Place at the Right Time’. Critical information, both strategic and productive, should be available for all players whenever it is needed in order to improve planning and minimize market response time. Further we will discuss more pre-requisites for collaboration as well as some more specific requirements for oil and gas upstream collaborative warehouses.

2.3.2 Transparency in supply chain

The effect of a transparent supply chain has been discussed in various papers related to logistics. Infamous ‘bullwhip effect’ is directly related to lack of necessary transparency in supply chain. Even so, it seems that the potential of this approach is clearly underestimated and the concept is generally not well received among the world’s CEOs. As with most strategies, it might have both a positive and a negative impact, depending on situation and intention. But can this be applied to the oil and gas industry? This seems to be a very interesting research question, as usually oil and gas is considered to be ‘closed’ and reluctant to ideas such as information sharing and transparency. But what is especially important, due to Deep Water Horizon incident and subsequent oil spill, international community became more aware of oil and gas industry opacity issues. So the current situation with transparency in this industry is likely going to change eventually.

According to a study done by Paul A. Bartlett, et al., [5] *"... the exchange of high-quality information as a part of an improvement initiative does lead to significant improvements in the overall performance of the supply chain..."* This means that despite the fact that some supply chain members may not feel comfortable with transparency across the chain, this approach could lead to better overall performance of that chain as a whole.

Table 2 below shows an extraction from a table done by Richard C. Lamming et al., [6] It shows the value of different levels of transparency within different elements in a supply chain relationship. The first geological row is three metaphors that describe the different levels of transparency. Then for each level, possible outcomes are considered. The most intriguing aspect of the table is that absolute transparency might not be optimal, as the best flexibility for both customer and supplier is achieved with partial transparency (translucency). On the other hand, transparency gives mutual understanding regarding disclosures and strategies, which improves the ability to quickly react to changes.

Table 2: Value Transparency: Its role in elements of a supply relationship (Lamming et al, 2001)

Relationship	Opaque	Translucent	Transparent
Geological	Light cannot even penetrate the surface of the substance	Light can enter and exit the surface of the substance, but in a partial or disturbed/ distorted fashion	Light enters and exit the surface relatively undisturbed
Flexibility for customer and supplier	None	Maximum	Limited
Disclosure	None	Limited by both customer and supplier	The disclosure of value creation, nurture, and delivery is bilateral and mutually understood
Strategy	Very difficult to be strategic -- little knowledge beyond own boundaries	Strategies become tactically delivered to allow for poor information	Permits strategy through mutual understanding; second order strategy needed for contingency
Accounting/ cost focus	The transaction	Cost reduction, sometimes open-book on some items	The value created and delivered through the relationship
Dealing with change	Little provision for planning surprises	Expectation of prior notice for changes; relies on formal, partial information	Flexibility should support "lumpy" development (quick response to changes)

For our needs the most appropriate degree of transparency would be ‘translucency’ as this would allow for the maximization of mutual benefits while leaving sensitive business information undisclosed. But even this semi-transparent solution would require a change in the Operators’ way of considering the organization of their business and supply chain. Here lies the greatest challenge for the future project team: convincing the operators of the necessity of information sharing.

The other challenge is a more technical one. It is to elaborate a way to ensure that even though the supply chain members are not speaking the same ‘language’ in terms of data they use to exchange information, each proprietary system knows how to interpret that data, making it perfectly clear for everyone involved. And this is where we need to discuss how we can implement modern collaboration practices for our needs.

Chapter 3: IT-aided collaboration. CPFR.

3.1 Seven steps to collaborative commerce

In the 90s consulting firm AT Kearney proposed a framework for building collaborative commerce organizations, which is commonly used in various publications and whitepapers on this topic. Usually it's called a "*stairway model*" (see Fig.2) and represents 7 steps companies have to follow in order to achieve effective collaboration.

Fig.2. Stairway model for collaborative commerce (proposed by AT Kearney, taken from [link7])

The first three steps are the most fundamental ones. Those represent the obligatory basis for IT-aided collaboration initiatives and insure companies are on the same level technology- and data-wise so they able to communicate efficiently. This is why these three levels are also known as 'Foundation' -- those basically provide all means necessary for collaboration.

Levels four through seven can be gradually implemented eventually to gain more benefits from collaboration.

In the original model, it is suggested to use the following approach to build ‘Foundation”:

- Level one, **Common Data Standards** is also called **Item and Location Identification**. By this framework developers understand using unique identifiers for item and company (branch, divisions) identification. This identifiers should be accepted and used by all involved parties and have global rather than local meaning, so that only one interpretation would be possible.
- Level two, **Single Item Registry** in some sources is also called **Communicate Item and Location Information.** This implies that there must be established a global system where all the information about various items and companies (branch, divisions) is stored. All involved trading partners would send information about products: features, detailed information on its attributes, announcements and availability to that system.
- Level three, **Item Synchronization** is also known as **Continuous Update of Item and Location Information.** This means that information in system should be up-to-date and reliable. Any company would automatically send new information on i’s products’ changes and this will be visible for subscribing companies. The same is true for new product could also be achieved by means of system established at level two.

The following 5 steps in this model require established collaboration basis which would be then enriched with additional functionality. GS1 committee, who is behind this approach, provides limited industry-specific tools which are not suitable for our needs. Therefore we will be using another model to set a direction for further advancements, which is called CFPR and in its principles is similar to what is considered in steps 4-7 of the stairway model.

3.2 Collaborative practices

3.2.1 Collaborative Planning, Forecasting & Replenishment

The concept of Collaborative Planning, Forecasting and Replenishment (CPFR) first appeared in the mid-1990s [8], [9]. It began as a joint research initiative co-led by Wal-Mart and Benchmarking Partners and was first known as CFAR, which, cleverly, is pronounced the “See Far” initiative. This abbreviation stood for “Collaborative Forecasting and Replenishment”.

Initial research was aimed at reducing inventories, costs, and overall waste in supply chains for consumer goods. Funded by Wal-Mart, SAP, IBM and other industry leaders [8], Benchmarking Partners was trying to develop an industry standard for Internet-aided supply chain collaboration. This led to the development of a set of specifications which was made publicly available in 1996. The framework was accepted by the Voluntary Interindustry Commerce Solutions Association (at the time it was Voluntary Interindustry Commerce Standards -- VICS) organization, resulting in more companies adopting it and therefore developing the concept further. Eventually “Planning” was added to the name to reflect the significant role of this activity in the collaboration effort. The simplified view of the resulting CPFR business process is represented in “nine steps in original CPFR model” in figure 3 (as described in [9]):

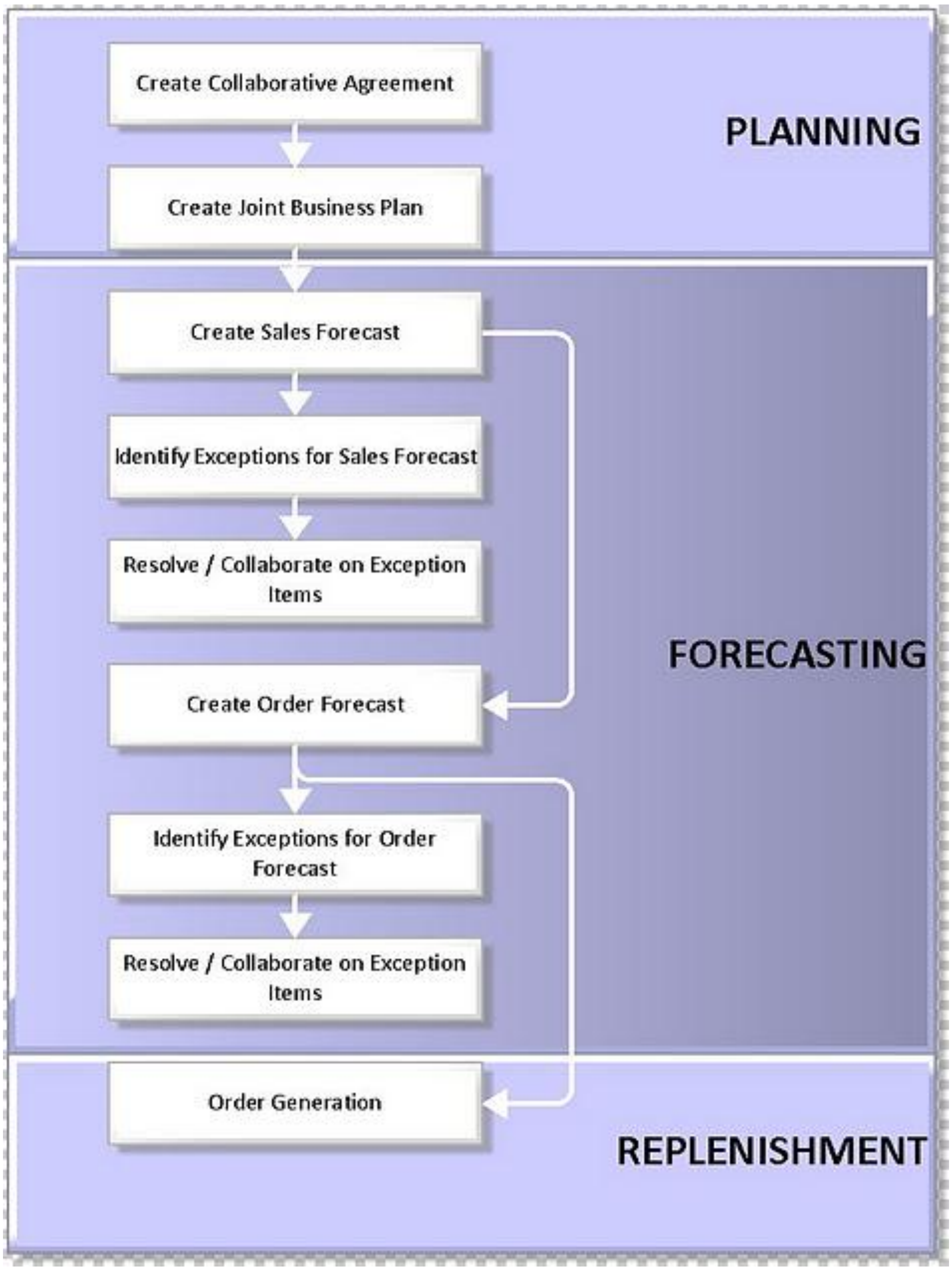

Fig. 3. Nine steps in original CPFR model

Ironically, the early CFAR projects coincided with the dot-com bubble development. Just as the dot-com boom was met with enormous excitement in financial circles, CPFR was met positively within the supply chain community. It was considered as the next big thing in supply chain management practices, and companies willingly invested in CPFR projects. However, similar to the dot-com burst, many CPFR projects met significant setbacks with implementation, especially while transitioning from small pilot projects to full-scale implementation. These issues lead to later disillusionment with the concept. In the meantime, it was not completely abandoned. Based on the prior concept, Vendor Managed Inventory (VMI) and Supplier Managed Inventory (SMI) concepts grew, and in modern supply chain practices CPFR transitioned from a rigid framework into something broader, which basically is *supply chain collaboration* in a more general sense.

The main limitation in the original "nine steps model" was its strict linearity and rigidness which significantly restricted adopters' freedom and flexibility, thus making it virtually impossible to implement it in many cases. The original approach obliged companies to implement the model step-by-step, for example even if a company was seeking only to share order information (steps 6, 7 and 8) they had to begin with sales forecasts (steps 3, 4 and 5). Many considered sales forecasts to be sensitive data without incentive to share. As such, VICS revised the process, allowing companies to focus on particular areas of collaboration and removing the linear step-based approach. Here is how VICS describe the amendments on their website [link9]:

> ***"Collaboration Participants****: The consumer has been placed at the center of the model, rather than off to one side, so the ultimate focus of collaborative efforts is clear.*
> ***Collaboration Activities****: CPFR has been transformed from a linear process to an iterative cycle of four activities: Strategy & Planning, Demand & Supply Management, Execution and Analysis. These Collaboration Activities rebalance the original model, maintaining the emphasis on planning and forecasting, while increasing the emphasis on execution and analysis. While activities are presented in a logical order, they are not numbered, and no predetermined sequence is implied.*
> ***Collaboration Tasks****: Eight Collaboration Tasks replace the "9-steps" of the original CPFR model. Steps 4, 5, 7 and 8 have been consolidated into a single "Exception Management" task, making room for new Order Fulfillment and Performance Assessment tasks."*

All these changes are reflected in the new process diagram in figure 4 below:

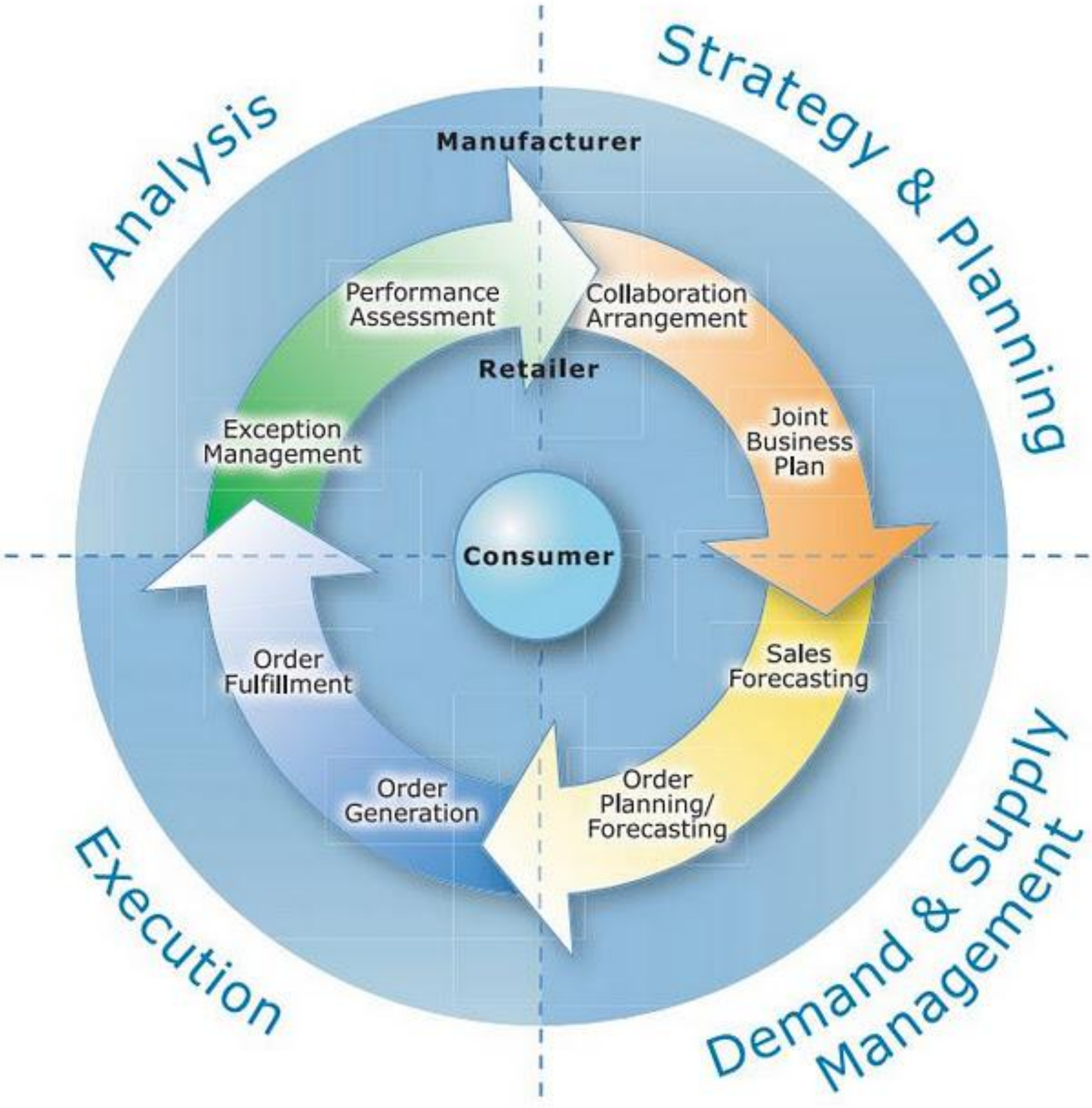

Fig. 4. Modern CPFR process diagram, taken from VICS CPFR webpage [link9]

In addition, a set of predefined CPFR scenarios are provided for the most common trading relationships based on implementation projects:

- *Retail Event Collaboration, for highly promoted channels or categories*
- *DC Replenishment Collaboration, for goods that are replenished through customer distribution centers*
- *Store-level Collaboration, for direct store delivery or retail DC-to-store distribution*
- *Collaborative Assortment Planning, for apparel and seasonal goods*

3.2.2 Vendor Managed Inventory

The concept of Vendor Managed Inventory first appeared in 1980s in retail business and represents the incentive to switch organizations' supply chain management policies to a more collaborative supply chain. Basically, this concept implies, that roles in inventory management and ownership shift, allowing organizations to decrease response time and improve operational flexibility. There are several levels of vendor's immersion in customer inventory, which are best illustrated by the following table (taken from [10]):

Table 3: Inventory Management Models

Inventory Process	Buyer Managed Inventory	Vendor Managed Inventory	Consignment/Vendor Owned Inventory
Inventory Forecast & Planning	Buyer	Buyer	Buyer
Inventory Ownership	Buyer	Buyer	Vendor
Inventory Management	Buyer	Vendor	Vendor

Thus the vendor's role in supply chain becomes much more significant, as responsibility for replenishment decisions and even inventory ownership can be moved from buyer to vendor. Depending on level of collaboration, there also could be different levels of vendor's involvement in inventory level monitoring and forecasting. At the same time buyer's involvement in inventory management may shrink to a mere information provider, so that vendor could restock items in time. Of course, this requires a certain level of information sharing between partners but in turn gives the whole supply chain more flexibility and decreases logistical costs. In fact, VMI has proven to be so useful since it was first introduced that now it is considered as a best practice and is included in standard enterprise resource software packages and more specialized warehouse management system packages (including SAP) for various industries.

