University of Stavanger

Faculty of Science and Technology,
Department of Mechanical and Structural Engineering and Materials Science

MASTER'S THESIS

Study program/ Specialization: Offshore Technology, Industrial Asset Management	Spring semester, 2015 Open / ~~Restricted~~ access
Writer: Juha K. Palola	(Writer's signature)
Faculty supervisor: Prof. Jayantha P. Liyanage External supervisor(s): -	
Thesis title: **Human Performance Improvement in Offshore Specialized Shipping** - **the operators perspective**	
Credits (ECTS): 30	
Key words: Dynamic Positioning Human Factors Reliability Engineering Resilience Engineering Risk Management System Safety	Pages: 99 + enclosure: 44 Stavanger, 15th of June, 2015.

Abstract

Offshore Specialized Vessels have various important functions to serve for the upstream Oil & Gas industry. These vessels are subjected to critical operations and are equipped with specific applications such as Dynamic Positioning System. Despite the availability of decision support mechanisms, rules, regulations, and procedures, the risk of having an accident still remains high due to dynamic operating conditions. In this context, the human is still considered to be one of the main contributors to accidents and incidents. This has direct implications on the exploration and production activities, and the high-risk conditions under which the business activities are managed.

Offshore specialized vessels are complex socio-technical systems, which have high potential to contribute to incidents leading to a major accident. Modern safety science and reliability engineering view serious accidents as a combination of several factors, ranging from organizational issues to individual human performance.

In addition to so-called action failures, the complexity of marine operations may trigger unexpected combinations of individually normal actions, resulting in variance in the system´s total performance. Resilience engineering recognized that the systems are adaptable and they tolerate variance but the variance can start resonating resulting unbearable loads towards the system. Human is the key component and more importantly it is not bimodal as the reliability analysis of technical systems tend to suggest. Performance variability is natural in socio-technical systems, and a valuable part of normal performance.

The research aimed to find factors and improvement potential in the process that enable humans to cope with the complexity and uncertainty of work. The thesis aims at identifying dominant risk influence factors with major potential to lead unwanted incidents towards major accidental risk. A detailed questionnaire was circulated among vessel operators in Norway. Data were gathered involving selected industry professional representing the highest expertise related to onboard offshore specialized vessels engaged in various operations offshore i.e. from drilling to anchor handling. The results indicated many attributes of human performance as the most powerful barrier against accidents. The research suggests principal solutions for identified challenges. Applying these solutions can create customer value and gaining competitive advantage by improving the operational safety and reliability of the total system by means of human performance improvement. Gaining a competitive advantage is crucial for Offshore Specialized Vessel owners due to the fact that cash flow, the lifeblood of the companies, is generated by providing high quality services by means of vessels or units with marine crews.

Table of Contents

Abstract 2

List of Figures 6

Abbreviations 7

Basic Definitions 8

1. Introduction 9

1.1 Background 9

1.2 Problem definition 10

1.3 Research Questions and Objectives 11

1.4 Data Collection 11

1.5 Limitations 11

2. Background 13

2.1 Introduction to Offshore Specialized Shipping 13

2.2 Vessel Types 14

2.3 Introduction to Dynamic Positioning 17

2.3.1 Control System and Work Station 19

2.3.2 Position Reference System (PRS) 19

2.3.3 Propulsion System 21

2.3.4 Power Generation and Management 21

2.3.5 Heading Reference 21

2.3.6 Environment Reference System 22

2.3.7 DP Class and Redundancy 22

2.4 Safety Management in Shipping 23

3. Theory and Method 25

3.1 Ages of Safety 25

3.2 Understanding of Accident Causation 26

3.3 Resilience Engineering 27

3.4 Basic Modelling Concepts 29

3.4.1 System Status 29

3.4.2 Accident Modes on Dynamic Positioning 30

3.4.3 Risk and Safety 31

3.4.4 Reliability and Redundancy 32

3.4.5 Probability 35

3.4.6 Active Error vs. Latent Error 36

3.4.7 Safety Barriers ... 36
3.4.8 Bowtie model ... 37
4. Human, Technology & Organization Components ... 39
4.1.1 Types of Human Behaviour ... 40
4.1.2 Types of Human Failure ... 42
4.1.3 Information Processing ... 43
4.1.4 Situation Awareness ... 45
4.2 Technology Component ... 46
4.2.1 Complex and Linear Systems ... 46
4.2.2 Tight and Loose System ... 48
4.3 Organization ... 49
4.3.1 High Reliability Organization and Interactive Complexity ... 49
4.3.2 Relation between Organizational Culture and Safety ... 51
5. Results and Analysis ... 55
5.1 Technology Component ... 56
5.1.1 Hardware Evaluation ... 56
5.1.2 Alarm system ... 57
5.1.3 Work System Design ... 59
5.1.4 System Knowledge ... 62
5.1.5 Bridge and Work Station Ergonomics ... 62
5.2 Human Component ... 63
5.2.1 Human Behavioural Safety ... 64
5.2.2 Safety Culture ... 67
5.2.3 Work Demands ... 69
5.2.4 Fatigue ... 71
5.2.5 Bridge Team ... 73
5.3 Organizational Component ... 75
5.3.1 Reporting ... 75
5.3.2 Training ... 77
5.3.3 Management Commitment for the improvement ... 79
5.3.4 Procedures ... 80
5.3.5 Bridge Team ... 84
6. Conclusions ... 86
6.1 Limitations ... 89

6.2 Recommendations for further research 90
References 92
APPENDIX 1 – Background Information 101
APPENDIX 2 – Questionnaire 105
APPENDIX 3 – DATA 126

List of Figures

1 Forces and motions (source: Kongsberg) 18
2 DP Operations Pyramid proposed by Verhoeven, Chen & Moan (2004) 19
3 Progression of Safety Sciences through eras of Safety by Reiman & Oedewald (2009) 26
4 Domino Theory by Heinrich (1931) 27
5 Swiss Cheese model by Reason (1997) 27
6 Functional Resonance model by Hollnagel (2006) 28
7 Jenga Game 28
8 Resilience Triangle by Furuta (2015) 29
9 Series Structure 33
10 Parallel Structure 33
11 K-out-of-N structure 33
12 Reliability Block Diagram DP 2 34
13 Bowtie Concept by Mullai & Paulsson (2011) 37
14 Human Control Loop by Wong (2002) 39
15 SRK-based behaviour by Rasmussen (1981) 40
16 Relation between Attention and Familiarity (DOE, 2012) 40
17 Generic Error Modelling System (GEMS) by Reason (1990) 42
18 Human Information Processing model by Wickens (1992) 44
19 Interaction/Coupling Chart by Perrow (1999) 48
20 The HSE Culture Ladder by Hudson (2007) 53

Abbreviations

AHTS	Anchor Handling Tug Supply
AUX	Auxiliary Engine
CSV	Construction Support Vessels
DP	Dynamic Positioning System
DPO	Dynamic Positioning Operator
DSV	Diving Support Vessel
ECR	Engine Control Room
EMS	Electrician/Electronic Maintenance Staff
GEN	Generator
GEMS	Generic Error Modelling System
GMDSS	Global Maritime Distress and Safety System
GUI	Graphical User Interface
HF	Human Factors
HMI	Human Machine Interface
HRO	High Reliability Organizations
IMO	International Maritime Organization
IMR	Inspection, Maintenance and Repair Vessels
ISM	International Safety Management Code
O&G	Upstream Oil & Gas Industry
OCV	Offshore Construction Vessel
OSV	Offshore Specialized Vessel
OIM	Offshore Installation Manager
ME	Main Engine
MODU	Mobile Offshore Drilling Unit
MPSV	Multipurpose Support Vessel
MSC	Maritime Safety Committee
MRU	Motion Reference Unit
NCS	Norwegian Continental Shelf
NMD	Norwegian Maritime Directorate
PLT	Platform
PMS	Power Management System
PSA	Petroleum Safety Authorities Norway
PSV	Platform Supply Vessel
RIF	Risk Influencing Factor
SA	Situational Awareness
SMS	Safety Management System
SRK	Skill-, Rule-, Knowledge based behavior
ST	Shuttle Tanker
STS	Socio-technical system
STSS	Short-Term Sensory Store
STWC	Standards of Training, Certification and Watchkeeping for Seafarers
TQMS	Total Quality Management System
UKCS	United Kingdom Continental Shelf
UPS	Uninterruptible Power Supply
VDU	Visual Display Unit
WIR	Well Intervention Vessels
WSV	Well Stimulation Vessels

Basic Definitions

Ergonomics refers to Greek words ergon (work) and nomos (law). Ergonomics has particular emphasis on designing the work systems user-friendly, both displays and controls. The evaluation of human physical dimensions (anthropometry) and human capacity with respect to sensing and control ability. According to Bridger (1995) the fundamental function of ergonomics is to "ensure that human needs for safe and efficient working are met in the design of work systems". Similar definition is proposed by SINTEF's (2011) "discipline that aims to create a working environment and the tools in them for maximum work efficiency and maximum worker health and safety"

Human Factors (HF) assesses the work system and setup in light of psychological factors the relation between requirements and capacity of the human component. SINTEF's (2011) defines Human Factors as "a scientific discipline that applies systematic methods and knowledge about people to evaluate and improve the interaction between individuals, technology and organisations". The goal is to create working environments that contributes positively to achieving healthy, effective and safe operations.

Dynamic Positioning (DP) System is an application for position keeping by help of active propulsion generation for any mobile unit afloat. Used mainly by the upstream Oil & Gas industry in remote offshore locations to provide stable working platform for any marine operation without the need of having anchors, mooring, or fixed structure from the seabed to surface.

High Reliability Organization (HRO) is a paradigm developed by Roberts et al. (1987) where the research group analyzed the safety management of highly complex systems, for example aircraft carrier where the socio-technical system has adapted to safe operations nevertheless the "organized chaos". The HRO theory draws attention to the analysis of organizations which are engaged in production or services that require extraordinary attention to avoiding incidents and accidents i.e. the tolerance for failure is low. Macondo Prospect (MC252) blowout and the explosion, and sinking of drilling rig "Deepwater Horizon" is good but unfortunate example of accident that not only merely lead to the destruction of BP, but caused an environmental catastrophe to the society at large. A HRO is an organization that has succeeded in avoiding accidents in an environment where accidents are to be expected due to the complexity and risk associated with the daily tasks and processes. High Reliability is the leading principle instead of high effectiveness and performance.

Socio-technical system (STS). By definition a socio-technical system comprises of hardware, software, and liveware (user). Hendricks (2002) states that "work systems are purposeful, goal-directed systems which produce a clearly identifiable output for a previously defined purpose". One view, expressed by Bridger (1995) draws attention to the fact that the two main components: Human (H) and Machine (M) (or technology) are embedded in local environment which influences the system. The DP system is a 'hybrid system' which in terms of system design domain is placed between fully automated system and manually operated one i.e. varying levels of automation and man-machine interactions on the dynamic (constantly varying conditions and requirements) operational framework.

Complexity is the interconnectivity and interactivity between system components i.e. their relationships resulting a massive number of possible interactions (Dekker S. , 2011); (Perrow, 1999).

Coupling is the slack, or buffer, or give between items i.e. what happens in one has an effect on what happens in the other. Loosely coupled systems have more time i.e. slack between them, while tightly coupled system have immediate cause and effect (little or slack) (Perrow, 1999).

Accident is an unwanted or undesirable outcome of unexpected events or occurrences that may cause loss of life, damage to health, environment or asset (Vinnem J.-E. , 2014a). In systems theory, accident is a failure on level three (subsystem), or four (total work system), hence disrupts the ongoing or future output of the system (Perrow, 1999).

Incident is an unwanted or undesirable event which under slightly different circumstances could have resulted an accident. In systems theory, incident is a failure on level one (component/part), or level two (unit) i.e. the damage is limited, hence the sub-system or total system is protected from an accident (Perrow, 1999)

Near-Miss is an unplanned event that did not result in injury, illness, or damage, but had the potential.

Barriers, or controls are technical, operational, and organizational elements used to protect health, safety and environment individually or collectively (PSA, 2014).

Risk Influencing Factor (RIF) is a collective name for any condition or circumstances creating system instability and increasing the probability of adverse event to occur i.e. factors that influences the performance of the barrier system (Vinnem J.-E. , 2014a).

1. Introduction

1.1 Background

The importance of shipping to world's economy is undeniable accounting for more than 90% of global trade. Most of the world's merchant fleet conduct their main part of the operations at sea, enabling the owners to dodge the regulations and gain economically (Stopford, 2009). The shipping industry has throughout the times experienced serious accidents and investigations has identified a common factor: Human Element (Rothblum, 2000). Thus the fact that International Maritime Organization (IMO) is responding accordingly with effective design practices, standards and associated management systems the maritime safety remains a concern.

Human contribution to maritime safety is widely studied in the conventional shipping but the risk picture, chain of events, and root causes leading for incidents, ultimately for accidents differs largely from what is experienced in offshore specialized vessels. The scope of work is very different, traditional maritime accident types: grounding, collision due to navigation error, breakdown, fire & explosion are plausible but unlikely in the context of offshore. The main difference is that an offshore vessel engaged in operations offshore is often coupled to a larger system where technical or human error can lead to loss of not only the system operated but to a greater extent. Engine stop on a tanker in the middle of Atlantic Ocean can most likely be fixed in some minutes to a few hours, and in the worst case if not reparable the company and authorities can be informed and a salvage operation planned and conducted. Consider the same situation, loss of power onboard a Semi-Submersible drilling rig engaged in well completion operations, due to the nature of the work the system has from second to some minutes (time frame directly proportional to the level of coupling and complexity) to restore full operational status or accident is inevitable.

Maritime safety is largely build upon assumption of root causes interpreted from analysing and modelling past accidents and incidents. One could claim that this reactive regulatory approach has many defaults given that underreporting is one of the main issues in maritime safety (Psarros, Skjong, & Strandmyr Eide, 2009) ; (Hassel, Asbjørnslett, & Hole, 2011). As a result enormous set of rules and regulations (barriers) in form of top down management is applied, the elite imposes a solution on problem and the operators of these highly sophisticated socio-technical systems are trying to follow them to the best of their knowledge.

In order to understand the nature of the studied subjects, I will first provide an overview on the existing literature concerning human factors, risk management in high reliability organizations, technology, and safety management of organizations engaged in complex and high-hazard activities. Furthermore, by analysing the research data with quantitative methods, this study aims to study the causality between rules and regulations in force and operation practices in the industry i.e. the gap between theory and practice.

Furthermore the reliability of human performance can be evaluated by qualitative or quantitative methods. This report takes a qualitative approach i.e. describing the reliability in words only. The quantitative method, estimating the human reliability by probabilities is a widely researched subject, and the results that researchers present with up to seven decimals accuracy keeps surprising, given that the researchers have limited knowledge on how the work systems are operated (and especially the underlying influencers), and the operators lack of knowledge on how to do research. I agree with Redmill, who notes the following on probabilistic approach of human reliability analysis "…although probabilities are derived, the approach taken in most cases is based principally on human judgement. The results are at best reasonable approximations, and worst wild guesses, but always they include considerable subjectivity…" (Redmill F. , 2002). Redmill's findings are similar to Kaplan's who advocates the problems on probabilistic approach on understanding the system safety (Kaplan S. , 1992).