We can conclude that vendor managed inventory in its various forms is one of the most successful examples of practical implementation of CPFR ideas, however, it is only one possible application of a more broad and powerful framework, which is the modern CPFR.

3.2.3 Data standards. Switching to Oil and Gas.

Let us return to Fig. 3. and try to consider how it could be implemented in Oil and Gas sector. Using the CPFR approach we can address the higher four steps of the initial seven-step model. But what about the foundation part, which is the prerequisite for these levels? Authors of the "staircase" suggest that GS1 standards would be used. But those are not optimized for the oil and gas industry, as those were developed for other needs.

There are different identification standards for various industries, e.g. barcode-based ISBN and ISSN in publishing and UPC and GS1 standards for use in consumer retail. Some of those are limited to a country or several ones, others are accepted internationally. Unfortunately, GS1 standards do not include any established recommendations for the Oil and Gas sector and cannot be used directly to work with petroleum upstream instances. However, we will use specific standards that have been developed with this industry in mind. This set of standards are being developed under common name of ISO 15926 and titled "*Industrial automation systems and integration—Integration of life-cycle data for process plants including oil and gas production facilities*". ISO 15926 still in development but there are already existing tools which could be applied in our project. In the following chapter we will provide an overlook on what hides under the ISO 15926 umbrella and how this could be used.

Chapter 4: ISO 15926 for spare parts in Oil and Gas

4.1 Why complex standards?

Nowadays production is extremely sophisticated. This is especially true for high-tech enabled industries, such as the oil and gas sector. With ever-growing demand, and as natural resources further deplete, more technologically-advanced machinery is required for extraction and refining. This technology race has led to a situation where we have millions of parts with alternatives from various suppliers, hundreds of companies, and thousands of people working on different aspects of one project. For example, the number of components in a modern FPSO (floating production storage and offloading) oil rig is around 10.000.000, which is 1000 times more than the number of parts in an average automobile. At the same time, oil and gas companies still operate older rigs which also require a tremendous amount of spare parts to keep them running, and which also come from various suppliers.

This complexity demands a robust, flexible means of interoperability and collaboration, so that information can flow and be interpreted seamlessly by various partners. The way to achieve this is to use a common 'translator', based on open standards, and this is the reason ISO 15926 was proposed and developed. A result of almost twenty years of research and development, this ISO establishes an industrial standard for information coordination in such demanding projects. It also provides a 'facade' for data interpretation with multiple views on data, i.e. from design, engineering, operation and maintenance standpoints.

The formal name of ISO 15926 is "Industrial automation systems and integration -- Integration of life-cycle data for process plants including oil and gas production facilities". According to POSC Caesar, who initiated the development of this standard:

ISO 15926 is a worldwide standard for exchanging complex information about plant objects during their lifecycle. If everyone uses a common standard a number of things will be easier:

- *We can exchange information without having to know anything about each other's data storage configuration.*
- *Information will be transferred directly from machine to machine without having to be re-keyed.*
- *The information will be transferred with high fidelity. We will not need human beings to review the information to make sure nothing is lost or added.*
- *A consortium of EPCs* [here EPC stands for Engineering, Procurement and Construction] *will be able to collaborate on designing a plant, each using its chosen plant design system with proprietary work processes. They will be able to share information without having to know anything about each other's data storage format beforehand.*

- *During design, vendor's and EPC's software will be able to connect to each other, so passing information back and forth will be much easier.*
- *Information turnover from EPC to Owner will be a non-issue. Owners will be able to receive the plant data by connecting to the EPC's 'interpreter' and then store it in the their own format.*
- *After information turnover, any of the owner's computer systems will be able to use the information. For instance, a Plant Operations System will be able to access the pieces of information it needed. A Plant Maintenance System will be able to access just the pieces it needs. Each application will take the pieces it needs and ignore the rest.*
- *Owners will be able to harmonize maintenance systems between production facilities that have incompatible information storage formats.*

ISO 15926 operates with a 4D model, which means it views a product as it changes throughout its lifetime. Thus it is a perfect fit for a system that needs to manage spare parts for various oil rigs' nodes, because those become damaged with time and require replacement.

4.2 ISO 15926 landscape and development

Currently, the ISO 15926 standard consists of seven parts, one of which is technically not a part of this standard, as during development it was annexed with another ISO. Additionally, several more parts are being developed to further specify standard's usage. Below we will briefly describe each part. If a part is already published, a corresponding abstract summary would also be included. In their 'Introduction to ISO 15926' published by POSC CAESAR authors often use natural human language examples to explain different ISO 15926 parts and illustrate their role. We will be using the same metaphor where it is applicable and appropriate.

4.2.1 ISO 15926 overview

Part 1 Overview and fundamental principles.

Abstract summary:
"ISO 15926-1:2003 specifies a representation of information associated with engineering, construction and operation of process plants. This representation supports the information requirements of the process industries in all phases of a plant's life-cycle and the sharing and integration of information amongst all parties involved in the plant's life cycle." [link11]

Basically part one is an introduction where standard overview is given and its purpose is described. The purpose is summarized as "to facilitate data integration by means of a data model that defines the meaning of information in a way that all users of the information will have the same understanding of what it means."

Part 2 Data model

Abstract summary:
"ISO 15926-2:2003 specifies a conceptual data model for computer representation of technical information about process plants...ISO 15926-2:2003 is a part of ISO 15926, an International Standard for the representation of process plant life-cycle information. This representation is specified by a generic, conceptual data model designed to be used in conjunction with reference data: standard instances that represent information common to a number of users, process plants, or both. The use and definition of reference data for process plants is the subject of Parts 4, 5 and 6 of ISO 15926." [link12]

When compared to natural language, Part 2 can be seen as a set of 'grammar rules' which describes the fundamental entities, basic types with high level of abstraction. All actual future entities must relate to it. Therefore definitions given in part 2 are not specific to any industry, but are sufficient to enable all domain specific entities to be described in this particular ISO.
It should be also noted that the data model can support all disciplines and life-cycle stages, and it can support information about functional requirements, physical solutions, types of objects and individual objects as well as activities.

Resources:

- POSC Caesar's OWL serialization of ISO 15926-2. See also ISO 15926 in OWL for more information on how ISO 15926 may be represented in OWL (Web Ontology language)
- ISO 15926-2 online version
- EXPRESS listing of ISO 15926-2

Figure 5 illustrates an ISO 15926 entity as it is represented in online version of ISO 15926-2

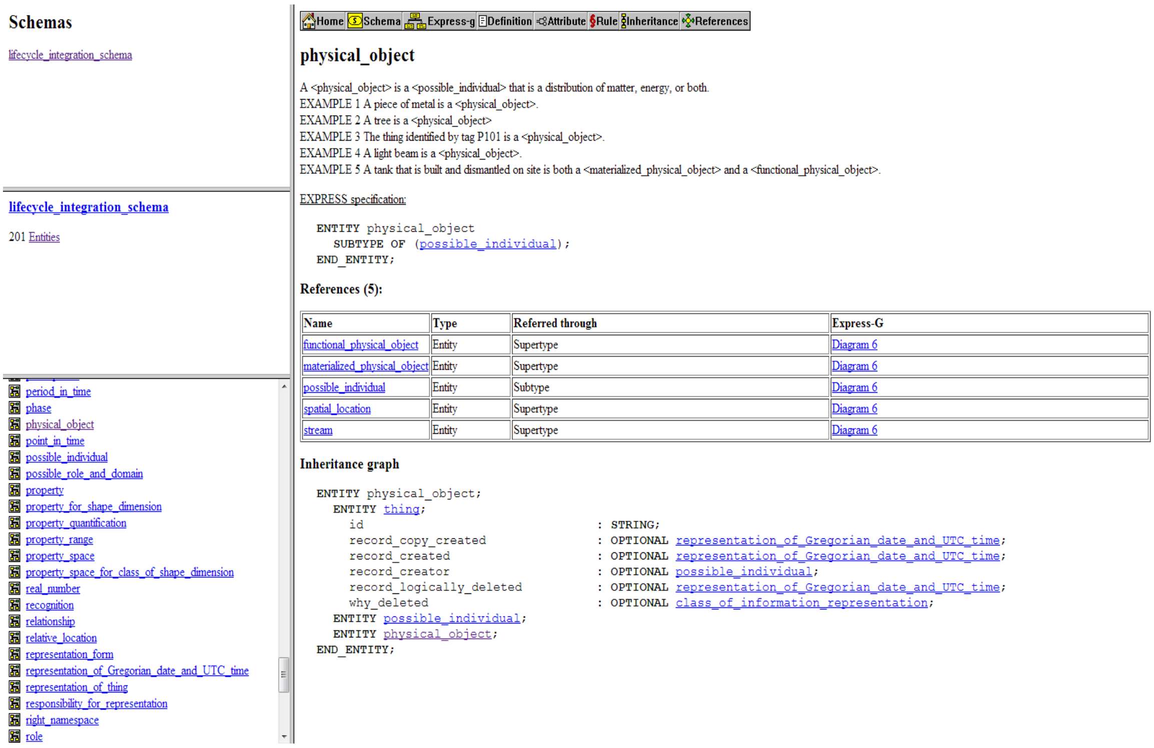

Fig. 5. Entity ‘physical object’ in ISO 15926-2 schema

Part 3 Reference data for geometry and topology

Abstract summary:

“ISO/TS 15926-3:2009 specifies geometric and topological concepts, enabling the recording of geometric and topological data using ISO 15926-2 and in a way consistent with first order logic.
It also specifies concepts related to mesh topology and functions defined with respect to meshes, enabling the recording of mesh topology data and the representation of property distributions.” [link13]

ISO 15926 Part 3 can be considered as a “graphics dictionary”. Based on common ‘grammar rules’ from Part 2, it describes the geometry and topology that can be used to represent objects in ISO 15926. When Part 3 is finalized, its adopters would be allowed to graphically represent and easily share various drawings, blueprints, 3D models etc. in ISO 15926 format.
There is a Geometry Special Interest Group in organization Fiatech, who are responsible for this part development. Part 3 is based on ISO 10303-42 (Integrated Generic Resource: Geometric and Topological Representation) and ISO 10303-104 (Integrated Application Resource: Finite Element Analysis).

Resources

- ISO TS 15926-3 (2007) REFERENCE DATA CLASS. This is the reference data item classifying all reference data items defined in ISO 15926-3 as represented in the POSC Caesar Reference Data Library of Feb. 2008

Part 4 Initial reference data

Abstract summary:
"ISO/TS 15926-4:2007 defines the initial set of reference data for use with the ISO 15926 and ISO 10303-221 industrial data standards" [link14]

In natural language metaphor, similar to Part 3 for graphical objects, Part 4 is a "dictionary'" which contains subtypes or specializations of basic types listed in Part 2 and describes various engineering classes, terms and objects required in facilities' design, building and lifetime operations. As per 2011, ISO spreadsheets stored nearly 20000 individual terms. The RDL is designed to be federated and as such can retrieve reference data from multiple sources and locations. In other words any ISO 15926 implementation project enriches RDL with new entries.
As a visual reference, **Figure 6 illustrates an RDL object as it is represented in online ISO 15926-4 spreadsheets**

Resources

- Web "browsable" version of the ISO 15926-4:2007 reference data items
- iRing wiki page dedicated to reference data recommendations, templates and links to project groups

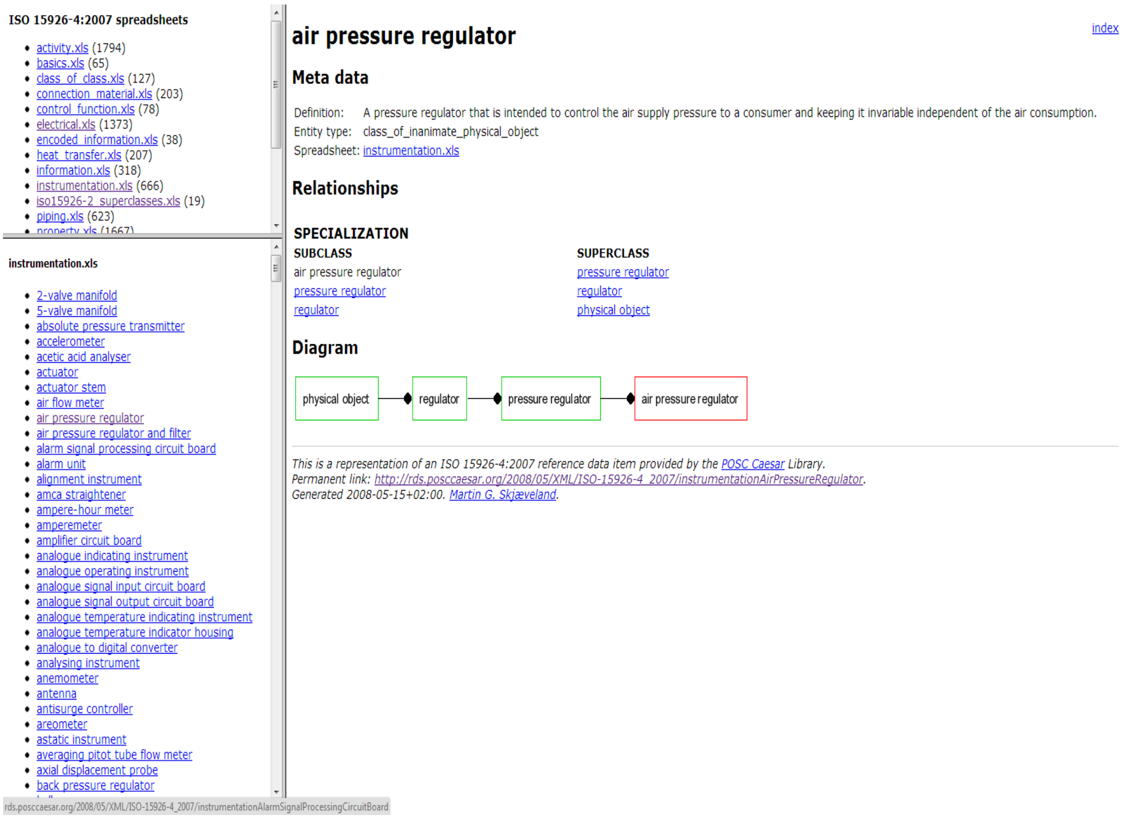

Fig. 6. Air pressure regulator as represented in RDL

Part 5 (formal): Procedure for development and maintenance of reference data in database format

Originally Part 5 was meant to describe how to maintain Part 4 in a database format. But during development this function was superseded by another ISO standard

(ISO TC184/SC4) for general use in class library maintenance for various ISO standards using RDLs. As the standard was aligned with the aforementioned ISO standard and annexed to it, it is no longer a part of ISO 15926.

Part 6 Scope and Representation for Additional Reference Data

Part 6 defines the methodology for the development and validation of reference data. It describes how to validate a reference data item to ensure that it is genuine. It describes what information is required for a new reference data item and approval procedure. Being a formal procedure, Part 6 is not available online or covered in materials available to general public. Basically it states that each reference data item requires a reference data item ID, a reference data item text description and formal relationships. No abstract is available as this part has not been finalized yet.

Part 7 Implementation methods for the integration of distributed system -- Template methodology

Abstract summary:
"ISO/TS 15926-7:2011 is a specification for data exchange and life-cycle information integration using templates based on the data model of ISO 15926-2. It provides a methodology for data integration of ontologies using mathematical first-order logic, which makes it independent of computer languages." [link15]

In natural language metaphor, ISO 15926-7 is a 'phrase book' which uses Part 2 'grammar rules' to define and test frequently used standardized 'phrases'. These 'phrases' are called templates and significantly simplify Part 2 implementation and speed up the ISO adoption projects when applicable.

Resources:
- [link17]
- [link18]
- Part 7 Templates online

Part 8 Implementation methods for the integration of distributed systems: Web Ontology Language (OWL) implementation

Abstract:
"ISO/TS 15926-8:2011 is a specification for data exchange and life-cycle information integration using Resource Description Framework (RDF) and Web Ontology Language (OWL).
ISO/TS 15926-8:2011 provides rules for implementing the upper ontology specified by ISO 15926-2 and the template methodology specified by ISO 15926-7 into the RDF and OWL languages, including models for reference data as specified by ISO/TS 15926-3 and ISO/TS 15926-4, and for metadata.
The electronic files attached to ISO/TS 15926-8:2011 provide the OWL declarations, together with example instance data." [link16]

Part 8 is the standardization of the implementation of Part 7 using RDF and OWL. RDF and OWL are standards developed to support the *Semantic Web*, an initiative to adopt common data standards in World Wide Web in order to improve machine-to-machine communication and allow for more usage of metadata in it. RDF is a way of making statements about things using what is known as a *Triple Store* of *Subject-Predicate-Object* expressions. OWL is a method of creating an ontology expressed in RDF syntax. In everyday natural language communication analogy using Part 8 is somehow similar to writing down "notes", which could be exchanged with other people.

Let us also give some definitions and disclose the basics of RDF syntax in accordance to W3C recommendations [link19], as this will be used later:

URI (Uniform Resource Identifier) is a string of characters which are assigned to an entity and used to explicitly identify it. There are two types of URIs: URLs and URNs, in some cases URI can be both URN an URL.
URL (Uniform Resource Locator) is a "locator" in a sense that it is an URI that identifies an "address" of an entity or a resource located in a network.
URN (Uniform Resource Name) is "name", which means it is an URI that identifies an entity or a resource in a given namespace.
Blank node is an entity that does not have an URI assigned to it. Therefore it is also known as anonymous resource.
Literal is a set of literal characters, such as strings or integer numbers

An **RDF triple** contains three components:

- the **subject**, which is an RDF URI reference or a blank node
- the **predicate**, which is an RDF URI reference
- the **object**, which is an RDF URI reference, a literal or a blank node

An RDF triple is conventionally written in the order subject, predicate, object.
The predicate is also known as the **property** of the triple.
An **RDF graph** is a set of RDF triples.
The set of **nodes** of an RDF graph is the set of subjects and objects of triples in the graph.

Strictly speaking, ISO 15926 is not limited in its implementation to RDF and OWL; it can be implemented even with XML, spreadsheets, text files, or word processor documents, just not as easily. The ISO 15926 developers have chosen RDF triples and OWL because they are already well developed for the Semantic Web for similar purposes and therefore can serve ISO 15926 as well.

Future additions for the standard:

There are also the following future additions to ISO 15926 currently in development:

Part 9 Façade Specification

With Part 8, organizations have "notes" with data they are willing to share. Continuing this metaphor, Part 9 can be viewed as a *storefront* or "*façade" for* machines where they can place these "notes". It is a standardization of the Web data exchange service using SPARQL (which is a special protocol for querying RDF data) as the method of access. So this enables applications to "talk to each other" over the Internet. Using a façade, an organization can also control how much information is made public but only copying certain amounts to the façade. Needed level of security comes from the fact that even trusted partners who have an access to façade are only able to query data there, while an organization's entire repository remains intact.
When ISO 15926 is mature, it is expected that all organizations involved in plant design and operation will have a Façade for efficient data exchange.

Part 10 Abstract Test Methods

Part 10 was created recently. It is aimed to develop a methodology to evaluate systems' ISO 15926 compliance. By 'abstract' it implies that these test methods would not depend on hardware or software a firm is using, rather focus on full compliance with ISO specifications.

Part 11 Simplified Industrial Usage including Gellish Implementation using Reference Data

Part 11 was proposed recently as an easier methodology to implement parts 7 & 8. We will cover its ideas in more details later on in section 4.3.

ISO 15926 Pyramid.

To illustrate how all ISO 15926 parts are interrelated, ISO 15926 pyramid is used. In the picture below, each layer is a subset of previous one and retains its semantics. The wider level is, the more specific and detailed instances contains related database. This pyramid is also known as a graphic representation of Oil and Gas ontology. In this paper we will be talking about parts with project data and predefined user classes and catalogues (lower two layers of the pyramid)

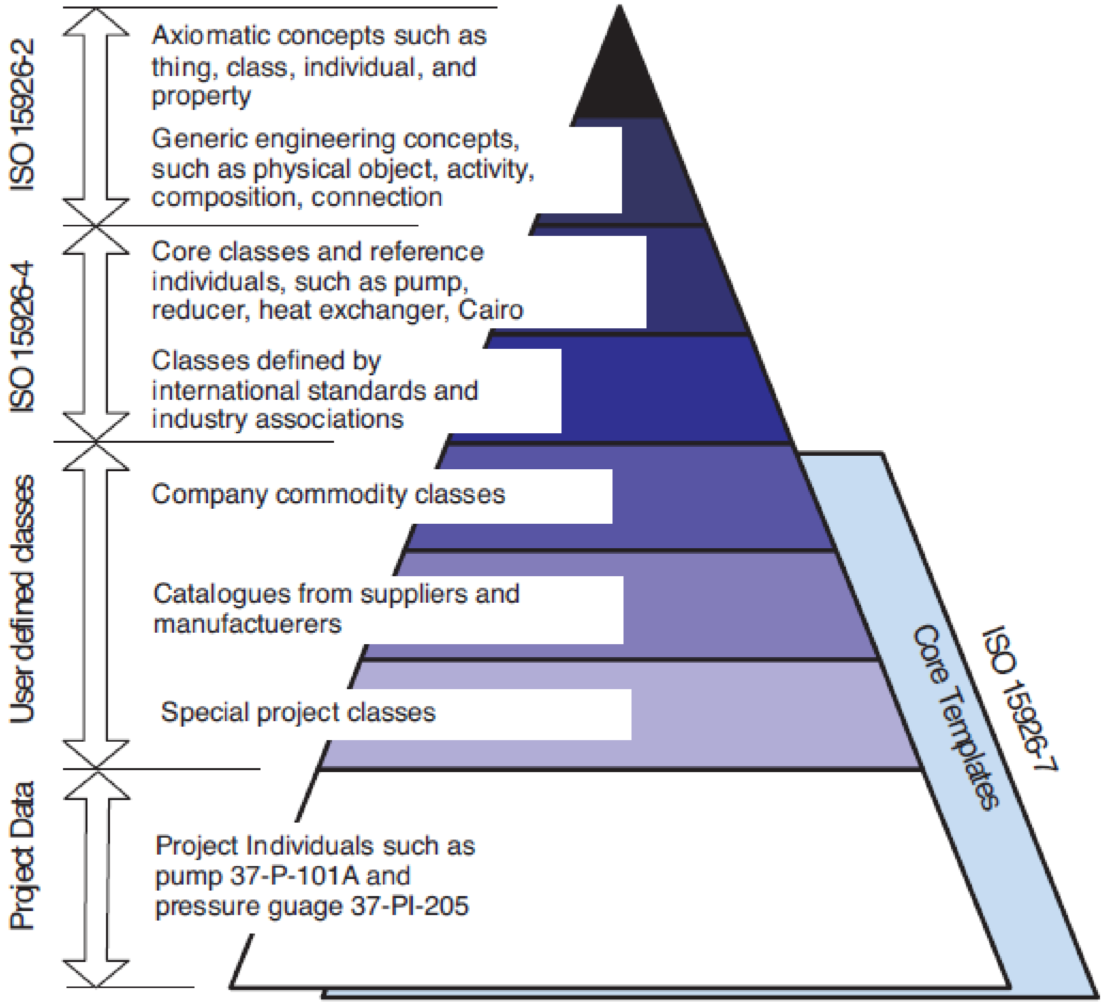

Fig. 7. *ISO 15926 pyramid (taken from "An Introduction to ISO 15926" [13]).*

4.2.2 ISO 15926 Enabling Infrastructure. JORD. iRing.

ISO 15926 development is already approaching that point when standard becomes mature and ready for wide scale implementation. But in order to simplify and speed up the adoption process, it requires rigid infrastructure, flexible tools, well-developed documentation, implementation methodologies and best practices. Therefore organizations behind ISO 15926 have special projects aimed at fulfilling of those requirements.

JORD project.

One of the key moments of ISO 15926 is public availability of Reference Data Library and definitions. This means that a special interface is required to validate terms for ISO 15926 compliance in real time and thus remove ambiguity. This service is called RDS (Reference Data Service). A special project called The Joint Operational Reference Data (JORD) is collaboratively lead by PCA (POSC Caesar Association) and Fiatech. It is dedicated to funding, developing and running this service. At the moment RDS/WIP endpoint for JORD projects has already reached version 2 and is available for subscribers and general public. There are interfaces for both human-to-machine and actual machine-to-machine queries available at the following address:

http://posccaesar.org/endpoint/

Figure 8 (taken from [link20]) represents a vision of how ISO 15926-enabled interoperability approach works with JORD RDS.

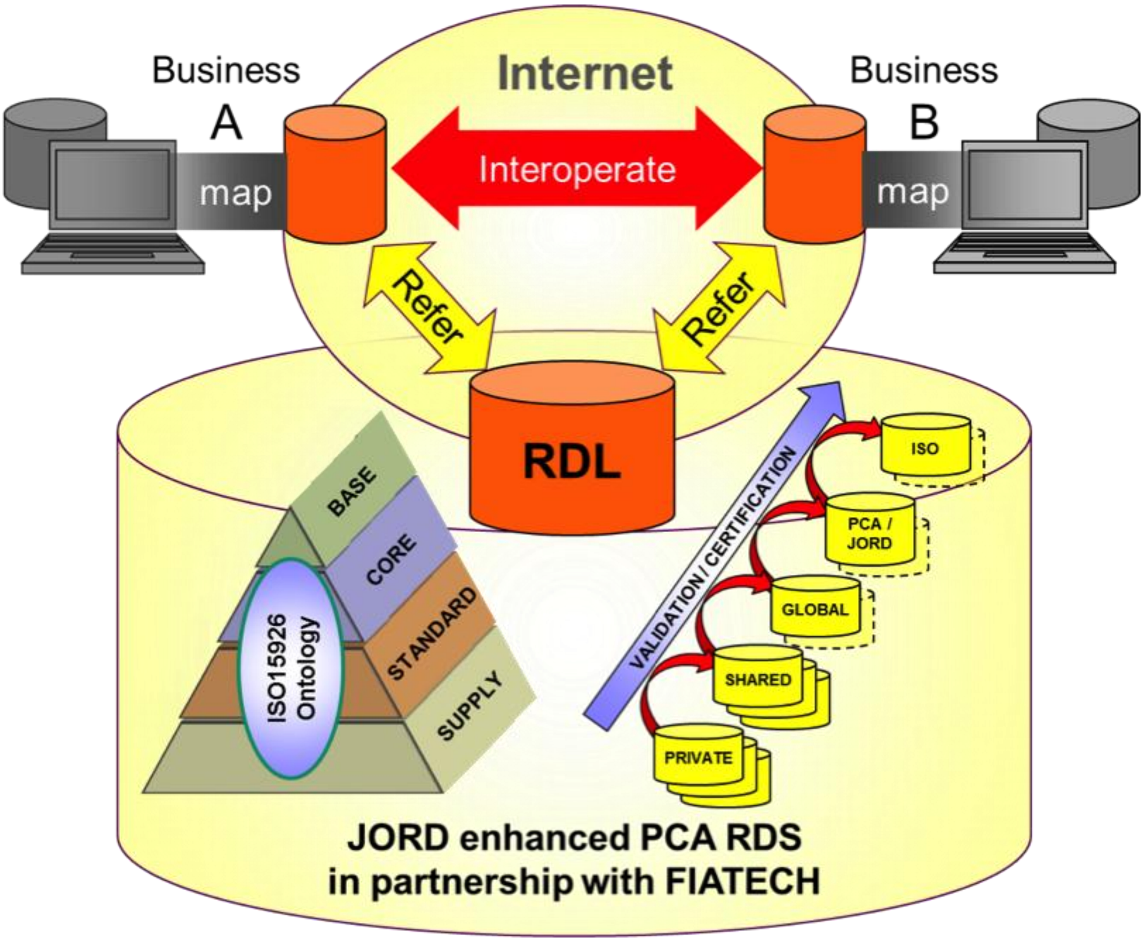

Fig. 8. JORD enhanced RDS for ISO 15926-based interoperability.

As it was described earlier, RDL is supposed to be open to new entries. These new RDL instances are about to be populated from new implementation projects. However, such additions require special attention and approvals from ISO 15926 committee. On practice this is ensured by step-by-step incremental approach to new entries adoption or “federation of cascade data libraries”. This means that new instances can not be added directly from project proprietary database in RDL. Instead, they will be evaluated on different levels, merged with similar deliverables from different projects where possible and only then end up in RDL. The lower right portion of the picture above shows a schema for such additions validation and certification process.

iRING

Name "iRING" is an acronym for "ISO 15926 Realtime Interoperability Network Grid" It has been used as a commercial brand name for an approach to information exchange that uses the full specification of ISO 15926. Under iRING umbrella there are various ongoing projects and development aimed at ISO 15926 popularization among software providers and key vendors, as well as best practices development. Described above JORD project is also a significant part of iRING.

The following picture is a more exchange-focused version of the previous one. It shows how different parts of iRING approach are working together (picture taken from "An Introduction to ISO 15926" [13] and modified a bit):

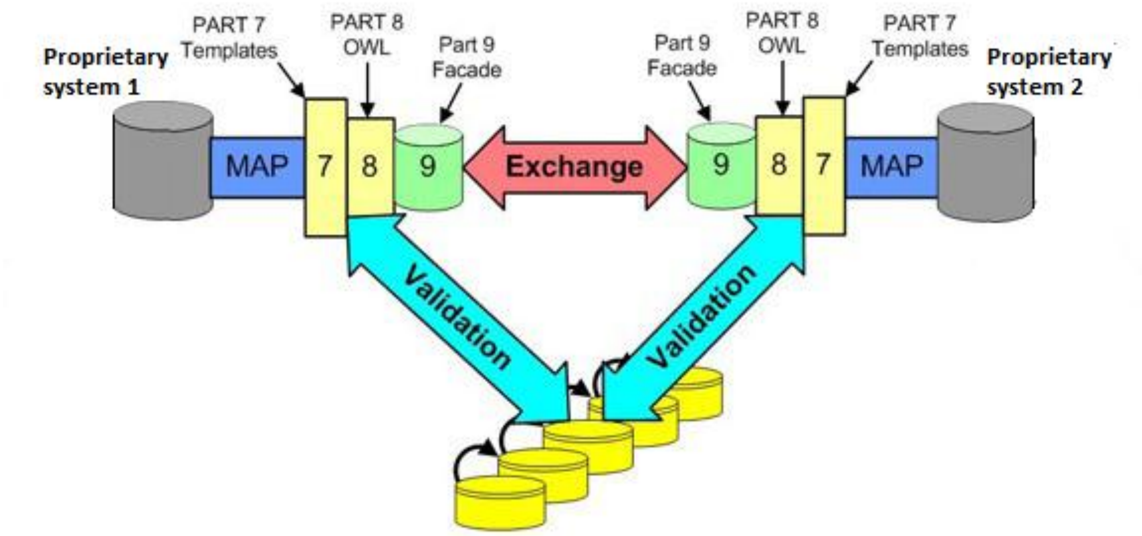

Fig. 9. iRING information flow.