1.2 Problem definition

Both the maritime and petroleum industry recognizes the importance of assessing the human component and its contribution to the safety and quality of the operations. The regulatory bodies have implemented and required effective design practices, standards and associated management systems. Offshore shipping is special case since it combines the elements of shipping (traditional risk picture in shipping) and control room operations in Complex High-Hazard Systems, while the system is operated in Dynamic Positioning mode. The current research has evaluated the risks involved in conventional shipping and offshore installations per se, commonly from the technical integrity point of view. According to the data from International Maritime Contractors Association (IMCA) the frequency of position loss is 10^{-5} per DP hour or 10^{1} - 10^{2} per vessel year (IMCA, 2003).

The hypothesis behind this research is *by having operators that can evaluate and improve their performance, the offshore shipping company will gain market advantage via providing higher quality of service for its charterer*. This is vital in shipping today since the vessels (technology: hardware and software) is more or less equal. Vessels have same specifications for large extent, being modern and equipped with same subsystem providers, and build in the same yards. This makes it difficult to evaluate the potential quality of the vessel by means of technical specifications. It is the crew that ultimately creates the difference between the vessels. It's justifiable to say that "ship is as good as its crew". The obvious questions is then: do we have the tools to improve the quality of the operators performance, and do the operators understand what Human Performance is and how to develop it?

On the other hand the vessels used in offshore specialized shipping has developed more and more complex socio-technical systems, and the expansion of OSV' has resulted a huge demand on Dynamic Positioning Operators (DPO's). However the attractiveness of maritime work has been decreasing in the western world i.e. there is a lack of competent DPO's in terms of knowledge and experience, which effects the risk level of the marine operations offshore.

The purpose of this study is to contribute to the research and improvement of maritime safety from the operator's perspective. We have come to the point where it is appropriate to ask if the rules and regulations in force does contribute to the risk mitigation, or have we reached the point where the energy and working capacity of the individual goes to the regulatory task and duties. Furthermore it is important to discover the organizational obstacles which has a negative effect on organizational-learning and information flow from offshore to onshore.

This thesis studies and proposes solutions to the challenges recognized from the human perspective. Thus that the thesis is analysing the work system as whole since the technology and organizational elements are largely contributing to the human performance.

The thesis includes terms like human factors, organisational factors, system safety, reliability, barrier etc. The definitions and distinctions of the terms and concepts are not always easily understood. A multidisciplinary approach where offshore industry is mixed with shipping industry introduces cross-disciplinary terminology causing difficulties about the concepts. The attempt to build a common ground for O&G and shipping industry is demanding one but necessary for improved cooperation and understanding of the requirements and operating practices as well as expectations for quality of the service.

1.3 Research Questions and Objectives

How do we improve the performance of the human component to increase the reliability, reduce the risk associated with maritime operations, and achieve competitive advantage by doing so?

The purpose of this thesis is to promote increased understanding of the sociotechnical system from other industries operating with high reliability assets, and determine the risk influencing factors for safe marine operations from the operator's perspective. The main objectives of this thesis are:

1. Determine the current understanding of human factors contributing to the risk, reliability and safety of the system.
2. Describe the basic concept of dynamic positioning, risk management, human and organizational factors.
3. Identify the human, technical, and organizational factors contributing to the total quality of the operations.
4. Evaluate the survey results and create principal solutions for identified challenges.

1.4 Data Collection

Both quantitative and qualitative research methodology was used in this research. The base data used in this study was collected through a web based questionnaire (appendix 3). The survey included 267 questions divided into three main categories and 15 subcategories. In addition to the 'Likert rating scale', respondents had the possibility to comment and share knowledge after all questions sets. The results of the survey were further given commentary (the qualitative part) by selected industry professionals (7 senior officers) for reasoning the trending answers from qualitative data. The target was Dynamic Positioning Operators working within offshore specialized vessels in Northwest Europe. The questionnaire was fully completed by 27 respondents, in addition 11 respondents answered the survey partly. None of the 38 respondents was censored from the questionnaire. It was also made possible to move to the next question set without answering all previous questions, if the respondent felt that he is not willing, or capable to answer, hence the number of respondents varies from 22 to 38 per question.

The questionnaire was formulated with help from various assessment tools to analyse human factors in safety critical industries, such as nuclear, aviation, petroleum, and maritime. The main framework for questionnaire-set was formulated from the Energy Institutes Human Factors briefing note-set including 20 modules (Energy Institute, 2015), and from the General Nordic Questionnaire for psychological and social factors at work (STAMI, 2015), both available online.

1.5 Limitations

The study is geographically limited to Northwest Europe. Firstly this limitation plays an important role since the operating environment in terms of rules, regulations and practices gives a common ground for the analysis. Secondly the equipment used is the most modern state of art machinery with similar technical solutions. Thirdly the environment plays a part in terms of operational limits, system limits and it also has an effect on human performance. Finally studies show that flags of registration, classification society and management style has significant impact on the overall performance of the vessels favouring the North European Flag Sates (Corres & Pallis, 2008). In recent years, offshore companies, both the ones specialized in shipping and the ones specialized in drilling, have registered the vessels (excluding vessels carrying cargo between more than one port in Norway) for the most part in flags of convenience such as Bahamas and Panama allowing companies to choose their jurisdiction, and tax and financial environment (Stopford, 2009);

(NMD, 2014). Despite this trend of optimizing the business, it has not had any significant effect on the human component on senior positions, nor to the management structure. The flag of choice has neither an effect on the laws, rules and regulations to be followed when operated in a specific continental shelf, hence construction vessels and drilling rigs working on NCS are not limited from the study.

The key personnel in offshore industry with dynamic positioning application generally includes Dynamic Positioning Operators (DPO), Masters, Chief Officers, Chief Engineers, Engine Room Operators (or Engineers), Electro Technical Officers (ETO), Electricians, and instrument technicians. This thesis is limited to the crew working on the bridge. The industry uses various terms for the marine officers in offshore but the unifying characteristic is that they have Deck Officers Watchkeeping certification (D1, D2, D3, or D4) according to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and holds the Dynamic Positioning Certificate issued by Nautical Institute.

2. Background

2.1 Introduction to Offshore Specialized Shipping

Offshore Specialized Shipping is one of the many branches in the worldwide shipping industry. There are two approaches to classifying the vessels in use: (1) by the type of design and (2) by the type operation it conducts. The shipbuilders provide the customer operational efficiency and performance by help of proven "off-the-shelf" designs and a portfolio of products manufactured internally or procured from other manufacturers. The components and subsystems include: machinery, propulsion, DP system, integrated automation system, power management system, alarm and condition monitoring system, and cargo handling systems etc. which limits the scope of work a specific vessel can do. In addition to the elementary solution the vessels might be equipped with various auxiliary equipment to fit for the operational needs, this includes (but are not limited to) remotely operated vehicles (ROV), drilling rig for well intervention or well work over, cranes, A-frame, pipelay equipment, towing winches etc.

Traditionally shipping is divided into four segments depending on the cargo transported. Bulk Cargo Fleet (e.g. oil, dry bulk), General Cargo Fleet (e.g. container, ro-ro), Specialized Cargo Fleet (e.g. reefer, LPG, LNG), and Non-Cargo Fleet which by tonnage is dominated by cruise ships, includes the Offshore Specialized Vessels as well (Stopford, 2009). According to Equasis statistics on world merchant fleet in 2013 there are 7'440 offshore vessels in total representing 9.1 % of world's total merchant fleet of 81'584 (EMSA, 2015).

Vessels equipped with DP system are engaged in operations where the stationary position keeping capabilities are required. Since the concept of DP is the same from one vessel type to another, a general list of responsibilities between the DPO's regardless of the type of work the vessel or unit with DP system is conducting can be represented. In addition to the general duties it is important to understand that there are special requirements and duties that comes along with different vessel types.

Manning of the unit can vary according to type of work carried out but the line of responsibilities is the same regardless of the vessel. The Master / OIM has the highest authority and responsibility onboard followed by the Chief Officer / Stability Section Leader, and 1st & 2nd Officers also referred as DPO's. Senior and Junior prefix i.e. SDPO and JDPO refers to the seniority among DPO's. In this project the term *operator* refers to anyone "on-desk" i.e. all marine officers regardless of the rank.

In general we can divide the operations into two categories: (1) operations without DP application, and (2) operations with DP application. During the transit between field and an offshore base the vessels are navigated as any commercial ocean going vessel by help of charts, gyros, and the vessels position is determined by help of global positioning system (DGPS) data. In addition to navigational duties the vessel is manoeuvred manually in ports and offshore locations. Cargo and ballast operations are also conducted by the officers on watch. Operations with DP applications are performed in situation where the vessels or units station keeping capabilities are required to perform a work efficiently and safely i.e. maintaining a position in relation to another moving vessel or maintaining a fixed position in relation to a fixed object e.g. wet tree, or wellhead.

During the navigational watch it is not required to have two operators with navigational certificate on watch, but during DP operations two DPO's have to be present at the bridge all times capable of controlling and intervening on the DP systems automated process. One is in charge of the DP system while the other takes care of other "bridge responsibilities" including but not limited to watch keeping, radio communication, etc.

These two DPO's shall take turns at the DP control station with intervals no longer than one hour on-desk i.e. responsibly of operating the DP. Duties and responsibilities for the DPO "on-desk" are (but not limited to):

- Operate the DP and related systems in accordance with operational procedures, guidelines and manufacturer's instructions, and act if necessary to ensure the safety, integrity and station keeping of the vessel / unit
- Monitor DP system performance and verify that station keeping is within acceptable limits (limits are defined by operational characteristics i.e. MODU's limits are defined by the water depth since the angle between the unit and wellhead is critical in order to prevail the integrity of the well)
- Monitor status and performance of thrusters, power generation and distribution, position, heading and motion reference systems
- Monitor environmental status and predict the development i.e. waves, wind, current etc.
- Maintain optimal heading to optimize positioning/ heading performance, and to optimize fuel consumption
- Keep communication with internal stakeholders i.e. engine room operator (ERO), ROV control etc.
- Keep DP logbook updated

Duties and responsibilities for the DPO "off-desk" are (but not limited to):

- Calling and liaising with the Master/ OIM and Client representatives as required
- Maintain marine watch and duties i.e. look-out, radar monitoring and AIS surveillance, update and maintenance of navigational equipment
- Ballast operations and stability calculation
- Respond to any central alarms e.g. fire or gas and ensure their cause is fully investigated, and if necessary initiate proper alarm and action
- Communications, including GMDSS, internal and external telephone, VHF and UHF with crane driver, deck watch, vessels and other rigs / units
- Obtaining up to date forecasts e.g. weather, current, extreme weather etc.
- Maintain Marine Log Book
- Administration of Permit to Work system and have up to date information about work carried out onboard
- Filling and administering of DP documentation and records
- In emergency situations assist the "on-desk" DPO unless ordered to other tasks by his superior officer (commonly the highest ranked person on bridge takes over)
- Controlling that unauthorized people are not on the bridge during DP operations
- Oversee that people permitted on the bridge, but who are not taking part directly in the DP operation do not interfere, disturb or endanger the safety or the performance of the DP operation

This list of duties and responsibilities is generally applicable for any vessel equipped with DP system, and collected from various sources: Bray (DP Operator's Handbook, 2008), Ritchie (Offshore Support Vessels: A Practical Guide , 2008) & (Practical Introduction to Anchor Handling and Supply Vessel Operations, 2004), and Chen, Moan, Verhoeven (Safety of dynamic positioning operations on mobile offshore drilling units, 2008).

2.2 Vessel Types

Platform Supply Vessels (PSV) are used for logistic support and transportation of goods, tools, equipment and in some cases personnel to and from offshore location. The cargo is divided into two categories deck and bulk cargo. Deck cargo includes containers, drill pipes, marine risers, tools etc. The bulk cargo is stored and transported in closed tanks under deck and it includes drilling fluids (mud), brine, dry cement/barite, fuel, methanol, potable and non-potable water, and chemicals used in the drilling process etc. In terms of human factors and requirements to the operators there is a couple things to highlight; substantial amount of manual handling of the vessel while entering the safety zones and in transit between the installation and or cranes in offshore complexes (e.g. Ekofisk etc.), the coupling from loosely coupled to tightly coupled changes during the watch through various cargo operations i.e. drift of situation when working with deck cargo has substantially higher limits than when working with bulk cargo hoses connected to the vessel. Finally the supply operations quality assurance is based on the performance of the crew at any given moment i.e. vessels with "client" onboard balances the action and acts as a higher controlling authority while onboard PSV the quality in terms of following rules, regulations and procedures are based on the individuals and the culture they have formed.

Anchor Handling Tug Supply (AHTS) are with respect to the cargo carrying capability similar to PSV's (but often reduced) thus some AHTS vessels are solely dedicated to anchor handling. Modern AHTS's are equipped with Remotely Operated Vehicle (ROV) which widens the scope of work carried out. AHTS's vessels can also be equipped with A-frame for lifting purposes due to the high capacity winches on deck. Normal operations are anchor pre-lay and towing of MODU's but due to the high propulsion power output (pollard pull) the vessels can be used for ploughing operations as well. The horrible accident of Bourbon Dolphin off the coast of Shetland on April 12, 2007 show the tight couplings in the towing operations involving high loads i.e. the time for corrective actions are significantly reduced when AHTS is connected with rig (active in a way that it can create loads that significantly exceeds the AHTS handling capacity) compared to plough (passive in a way that all forces acting on the plough are created by the vessels towing it).

Construction Support Vessels (CSV) are equipped with offshore (G5) cranes with lifting capacity between 250 - 400 t. and ROV's. The main function of the CSV's is various installation and decommissioning projects of subsea and surface structures and installations. The DP application is used during the construction phase offshore but considerable amount of time is consumed onshore on various mobilization and demobilization works causing idle time for DPO's. Since ROV's is a standard solution for these types of vessels they are utilized for various survey campaigns to maximize the use of the vessel by charterer. The scope of work determines the workload created for the DPO's i.e. ROV survey on platforms steel jacket (legs) is stable in a way that the vessel is in fixed location where of the work is carried out. In pipeline surveys the vessel is moving along the ROV for fast and smooth operation. To follow the moving ROV requires higher concentration and more hands-on work from DPO's who intervenes with the DP system upon the requirements and limits of ROV (due to the physical restrictions on ROV and its umbilical's / cage).

Diving Support Vessel (DSV) are largely similar to the CSV's but in addition they are equipped with saturation dive system including: living chambers, diving bell, bell handling system and moon pool (structural hole amidships to provide shelter, protection, and damping of the vessels roll and pitch movement). The design principles and operation of a dive system are detailed by the relevant Classification Society. DNV GL has specific "Rules for Certification of Diving Systems" dividing the vessels into three categories by depth restrictions and maximum operation time (surface, bounce, and saturation DSV) (DNV, 2010). The duration of diving operations can be several days when done by rotational diver teams which means that the DPO's have to monitor the DP system for days, without intervening on the dynamic process of the system if and when it performs stable. The process is tightly coupled and can be labelled as high risk since loss of position would directly affect the divers who are connected to the diving bell and furthermore to the vessel being dependable on the heliox (breathing gas composed of a mixture of helium (He) and oxygen (O_2), warm water, light, communication etc.