With iRING Fiatech and PCA are now also focused on bringing ISO 15926 interfaces and tools for commercial engineering software. Availability of such interfaces is a significant enabler for ISO 15926 implementation as those allow to use the standard within existing commercial software without additional preliminary software modification.

Currently the following software has been released with native iRING support:

- **iRINGTools**, [link21] which is, as stated at their website, *"a set of free, public domain, and open source software applications and utilities that implement iRING protocols. iRINGTools provide users with production ready deployable solutions. iRINGTools also provides technology solution providers with usage patterns for the implementation of iRING protocols in their respective solutions*."
- **.15926 Editor**, which is a universal editor for ISO 15926 data, designed to explore reference data "*in as many formats as possible"*, verify it, and engineer new reference data "including automated reference data creation through mapping from external sources".

- **Proteus project**, [link22] deliverables aimed at data exchange between P&IDs (Piping and instrumentation diagram) projects, P&IDs and 3D models projects and between different proprietary 3D models projects.

On October, 26th, 2012, it was announced on official Fiatech website, that Fiatech and PCA are unifying all industry interoperability activities under the iRING name]. As it is stated in the announcement, "*The iRING name represents the solution architecture and best practices for achieving global information interoperability based on the ISO 15926 reference data standard and includes: documentation, methodology, certification, services and technology solutions -both commercial and open source*."

4.3 An approach to practical implementation of ISO 15926 using Gellish language

4.3.1 Gellish language

As it was mentioned before, part 11 of the standard is dedicated to ISO 15926 implementation using Gellish language.

As defined at its official website [link23], "*Gellish is formal language for the expression of information and knowledge and for the storage and exchange of data in an open, system independent, human and computer interpretable way. Gellish is an Open Standard that is derived from natural languages and is based on various International Standards, such as ISO 10303-221 and ISO 15926."* Here is where lays the main difference between Gellish and XML or RDF/OWL. While the latter are just tools for creating a language, Gellish is a language and it can be used on top of these tools. Also Gellish is a controlled subset of natural language. Therefore it can be built on base of any human language and used in engineering where ambiguity should be minimized.

According to description at official website [link23], Gellish consists of the following three components:

- ***"The Gellish grammar** (upper ontology). This component defines how 'facts' about any kind of object, activity or aspect can be specified in a consistent computer interpretable way and how a number of 'auxiliary facts' about every main fact can be specified. This enables to store and exchange information and knowledge(including documents and 3D models) in a neutral format and also to manage all those data and documents. The grammar is based on the ORO principle (the Object-Relation_type-Object principle). The core of the language specifications is formed by the definition of standard relation types and the definition of the kinds of things that can play a role in those relation types. Gellish enables automated translation of expressions between natural languages. The language also covers the expression of queries and response messages.*

- ***The Gellish Data Table structure*** *(syntax).This component defines how every Gellish database or Data Exchange File or Query and Response Message should be structured. It thus defines a universal data table structure. This universal structure, in combination with the application of the usage of a common language for the content enables data integration for multiple sources. It also enables the seamless cooperation of multiple central or distributed databases as if they were one consistent database. A Gellish Database is a semantic database, which means that it includes not only ordinary data, but it also contains the definitions of the used concepts as well as system independent rules for the interpretation of the stored facts.*
- ***The Gellish Dictionary-Taxonomy*** *and its Domain Dictionaries-Taxonomies. The Gellish English version includes an extensive electronic smart English Dictionary-Taxonomy that consists of a Core Dictionary-Taxonomy section that defines common general concepts and various Domain Dictionaries-Taxonomies. The Dictionaries contain definitions of concepts and terminology (including synonyms as well as homonyms) from a large number of application domains. A Gellish Dictionary is called a Smart Dictionary, because it contains human and computer interpretable knowledge due to explicit relations between the defined concepts. For example, the concepts in the Dictionaries are arranged as Taxonomies (being a subtype-supertype hierarchy) which enables inheritance of characteristics from generic concepts to more specific subtype concepts. The core Dictionary-Taxonomy and the Domain Dictionaries-Taxonomies together form one consistent whole. The Dictionaries-Taxonomies are extensible with other domain specific concepts and terminology as well as with proprietary concepts and terminology. New specialized Domain Dictionaries may be added. Standard product types and manufacturer's models are defined in Gellish as further specialized proprietary extensions of Gellish Domain Dictionaries."*

But this is a pure theoretical thing required for building ontologies, so let us consider how this can be applied to ISO 15926 implementation projects.

4.3.2 ISO 15926 implementation with Gellish

In the table below, basic ISO 15926 entities are listed and some applicable relations are given. These are *taxonomies* and *relationships* which were mentioned above.

Table 4: *Basic set of 15926 entities and Gellish semantic relationships (Leo van Ruijven, 2007)*

Entry for 15926 part 4 (15926 part 2 entities)	Example applicable Gellish relation	Inverse Gellish relation
Class Of Individual	has aspect	is an aspect of
Class Of Physical Object	is physically connected to	is physically connected with
Class Of Property	is quantified as	is a quantification of
Class Of Functional Object	is logically connected to	is logically connected with
Class Of Activity	has as subject	is subject of
Class Of Event	cause of event is	event is caused by
Class Of Person	is author of	has as author
Class Of Organisation	is responsible for	is responsibility of
Class Of Information Object	is description of	is described by
Class Of Compound	is made of material	is material for
Class Of Feature	is a part of	is whole for
Role	is approved by	is approver for
Spatial Location	is located at	is location for

As described per prof. Leo van Ruijven in various papers available online [link24] on practical aspects of data integration projects based on ISO 15926, the project team would be required to use the following building blocks to build those facts:

Principle of life-cycle data integration

(in accordance with ISO 15926)

Building blocks for defining a system (including projects):

- Objects: Physical things, activities, functions, people, documents, etc.
- Properties: Characterize objects
- Relations: Meaningful, semantical relationships between objects

In the figure below there is a simple example (taken from [link24]) of the use of such building blocks for describing different objects and their properties. Boxes represent various objects, and arrows represent semantic relationships between those objects.

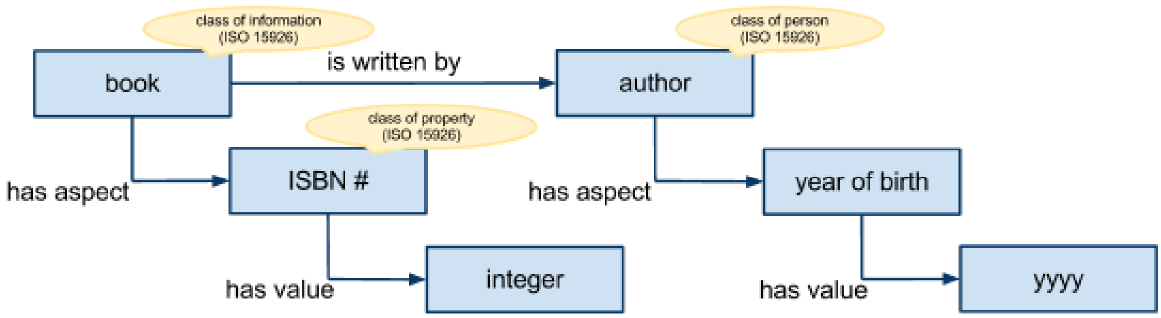

Fig. 10. An example of Object-property-relationship representation.

This example can easily be expanded further by adding, e.g., a bookstore having this book for sale, or a library holding it on a shelf, or a process of purchase (which would require new classes of objects and information, such as 'purchase order' and 'customer').

The example helps in understanding how various objects are classified when using ISO 15926. After the classification all objects related to a class are grouped into hierarchies, which combine into a reference data model intended for holding all the information about various objects related to a project. To illustrate this, let us consider a couple of small fractions from hierarchies taken from a reference data model:

1) A subset for Class of Property (specialization hierarchy):
...

- radiant intensity
- radioactivity
- rate
    - absorbed dose rate
    - energy fluency rate
    - exposure rate
    - flow rate
        - flow rate mole basis
        - flow rate per area mass basis
        - flow rate per area mole basis
        - flow rate per area volume basis
        - flow rate per length mass basis
        - flow rate per length volume basis
        - heat flow rate
        - mass flow rate
    - radiant flux
    - shear rate

…

2) A subset for Class of Physical Object (specialization hierarchy):

…

- switchgear and controlgear
- switching device
    - mechanical switching device
        - auxiliary switch of a mechanical switching device
        - circuit-breaker
            - air circuit-breaker
                - earth leakage circuit-breaker
                - miniature circuit-breaker
                - moulded-case circuit-breaker
            - circuit-breaker with lock-out preventing closing
            - current-limiting circuit-breaker
            - dead tank circuit-breaker
            - gas blast circuit-breaker
                - air blast circuit-breaker

…

Gellish language operates with data in the form of *facts*, comprised of left-hand term, relation and right-hand term, these are also known as *tuple*s. For example, in the above example of a book, the main fact is "book" (i.e. left-hand term) "is written by" (i.e. relation), and "author" (i.e. right-hand term). The main fact contains meta data, such as:

- Unique identifiers left-hand, right-hand
- Definition of left-hand object
- Context of the fact
- Status of the fact
- Source of the fact
- Language
- Begin of life date of the fact
- Modify date of the fact

Thus each object in the reference data model has various properties and relationships with other elements, which creates a "cloud of information" surrounding each object. This information can be captured and standardised by using an "Object Information Model" (OIM). Therefore, additional information about an object, its semantics becomes easily accessible and available for machine search. This is what *semantics*, or build-in information of Gellish data table structure, mentioned above, implies.

Using left-hand terms, right-hand terms and relations from the dictionary, Gellish databases can be built. Gellish databases enhanced with OIM can store every type of relation between various complex project instances. Further, they can be expanded by introducing unique identifiers (UIDs), for even more formalized form. When a complete Reference Data Library is built based on Gellish databases and enhanced with OIM, it is easy to use the Library to search by a needed parameter or to find substitutions for missing detail.

4.4 OLF and ISO 15926. IOHN.

One of the most important things about ISO 15926 is that it has officially been recognised by the Norwegian Oil Industry Association (Oljeindustriens Landsforening, OLF) as a tool for data integration in the upstream oil and gas industry. This makes practical implementation of this standard a valuable capital investment in preparation for the industry's evolution.

Since 2004, several industry-wide projects were developed. The first one was the Integrated Information Platform (IIP), which aimed at establishing a real-time information pipeline for use in daily drilling and production routines and developing ontology for drilling and extraction equipment. Fourteen key players participated in it, including oil companies, IT vendors, engineering and service companies. It was finished in 2008, resulting in the development of the aforementioned ontology as well as standardized solutions for drilling and production reporting.

Another, even more ambitious project using ISO15926 and IIP deliverables is currently in operation. The project is called Integrated Operations in the High North (IOHN). This is a joint effort by 22 different companies aims to, "Design, implement and demonstrate the digital platform for next generation Integrated Operations", as is stated on its official homepage [link25].

The project was kicked off in May 2008 as a four-year endeavor to enable oil production under extremely harsh arctic conditions. To minimize direct human involvement in operations on remote facilities in the arctic setting, the use of "heavily instrumented facilities (fields)" is planned. Of course, such facilities would require new operational concepts to keep them running.

In the development phase, the following concept was proposed: instrumented fields are operated from "lean local organization" which is remotely aided by a set involving an "asset organization", "multi-asset support centers", and "external expert centers", providing the necessary competence for rapid decision making [link26]. This concept is called Integrated
Operations Generation 2 (IO G2) and is illustrated below.

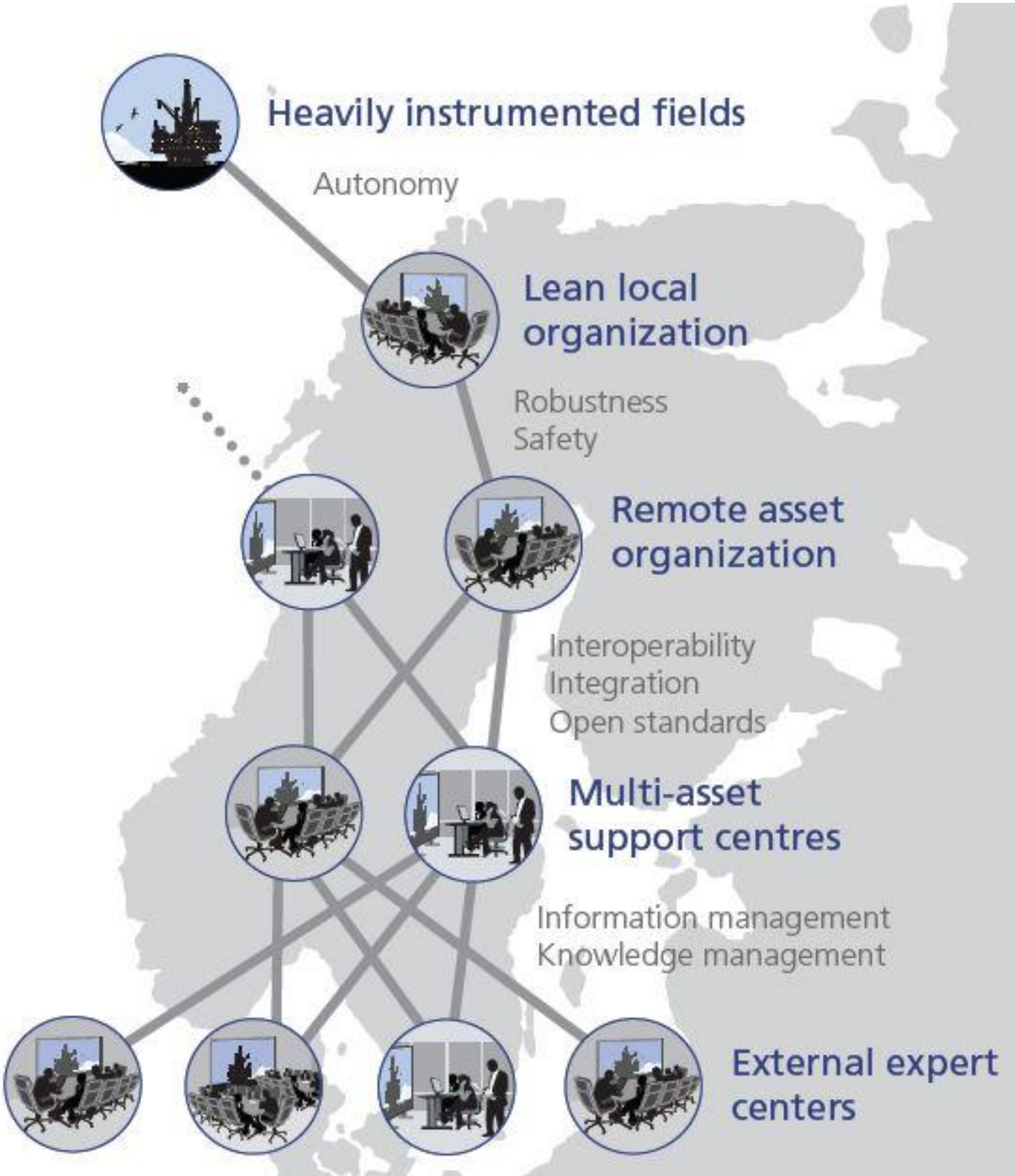

Fig. 11. Integrated Operation 2 (IO2) concept (taken from official IOHN project page [link25]).

This concept requires robust and reliable means for capturing and transferring operational data to decision makers in real-time. It is absolutely crucial to provide technology to deal with this challenge, and so the main focus for IOHN has been on the development of a "digital platform" to enable seamless data interchange. To ensure that high interoperability demands would be met, this "digital platform" is based on open standards and sophisticated semantic web algorithms with ISO 15926 being its cornerstone.

4.5 EqHub

The problem with general ISO 15926 is that it is just a standard. It is a set of recommendations for data organization in oil and gas projects that is not yet finalized, and actually implementing the standard from scratch could be a serious challenge for system architects and a project team. Luckily, as it was mentioned in section describing iRING, some tools are already available on the market that is based on ISO 15926 and could be incorporated in the system. For system we are going to build, the most interesting tool is called EqHub.

Basically, EqHub is a common equipment repository created specifically with Norwegian Continental Shelf industry's needs in mind. The development was initiated by OLF and is owned by EPIM (Exploration & Production Information Management Association).

In the figure below, an intended business model for EqHub is presented (taken from EqHub presentation).

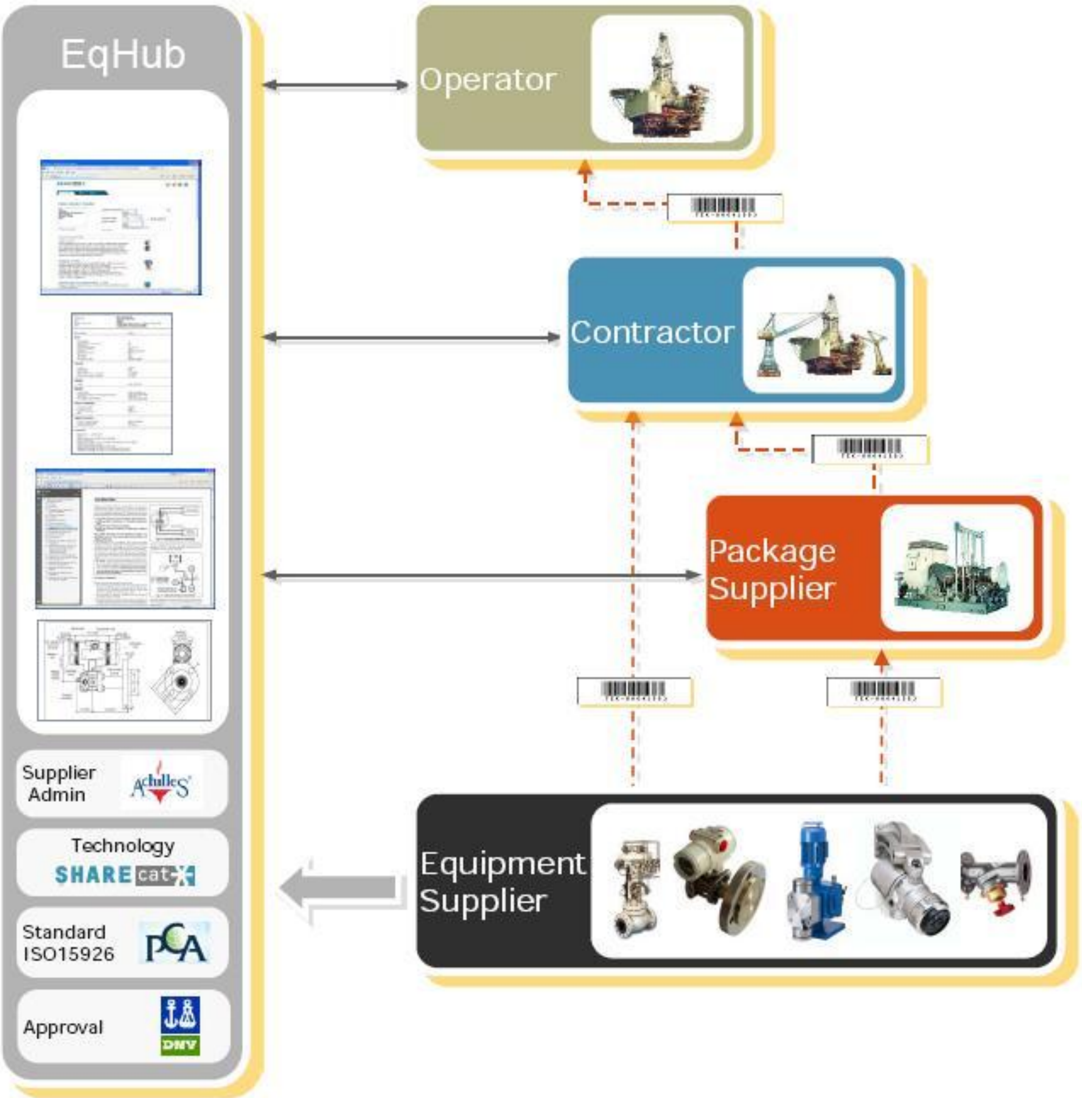

Fig. 12. Eqhub operational model

As shown in the figure, EqHub is working with all the members of the Oil and Gas supply chain to provide a single catalogue for different equipment, which is used in petroleum upstream. This is based on ISO 15926 and existing Sharecat database technology for oil and gas. When a new piece of equipment is presented by a supplier, it follows the process of being assigned a unique ID and being added to the database. The whole process of getting a new detail in the system looks like the following:

Fig. 13. Process of adding new equipment in EqHub

As technology owners claim in their promotional materials, using EqHub would help to address the following issues related to inadequate information from supply chain and associated procedures, which are costing the process industries billions of dollars a year [link27]:

- Plant startup delays
- Needless capital expenditure on inventory
- Procurement, operational and maintenance inefficiencies

- Unnecessary facility shutdowns and potential HSE issues

EPIM also underlines that by purchasing EqHub, the customer receives a flexible hand-over strategy to member IT systems. That is extremely significant for us, as EqHub can be incorporated in the WMS solution we are building. Also, the following benefits for equipment suppliers are promised:

- Common information/documentation requirement from the industry
- Information/documentation delivered “once and for all”
- Standardized delivery means reduced effort
- Improved sales efficiency
- Showcase for products and companies

The tool was launched in 2010 (the first set of product information was certified in January 2011) and since the launch it has received support from various players on the market, including the biggest ones like Total and BP. This trend is expected to continue, meaning that EqHub is likely to become an industry standard for the oil and gas sector. As such, investments made in EqHub would not be sunk costs for a firm which is working with industrial catalogues and looking to implement ISO 15926.

Chapter 5: Looking for a joint spare parts handling process

A great idea solves multiple problems at the same time -- *Shigeru Miyamoto*

5.1 Spare parts handling process

5.1.1 Warehouse business processes alignment

Let's consider spare parts logistics flow on example of one of the Operators routines. The following slide is taken from internal Statoil presentation and illustrates the whole cycle of logistics operations on a base from Operators' perspective.

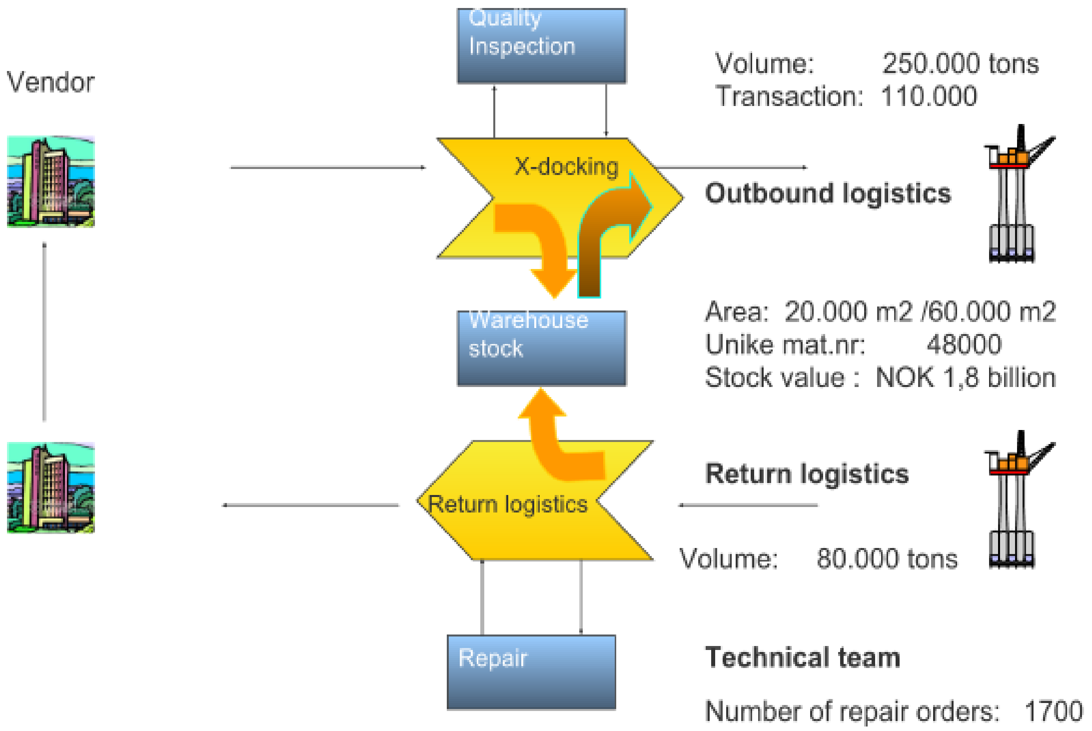

Fig. 14. Supply base logistics operations at Statoil.

In this paper we will focus on outbound logistics process. Return logistics routine in its core is very similar to outbound process, but it has an additional layer of strict regulations by government and customs policies, which requires special attention. Thus even though returns handling would also benefit from implementing of virtual warehousing and interoperability standards, this is a topic of a separate study.

For Operators it is a common practice to use cross-docking for non-specific equipment rather than to stock it in onshore base warehouses. However, there are more than 40000 SKUs of specific equipment which should be stored on site in order to insure normal daily operations and allow rapid maintenance in cases of emergency. These units vary in cost and lead time from producers and need to be inspected regularly. Introducing of interchange between Operators and common planning at least for this type of stock would allow decreasing necessary stock level, avoiding emergency situations when the required stock is not available for some reason and simplifying the inspection. Therefore this would lead to overall service level increase and presumably save costs.

In order to achieve that, introduction of some common standards in the supply chain would be very effective, but as beneficial as ISO 15926 and EqHub might appear in terms of master data, it is not enough to build an effective collaborative process. As such, when planning our IT system module, based on those principles and incorporating existing tools, we must ensure that seamless data flow and reliable interpretation can be maintained, even with systems that do not support ISO 15926. For warehouse purposes, this means we must provide processes and spare parts lists (material master data) alignment, and additionally introduce data mapping rules and interfaces for various systems involved. To do that, we need to work closely with operators' representative persons who are responsible for warehouse operations and have material master data in their ERP systems. To start with, the following questionnaire might be distributed:

How do various operators process spare parts replacement?

- How is the procurement process organized?
- Which suppliers do the spare parts come from?
- Are there any specific requirements for spare parts holding/delivery?
- What are the requirements for storage inspections and warehousing conditions and maintenance?
- What are the critical items? How many individual SKUs are stored at each warehouse? What level of service (and related safety stock) is expected?
- Is there any difference between spare parts (e.g. different manufacturers, or physical or chemical properties)? Could those parts be replaced or are those unique properties? Are there any legal issues?
- What is the information flow:
    - Who is responsible for ordering and other related decision-making?
    - What are the steps in procurement and goods receipt processes?
    - What form of reports and documents for controlling are needed?
- Additional operator-specific requirements and considerations.

Based on the answers and in close cooperation with process owners, the decision on aligning processes should be made by a project team and approved by involved operators.

In order to better understand possible flaws, information and material flow charts (and/or UML models) should be built and analyzed for each operator. This requires direct interaction with operators' warehouse managers and key users and therefore is not feasible in Master Thesis scope. However, we will consider a less-detailed flow model and show how it should be changed for our needs.

To begin with, let us consider how information and material flows in materials handling process at NSG warehouses currently look like in their most abstract form:

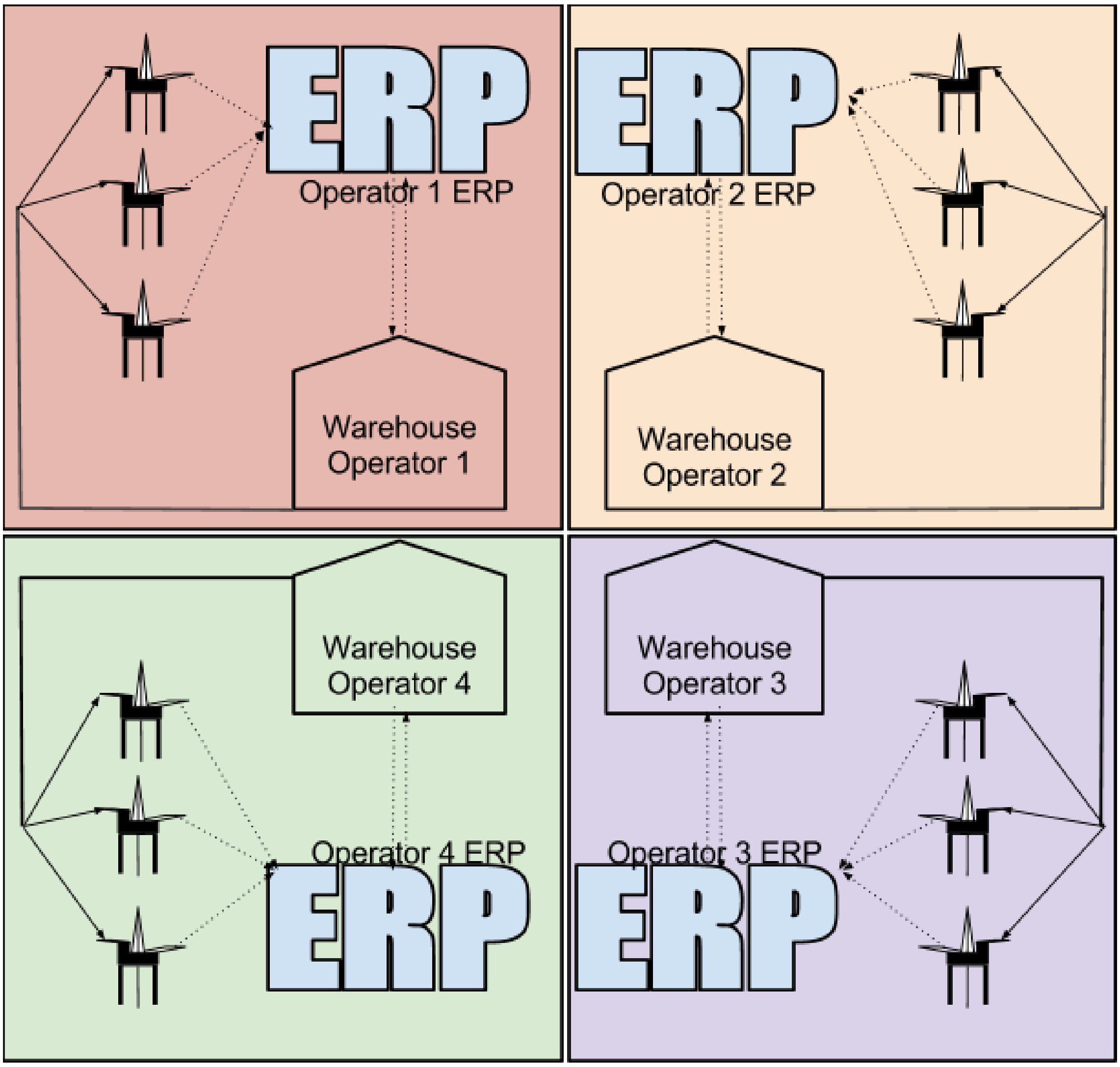

Fig. 15. Current Internal Flow.

Each Operator has its own "ecosystem" whereas NSG's role is only to provide warehouses to store spare parts, workforce to handle them and means to transport required components from onshore bases to oil rigs.
When a need for some specific material is realized at a rig, it is being communicated via Operator's ERP system to Operator's warehouse onshore, where picking and packing occurs so it could be included it in the next scheduled shipment to a rig.

External process at its core is organized in a similar way to internal. Each Operator work on its spare parts stock independently. Each have an established range of suppliers and ERP system is calculating and scheduling inbound delivery options.