Multi-Purpose Support Vessels (MPSV) is a combination of supply vessel and construction vessel i.e. it has the cargo carrying capacity of a supply vessel but with significantly larger living quarters and additional position reference system for underwater positioning. The hull can be strengthened for light G5 crane (including hydraulics and electronics) and helideck can be added if operational requirements demand it. The biggest differences with regards to a pure construction vessels are the lifting capacity, high cargo rails suited for deck cargo carrying, no ROV hangars or control room, and smaller living space without large office spaces for client crew.

Inspection, Maintenance and Repair Vessels (IMR) primary task are the inspection and repair of subsea facilities and installations like any construction vessels, one may argue that it is just a commercial name of any CSV for marketing purposes. The work performed by IMR's are: visual inspections and mapping, installing equipment at great depths, supporting ROVs, diving support - laying cables, umbilical's, hoses or rigid pipes, subsea interventions - well stimulation support, drilling support (Serck-Hanssen, 2013).

Accommodation is a general term for DP vessel used for accommodate offshore crew when extra living capacity is required. The application is commonly used in *Flotel* type semi-submersibles that are connected to a fixed platform where, for example, significant maintenance and commission work is carried out and the platform itself cannot support the living arrangements for the service personnel. The other application is the combination of an MPSV and the bridge transporting maintenance crew to and from unmanned riser platforms. The Flotel type platforms are normally used for extensive periods of time setting high reliability requirements for the stable performance of the DP system with minimal operator intervention.

Cable- and Pipe-Laying Vessels categorized upon the laying technique to S-lay, J-lay, and reel lay depending on the pipe type and diameter, and water depth (Bai & Bai, 2010). These vessels, regardless of the laying method, are used for laying a pipe along a designated seabed channel or route as the vessel is moving slowly along this intended channel or route. With respect to human factors the most important aspect of the vessel's operations is the maintaining of the pipe tension since the pipe is supported by its own tension only in the span between the ramp or stinger and sea bed "touchdown" point (sagbend zone), too much or little tension makes the pipe rupture or collapse. An unfortunate example of this happening is the "Skandi Navica" accident where the operator by mistake applied an additional number to the tension control setpoint causing the pipe to rupture. The level of "coupling" is based on the characteristics of the pipe since some pipes are more tolerable i.e. by having larger tension "window" than others directly effecting to the time available for corrective actions upon failure on DP capabilities.

Shuttle Tankers (ST) are using the DP application during the loading of stable crude oil product offshore from Floating Production, Storage, and Offloading (FPSO) unit (sometimes referred to Floating Production Unit, FPU) by means of a bow manifold. The ST operates on a position-circle and or weathervaning principle where the operator is responsible of keeping the tanker within specific maximum and minimum distances of the FPSO ensuring that there is no risk of rupture of the loading hose or contact with the FPSO. The loading (+connection/disconnection) time is depending on the pumping rates and amount of deliverable product from the FPSO normally around 24 hrs (North Sea). In addition to the position keeping the operators have to consider the development of the weather conditions due to the disconnection time.

Mobile Offshore Drilling Unit (MODU), type Drillship or Semi-submersible is used for various well intervention and drilling operations, and also for the Subsea Production System installation. The main function of DP application is to provide stable platform for drilling operations by means of keeping the unit within acceptable limits i.e. the angle between the unit and the wellhead (Lower Marine Riser Package), the typical drilling operation excursion limits are categorized into green, yellow, red, and to physical limits of the system. Different systems have different limitations but in general, the deeper the water, the larger the system tolerance i.e. if the standard drilling blow out preventer and marine riser system require to be disconnected before the lower flex joint angle reaches its physical limit of 8° in shallow water depth of 500 m the maximum allowable offset would be 70 m. From this example we can easily interpret the concept of loose/tight coupling i.e. considered that the forces acting on the MODU makes it to drift with a speed of 1 m/s hence the total available time before the physical limits are reached is 70 seconds (in deep and ultra-deep water the time span would be in order of minutes). In drilling operations the DPO's role can be considered passive monitor of the DP systems performance, due to the duration of the drilling work (magnitude of tens of days on one single well, months in same location when engaged in drilling campaign). Difference between ship shaped and semi-sub drilling MODU's are motion characteristics favouring semi-sub but drillship has larger payload capacity (i.e. to carry the marine raiser filled with heavy mud in ultra-deep water operations) and transit speed.

Well Intervention Vessels (WIR) is "lighter" type of drilling vessel used for various operations that was carried out by "heavy" work over rigs in the past. Due to the high day rate of work rigs WIR's was introduced for operations that are not that sensible and advanced in terms of requirements and complexity i.e. a typical operation could be "pumping" which is one of the simplest form of intervention since the vessel is connected to the subsea system from kill valve for chemical injection and well control with marine riser is not required. Example works are general maintenance on wellhead / christmas tree (lubrication, pressure etc.), slickline (fishing, gauge cutting, deploying or removing wireline retrievable valves etc.), coiled tubing etc.

Well Stimulation Vessels (WSV) are used to provide high pressure chemical injection for improving the flow of hydrocarbons from the drainage area into the well bore. These vessels have the same characteristics as any supply vessel with high cargo carrying capacity, in addition the vessel has high pressure pumping system which is coupled to a production well through platforms riser. The operations are weather sensible since when the WSV is connected to a platform its movement is highly restricted due to the hose.

From the description we can conclude, that the work scope of a system using the DP application, whether it involves divers, remotely operated vehicles, survey operations, crane operations, drilling, or flexible or rigid pipe lay operations, requires the vessel to remain in an as accurate and stable position possible. And when the human intervention is required the time available for the recovery actions is determined by the level of coupling and interdependencies between the systems.

2.3 Introduction to Dynamic Positioning

In order to understand the context where Dynamic Positioning Operators (DPO) are working it is essential to present the reader a concise introduction to the Dynamic Positioning (DP) system.

The increased price and demand of petroleum related products in the late 1960's has made the petroleum industry seek for deposits of oil offshore. The drilling in shallow waters was a commercial success and new needs and requirements raised when the industry started to move into larger operational depths and harsher environments. In deep-sea areas alike offshore Norway the usage of traditional positioning keeping methods like anchors or usage of the jack-up type drilling units were no longer applicable. The industry learned from marine operations between supply vessels and drilling units fixed to seabed that that the vessels operated manually for position keeping had high accident rate. The human operators who manipulated the propulsion system continuously was too vulnerable for human error, subsequently DP system was invented. Nowadays DP is well established technique in the world of Offshore O&G but the element of human error is still present.

A Dynamic Positioning system is an example of an automatic closed-loop control function i.e. computer-controlled system to fulfill a specific task namely to maintain units position and heading by means of using its own propellers and thrusters. Operators (or human) are required to monitor the dynamic performance of the system and make adjustments (manual input) or intervene in the event of malfunction. The simple definition of DP is “a system which automatically controls vessels position and heading by means of active thrust” (Bray, 2008); (Strand & Sørensen, 2001); (IMO, 1994).

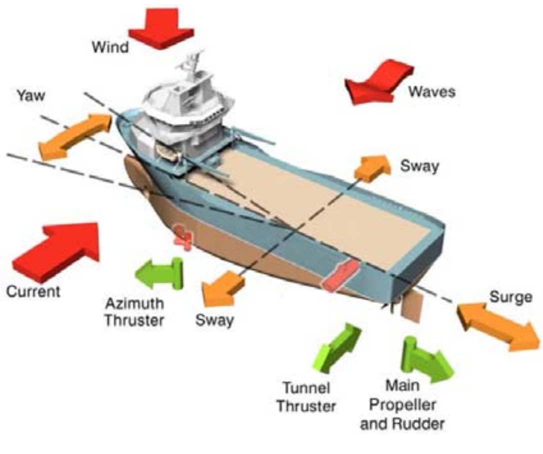
Any system afloat is subject to external forces: wind, waves, swell, and current as well as forces generated by the propulsion system. The system responds to these external forces by changes in position, heading and speed. Those parameters are measured by the position reference systems (PRS), the gyrocompass and the vertical reference sensors, hence the DP control system calculates the forces that the thrusters must produce in order to control the vessel’s motion in three degrees of freedom: surge, sway and yaw (Bray, 2008). A seagoing vessel has 6 degrees of freedom enabling it to move around the x-, y-, and z-axis:

Controlled motion

- YAW is the rotation of a vessel about its vertical axis (heading)
- SURGE is the linear longitudinal (fore and aft) motion
- SWAY is the linear lateral (side-to-side) motion

Uncontrolled motion

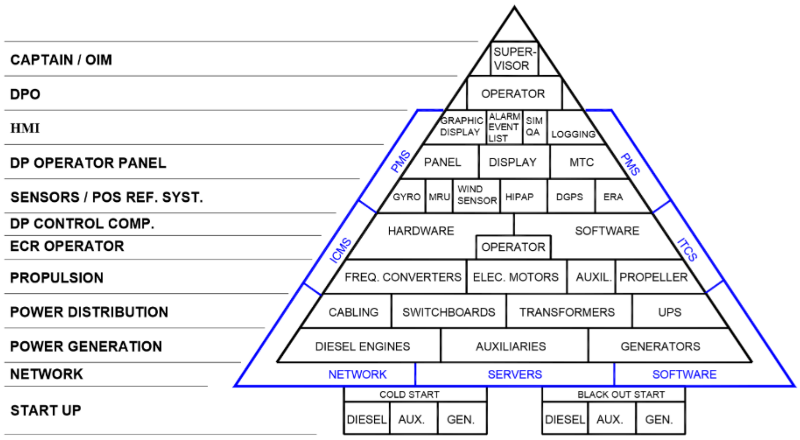
- HEAVE is the linear vertical (up/down) motion
- ROLL is the rotation of a vessel about its longitudinal (front/back) axis
- PITCH is the rotation of a vessel about its transverse (side-to-side) axis



1 Forces and motions (source: Kongsberg)

In order to conduct more thorough reliability analysis of the work system one should understand that DP system is not a single piece of hardware or software. It is a capability provided via a set of components creating subsystem and functions that directly or indirectly affects the units or a vessels automatic position keeping ability exclusively by means of thruster force. DP system means the complete installation with subsystems consisting of (1) Power Management System, (2) Thruster System, and (3) DP-control System

(IMO, 1994). In order to operate the system a fourth component has to be involved namely Key DP Personnel (Chen, Moan, & Verhoeven, 2008). The Key DP Personnel generally include bridge crew and engine crew responsible for operating and maintaining the system. IMCA has limited the Key DP Personnel to six positions onboard a unit or a vessels: Master/OIM, Senior DPO, DPO, Chief Engineer, ECR Engineer, and Electrician Maintenance Staff (EMS) (IMCA, 2006).



2 DP Operations Pyramid proposed by Verhoeven, Chen & Moan (2004)

2.3.1 Control System and Work Station

The Control System is the heart and brain of any DP system. It receives data inputs from position reference system, environment reference systems, heading reference, and propulsion feedback parameters creating propulsion commands as output. Input can also be applied by the DP Operator who determines a Set Point value. Like any modern complex control system the DP uses mathematical modelling techniques to support the control functionality. The mathematical model encloses static data on the vessels parameters and in addition it has the adapting feature (Sørensen, 2011). In practice this means that the vessels station keeping capability improves by time since it adapts to the prevailing weather conditions and vessel configurations (forces acting on the vessel). Operators uses the term “building up the model” which refers to this process, notice that the system is subsequently dynamic and it continually adapts to changes in the environment or vessel. This function enables the vessel to operate in varying environmental and operational conditions within safety limits.

DP Operator and the Work Station / Operator Station is suggested by Ritchie (2008) to be a part of the Control System. DP Operators only possibility to monitor and involvement in the dynamic process is through the work station. Work Station main function is to present complex information from DP Systems performance and status to the operator who is responsible for intervention upon any irregularities or changes that can be hazardous to vessel or crew. Safe and efficient operations require comfortable work environment supported by a well-designed graphical user interface (GUI) and visual display units (VDU) (Bjørneseth;Dunlop;& Strand, 2008).

2.3.2 Position Reference System (PRS)

Position Reference System (PRS) is a collective term for a system providing position data for the DP system to determine the position and movement of the vessel or unit in Surge and Sway axis. The OSV’s are equipped with a combination of PRS’s to fulfil the class requirements with respect to redundancy. The geographical area of operation and scope of work give advantages and disadvantages of the available position reference systems therefore it is difficult to go into specific details about the reliability and availability of a particular system.

Differential Global Positioning System (DGPS) is the most widely used PRS in DP application. The system is based on reference satellites orbiting the earth and transmitting radio signals. Signals sent by satellites can be received by the GPS receivers fitted onboard the vessels. The positions of the satellites are known at any given time, thus the time period for the signal transfer can be calculated, and the GPS receiver can determine the range of the receiver from the satellite. If three satellite signals are received, then a latitude and longitude position can be determined. In order to enhance the quality of "raw" data the differential correction is used. The principle is simple; reference station on accurately known position onshore are used to correct the errors between measured and calculated ranges resulting improved accuracy fulfilling the need of DP (Chen;Moan;& Verhoeven, 2009). Major disadvantage and limitations of DGPS is "multipath" problems and loss of correction data in "shadows" i.e. when two or more units are operating closely can hinder the signal path both from satellites and correction stations.

Laser based PRS is based on laser beam projected horizontally. Beam of light is pulsed at very high frequency from a projector and a scanner unit with a radar principle. This allows the unit to monitor and track fixed reflector targets on a stationary target deducing the range and bearing. It is critical to ensure an unobstructed line-of-sight. The major disadvantages and limitations of a laser based system are atmospheric conditions (e.g. rain, mist, fog, sleet etc.) which reduce the availability of the system and movement of the vessel which can lead to the reflection loss disabling it from DP.

Hydroacoustic position reference systems use a vessel-mounted transducer (transmitter and receiver) and a transponder located on the seabed. In addition to position reference, the acoustic technic is used for monitoring and controlling of underwater functions i.e. in case a target needs to be followed the transponder can be fitted onto ROV etc. Disadvantage and limitations of hydroacoustic PRS are degradation due to interfering noise and aeration; also due to the waters properties e.g. temperature (layering), turbulence, and impurities that can interfere with other hydroacoustic systems in the area and in general the presence of large underwater structures can create inaccuracy.

Taut Wire system consists of a deck mounted davit arrangement and of a weight on a wire which is attached to the davit arrangement via a constant tension winch. With the wire deployed in the water and the weight resting on the seabed the gimbal head on the top of the structure measures the changes in the wire angles providing the position change information for DP system. Disadvantage and limitations of taut wire: the vulnerability to fouling with any underwater obstacles (ROV, cables, subsea structures, jackets etc.); limitations on shallow and deep water (limited angle and bending of the wire); mechanical in nature requiring regular maintenance.

Microwave based PRS has the same working principle as laser based but it can overcome some of the operational limitations that affects laser based systems.

DP Class 2 and 3 require both a minimum of three independent PRS's allowing the DP system to "vote" and "weight" the quality of position data received from the units. PRS's that have common-mode failures should be used with caution i.e. one root cause can result the loss of position data from two or more PRS's. In case of *position dropout* the system automatically switches to *dead reckoning* mode where the position keeping is based on the previous data collected to the matrix algorithm combined with vessels mathematical model. Dead Reckoning is not a position keeping mode i.e. it is an automatic response from the system in in case of an emergency situation to acquire time (reduce the tight coupled nature of DP) for the counteractions by the operators.

2.3.3 Propulsion System

The propulsion system consists of diesel engines, generators, transmissions, thruster and propellers. In general, three types of propulsion generating units are found on OSV's: controllable pitch propeller with associated rudders, tunnel thrusters, and azimuth thrusters. Thruster and propeller in this document are defined as the general expression for thrust or propulsion generating unit. A majority of OSV's are equipped with diesel-electric power configuration, hence propellers and thrusters are driven by electric motors in conjunction with variable speed drivers i.e. fixed pitch where thrust force is generated varying the speed of the drive. Design principle for the propulsion configuration is to ensure adequate level of redundancy, and propulsion force for various environmental conditions and forces. Note that the propulsion units can be operated both manually and automatically when enabled in DP. Furthermore the use of azimuth propulsion in manoeuvring operations differs largely from manoeuvring with traditional propeller and rudder combination. The human or operator is very adaptable but especially older crew that has background from merchant fleet, AHTS vessels and older supply vessels with direct shaft drive are experiencing surprises when using these 360 degrees turning azimuths.

2.3.4 Power Generation and Management

Power generation has a central role in any offshore vessel. Power is supplied for manoeuvring systems (propellers, rudders, tunnel thrusters and azimuth thrusters etc.), all auxiliary systems (vessel type dependent), and for DP control and position reference systems. The power generation system must be flexible,to the able to respond rapidly in various environmental loads and power consumer requirements upon demand. As a minimum requirement the generators and distribution system have to ensure power supply capacity that safeguards reliable DP station keeping capabilities. The role of Power Management System (PMS) is to assure the adequate and reliable power supply for all consumer prioritizing from the most critical for safe operations of the unit, namely propulsion generation and instrumentation. PMS will automatically control the loads to reduce the risk of overloading the generators by disconnecting low priority consumers. The power is delegated through switchboard which is commonly divided in at least two separate parts, to provide redundancy with help of bus-tie breakers. The separation is done to avoid common cause failures which could be transferred throughout the systems, including overloading and short-circuits (see 3.4.5: Reliability Block Diagram).

2.3.5 Heading Reference

The DP vessels heading and changes (Rate of Turn) on heading or yaw are measured by gyrocompass units. The vessels are fitted with two to three non-magnetic gyrocompasses to ensure adequate redundancy levels. The basic principle is a fast-spinning disc which is affected due to the rotation of the Earth, the result creates the gyroscope to automatically point true north. Some vessels are fitted with two gyros and one GPS compass. The main advantage with gyro is that once it is calibrated the only error source is “speed error” witch increases as the speed increase, since Dynamic Positioning and speed in the traditional sense are exclusive speed error is not an issue. The GPS compass is widely used due to the low price of the unit, but people who have to operate the systems are highly critical to it. The accuracy is based on the movement of the vessel i.e. the change in GPS receivers' position indicates the heading change. Like PRS's the heading reference unit's work with voting principle i.e. the system compares the data and selects two-out-of-three which are believed to be accurate (low deviation).

2.3.6 Environment Reference System

Motion Reference System (or Vertical Reference Unit/System) provides data to control system with regard to vessels motions and position in roll and pitch (2-axis), and in addition heave movement if 3-axis structure. The roll and pitch information improves the quality of PRS data, since it compensates the vessels movement from measured values. For example, if the vessel rolls due to the swell 3 degrees from side to side, and the GPS antennas are in the height of 35 meters the maximum measured error between position could be up to 3,66 meters (sin3°=X/35) although the vessels position has not changed (surge and sway). Heave data is not important for PRS data quality but it is used e.g. to provide helicopter pilots information about vessels movement, hence they can adjust their landing strategies. Heave movement can also be used as decision making criterion for various operations and their feasibility at specific weather conditions.

Wind Sensor data is used to determine the wind-induced forces acting upon the vessels superstructure and hull area above water line. Forces acting on the vessel are calculated by the use of thruster force i.e. how many tonnes have to be created by the thruster(s), and to what direction in order to compensate the forces acting on the system afloat. By help of wind sensor we can determine what proportion of force, which is caused by wind, by disenabling the wind sensor all forces are designated to the "DP Drift" (swell, current, other forces e.g. tension etc.). Strictly speaking the wind sensor are not critical to DP operations but operators use the data provided by wind sensor to trend the past and current wind situation, and preparing for counter actions (change of heading, preparations of operation discontinuation if time consuming etc.) if wind limits are expected to be exceeded.

Draught is determined by help of draught sensors, hence vessels draft information can be manually set to the DP System by DPO. This improves the quality of the model since vessels hull shape at any given draught effects on the vessels behaviour differently.

2.3.7 DP Class and Redundancy

Offshore Specialized Vessels undertake safety critical tasks operations where the consequences of DP systems failure must be taken into account. The consequences of DP system malfunction can vary largely depending on the operational context but in the worst case catastrophic; risk of death or injury to personnel, damage to the asset(s), and risk of environmental hazard.

Redundancy is introduced to the system design to ensure that system function remains subsequent in case of element or subsystem loss. Depending on the DP Class various technical solutions has been applied to increase the redundancy. Perrow (1999) identifies two interacting variables which fully characterizes accidents i.e. coupling and interactions. Coupling is a term used to describe the interconnection or interactivity of two or more systems. Interactions are the joint actions among parts, units and subsystems of the system. A practical view of redundancy can be argue by help of Perrows theory since redundancy after all is used to "buy time". System without redundancy does not tolerate delay (time-dependent processes) and have invariant sequences and negligible slack while redundancy level adequate to operational requirements allows the operation to be safely suspended. Operations like drilling, dive support, or subsea construction cannot be safely suspended without continued provision of DP position keeping capability.

The expansion of vessel with DP application made IMO to introduce the guidelines for design and construction of Offshore Specialized Vessel in 1994. IMO MSC Circ.645 "Guidelines for Vessels with Dynamic Positioning Systems" definitions for the equipment classes are as follows:

For equipment Class 1, loss of position may occur in the event of a single fault

For equipment Class 2, a loss of position is not to occur in the event of a single fault in any active component or system. Normally static components will not be considered to fail where adequate protection from damage is demonstrated, and reliability is to the satisfaction of the administration. Single failure criteria include; any active component or system (generators, thrusters, switchboards, remote controlled valves, etc.), and any normal static component (cables, pipes, manual valves, etc.) which is not properly documented with respect to protection and reliability.

For equipment Class 3, a single failure includes: items as listed above for Class 2, and any normally static component is assumed to fail; all components in any one watertight compartment, from fire or flooding; all components in any one fire subdivision, from fire or flooding.

These fundamental requirements sets the base level but in practice the level of redundancy and system structure are agreed between the vessel owner/manager and client based on the operational risk picture. Since vessels are classified by the classification societies not by IMO, classification societies have used the IMO principles of equipment class and redundancy requirements as basis for their class notation. National requirements in operation area can influence on minimum class requirement like in Norway all vessels engaged in drilling and well activities are equipped with class 3. system setup. In practice all companies engaged in offshore activities are members of the International Marine Contractors Association which proposes additional requirements to improve the technical integrity of the asset, w.r.t. redundancy: IMCA M 103 - Guidelines for the Design and Operation of Dynamically Positioned Vessels (IMCA, 1999).

2.4 Safety Management in Shipping

Safety has always been a concern in maritime sector. Casco an Italian word for ship's hull is today commonly known as insurance for cars, but it has its origins in insuring the loss or damage of ships and possible cargo claims. The earliest recognized joint-stock company in modern times was the British East India Company which issued shares not only for financing purposes (pooling capital) but for shared risk of the highly vulnerable sea routes between Fareast and Europe. Lloyds Coffee House in London was the first insurance market where ship owners, merchants, and masters representing the shipping industry met for insurance purposes; insuring cargo and ships, and those who were willing to underwrite such ventures. The premium varied based on the estimates of variable risk from seasons and pirates (Franklin, 2001).

The maritime safety regime has been emerging from major accidents. The unsinkable passenger liner RMS Titanic collision with an iceberg resulting loss of life of over 1500 passengers and crew in 1912 led to the maritime safety treaty: International Convention for the Safety of Life at Sea (SOLAS), which in 1914 necessitated the shipping companies to comply with minimum safety standards in construction, operations and equipment. In 1966 and 1969 the Load Line Convention for maximum loading and hull strength, and the Tonnage Convention respectively was amended due to the loss of numerous vessels caused by overloading. The growing number of ocean going ships led to collision at sea resulting not only loss of lives, cargo and vessel but potential threat for the environment. In 1972 the International Convention of the International Regulations for Preventing Collision at Sea (COLREG) was set on force shortly followed by the International Convention on Standards for Training, Certification and Watchkeeping for Seafarers (STCW) in 1978. MARPOL 73/78 is the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 resulted from the accident and oil spill of the supertanker Torrey Canyon which struck Pollard's Rock on Seven Stones reef between the Cornish mainland and the Isles of Scilly in the peninsula of the Great Britain in 1967, and the accident of Amoco Cadiz in 1978 when she ran aground on Portsall Rocks resulting the entire cargo of light crude oil spilled to sea approx. 220´000 tons. (IMO, 2015); (Stopford, 2009); (Vassalos, 1999).

International Maritime Organization (IMO, previously known as IMCO) is a specialized agency of the United Nations founded in 1948. IMO uses its control as standard-setting authority for the safety, security and environmental performance of international shipping domain including all types of commercial shipping branches from passenger liners to mobile offshore drilling units. Its main role is to create a regulatory framework for the maritime industry that is universally adopted and implemented by member nations (IMO, 2015). In 1993 the IMO adopted the International Safety Management (ISM) Code requiring all shipping companies operating certain type of vessels to establish a safety management system (SMS) this included the whole offshore specialized shipping. The ISM Code for the Safe Operation of Ships and for Pollution Prevention was the result of IMO's concern on the human and organizational factors in shipping mainly influenced by the accident of Herald of Free Enterprise in 1987. According to Schröder-Hinrichs et al. (2011) human and organizational factors was not discussed in maritime industry prior to the accident, nevertheless aviation industry for example, had done systematic gathering of information on human factors since 1970's. The ISM Code is designed to provide a framework for companies to reduce accidents by integrating the various stakeholders from micro (seafarer), meso (shipping management), to macro (maritime administration) level (Schröder-Hinrichs;Baldauf;& Ghirxi, 2011). In practice the ISM Code was the fundamental document for shipping companies to develop a Safety Management System (commonly referred as Total Quality Management System, TQMS) for assuring an integrated approach between all stakeholders to the daily operations of the vessel or unit by help of manuals, procedures, rules and regulations. The ISM Code does not go into detail how this is to be achieved, but the vessel managers and owners in the North Sea uses web-based software's structured for a wide variety of quality controls for systematic measures to establish and maintain levels of safety. A central role in the Safety Management System plays the ISO 9001 (Quality) and 14001 (Environment) standards. Based on ISO 9001 an ISO/TS 29001 standard incorporates supplementary requirements emphasising defect prevention and the reduction of variation for the O&G industry. 29001 defines the quality management system requirements for the design, development, production, installation and service of products but it is limited to the operators (ISO, 2010).

3. Theory and Method

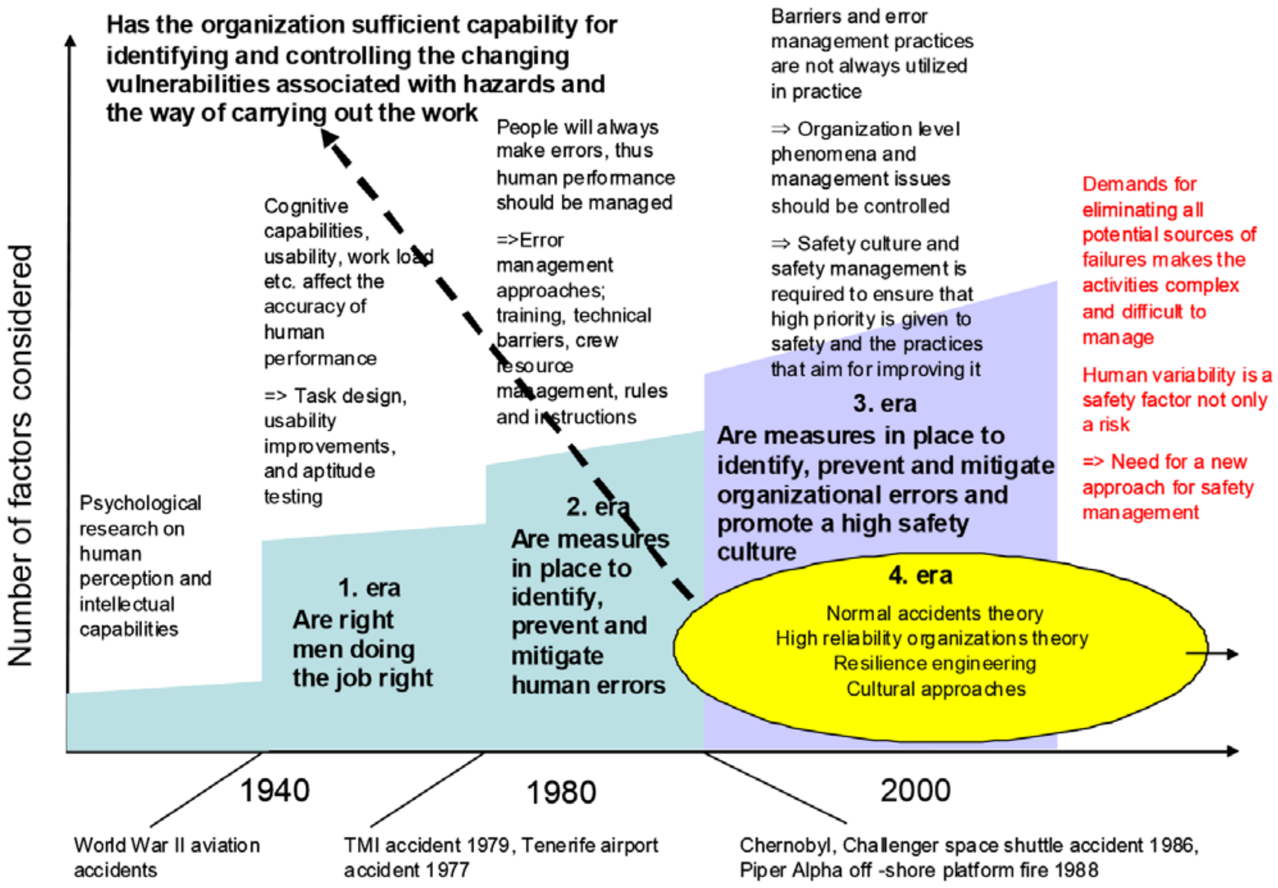
The aim of this chapter is to present the essential terms and concepts covered in the literature review concerning the human factors in offshore specialized shipping. Before going into details it is important to understand the nature of accidents. Furthermore we have to determine the socio-technical system envelope, the organizational and human factors, and the work system where interactions take place.