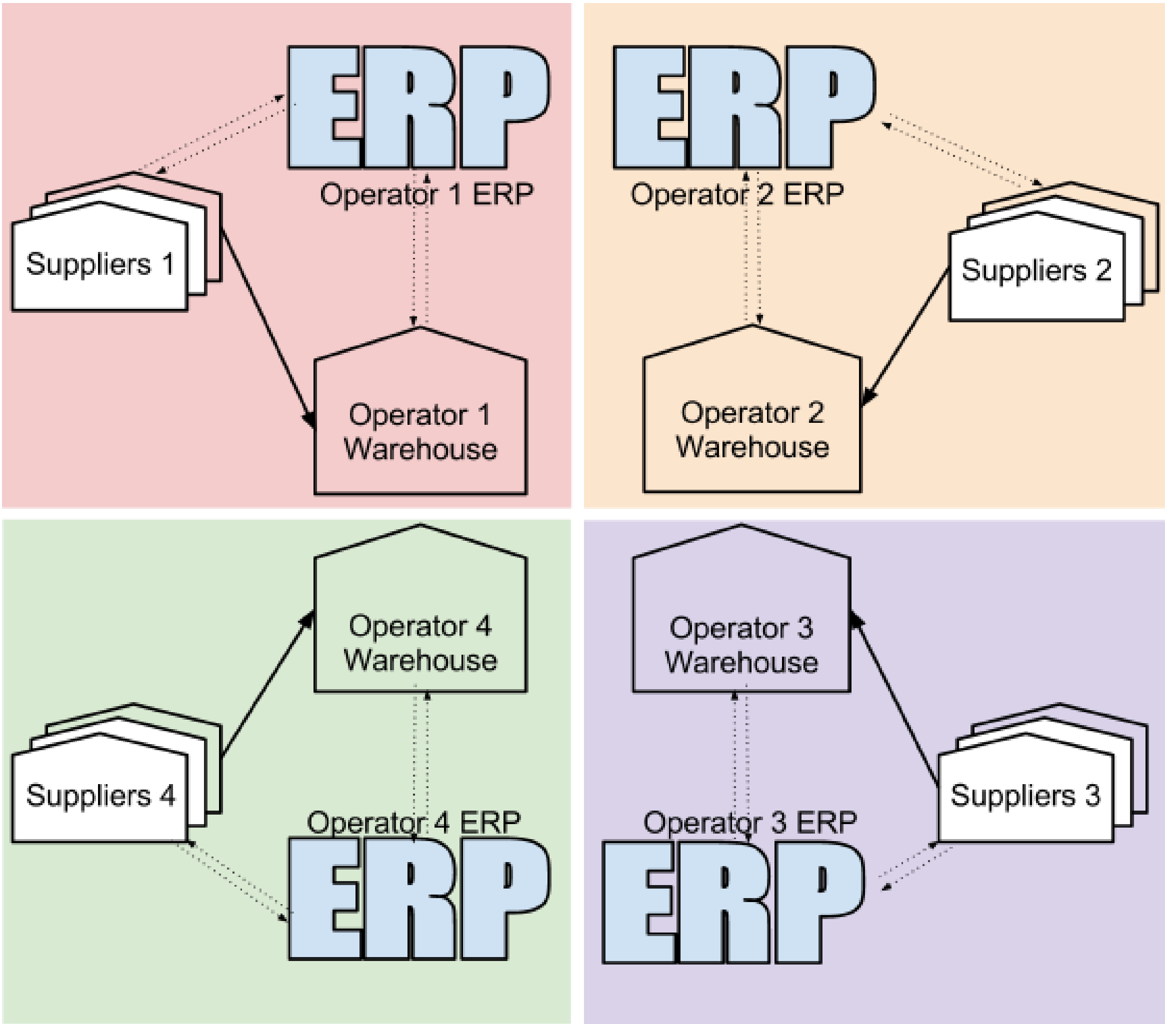

Fig. 16. Current External Flow.

As shown at the figures above, current approach to material handling does not allow material flow between warehouses and information flow between Operators' ERP systems. We consider this approach ineffective for several reasons:

- Various operators' warehouses are located on the same bases and many items stored in different buildings at one location are the same or very similar to each other. This means that if we consider each base as a whole, there are duplicated unnecessary stocks of items which are being kept in isolated warehouses. By introducing interoperability, thus expanding individual supply chains and merging them to some extent, that stocks could be virtually aggregated and used by all participants. This could save that 'expanded' supply chain money by reducing logistics costs and improving efficiency.
- In terms of information flow and procurement, ordering decisions are made independently, which leaves space for cost-saving by aligning lists of materials and suppliers and sending aggregated orders to common suppliers. This could also improve warehouse task planning, as aligned restock shipments would be provided in a more 'smooth', predictable manner.

- In terms of regular inspections, each operator needs to periodically conduct inspections. Having one merged warehouse system and a common inspection group among operators would mean that this procedure could be held much less frequently in the same period of time, yet retain the same quality.

5.2 Information flow

As pointed out earlier, the current schema, where each Operator deals with an ecosystem of its own and cannot exchange information and materials with other operators, who are served from the same base, can be improved by introducing collaboration. Here by collaboration we mean joint warehousing. This new approach would also require changes in different aspects, including (but not limited by) aligning warehouse processes and policies, organizing means of communication between participating Operators' IT systems and pooling materials for common usage.

A joint Supply Chain Management initiative implies that all actors in the chain, both upstream and downstream, must develop and accept a set of 'common rules' and this means implement changes for the benefit of the supply chain as a whole. In order to make these changes the least painful for Operators; we will consider several approaches and see which is the most suitable for our needs.

5.2.1 Intersystem communication

While there is almost nothing that could intervene with basic physical exchange of stored materials between different operators' warehouses, this material flow requires associated information flow for directing, accounting and controlling incoming and out coming items.

The problem with industrial data is that even when using the same ERP vendor, master data in different systems will be very different from one another, due to high level of customization such systems allow and different usage logic. So when one of operators is talking about some random item, say, SWY137534T, another operator would not have this in its database in the best case, or -- what is even worse -- there would be a completely different item under the same database entry. Of course, such inconsistency should be avoided at any cost. So in order to achieve stable information flow between Operators' IT systems we need to insure that they are 'talking the same language'. So this means that Master Data they use has to be either pooled and aligned or efficiently mapped in the real time. Also they should be mutually able to interpret each other's transactional data. Of course, there might be different possible solutions for that, including:

Ad-hoc communication.

As reflected in its name, ad hoc approach may be used when there is no need in constant communication between systems, but occasionally such connection is required. Ad hoc connection doesn't require much preliminary work in terms of data or business processes unification, in order to establish it. But, partly due to this fact, it's exceptionally resource-consuming and requires significant effort and involvement of various specialists from both sides. As such, It is also unreliable and prone to human error.

Another problem is that In case when more than two different participants are involved, amount of required work is increasing drastically. According to graph theory, there would be total

$$a = n*(n-1)/2$$

connections when there are **n** participants, so amount of connections **a** is increasing in a quadratic manner. And each particular connection requires manual or semi-manual data processing, such as comparison, analysis, verification and confirmation from both sides. In existing conditions **n** may vary up to a dozen, which potentially brings **a** to the order of hundreds, thus making each "lookup" a painful and expensive project.

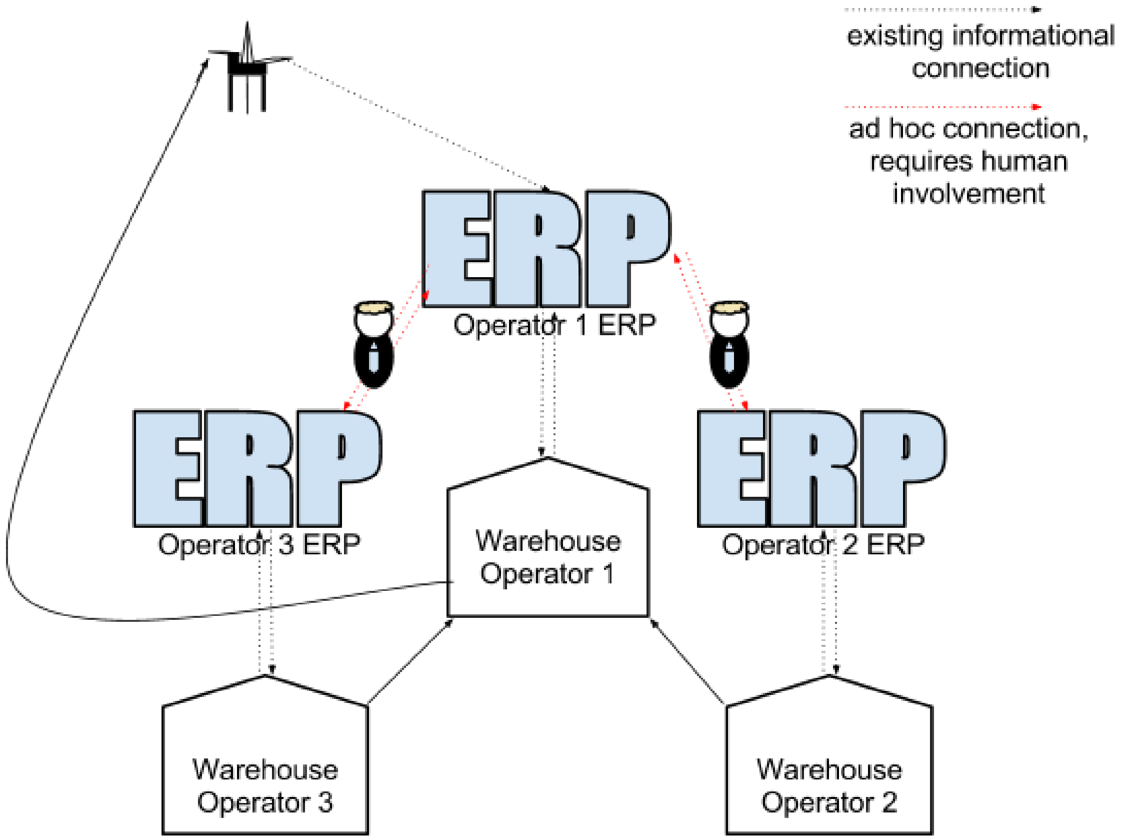

Fig. 17. Ad hoc information flow in case of three operators.

However, among benefits of such approach are its relatively fast rollout and absence of preliminary preparation phase. But due to its costly and unreliable nature, this approach can only be suggested in emergency cases requiring data and material exchange between Operators.

Common centralized system to handle warehouse-related transactions.

As a complete opposite to ad hoc connections, the most radical step towards collaboration for Operators would be to integrate their systems to a large extent, possibly even merging their warehousing modules into one centralized WMS (warehouse management system) module, entirely operated by one of the players. Other implementation of the same approach could include merging of master data in a common data warehouse and unification of warehouse business transactions so that external WMS system could be introduced instead of operators' warehouse management modules. In each case resulting WMS system would be closely connected to ERP systems of Operators and directly accepting data from Oil rigs and exchanging data with Operators ERP systems extensively.

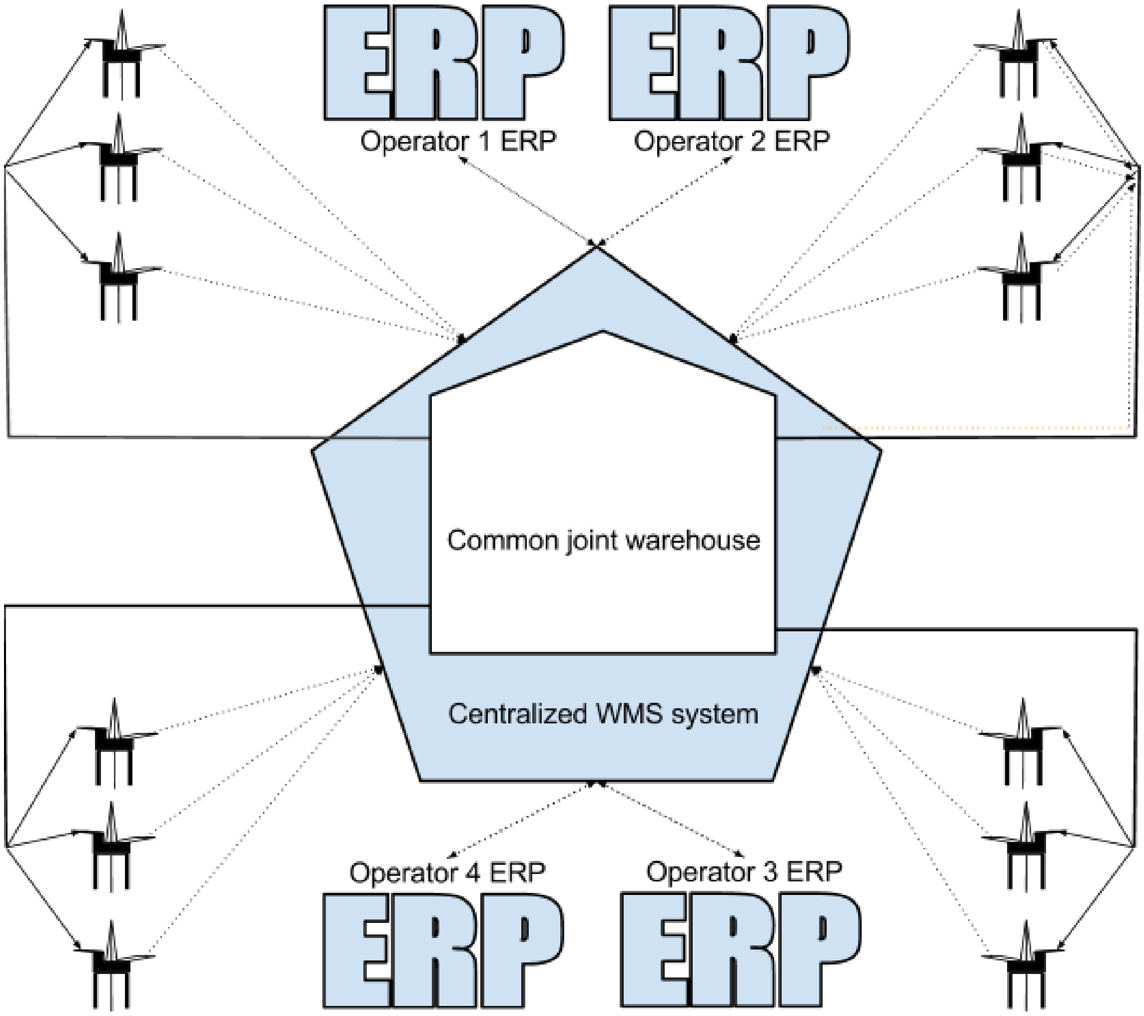

Fig. 18. Centralized warehousing.

There are several drawbacks related to this approach. First of all, as it was described earlier, Operators feel unsure and reluctant towards information integration at this point. Even if they agree upon terms and conditions of such a system merger, it would require tremendous amount of time and financial investments to aid the preparation work for migration and unification of material master data as well as business processes alignment.

The next issue that needs to be considered is that this approach does not allow the incremental step-by-step implementation, instead requiring participants to instantly dive into collaboration. This also means that there would be no sense to use trial-and-error process in pilot project with limited number of participants providing small amounts of data, because such implementation would not demonstrate the full potential.

Another significant problem is that this approach works best of all if amount of participants is fixed during the project lifecycle. In case there is a new company looking to join, it would require to run the project practically from scratch for that new player and additional effort for data merge, which implies significant entry costs. And what is worse -- if some of participants for some reason decide to cease collaborative practices and return to his legacy system and warehousing principles, this would be virtually almost impossible due to level of interdependability this approach implies.

ISO 15926-enabled approach. Virtual warehousing.

Being applied the right way; this approach could allow combining the best of two previously considered methods in one. It is scalable and does not require all players to adopt a new common data instantly. Instead, it uses ISO 15926 parts 4, 7 and 9 and mapping principles to ensure seamless information exchange.

There is no need for complex master data alignment process and direct system connections. Each participant in this schema is supposed to adopt a way to support ISO 15926 standard for intercommunication. However, this is much easier process than pooling master data between various Operators in previous approach, as it does not require any additional coordination between participants at this stage, only implementation of ISO 15926 recommendations.