3.1 Ages of Safety

The concept of safety management and initiatives to evaluate the safety of a system has developed gradually (Reiman & Oedewald, 2009; Borys et al., 2009; Hale & Baram, 1998). Modern safety science views accidents not as a result of individual acts of slips, lapses, mistakes and violations or carelessness, rather they result from a divergence of influences emerging over time, combining to an unexpected combinations enabling alignments unbearable to the system (DOE, 2012).

Hale and Baram (1998) evaluated the evolution of safety management in O&G exploration and production domain through 'ages of safety' recognizing three distinct periods. The first age was a technical age, the second a human factors age and the third age has focus on safety management systems and managerial issues. Hudson (2007) proposes a different sequence of safety development, arguing that safety has evolved through three waves. The first wave was technical, the second a systems wave, and the third a culture wave. Borys et al. (2009) proposes that we have entered into the fifth age of safety: the 'adaptive age'. The fourth age, the 'integration age', builds on the first three which can alternatively be seen as the ages of engineering, system thinking, and by psychology and sociology respectively. Whether or not the scientist agrees on what conceptual "age of safety" we are, the safety and performance in complex socio-technical systems strives towards a more realistic and comprehensive view of organizational activity (Reiman & Oedewald, 2009).

The concept of 'adaptive age' accepts that the reliability of the system and barriers are not enough to ensure safety, the emphasis should be put on anticipating the constantly changing organizational behaviour and the ability of the organization tolerate variance (Reiman & Oedewald, 2009). In practice the variance can be understood as duality of "work-as-imagined" (no variance) versus "work as done" (variance creating processes), "work as done" is not limited to human actions it means all the dynamic processes in general. This perspective of safety is known as Resilience Engineering.

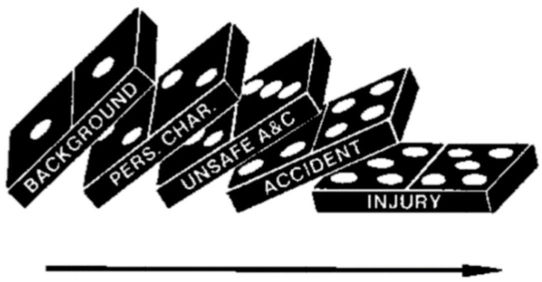


3 Progression of Safety Sciences through eras of Safety by Reiman & Oedewald (2009)

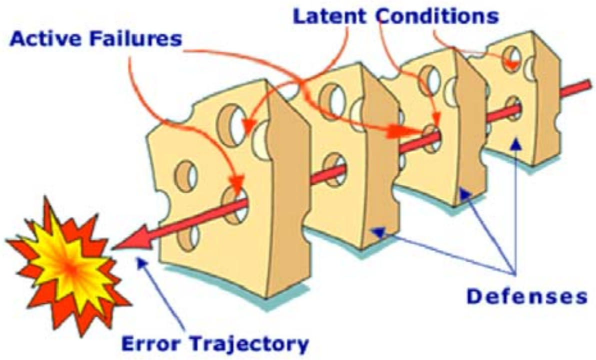
3.2 Understanding of Accident Causation

'Sequence of Event Model', or better known as the 'Domino Theory' proposed by Heinrich (1931) is still the dominant view of modelling accident causation in offshore related literature. Accidents are seen as the natural culmination of a series of events or circumstances, in linear cause and effect model, claiming that accidents to happen, something must break, something must give, something must malfunction (DOE, 2012) (Dekker S. , 2011). The model is picturing accidents as the result of row of dominos falling or collapsing, and the focus is to design barriers between the dominos to interrupt the series of events before it leads to an accident. Alternatively weak links or dominos can be replaced or eliminated. Based on the assumption that accidents are prevented by eliminating the error source we build multiple or hierarchical sequence models like event trees, fault trees, or critical path models to identify the initiating event or condition. The main advantage with sequential models are that they are easy to understand and represent graphically. The modern understanding of accident causation claims this approach to be limited because it requires strong cause and effect relationship (Dekker, 2011; Reiman & Oedewald, 2009; Hollnagel, 2006). Cause and effect relationship can be found in equipment failures but causal relationships are extremely weak when addressing socio-technical systems (DOE, 2012). Large scale industrial accidents: Three Mile Island (1979), Bhopal (1984), Space Shuttle Challenger (1986), Chernobyl (1986), Piper Alpha (1988) etc. led to the conclusion that sequential models could not fully explain the disasters (DOE, 2012);(Reason et al., 2006). In response accident investigators proposed that accidents should be viewed as a combination of factors both active and latent that coexisted at the time of accident: the epidemiological failure model development was initiated (Hollnagel, 2004).

Epidemiological, or Latent Failure Model is a complex, linear cause and effect model where the combination of active failures and latent conditions result an accident. The epidemiological view associate accidents with the propagation of disease where the latent conditions are seen as "pathogens" in the body (system) that lay inactive until triggered by the active error (DOE, 2012). The well-known and widely used representation of epidemiological model is the 'Swiss Cheese' model developed by James Reason. Reason (1997) distinguished between: active errors; mistakes or violations by the sharp end; and latent errors / conditions. A healthy body (system) keep errors causing accidents from happening by help of defences (barrier) i.e. the accident "path" needs to pass through defences in order to cause accident. The layers of "Swiss cheese" represents defence-in-depth strategy where the probability of an accident to happen is reduced, since the likelihood of holes to align is reduced, hence the accident path not able to slip through. Furthermore Reason et al. (2006) draws attention to the dynamic nature of the holes: can be caused short-term due to operator's active error, or by higher level latent conditions ("build-in" on technology, organizational issues etc.).



4 Domino Theory by Heinrich (1931)



5 Swiss Cheese model by Reason (1997)

Normal Accident Theory proposed by Charles Perrow took different approach to the accident causation modelling. According to Perrow (1999) the combination of tight coupling and interactive complexity is inevitably causing accidents that he describes as 'normal'. By 'normal' Perrow draws attention to the fact that socio-technical systems with interactions between parts, units, sub-systems, and systems with environment, so complex and unpredictable that accidents cannot be effectively unavoidable, therefore accidents are inevitable i.e. 'normal' (Perrow, 1999). Like in the sequential and epidemiological models the accident starts from component failure, but involves the unanticipated interaction of multiple independent system failures, unexpected and incomprehensible to the system designers or operators (Perrow, 1999).

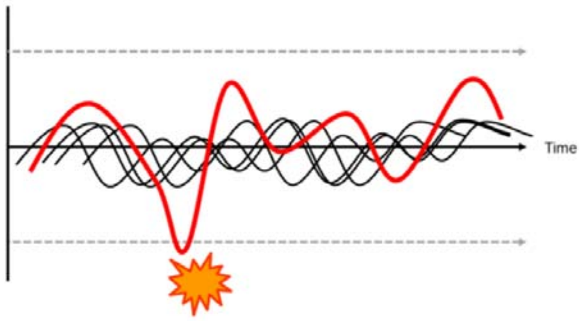
The theoretical bases of safety management and system safety have evolved continuously to a point where many theorists claim that some new and radical epistemological changes to the safety management approach has to be taken. The socio-technical systems have more complex interactions than ever; components are packed on top of another in overlapping and thick networks. These networks create environments where complex interactions between components and subcomponents occur inevitably, and it necessitate significant efforts for teamwork, cooperation, and co-dependency to ensure safe high reliability operations. 'Systemic Model' or better known as Resilience Engineering proposed by Hollnagel provides one approach to understand, describe, and communicate the phenome.

3.3 Resilience Engineering

Resilience Engineering represents the latest wave of the understanding of system safety. The basic premise is that even in the highly regulated industries, it has to be acknowledged that unforeseen phenomena will occur. These phenome's rises from all system stakeholders: human or behavioural, organizational, and technology (software and hardware). (Reiman & Oedewald, 2009).

Resilience engineering is a complex non-linear model that assumes that both accident and success emerges from combinations of variability in the process. Accidents are triggered by unexpected combinations of normal actions which combine in a way that they start resonating with the normal process variability in the system (DOE, 2012).

This concept is presented graphically by help of 'Functional Resonance' model which visualizes the constant variations inside the systems capability framework and variations can start resonating causing the system to loose stability and eventually fail. Variance is a measure of the "spread" with respect to mean. Mean can be viewed as optimal (designed) process performance, due to the complexity of OSV's there is a large number of simultaneous processes (the black variables on picture 6.). The grey dashed line represents the system boundaries i.e. how much variance it can tolerate.



6 Functional Resonance model by Hollnagel (2006)

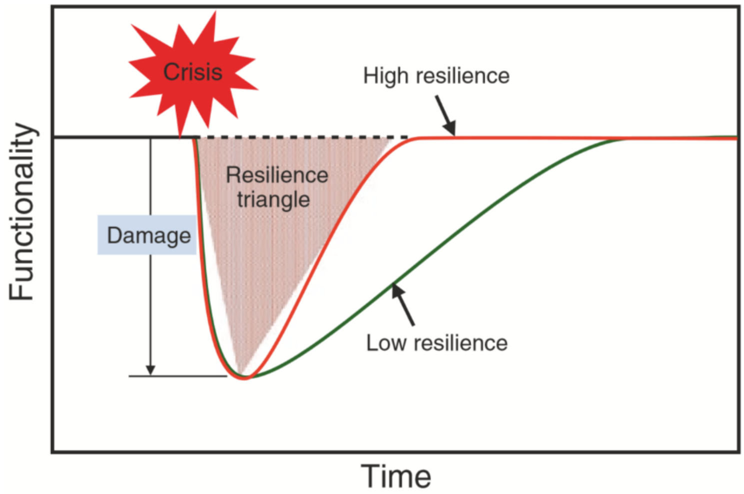
7 Jenga Game

Other metaphor used to describe the concept of resilience engineering is the "Jenga" game i.e. a wooden tower were each block removed is balanced on top of the tower, creating a progressively taller but less stable structure (the "Jenga" is especially used by economist to describe the instability of the world financing systems). The blocks represents the components and sub-system that ensures that the work system can function. The missing blocks characterizes the latent conditions and instability of the system. The instability can also be viewed from point of view that adequate number of blocks are found on the system but due to poor engineering they are placed on top of the system, instead of to the "correct" places where they would have supported the structure. Traditionally individuals are blamed for the accident i.e. human error, but the analysis and conclusion typically fails to recognize how unstable system they have had to operate, and that there would not have been event, nor consequences of the event if the "missing blocks" had been on place in the first place.

According to Hollnagel (2006) resilience engineering is "a paradigm for safety management that focuses on how to help people cope with the complexity under pressure to achieve success". The complexity Hollnagel draws attention to can be found onboard any offshore assets having both the socio-technical system and high reliability organization characteristics. Such systems can show impressive safety record of stable performance over long periods, but in case of failure the consequences can lead to extreme losses (definition of HRO). The history has proven that any system can fail and we have to accept that as a fact, or as Charles Perrow (1999) states that "human-made catastrophes appear to have increased with industrialization as we built devices that could crash, sink, burn or explode". Resilience engineering proposes that the focus should be on the socio-technical systems ability to adapt to changing operational conditions and circumstances i.e.

the system and all its stakeholders should be able to cope with great variations in its operational envelope. Term resilience comes from ecology and it means to populations ability to survive under various conditions, ability to adapt in changing conditions, and the ability to recover to a state of equilibrium after disturbance (Holling, 1973).

Resilience engineering does not necessary mean that the system has only stabile processes. Production systems are commonly designed to have reliability, availability, and stability. Westrum (2006) argues that stability is needed to cope with expected disturbances, while resilience is needed for surviving trough the unexpected events, novel situations, and black swans etc. Systems rarely collapses by a single failure, it is the accumulation of failing components, hence structures that kept the system functioning (Jenga blocks). Resilient system restores the state of equilibrium quicker while low resilient system can be exposed to a condition that destroys (infects larger set of components) the fundamentals consequently leading to an accident (Furuta, 2015).



8 Resilience Triangle by Furuta (2015)

Westrum (2006) proposes that unwanted events are categorized into three types: the regular event, the irregular event, and the unexampled event. The regular event describes the events that have predictability of some degree i.e. disturbances that we try to manage with barriers (see 3.4.7) i.e. loss of position, engine malfunction etc. Irregular events are foreseeable but the probability of such an event is so low that we do not expect them to occur i.e. sinking of unit, loss of well integrity causing explosion (Deepwater Horizon) etc. Irregular events represents the unimaginable. Westrum uses the 9/11 as an example of unimaginable the same ways as Taleb (2007) in his book 'Black Swan´ referring to events with extreme consequences, which are surprises related to one's knowledge, or in terms of probability: extreme values. If risk is not equal to the expected value due to the fact that expected values could deviate strongly from the actual outcome or consequence (Aven T. , 2010) leads us to the fundamental problem of designing a system that is safe. Since it is impossible to prevent some events from happening the system should be resilient in a way that it tolerates instability.

3.4 Basic Modelling Concepts

3.4.1 System Status

State of the system at any vessel or unit engaged in dynamic positioning operations can categorized into three levels: [A -GREEN] Normal State, [B -YELLOW] Degraded State, and [C -RED] Emergency State. IMCA

(2009) defines the three levels in the document IMCA 182 "International Guidelines for The Safe Operations of Dynamically Positioned Offshore Supply Vessels" as follows:

A. Normal State indicates full operational capacity and all operations can be conducted within safe working limits. Position (Sway/Surge) and Heading(Yaw) are in acceptable limits and:
    - Power and thrust outputs are within limits for capability of vessel
    - Environmental conditions are acceptable
    - Minimum risk of loss of position
    - DP equipment redundancy is intact and DP system is operating within 'worst case failure' limits
B. Degraded State indicates the vessel has suffered a failure or reached safe working limits, such that any additional system degrading event would cause an emergency state. Operations should be discontinued and the priority is to take action to ensure an effective and sufficient recovery to Normal State (Green). Condition indicating the Degraded Status:
    - Position or heading out of acceptable limits for more than momentary or isolated period
    - Power and thrust outputs are greater than the limits for capability of vessel for more than momentary or isolated periods, in practice constant power consumption over 50 % of the total available power
    - Environmental conditions or other conditions considered unsuitable for continuing DP operations within acceptable operation limits
    - Increased risk of loss of position, collision, or damage to the hardware
    - Failure in DP equipment that result in loss of redundancy and the vessel operating outside 'worst case failure' limits
C. Emergency State indicates incident that can escalate to an accident causing damage to the health, safety and environment. System status indicating Emergency Status:
    - Loss of position i.e. capability to maintain the position by means of thruster force, and consequently has a position excursion beyond Degraded State.
    - Imminent threat of contact or reaching the physical limits of any hardware
    - Any other emergency situation (e.g. loss of power, -system, -subsystem, stability, unexpected loads or tensions, etc.)

3.4.2 Accident Modes on Dynamic Positioning

The traditional risk management and system safety analysis in offshore specialized shipping starts from the point where the system is in Emergency State (Red). Verhoeven et al. (2004) proposes three failure modes of loss of position, these basic modes are:

Drive-off: Failures onboard of OSV resulting in active thruster forces driving the vessel away from its target position. The drive-off may involve, false position information, DP control failures, thruster failures, and operator errors as primary or secondary causes.

Drift-off: Failures onboard of OSV resulting inefficiency of thruster forces in relation to the environmental forces, e.g. partly or total loss of power i.e. "blackout". The unit is drifted off position due to insufficient or total loss of thruster force.

Force-off: No failures onboard of the vessel, but due to a sudden change in environmental conditions, the vessel is operating outside its position keeping capability envelope and is forced off position due to insufficient thruster forces. "Bourbon Dolphin" accident is an example of force-off situation where not only the adverse weather conditions but also the unbearable tension of towing wire resulted the capsizing of the AHTS vessel.

3.4.3 Risk and Safety

Traditionally the reliability of the marine operations are addressed by term 'safety' (IMO, 2015), while offshore industry addresses the reliability by probabilistic methods i.e. frequency (probability) and consequence of undesirable events. Weick (2007) uses reliability as a synonym for safety noted that safety is a "dynamic non-event", and Reason (1997) proposed that "safety is noted more in its absence than its presence". Aven (2008) among other risk professionals and researchers in the field of reliability engineering and system safety use the term 'risk' to reflect the uncertainties arguing that the risk concept based on probabilities and expected values (risk = probability x consequence) is too narrow for understanding the risk picture of highly complex system and its interactions. The basic concept of risk is to understand and act accordingly to the broader risk picture created by thorough analysis, highlighting uncertainties beyond expected values and probabilities (Aven T. , 2008). Furthermore the main component of ´risk' is uncertainty not probability. The concept of risk and safety are interpreted in many different ways depending on the situation and domain but the connection is clear: high risk means low safety and vice versa

Safety in the maritime context is defined as "the combination of preventive measures intended to protect the maritime domain against, and limit the effect of accidental or natural danger, harms, damage to environment, risk or loss" (del Pozo;Dymock;Feldt;Hebrard;& Monteforte, 2010).

The literature used by offshore oil and gas industry defines the term "risk" with numerous ways and no unified definition for the term has been agreed. Aven and Renn (2010) presents several common risk definitions:

1) Risk equals the expected loss (Willis, 2007).
2) Risk equals the expected disutility (Campbell, 2005)
3) Risk is the probability of an adverse outcome (Graham & Wiener, 1997)
4) Risk is a measure of the probability and severity of adverse effects (Lowrance, 1976)
5) Risk is the combination of probability and extent of consequences (Ale, 2002)
6) Risk is equal to the triplet (s_i, p_i, c_i), where s_i is the *i*th scenario, p_i is the probability of that scenario, and c_i is the consequence of the *i*th scenario, i=1, 2, 3... ,N. (Kaplan S. , 1991) (Kaplan & Garrick, 1981)
7) Risk is equal to the two-dimensional combination of events/consequences and associated uncertainties (Aven, 2009; 2008; 2007)
8) Risk refers to uncertainty of outcome, of actions and events (SU, 2002)
9) Risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain (Rosa, 2003; 1998)
10) Risk is an uncertain consequence of an event or an activity with respect to something that human's value (IRGC, 2005)

The above-mentioned definitions of risk may be grouped into two main categories (Aven and Renn, 2010): (1) risk stated as probabilities and expected values (1-6), and (2) risk stated as events/consequences and uncertainties (7-10). Aven (2010) argues that probabilities per se are imperfect tools for expressing the uncertainties since probabilities are conditioned on a number of assumptions. Assigned probabilities are subject to background knowledge and the strength dimension of it, which can camouflage factors effecting the risk (Aven & Krohn, 2014).

The literature research regarding to the safety of operations, the following conclusion can be done: traditional maritime industry is improving the safety while the offshore oil and gas is reducing the risk. As stated earlier the safety and risk definitions can be used as antonym but it is justified to use the term risk which scopes more thoroughly the risk elements i.e. combination of events / consequences, and associated uncertainty.

To make sense from the rather abstract concept of risk Aven (2008) proposes that risk picture should be defined as combination of events, their consequences and related uncertainty (A,C,U) since Risk (U) is about the uncertainty of future Events or Activities (A) and their Consequences (C) (note that consequences can be both negative and positive). Furthermore risk is described by expectations and predictions of the consequences (C´) together with uncertainty (Q), conditional on our background knowledge (K), hence risk description becomes (C',Q,K). Uncertainty (Q) measure represents the subjective probability conditional to the background knowledge (P|K).

Finally Besnard & Hollnagel (2014) argues that 'safety' should be seen as process, not as a system property i.e. safety is something that organization *does* instead of something that it *has.* Safety can be seen dynamic the same way as any process is seen in resilience engineering meaning that it varies continuously in response to and anticipation of changes in operational conditions. In practice, the human component takes less risk when the system is operated in poor weather conditions and uses more energy on being vigilant while monitoring the system. On the other side good weather conditions might cause the operator to take more "laid-back" approach to the system monitoring trusting the automation to manage the situation. Safety focuses on what goes wrong, while Besnard & Hollnagel (2014) argues that the emphasis should be on what goes right. The preoccupation of what goes wrong fails to recognize that the operators are doing hundreds of things right in varying conditions i.e. the sole purpose of safety is to ensure that things go right.

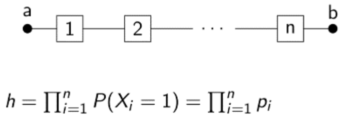
3.4.4 Reliability and Redundancy

Reliability can be defined as a "characteristic of the ability of a component or a system to perform a specific function" (Rausand & Høyland, 2004). According to Hollnagel (1993) the reliability depends on the "lack of unwanted, unanticipated, and unexplainable variance in performance". Mathematically reliability function R(t) is defined as the probability of a system to be at operative state during a specific period of time i.e. reliability function R(t)= 1 - distribution function F(t). The reliability function R(t) is also called the survivor function.

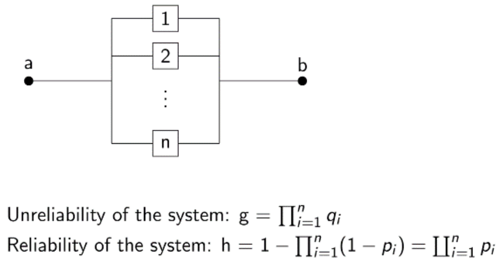
$$F(t) = \Pr(T \leq t) = \int_0^t f(u)du \ , for\ t > 0$$

$$R(t) = 1 - \mathrm{F(t)} = 1 - \int_0^t f(u)du = \int_t^\infty f(u)du$$

The concept of reliability was first introduced during the World War I. Used for comparing the operational safety of airplanes with various engine combinations from one to four engines in connection with accidents per hour of flight time. Walter Shewhart, Harold F. Dodge, and Harry G. Romig was the pioneers for proposing the theoretical basis for utilizing statistical methods in quality control at the beginning of the 1930s. During the World War II Germany was developing V-1 missile which failed to function as intended. A mathematician Robert Lusser analysed the missile system and derived quickly the "product probability law of series components" (Aven T. , 1992). This theorem concerns a system to be functional if all the components are functioning i.e. the reliability of such system is equal to the product of the reliabilities of the system. This lead to the insight of reliability and redundancy. Hence the basic form of system structures are (1) *series* where system works only if and only if all components in the system functions, and (2) *parallel* systems which is functioning if and only at least one component is functioning.

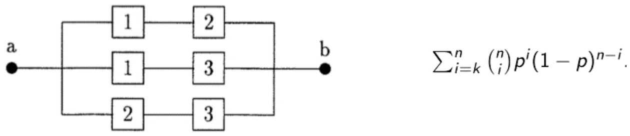


9 Series Structure



10 Parallel Structure

Furthermore a part of DP system reliability block diagram can be constructed with so called *k-out-of-n* structure where system is functioning if and only at least *k* out of *n* components are functioning. As an example DP class 2 vessel would keep position if and when 2-out-of-3 position reference system (PRSs) would be functioning.



11 K-out-of-N structure

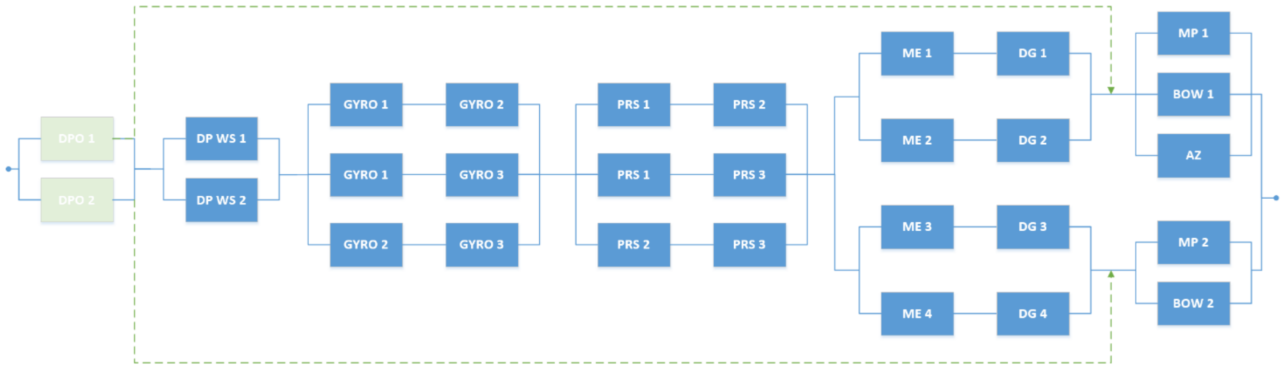
Let us presume that component 1 is DGPS I, component 2 is DGPS II, and component 3 is CyScan assuming that the components are independent and reliabilities are (p_1=p_2=p_3) = 0.9 we can calculate a reliability of the system (h) is thereof 0.972 (hence $\sum_{i=1}^{n} X_i$ has a binomial distribution with parameters *n* and *p* under the given assumption). In case of independent components where $p_1 = p_2 = 0.9$ and $p_3 = 0.8$ the reliability of the system (h) is 0.954. The use of k-out-of-n systems in DP follows the principles of triple-mode redundancy (TMR). The triple-mode redundancy is a fault-tolerant form of N-modular redundancy, where three systems perform a process, and the result is processed by a majority-voting system to produce a single output i.e. position of the vessel (Mili et al., 2014). If any one of the three systems fails, the other two systems are still considered to provide high quality position data, hence position is not lost and the operator takes counteractions to retrieve from the degraded to normal system status.

$$h(p) = \binom{3}{2} p^2 q + \binom{3}{3} p^3 q^0 = 0.972$$

$$h(p) = (1 - p_1)p_2 p_3 + p_1(1 - p_2)p_3 + p_1 p_2 (1 - p_3) + p_1 p_2 p_3 = 0.954$$

By using the reliability block diagram one can estimate the systems total reliability and availability. It is an important analysis to be considered since it reveals the importance of the human component and its contribution to the total safety of the system. The analysis gives a coarse estimate since there is no available data to assign the probability of the failure of the “human component”.

A typical DP Class 2 vessel can be modelled by help of reliability block diagram as:



12 Reliability Block Diagram DP 2

The reliability block diagram presented above reflects a hypothetical offshore vessel with diesel-electric power generation and redundancy as required for Class 2 certification. The blocks are components or elements forming subsystem in series and parallel structure, as well as in *k-out-of-n* structure. *K-out-of-n* structure can be found throughout the subsystems since DP Class 2 as defined by IMO guidelines "loss of position is not to occur in the event of a single fault in any active component or system" (IMO, 1994). Notice that IMO uses the term system from set of components that the current reliability analysis considers as subsystems. From left to right: the first subsystem is the DPOs who are overseeing the dynamic performance of the system, followed by DP workstations and computers. The DP controllers gathers information from heading reference systems (gyros) to control heading (yaw) and from positioning reference systems to determine the vessels position (surge and sway) in order to be able to apply active thrust to maintain the operators predetermined set point. The main engines produce electric power which is supplied to the electric motors connected to the propulsion units (main propellers, bow thrusters, and azimuth thruster), in the diagram above the power generation is divided further into two separate structures on the switch board i.e. the bus bar is open for improved redundancy; a common practice onboard OSV's. The light green cut lines reflects the operator's availability to intervene in a case of system malfunction directly into the propulsion units for positioning the vessel or unit manually given that the system is able to produce electricity. As the diagram show DP system is an example of an automatic closed-loop control function where the operator has been designed "out of the loop" for reducing the overall risk of the system failure.

The subsystems can be further split into sub-subsystems, for instance: power system consists of engines, generators, fuel feeding, drives, power distribution, power management system etc. With this example I wanted to stress the fact that these systems have complex interactions; components are packed on top of another in overlapping and thick networks. These networks create environments where complex interactions between components and subcomponents occur, and it necessitate significant efforts for teamwork, cooperation, and co-dependency to ensure safe high reliability operations (Roberts & Gargano, 1990).

Note that the numbers used on the reliability analysis example does not reflect the reality by any means. These exceedingly poor numbers are used to demonstrate that any system appearances reliable on drawing board. In genuine reliability analysis the system appears extremely reliable (MTBF –hrs in magnitude of 10'000 to 200'000 per component), unsinkable could some declare by interpreting the reliability analysis, nevertheless what operators are experiencing on the field.

3.4.5 Probability

The application of probability has paramount function in the reliability engineering and system safety analysis albeit there is only a few papers trying to explain what probabilities introduced mean and how they should be understood in practice (Aven T. , 2013). The concept of probability has three common interpretations: (1) classical probabilities, (2) frequentist probability (also referred to as 'physical' or 'objective'), and (3) subjective probability (also referred to as 'evidential' or 'Bayesian').

The classical interpretation applies in situation with infinite number of outcomes equally likely to occur i.e. P(A) = number of outcomes resulting A / total number of outcomes. This interpretation is problematic since it applies only if there is no evidence that some outcome is more likely than the other i.e. "the principle of indifference" (Aven T. , 2013). This interpretation is interesting from the theoretical point of view but not applicable in real-life situations.