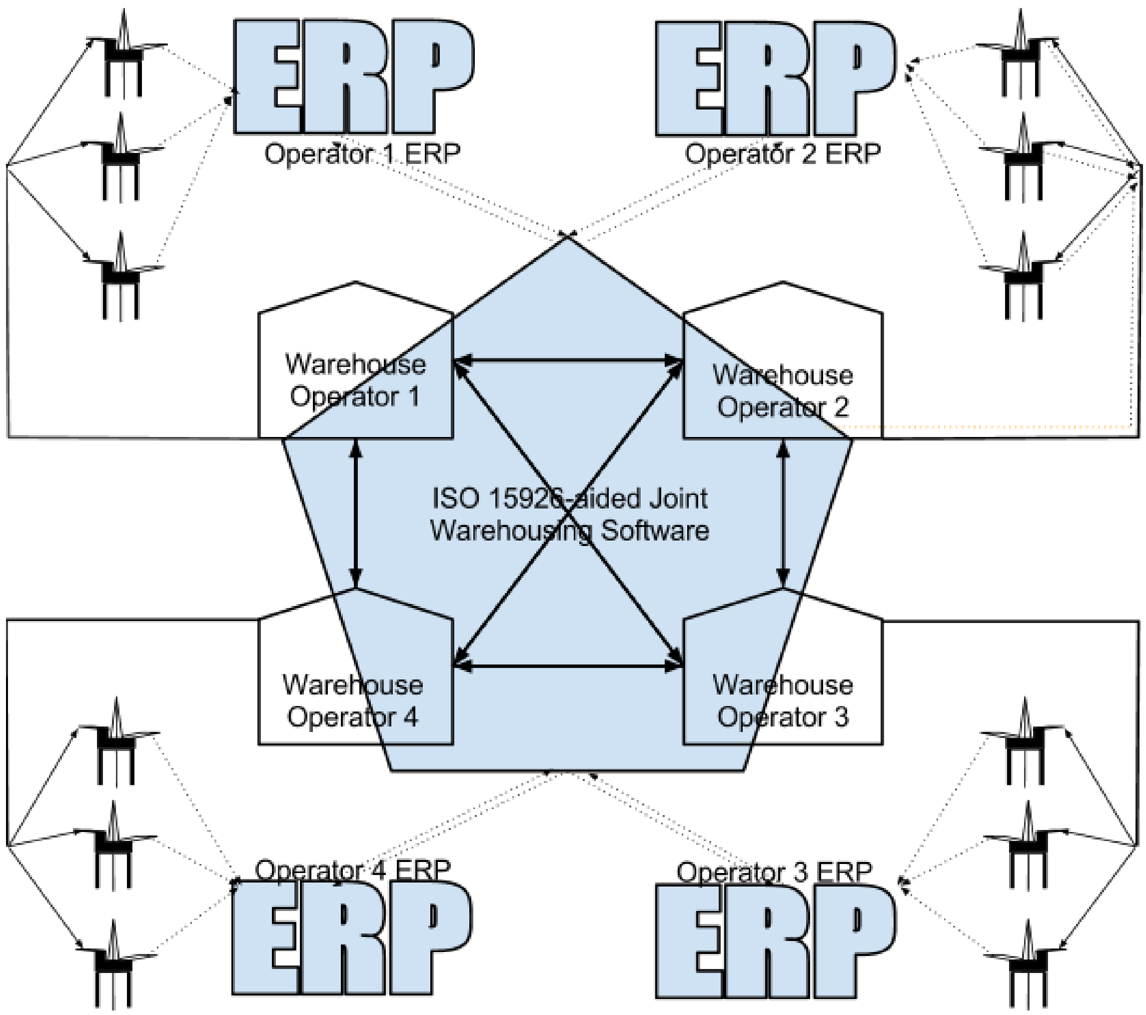

Fig. 19. Suggested Material and Information flow with ISO 15926-enabled software.

Another noticeable advantage of this approach is it can be rolled-out in a flexible incremental manner. This means that whenever any two operators are ready to participate from the legal side and technical pre-requisites are met to enable information exchange, they can already start implementation project and enjoy the benefits of joint warehousing.

Apart from step-by-step roll-out by participants' readiness, project can also be rolled-out "by base" (pilot project being run for a single base) or "by spare part" (pilot project enables joint approach only for some particular item groups, e.g. only most valuable and critical items). And of course, this pilot project can be evaluated to make a further decision on possible extension.

We are using the term "Virtual warehousing" for this approach as actual warehouses are still owned and operated each by its own Operator. However, there are contracts for material exchange in place and a special software module that allows for data exchange as an enabler for real time material identification and management. So a spare part may be shipped from any warehouse, making this approach similar to virtual warehousing concept.

5.2.2 Spare parts classification and material data lists alignment. RDF mapping

Each IT system uses its own classification approach for different entities. Author of this paper has more than five years of experience of participation in SAP implementation and support projects, and from this experience he knows that classifications and naming are so client-specific, that even two different implementations of SAP would have two different set of material numbers and hierarchies for the same entities. And when you use IT systems from different vendors those differences only get worse. This raises another important prerequisite for virtual warehousing. That is to build a common list of spare parts, identify gaps and duplicates and thus insure seamless spare parts data interpretation between participants proprietary systems.

There might be different approaches to classifications alignment. One of the most obvious straight approaches is to use direct mapping where project team would need to acquire complete lists of materials from participating operators systems and based on those, with help of engineers and key users from each side, build a common list, where all the differences would be considered and all specific requirements would be met. This approach requires significant investments of both time and funds. Any decision must be coordinated among all participants, which might be very difficult time consuming process, especially when there are many participants in the project.

The easiest way to provide the classification would be to acquire complete material lists from operators' ERP systems. Another possible solution would be to implement ISO 15926 directly (setup ISO 15926 - **Part 9 Façade**) or via external soft, such as EqHub. Entries for each Operator are set up and build the list based on these. Resulting database would be used for statistical data collection and analysis. It also could serve as a basis for purchasing orders aggregation. The following schema for classification is proposed:

- **Costs**
  - Logistical Costs
    - Procurement costs
    - SKU keeping costs
  - Price

- **Suppliers**
  - Are there long-term contracts with operators/NorSea?
  - Are there any other available suppliers for the same part?
  - If there are multiple suppliers available, is there a preferable supplier among those?

- **Level of importance**
  - Different levels of importance, depending on how vital the part is for rig operations.
  - Level of importance also reflects availability of the item from suppliers and if critical, the lead time.
  - Colour-coding may be considered.
  - Additionally ABC analysis could be applied.

- **Specifications**
  - Physical dimensions
  - Packaging
  - Functional specifications
  - Obligatories for Certification
  - Reusability
    - one-time use only
    - reusable
      - if yes, further analysis is required: *how to reuse* (procedure, terms and conditions)
  - Interchangeability
    - If parts are eligible for it, create corresponding links in database.
- **Parts Hierarchy**
  - Should the part be assembled?
    - if yes, specify BOM (Bill Of Materials); is there an alternative BOMs?
      - if yes, specify
  - Is a part unique or can it be replaced by some other part, i.e. other manufacturer or different node fitting in for the same purposes, possibly used by some other operator?
    - if yes, create links
  - Is it a part of another, more complex part which might (or should) be replaced as a whole?
    - if yes, specify BOMs
  - Level in hierarchy
    - subcomponents
    - part of a bigger component
    - stand-alone part
  - Graph approach for complete hierarchies, bundles may be moved as a whole graph or sub-graph to simplify tracking
  - Eligibility for tracking (no sense in RFID tracking for bolts and nuts, but Canban-like approach of ‘boxes’ may be used for small and cheap parts)
  - Quantitative characteristics
    - average demand per facility per month
    - standard deviation
    - etc.

5.2.3 Inventory ownership and buying decisions

After alignment processes are finalized, exclusions and specific requirements are understood and common approach and standards are negotiated, the question of inventory ownership rises. Indeed, if everyone is allowed to “borrow” required spare parts from the common pooled inventory, who will be actually paying for that stock?

The answer to this question most likely would be different for different product groups and could change over time, during project development. For instance, for the most common, standardized products which do not require any specific customization, a vendor-managed inventory approach (VMI, as described in Chapter 2), in which NorSea owns the inventory, seems reasonable. For more specific products, like unique parts required only on some particular platform, the situation may be different; such parts can be stored at and shipped from the same common warehouse, but owned by a corresponding operator.

We suppose that for pilot project, inventory ownership should be left as is, but with help of statistical data, gathered during the project, further ownership decisions could be made.

5.3. Software realization: warehouse item coordination

By implementing ISO 15926: directly, as a ‘translator’ module between internal data warehouse and external systems, or indirectly, as a part of the EqHub solution described in previous chapter, Operators insure that they can exchange information freely. But how could we integrate functionality required for internal item allocation, routing and data logging within NSG’s IT infrastructure?

5.3.1 Tag-hub integration

Of course, there could be variants. The system can be written from scratch or integrated in one of the existing IT tools. And the most relevant candidate tool for this integration is Tag-hub.

As described earlier, NorSea’s services for Operators include access to Smart Management’s AS tracking software, Tag-Hub, which allows real-time tracking automated for important items by means of RFID technology and 2D barcodes, EPCs (Electronic Product Code) and GPS (Global Positioning System).

Tag-hub already works with individual spare parts when it is required and provides interested authorized parties with real-time information on item location. Its role could be extended by introduction **virtual warehouse coordination** functionality by implementing an additional software module for it.

Let’s again have a look at the Fig. 5.5. With the help of Tag-hub, another significant advantage could be introduced in comparison to the current process. That is being able to get real-time information about materials location even during transportation. This means that there is no such thing as ‘pure’ material flow any more. Each arrow line at the picture represents information or material + information flow now. This also means that information exchange now is not limited to transactional data, but rather it is real-time data, which makes possible to improve decision-making process in critical situations.

Pilot project could have consciously limited scope with no organizational changes in physical warehouse structure, pooling and real-time tracking enabled for selected items only. But as Tag-hub is used for real-time tracking, at the same time it could be used for gathering statistics for other items to use it as an additional factor in items classification and decision making on further pilot project expansion..

Ideally, after items stocks are aligned and pooled and IT module is fully functional, all the participating operators would be served from one set of suppliers. Orders would be aggregated and collected to achieve ordering cost savings. Regional warehouses on a single base would be used to store pooled "common" items and which serve all the nearby rigs, to decrease stock-keeping costs.

In terms of material flow, all the individual operators' warehouses would be combined in one virtual "pooled" warehouse (per base) where each operator virtually has access to any spare part, unless it is already assigned to another operator. It is crucial that each operator has an ability to access NorSea's warehouse coordination system in real-time to check items' availability and order additional quantities in case of emergency.

5.3.2 RDF graph in classification mapping. Virtual warehousing system data model

Internal mapping with RDF graphs.

As it was mentioned in 5.2.2, each partner would have its own classification system for spare parts and the only way to ensure interoperability is implementing ISO 15926 part 9 or related software for all involved systems. On practice, not all spare parts would be available in EqHub, and Façades from different partners systems would require significant time to set up, or in some cases might not be available at all. Therefore an additional internal mapping would be required. We may start with with most common equipment which is already classified in EqHub and build a preliminary mapping system as a WIP-system (work in progress) in the following way, similar to how RDS is being build:

Whenever we deal with a new spare part coming from either partner's system, we create a URL with RDF record for it where the following information and related semantics is stored:

- Name and short description
- Partner's ID and Internal partners' classification information -- this would form a triple for identifying an item in a given partner's system
- Eqhub ID (if eligible)
- Triples for the same item in other partners' systems
- additional data depending on required functionality, such as Oil rig type, date of addition, responsible personnel,

This would require incremental approach to identify duplicate entries created from different partners inquiries, but as long as f we add various partners systems' classification information in a RDF entry and store it under unique URIs for each object, then we'll gradually build an explicit way to relate spare parts between various systems without need to map it directly between partners' systems.

Thus we will have a system-independent or neutral external ISO 15926 based representation that can be easily mapped with other external systems when such need arises.
Such mapping entries may be used in various notations. for example we have built a preliminary model for structured databases.

There are two most common ways of representation the data in databases: relational approach and XML. Let us consider both variants as both of them have their advantages and disadvantages. It is considered, that the most appropriate for system-to-system communications is relational database approach, which has a rigid structure and is easily interpret.

The following picture shows how spare parts can be described in relational database:

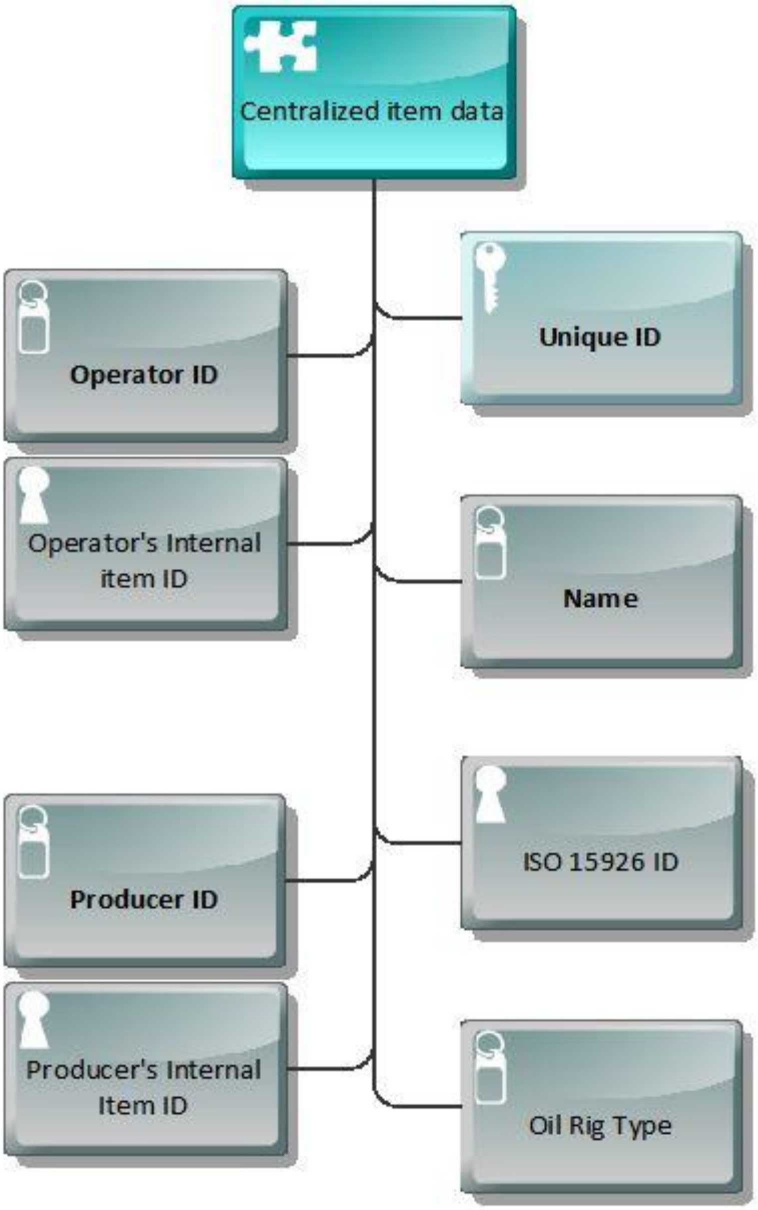

Fig. 20. Warehouse coordination system data entry model build for relational approach (built with ARIS Express 2.3 software).

This model is for reference only, it includes the following attributes:

Unique ID (primary key) -- global item identifier, this value explicitly points at this specific object. (Possibly merge with ISO 15926 ID?)
ISO 15926 ID (foreign key) -- a link to the item's entry in oil and gas ontology database or in EqHub (if the item is already described there)
Name (attribute) -- self-explanatory
Oil Rig Type (attribute) -- as there are different generations of Oil Rigs being served from onshore bases, and they could have specific spare parts properties, we need to distinguish spare parts by type of oil rig they belong to

Operator ID (attribute) -- shows the original owner of an object, i.e. specifies from whose system it was first extracted during the spare parts information alignment process.
Operator Internal item ID (foreign key) -- this information may be required in case of recurring activities involving this object in operator's (legacy) warehouse management software. In conjunction with Operator ID it can relate to operator's internal database.
Producer ID (attribute) -- an identifier specifying item's producer
Producer internal item ID (foreign key) -- this information may be required in case when producer does not support ISO 15926 standards. Using this in conjunction with Producer ID we can relate to internal producer's database.

XML, from the other hand is much more flexible and is widely used in modern data exchange. Semantic web approach and ISO 15926 are also based on XML data, so dropping it out would be a really shortsighted action. An XML model can be written in various ways, for example we will use what is called an XML schema, which is a way to introduce XML model in XML form:

```
<?xml version="1.0"?>
<xs:schema>

<xs:element name="Centralized item data">
 <xs:complexType>
          <xs:element name="Unique ID" type="xs:string"/>
          <xs:element name="ISO 15926 ID" type="xs:string"/>
          <xs:element name="Name" type="xs:string"/>
          <xs:element name="Oil Rig Type" type="xs:string"/>
          <xs:attribute name="Operator ID" type="xs:string"/>
          <xs:attribute name="Operator internal item ID" type="xs:string"/>
<xs:attribute name="Producer ID" type="xs:string"/>
          <xs:attribute name="Producer internal item ID" type="xs:string"/>
 </xs:complexType>
</xs:element>

</xs:schema>
```

It should be added that if Operators implement ISO 15926 Facades from their sides, it won't be necessary to build this database, as all information would be available via RDS.