The frequentist probability of an event 'A' is defined as "the fraction of times the event 'A' occurs if the situation were repeated an infinite number of times" (Aven T. , 2008) i.e. reflecting variations in a phenome. Thus the frequentist probability uses "mind-constructed" quantities the concept is founded on the law of large number of frequencies under certain preassigned conditions. Neither the frequentist probability interpretation is suitable in practical use due to the dynamic nature of maritime operations i.e. there is no infinite 'similar' nor 'randomness' properties in the scenarios offshore. This approach is useable and used to model the reliability of the technology component of the OSV's but fails to scope with real life scenarios and interactions of the multi-layered socio-technical system being "unique" at any given time. For the very same reason the reliability of the OSV is seen in very favouring light when the analysis is based on the belief that human component is 'out-of-the-loop' and all technical components are in the function state without interference from any system levels.

The subjectivist interpretation is based on degrees of belief for the outcome of an event 'A' (Aven T. , 2013). This approach is justified to be used in the context of safety in marine operations since there is not only a lack of sufficient data for applying the frequentist interpretation but also the dynamic ever changing nature of work makes it impossible. In practice the subjective probability is determined by group of industry experts assigning probabilities or likelihood for the various outcomes of an event based on their subjective judgement. Lindley (2000) proposes the concept of subjective probabilities to be related to one's uncertainty standard. If a person assign a probability of P(A|K)= 0.1 for an event 'A', he compares his uncertainty or degree of belief of 'A' occurring with drawing a specific ball from an urn containing 10 balls. The subjective probability is always conditional to our background knowledge (K). Furthermore it is important to realize that the background knowledge (K) is also conditional to the strength of knowledge, and the "true" risk can deviate vastly from risk perception due to the value judgement domain of an individual.

In order to be able to describe and communicate the risk between operators it is proposed that they adapt the subjectivist interpretation to describe the risk. In practice, it means that when operator states that his belief is that he is able to manoeuvre the vessel without the risk of collision 9'999 out of 10'000 attempts in prevailing conditions, or if he would pick up a ball from the urn the likelihood of getting black one is 1/10'000, and 9'999/10'000 to get a white one i.e. success. When the condition or setup is changed (e.g. poor weather, visibility, some technical malfunction), the operator is capable of taking given background knowledge into consideration, and conclude that taking these risk influencing factors into consideration he could manage to do the same manoeuvre 999 out of 1'000 attempts. By help of this rationalizing the operators can describe and communicate the risk, eventually taking the decision of whether, or not, the risk level in acceptable.

3.4.6 Active Error vs. Latent Error

Active Errors, or unsafe acts (observable, direct, and responsive) are errors that has almost instantly observable effects associated with direct, responsive operations, such as those performed by driller, dynamic positioning operator, or engine crew etc. A DPO who is manipulating the, or making an intervention to the automation system is subject to active error i.e. DP-operator on a pipe lay vessels adjusts the tension set point to 100 metric tons instead of 10 metric tons causing the pipe to rupture (e.g. pushing an incorrect button). Other typical active errors onboard OSV's could be opening a wrong valve from the automation system, or forgetting that you have had a system running and forget to switch it off before some observable happens (e.g. pumping ballast, loading, discharging, cargo transfer between tanks etc.)

Latent Errors, or unsafe conditions (non-observable, hidden, time and synergy effects) are undetected errors or conditions that concretizes upon demand i.e. they are not observed until they combine with other factors which can happen in relatively long time. Latent errors are commonly related to maintenance personnel, design and managerial person. For example, an oil leak on the main engine can be occurred because a maintenance engineer had not replaced the gaskets following routine maintenance. An error that remained undetected (latent) when the supervising engineer failed to test run the engines as required by the maintenance procedures. The failure of the one of main engines was detected when the engine was needed online. The latent condition are not limited hardware: latent conditions can have non-physical characteristics such rules and regulations that fails to scope with the operational needs or organizational weaknesses that can provoke error and degrade the defences and barriers in place i.e. poor maintenance planning, training of the crew, workplace conditions and ergonomics etc.

3.4.7 Safety Barriers

Barriers, or controls are technical, operational, and organizational elements used to protect health, safety and environment individually or collectively (PSA, 2014). Barriers are the core principle of safety serving two purposes; to prevent concrete failures, hazards, and or accidents from occurring, and to mitigate and limit the harm or consequences if an unwanted situation would occur.

Safety barriers are physical or non-physical, or a combination thereof (PSA, 2014). Physical means technical, hardware, or software, while non-physical refers to human, organizational, operational, management, procedural, administrative, and behavioural factors. Furthermore several attributes are necessary to include in order to characterize the performance of the barriers; functionality/effectiveness, reliability/availability, response time, robustness (Sklet, 2006).

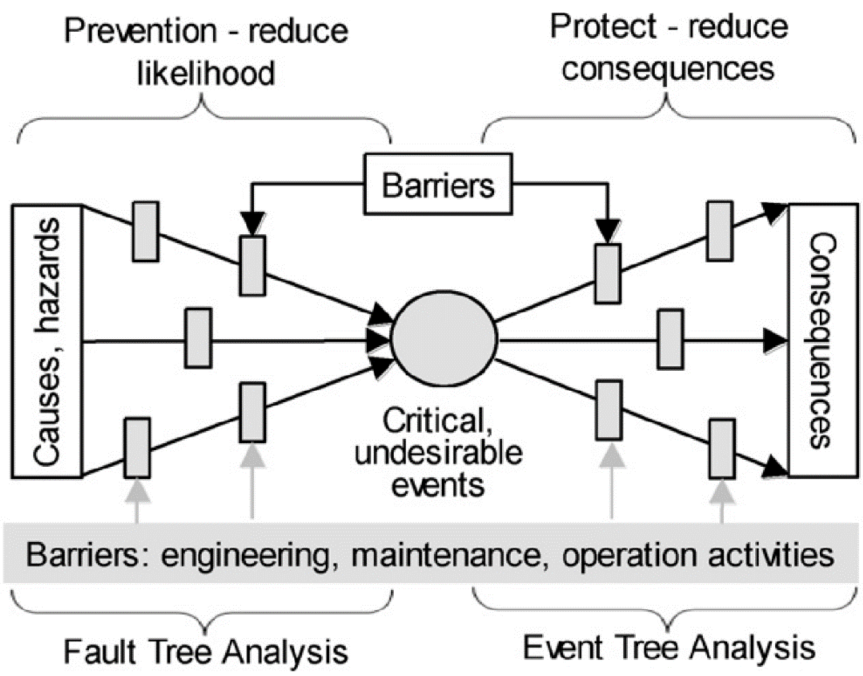
The concept of defence-in-depth proposed by Perrow (1999) is based on barrier principle, the barriers i.e. layers of cheese compensate various failure sources. Within the concept of Human Technology Organization safety barriers are defined as "any operational, organizational, or technical solution or system that minimize the probability of events to occur, and limit the consequences of such events" (Bento, 2003).

Function of a barrier is to arrest the accident from developing further to the next event i.e. the chain reaction nor the critical event is actualized, or to mitigate the consequences of the event. The identification and categorizing of the functions are based on the defensive function they are designed to serve, according to Chen et al. (2008) falling into three types: (1) prevention (reduce the likelihood of a hazardous event), (2) control (limit the magnitude and/or duration of a failure/hazard/accident, and to prevent the escalation), and (3) mitigation (reduce the consequences). Chen et al. (2008) identified also three barrier functions in their study of the safety of Dynamic Positioning operations on mobile offshore drilling units (MODU): (1) to prevent loss of position, (2) to arrest vessel movement, and (3) to prevent loss of well integrity.

The operators are dealing with a great amount of barriers in their everyday operations. Functional barrier systems serving the purpose of preventing accident from happening are e.g. alarms and work station interfaces. Symbolic barriers are rules & regulations, procedures, while incorporeal barrier system is the safety culture onboard the asset and in the organization. It is difficult to improve something you are not aware of, hence understanding the concept of barrier system is vital for risk conceptualizing. A bowtie model is suitable graphical way of present the concept and understand the operational safety modelling.

3.4.8 Bowtie model

Bowtie model provides an illustrative method for communicating how accidents may occur in systems. The bowtie is a simple causal modelling of the risk. Left side of the bowtie represents the causes, hazards, and threats. The right hand side represent the various scenarios that can develop from the undesirable event, hence resulting consequences. Bowtie combines the concepts of fault and event trees. Fault tree is a logical diagram that shows the correlation between a specific unwanted event (e.g. failure of barrier element, or initiating event) and root causes leading up to this event. Event tree is a "forward-thinking" process, used to study the consequences of the initiating event i.e. expectation and predictions of what can happen based on background knowledge subject to uncertainties (Aven T. , 2010).



13 Bowtie Concept by Mullai & Paulsson (2011)

The starting point is that the operator identifies scenarios that can lead to unwanted consequences. The fault tree analysis (left side) can be considered as cause analysis i.e. initiating state, while on the event tree (right side) is the recovery analysis i.e. recovery stage. Let us imagine a scenario where supply vessel is working alongside a platform, and in addition to the deck cargo operation a diesel hose is connected and marine gas oil transferred. Consider loss of position reference systems as undesirable event. The causes can be e.g. poor PRS data, malfunction of the system etc., and the consequences e.g. loss of position, collision, oil spill etc. Barriers for such undesirable event are training of the operators, procedures, redundancy to mention a few. If the loss of position reference systems would occur, the consequence mitigation barriers could be working on the drift-off side, training so that the operators can handle the system manually, emergency disconnection of the fuel hose. The causes, preventive and mitigating barriers, and the consequences in this example are not extensive by any means, but used to present the idea how the use of bowtie modelling can assist the DPO’s in finding potential control and recovery actions, and formulating a decision strategy for safer operations.

Despite the fact that bowtie diagram is modelling accident causation as a linear process, the advantage is that it is simple and easily understandable tool to communicate operational safety. To understand the interrelationships of the different components in various layers, tools such as functional resonance accident model (FRAM) proposed by Hollnagel should be considered. In the operational safety modelling, done by the operators on duty, FRAM would be too complicated and difficult to use, hence quantitative risk analysis based on the use of bowtie is recommended.

Furthermore we can present the concept of risk influencing factors (RIF) through barrier theory and bowtie model. RIFs are also called barrier performance influencing factors (Vinnem J.-E. , 2014a) i.e. factors that influences the performance of the barrier system. Consider the DPO’s operating the work system alongside a production platform. If the system status is reduced, hence position lost, the factors that will influence the ability of the DPO’s to stabilize the system are e.g. experience, training, manoeuvring skills, situation awareness, procedures in emergency situation etc. Applying the defence-in-depth concept proposed by Reason (1997) into the bowtie model we can conclude that there is a need for both physical and non-physical barriers in multiple layers in the form of technology, organization, and human to ensure acceptable safety level. Note that defence-in-depth is not limited to a number of layers i.e. primary barriers, but also secondary barriers meaning that they can protect one another e.g. two DPO’s on bridge while vessel on DP serving the same purpose, or multiple position reference system as a barrier for loss of position etc.

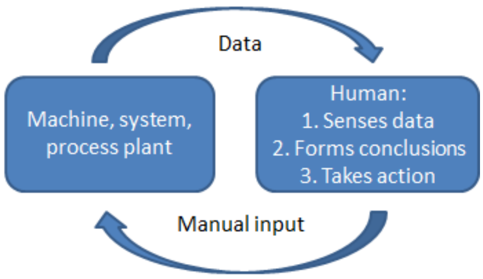
4. Human, Technology & Organization Components

This chapter provides rationale behind the human, technical and organizational factors and how they are linked together creating the socio-technical work system.

The human element reflects the performance of the personnel involved in an operation. There is naturally large individual variance between humans, but many common factors can also be found. The operational environment influences the level of human performance in many ways. Organizations do the initial selection of personnel and set the compensations and reward system, regulatory environment addresses training and qualifications, and the physical environment working conditions.

The operations are run by humans, the human performance affects all functions in the system. Depending on the source and what counts as human error, the contribution of human error to accidents vary between about 30% and 96% (Kristiansen, 2013; Oltedal, 2012). The key point is that the human flexibility compensates for the instability of work system, since we are unable to engineer systems with low variance processes the human component has to navigate the system through rough seas.

A Dynamic Positioning system is an example of an automatic Closed-loop control function i.e. computer-controlled system to fulfill a specific task, namely to maintain units position and heading by means of using its own propellers and thrusters. Operators, or the human component are required to monitor the dynamic performance of the system and make adjustments (manual input), or intervene in the event of malfunction.



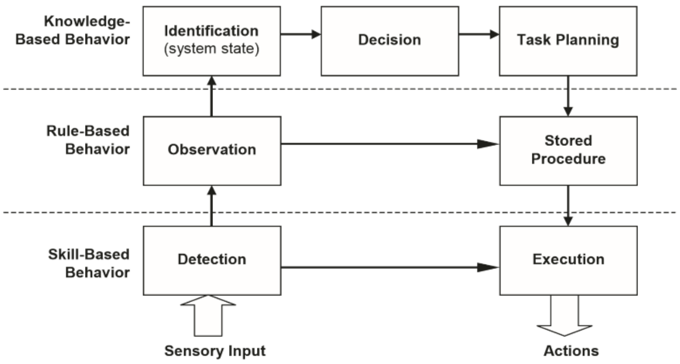
14 Human Control Loop by Wong (2002)

The DP system collects a vast amount of information from position reference sensors, combined with wind sensors, motion sensors and gyro compasses, providing information to the DP computer which analyzes the magnitude and direction of environmental forces affecting unit's position (Bray, 2008). In addition to position related information the system needs to analyze power management system (PMS) and propulsion system. From DP system description it is easy to make the conclusions that the amount of information would cause information overload resulting the operator to become confused. A good design (logical order, symmetry) of the control system displays with relevant information that is grouped and segregated accordingly is vital. In the DP system it is common to have own screen for a specific group of subsystem (PosPlot, PRS, PMS, thrust etc.) which makes the judgment of error source easier and faster to adapt counter measures. The system can also be adjusted to operators own configurations which improves the possibility of correct actions in a moment of panic or loss of concentration. In the world of dynamic positioning abnormal situations will occur which may need abnormal actions from the operators.

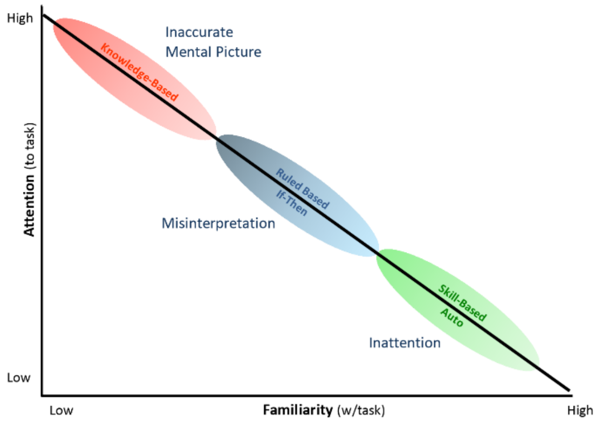
We can summarize the interconnected nature of "human control loop" proposed by Wong (2002) by help of DP system. The DP system is undertaking a dynamic process (capability of adapting upon changing parameters) and data is provided to the operator. Operator can do the analyzing of the prevailing situation and form conclusions. Based on his or her conclusions / expert judgments a manual input can be given to the system. The system will give feedback to show the effect of control actions and a new judgment can be done.