5.4 Suggested Virtual Warehousing module IT requirements

As all parts will be stored together in a common warehouse operated by NorSea, and operators will still require access to it, the IT system should be able to provide full access with online tracking and live updates ensuring that no overlaps occur.

- *Data-centric architecture*

This means that the system is intended to work with structured data sets, where documents are generated based on those sets when needed for legal, audit, or controlling needs – not vice versa. This is applicable for systems designed mainly for automated information flow with high levels of collaboration.

- *Security for valuable business data*

This seems to be a straightforward requirement, but it is among the most critical. In order to build a long-term relationship within the supply chain, it is necessary to develop trust and ensure that no business data can be accessed without proper authorization. Another possibility to ensure sufficient security would be to adopt the 'Façade' approach described in ISO 15926 part 9.

- *Databases and data processing reliability*

It is necessary to ensure that product data is available when and where it is needed. The contemporary way to provide the necessary level of reliability and avoid data losses is to use cloud-based technologies for data warehousing with the possibility of switching to local replicas in emergency cases. Data streaming, which is another modern approach, could be considered for tracking purposes.

- *Interfaces for uploading/downloading data to various ERP systems*

Operators and other actors in the supply chain use various IT systems suitable for their needs, such as SAP R/3, Oracle and other ERP-class solutions. It is necessary to ensure that proper interfaces are set up to make dataflow seamless between NSG's WMS system and corresponding modules of partners' solutions.

- *Reliable mapping for existing data systems*

As it was already stated, we cannot ensure that all players in the supply chain use common standards and that all product data is available. This is why we must provide mapping techniques to support that obsolete data.

- *Limited transparency for clients' ERP systems and individual access through authorization system*

The WMS system should provide partners with various possibilities of operating with data. First of all, both operators' ERP systems and authorized individuals should be able to have full access for any business-needed data such as transactions, various queries, statuses, items' stock levels, and technical specification data for stored spare parts, etc. At the same time, flexible authorization rules should restrict access for each individual operator to another's business data.

- *Web-based user interface*

The problem with the classical approach to interfaces for business IT systems is that they are platform-dependent; a version must be developed for each software platform to be used by involved parties, be it Windows, MacOS or some Linux variant. This adds to program development and support costs and requires additional coordination. Another problem with such an approach concerns giving access to a rapidly growing park of mobile devices, like a manager's iPad or forklift-driver's mobile phone. More development effort would be required. Yet, it is possible to avoid these platform-related problems by using a 'thin client' approach. On par with the cloud-based approach mentioned previously, this would involve *web-based* developed interfaces using open standards with low system requirements and the maximum level of support from Internet browser developers.

- *User interface customization*

Different users need different system aspects for their job, so to help them to get to business faster, it is a good idea to offer users the possibility of grouping the functions and transactions they need in one place. In order to help the newcomers, some basic common functions should be made available as presets for various user groups.

- *System based on open expandable IT standards for possible future amendments*

Since the time when IT was accepted as a useful tool for business needs, technology has been rapidly developing. What was cutting-edge 20 years ago is now obsolete. So when planning a new system, this tremendous rate of IT development should be taken into consideration. Basing the WMS system on appendable and expandable open standards we make sure that when new technology appears, the existing system can be adjusted rather than re-engineered.

- *Individual processes that are clearly set and transparent for management and operators, so that problems could be easily identified and addressed as soon as they appear.*

Before moving on to the actual implementation of some process functionality in the WMS system, it should be made absolutely clear on the drawing desk what must be done, who is responsible for what, and what is the exact sequence with possible alternative routes. Otherwise, we will have a case of 'automated mess' which is even more clumsy and inefficient than the original man-powered mess.

- *Ability to generate forms for hard copies of required documents*

It is clear that a centralized IT system will digitize and computerize paperwork to the fullest extent, especially when it comes to internal document flow. This will make document flow much faster and will eliminate hard copies. Secured communication protocols and digital signatures can ensure security and reliability. However, for external communication and audit reasons some specific documents are required in hard-copy with necessary signatures. Such documents should be generated and printed at the appropriate time during various processes' execution.

- *Product data warehouse based on ISO 15926*

This was explained in detail previously, when considering the ISO 15926 standard. As a platform, EqHub could be implemented.

- *Ability to look for possible replacements in emergency cases*

Combining an ISO 15926-based data warehouse with an effective tracking system provides us with the unique ability to look for similar interchangeable replacement parts on other bases in real-time.

- *Ability to store and process large amount of statistical data*

One of the most useful capabilities of modern IT systems is to store and analyze high volumes of statistical data. Those features are often underestimated, but provide a powerful tool for forecasting and business improvement. For a statistical module it is a good idea to be able to provide breakdowns at various levels for monitoring the most critical nodes, re-thinking various suppliers' contracts, and improving processes.

- *Process and logic scalability and flexibility*

Depending on various possible supply chain and warehouse configurations, as well as the contract and legal environment, the system should be able to handle isolated central warehouses and region-wide chains.

- *Internal and external processes and materials tracking*

Tracking is one of the most crucial parts in modern systems which work with materials distribution. We'll provide more information on this topic in the next section.

- *Event notifications (alerts) to allow fast response and proactive decision making*

The system should be able to track business processes as they happen, and send notifications to the people responsible in the event of critical deviations or exclusions from the normal process flow. This will enable a 'manage by exception' approach, empowering process owners to act upon exceptions and thus helping to avoid or mitigate serious consequences following unforeseen difficulties. Furthermore, valuable information on external events (issues with supplier's capacities, supply channel unavailability, etc.) could also be added into the picture to aid decision making. The usage of alerts and event notifications should be well weighted and enhanced with an analytical module, in order to avoid unnecessary turmoil in case of insignificant or easily managed process deviations.

Lean-oriented IT system:

It should be mentioned that what we have suggested could help to build a system which could be partially described as a 'lean-oriented' IT system. The idea of leanness in logistics is the elimination of waste, meaning some unnecessary spent resource in some process. In terms of IT the concept of waste can be considered as duplication of data, excessive data, poor data organization, or even the necessity for manual input where it can be done automatically. All these issues can be addressed during the planning stages in the following way:

Duplicating data can be eliminated or significantly diminished by introducing one common repository for data and using common standards. In our case those are ISO 15926 and EqHub (as well as reliable data mapping for obsolete systems) which will help to eliminate this sort of waste.

Excessive data can appear in the form of wrong data selection or data that is too exhaustive for the task at hand. For example, high-level managers and operators do not need data on forklift personnel assignments for the current week. This problem can be addressed by introducing various customizable groups of users and setting clear rules for data view and maintenance for each of those.

Poor data organization is partially covered by the two above-mentioned issues, but also adds its own technical aspect by way of inappropriate or non-optimized tools and algorithms used for accessing multiple databases. This can cause a situation in which there is a 'data rich but information poor system' -- a system which cannot function sufficiently to provide information when it is needed.

By introducing data mapping, ERP systems interfaces, and a powerful tracking module, we avoid the problem of unwanted additional manual data re-keying.

5.4.1 Tracking

One of the most crucial features for rapid-response efficient warehouse management is items and events tracking. Tracking allows authorized users to monitor various processes as they happen in real-time, which helps to plan more efficiently and react faster in emergency cases.
There are various approaches for tracking in terms of physical means, but the basic idea is the same: we have some sort of IDs on which to store information, and a means of reading and writing information to it in an automatic or semiautomatic way. This also requires an established infrastructure so that data can be read continuously or in event-based conditions.

Currently NorSea is in the process of implementing ‘TAG-HUB, a modern system created specifically for the needs of the oil and gas sector supply chain, developed and supported by Norway-based Smart Management AS. As it is stated on their website: “…*by connecting systems and automating inspection routines, the TAG-HUB represents progress and cost efficiency.”* NorSea already benefits from this collaboration with their critical assets tracking project, so Smart Management (partly owned by NorSea) is already involved in NSG’s internal operations and is aware of their needs. We suggest deepening the collaboration and adopting TAG-HUB as a basis for NSG’s system tracking module.

Let us consider some specific tracking module needs that would be required for successful system operation of virtual warehousing module:

- *Technical possibility of using various modern means for tracking and flexibility in future changes*

The technical progress is ever-lasting and new tracking technologies are constantly introduced. Just like with virtual warehousing module itself, the tracking module should support the latest applicable technology (both in terms of software and hardware where it is economically reasonable), but also be easily expandable for possible innovation.

- *Distinguish between in-house tracking and outbound tracking with easy way to switch from the first to the latter when items leave the warehouse*

Since NSG is providing services for off-shore operations, final shipping is handled via vessels in the open sea. Therefore, we should distinguish internal warehouse tracking and external shipping tracking, but have a set of means to virtually connect one to another so that no data or material could be lost. This can be solved by various means, e.g. using mixed video/optical tracking with QR-codes (2D barcodes) and passive RFID chips for in-house needs, and applying expansive long-range active RFID labels only for outbound containers.

- *Restricted access to tracking*

If necessary, viewing access should be restricted to allowed parties; some partners may refuse complete warehouse information sharing. For this reason, items might become ‘invisible’ for all the other clients after being assigned to one of the operators.

- *Clear rules for items assignment tracking, easy way determine if an item is already assigned*

In order to avoid misunderstandings and confusion, items could be checked by floor personnel before any action. This may be implemented in the form of easy-to-assign database fields or a set of fields (also in an ID tag) identifying when some material is assigned to a specific operator/rig. That way, no other assignment could occur unless the initial assignment is lifted. This also allows a particular operator to track its items directly.

- *Consider a **RDF graph-oriented** approach for storing bundle information and other relationships between materials*

For more cost-efficient tracking of outbound item bundles, we suggest using a graph-based approach for items assigned for shipment to a facility. In other words, all items assigned for delivery to a rig would be considered a bundle and would be represented by a connected RDF “cargo” graph, similarly to the one we are using for storing classifications (see 5.2.2, however, we don’t need to store these graphs under constant URLs). Thus, we can simplify the tracking process by putting a tag on a single main item (or a container), while the other items are virtually considered to be connected to it. We must ensure, though, that all items are actually loaded and none lost along the way. This might be achieved by automated or semi-automated addition of loaded items in cargo graph only when they are actually loaded in a container with help of RFID and QR-code scanners.

Chapter 6: Conclusion

Currently, when it comes to onshore supply bases, NorSea Group only lends buildings and workforce to its clients -- Operators. Thus each Operator has its own established infrastructure both in physical and IT senses, and there is almost no data or material exchange between those. However, when the stock itself is considered, this means that different Operators store the same or similar interchangeable equipment in different warehouses which in some cases are even located in close vicinity at one supply base. These facts leave room for potential savings. The purpose of this paper was to elaborate an approach to reorganize warehousing operations at onshore supply bases in a way that would allow decreasing amount of funds tied up in expensive specific equipment.

This aim might be achieved by allowing spare parts exchange between Operators. The proposed solution describes an expansion to existing IT infrastructure in a form of additional “Virtual Warehousing” module. It would include technical means to support spare parts exchange process between Operators and thus improve overall service level.

The suggested approach is taking existing collaborative frameworks as a basis and focuses on ISO 15926 standard for interoperability. It also considers key technical prerequisites and suggests possible implementation decisions based on modern IT trends and existing ISO 15926-enabled software products. Using this basis and adding it to existing IT infrastructure, project teams can ensure that the necessary level of transparency would be achieved and any customer security and data protection requirements would be met without compromising functionality.

It is expected that when a “Virtual Warehousing” module is up and fully functional, it would serve to improve efficiency and service quality and provide more visibility of various steps during order fulfillment process. As an example, in cases of emergency, this would allow to identify possible replacements and their current location in real time.

Simultaneously, this approach is aimed to serve as a stepping stone in improvement of overall collaboration level in upstream Oil and Gas supply chain. ISO 15926 has been explicitly approved by OLF (Norwegian Oil Industry Association) as a standard for data integration at Norwegian Continental Shelf. Thus implementing ISO 15926 interfaces and data standards becomes a significant IT enabler for various parties interested in further supply chain interoperation and collaboration activities in Oil and Gas industry.

References

Books, publications and whitepapers:

1. Jan Hagland: The Norwegian Oil and Gas Adventure
2. Christopher M. Chima: “Supply-Chain Management Issues In The Oil And Gas Industry”, Journal of Business & Economics Research, volume 5, Number 6
3. John K. M.: “Trends in Upstream Oil and Gas Supply Chain Management”, Petroleum Africa, March 2007
4. Eric Anderson: “Supply Chain Strategy in the Oil and Gas Sector”, Exploration & Production: The Oil & Gas Review - 2003
5. Paul A. Bartlett, Denyse M. Julien, Tim S. Baines, (2007) "Improving supply chain performance through improved visibility", International Journal of Logistics Management, The, Vol. 18 Iss: 2, pp.294 - 313
6. Lamming, R. C., Caldwell, N. D., Harrison, D. A. and Phillips, W. (2001), Transparency in Supply Relationships: Concept and Practice. Journal of Supply Chain Management, 37: 4–10.
7. Bradley S. Fordham “Sharing Secrets: Online Insight’s Golden Nugget Breakthrough for Relationship Management”
8. Larry Lapide, “A History of CPFR”, Journal of Business Forecasting (Winter 2010-2011)
9. Ron Burnette, “CPFR: Fact, Fiction, or Fantasy?”, Journal of Business Forecasting (Winter 2010-2011)
10. Peter D. Franke “Vendor-managed Inventory for High Value Parts”
11. Stuart Emmett “Excellence in Warehouse Management”
12. Michael ten Hompel, Thorsten Schmidt “Warehouse Management”
13. Gord Rachar’s "An Introduction to ISO 15926"
14. Peter J. Metz, Demystifying Supply Chain Management, Supply Chain Management Review, Winter,1998

Internet Links:

link1 http://www.iooa.ie/securing-the-future-page41390.html
link2 http://www.eia.gov/countries/cab.cfm?fips=NO
link3 http://www.norseagroup.com/home.aspx
link4
http://www.panalpina.com/content/dam/internet/industry_verticals/downloads/english/oil_gas.pdf
link5 http://fm.sap.com/pdf/bf05ho/8_McBroom_Extended_OG_Supply_Chain%20.pdf
link6 http://www.idii.com/wp/7ImmutableLaws.pdf
link7 http://download.microsoft.com/download/7/c/7/7c71dd3b-454e-4311-9dcf-29b032edf240/Cactus_GDS_Executive_Overview.pdf
link8 http://www.vics.org/docs/standards/CPFR_Overview_US-A4.pdf
link9 http://www.vics.org/committees/cpfr/
link10 http://fiatech.org/images/stories/techprojects/project_deliverables/iso-intro-ver1.pdf
link11 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=29556
link12 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=29557
link13 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=42875
link14 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=41329
link15 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52455
link16 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52456
link17 https://www.posccaesar.org/wiki/ISO15926
link18
http://communities.bentley.com/communities/other_communities/iso_15926/w/wiki/default.aspx
link19 http://www.w3.org/TR/rdf-mt/
link20 http://iringtoday.com/about-jord/

link21 http://iringug.org/wiki/index.php?title=IRINGTools
link22 http://fiatech.org/index.php?option=com_content&view=article&id=1115:proteus-project&catid=196:project-deliverables-information-management
link23 http://www.gellish.net/topics/gellishlanguage.html
link24 http://www.european-pedc.eu/Presentations/van%20Ruijven%20%20Leo.pdf
link25 https://www.posccaesar.org/wiki/IOHN
link26 http://www.plcs-resources.org/papers/s1000d/day3/Integrated%20Operations%20on%20the%20Norwegian%20Continental%20Shelf%20-%20Dr.%20Thore%20Langeland.pdf
link27 http://www.pidx.org/meetings/may2011/11%20-%20Pettersen%20-%20EqHub%20pidx%20conference%20may%202011.pdf
link28 http://science.howstuffworks.com/environmental/energy/offshore-drilling8.htm
link29 http://www.ibm.com/smarterplanet/global/files/us__en_us__oil__che03002usen.pdf
link30 http://fire.nist.gov/bfrlpubs/build04/PDF/b04022.pdf
link31 http://myweb.polyu.edu.hk/~lgtpwong/TOT/TOT-Tanzania/Warehouse/Reference%20reading%20-%20vitual%20warehouse.pdf
link32 http://www.idii.com/wp/jvd-virtual-warehousing.pdf
link33 http://www.univ-lehavre.fr/actu/itlcsge/fung.pdf