4.1.1 Types of Human Behaviour

The human or operator is an interactive component of a work system balancing with socio-technical system and its elements (term technical refers to the structure and a broader sense of technicalities; not necessarily imply material technology). In order to design an effective work system we have to consider the complexity of system and take efforts to humanize it for the operator's. Automation and "joint optimization" is intended to reduce operator workload and fatigue. It improves safety and it facilitates faster and more accurate control of multiple simultaneous tasks. Nevertheless it can also lead to problems in the interaction between operators and automated systems i.e. reduced operator system awareness, increased workload in monitoring, and reduced manual skills (Chiuhsiang, Tzu-Chung & Chih-Wei, 2010). These interaction problems can be addressed by help of the Skill, Rule, and Knowledge (SRK) model proposed by Rasmussen (1983). The SRK model is a classification that can be used to characterize various categories of human behavior and to distinguish among them (Rasmussen, 1982). Three categories of human behavior can be identified using SRK framework.



15 SRK-based behaviour by Rasmussen (1981)



16 Relation between Attention and Familiarity (DOE, 2012)

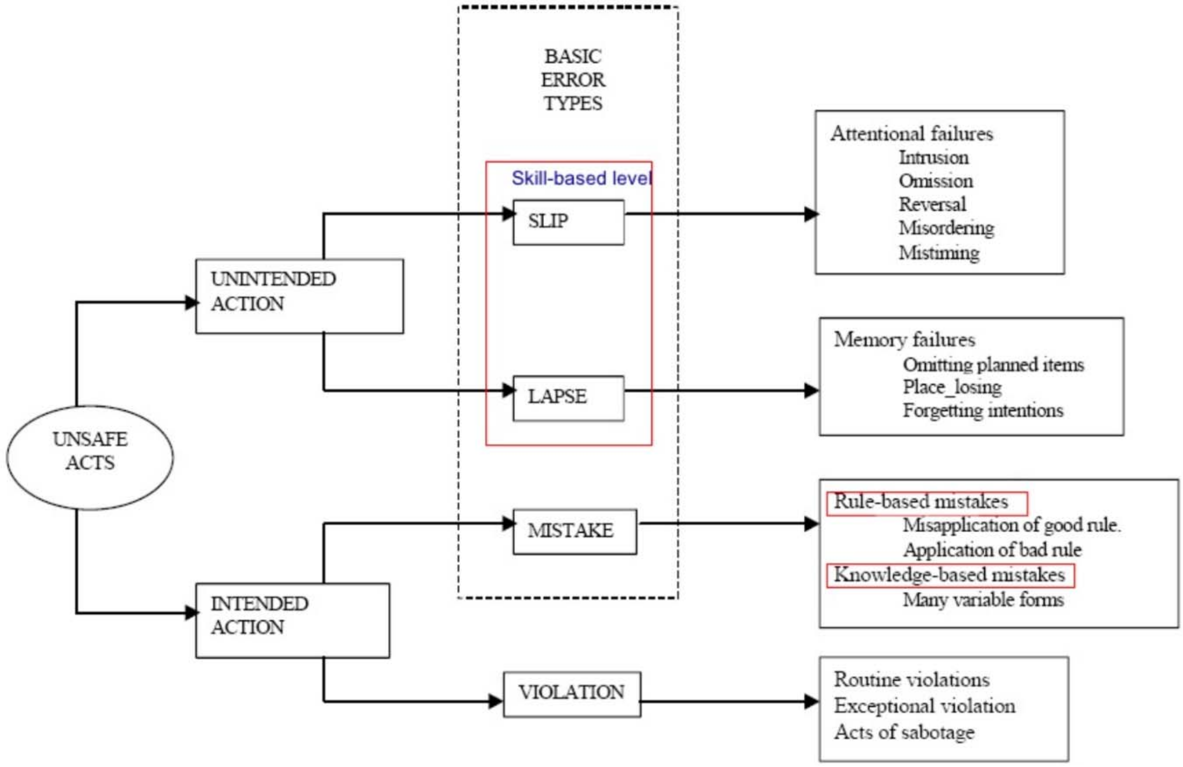
At *Skill-based level*, human performance is governed by stored patterns of pre-programmed instructions i.e. very familiar situations in which there is little conscious monitoring. When the OSV is running normally the operation mode is familiar to the operator and low amount of attention is given to the system monitoring e.g. information provided by the integrated automation system (DP, Radars, ECDIS etc.) is processed with little or no allocation of attention resources i.e. automatic processing. On skill-based the level the operator is working "without thought", meaning that the extensive amount of practice to perform the task or job by functioning effectively using preprogrammed sequences of behavior not requiring conscious control. To control the safety and efficiency level in skill-based level can be done by help of simulator training, theoretical courses, and practical "on duty" evaluations by other crew. Rasmussen & Vicente (1990) stresses the fact that safety and efficiency is improved by implementing signals into the display interface to describe the appropriate action for example. The use of checklist is on good measure since when the operations and actions get too familiar there is the tendency of overlooking the basic steps. The root cause for skill-based performance is inattention: execution errors, action slips and lapses in attention and or concentration.

At *Rule-based level*, human performance is governed by stored rules regarding diagnosis and remedial action. The operators switches from Skill- to Rule-Based performance when he or she notices a need to modify individual's pre-programmed behavior (individual apply memorized or written rules) due to some operational change (alarm e.g.) in the situation. Typically the operator evaluates the situation and applies appropriate rule as a result of conscious rationalization to verify the quality of decision and or solution. For example the stimulus from DP (Warning, or Alarm message etc.) results an automatic reaction where the operator is matching signs and symptoms of the problem to the stored knowledge structure and or written manual. Since the goal is to improve operators interpretation of the work situation the most effective way is to support the individual's professional growth by training i.e. simulation of possible undesired scenarios. By expanding the operators comfort zone, action which individual has done in Rule-based level can be moved to Skill-based behavior. Root cause for Rule-based error is misinterpretation since the operators was not capable of understanding or detect the condition of the system and due to this fails to add correct response. Investigation reports indicates that in many accident the operators have failed to apply correct procedure, or applied wrong response to the situation, it is also possible that you apply correct sequence of procedures to wrong situation (Reason J. , 1990).

At *Knowledge-based level*, human performance is governed by participation in novel ("Black Swan") situations in which actions must be planned using conscious analytical processes and stored knowledge (DOE, 2012). Knowledge-based behavior could in my opinion be called "lack of knowledge" behavior since the operator has inaccurate picture of the prevailing condition, and attention to task is high since familiarity is low, as a result individual is sliding into panic zone and applying incorrect counter measures. Covey divides human cognition into three zones comfort, stretching, and panic zone (Covey, 1990). Colgan Air regional flight 3407 accident provides a good example of operators who make unthinkable and illogical decision when in panic zone and under pressure. Training and experience in terms learning by doing is the most effective way of reducing risk but the problem with complicated socio-technical systems are that it is impossible to prepare for everything, neither can we recognize every possible scenario. When the operators are responding to an unfamiliar situation they slides inevitable into Knowledge-based mode (no skill, no rule is recognizable to the individual). Operators must rely to the prior understanding and knowledge, conclude perceptions of prevailing circumstances and act, a decision is a decision whether it's good or bad, and no decision or "freezing" is unacceptable i.e. rational reasoning and quick decision-making skills are the "top tools" of any individual working in high reliability systems. When to operator is in Knowledge-based situation it is important that the system is designed in a way that it helps the operator to constrain the problem by providing only high-level information e.g. if your main consideration is to ensure that the vessel in colliding with an platform, alarms from sub-systems not contributing to these actions just rises the level of stress and anxious.

4.1.2 Types of Human Failure

The Skill, Rule, and Knowledge (SRK) model proposed by Rasmussen (1983) describes the human behavior i.e. cognition, but in addition we have to determine the types of human failures which behavior can lead to. Generic Error Modelling System (GEMS) based on the work by Reason and Rasmussen incorporates how the human component make use of information and how performance is changing between levels of attention leading to unsafe acts. From the model we can determine that human failures can be divided into 'errors' and 'violations' deriving from unintended or intended actions.



17 Generic Error Modelling System (GEMS) by Reason (1990)

Errors can be categorized into 'slips', 'lapses', and 'mistakes', or 'cognitive errors' (skill-, rule-, knowledge-based). A slip is where a process and the implementation of it are familiar to the operator but the result of action is error. For example, operator opening a remotely operated valve 'A' on the units ballast system, however valve 'B' is opened because it has identical symbol on the screen and it is placed on the place where the operator expected to find valve 'A'. This case is a typical example of slip or skill-based cognition error i.e. the operator simply overreaches. A lapse is where attention or memory fails i.e. failing to do intended action due to forgotten or missed a step in a sequence of actions through momentary distraction. For example, the operator failing to lift the retractable azimuth thruster due to forgetting the point on checklist, or was distracted due to communicating on the radio. A mistake is always intended actions based on rule- or knowledge-based cognition. A rule-based mistake is an unsafe act where rule is incorrectly applied to the prevailing scenario, or a bad rule is applied to a recognized scenario. A knowledge-based mistake has many variable forms, to understand the unsafe acts based on knowledge-based cognition the human information processing and situation awareness has to be applied to the analysis. There is a great number of incident and accident reports where the attending vessel has collided with platform since the operator has not been able to recognize that the vessel was still on autopilot mode, whilst it was believed to be on manual and manoeuvred by the operator. Not being able to recognize that the autopilot was still engaged can be categorized as knowledge-based mistake. Furthermore knowledge, experience, and mental model are prone to biases of the prevailing situation combined with uncertainties and unfamiliarity. These factors combined with the fact that decision making time is limited we make assumptions, “quick fix” solutions, believe that the first diagnosis is correct, and reject the information not supporting our first judgement. The irony of knowledge-based mistakes are that the oil companies threat then as violations and the system receives a new set of procedures to follow, to protect the system that would work without unreliable human component.

Violations are different from an error. Violations or non-compliance is intended action by the operator knowing that it is incorrect, or against the procedures and rules & regulations. Energy Institute (2015) has recognized a total of six types of non-compliances: (1) unintentional e.g. breaking a rule because it has been misunderstood or misinterpreted; (2) situational i.e. it is not possible to get the job done by following the rules strictly; (3) exceptional e.g. deviation from rules under unusual circumstances; (4) organizational benefit e.g. breaking the rules for the (real or assumed) benefit of the company; (5) personal benefit e.g. there is some reward for the individual, it is less effort, faster or more exciting to break the rules; and (6) reckless e.g. breaking rules despite known dangers to self and others. (Energy Institute, 2015).

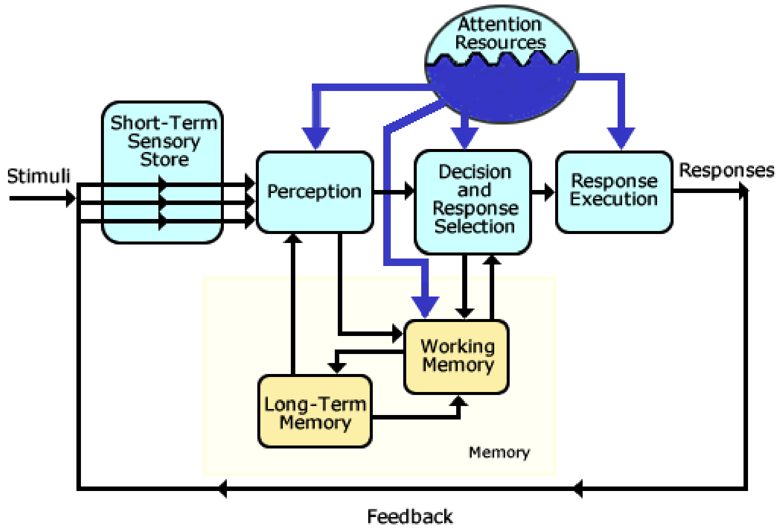
By definition errors are unintentional. Violations are intentional, but what should be understood is that non-compliances are a result of an attempt to solve a problem, not to cause them. Human failures have s strong correlation with organizational culture (see 4.3.2). It is management responsibility to understand the human behavior and promote remedies that ensures that unsafe acts are handled.

4.1.3 Information Processing

In addition to Rasmussen’s SRK step-ladder model, which was originally designed for process plant operators, Wickens (1992) has developed a ‘human information processing’ model for aviation pilots. The model proposed by Wickens is qualitative and it provides the framework for examining the critical stages of information processing involved in human performance. Each stage of processing executes conversion of the data and demands some time for its operation (Wickens, 1992). These two models form the foundations for understanding the human performance in marine operations with DP application.

The components and stages of information processing can be a useful tool for finding the potential limitations in performance. The components from left to right: Sensory Processing, Short-Term Sensory Store, Perceptual Encoding, Decision Making, Response Execution, Feedback and Information Flow, and Attention.

Sensory Processing means the operators capability of collecting data through visual and auditory senses i.e. eyes and ears, and the proprioceptive or kinesthetic senses of human body. The human brain collects data through these senses and each “sensory” has its own pros and cons on collecting information in terms of quality and quantity. For example, in engine room there is a certain volume and frequency, and additional alarm light flashing upon engine alarm due to the noisy work location whereas engine control room (ECR) is equipped with totally different usually low “comfortable” (should not increase the stress level of the operator) sound combined with text on the screen specifying the alarm type and source.



18 Human Information Processing model by Wickens (1992)

Short-Term Sensory Store (STSS) is human's nerve system which stimulates from the stimulus or irritant. According to Wickens (1992) the STSS makes it possible to store environmental information to be preserved temporarily and deal with later when attention is diverted elsewhere. STSS can be characterized according to three general properties: it is pre-attentive (no conscious accumulation of information from the environment), it is veridical (preserving the physical details of the stimulus e.g. conscious of alarm light or sound), it is rapidly decaying (for audible and visual observation some seconds, Wickens give an illustrative example of Polaroid picture in reverse process)

Perceptual Encoding is the information processing in higher nervous system while STSS preserved the details only briefly and without attention. In this level the brain can direct to stimulus to previously learned and stored information in the brain. There is various types of stimulus and combination of them which can be categorized to numbers of levels of complexity. Consider a dynamic positioning operator (DPO) who is navigating the vessel by help of radar. The monitor is showing radar targets without automatic identification system (AIS) information which leads to greater complexity; the operator has to recognize, identify and categorize the echo or possibly false echo (speed, size, course, lantern pattern etc.) instead of just perceptual categorization: is it a ship "yes" or "no" (AIS shows a unique symbol on ECDIS). The complexity of tasks is affected by whether one physical dimension is the basis of perceptual categorization of the stimulus or whether instead several multidimensions are to be considered. Like in the radar example where the echo is "multidimensional consideration" to typify the pattern i.e. the navigator associates a unique combination of e.g. speed, size, shape etc. from various screen and displays (dimensions), and visual observations. The final aspect of perception is judgment of continuous levels that have direct implications for action instead of categorizing into discrete states i.e. consider maneuvering a ship in port.

Decision Making is done once a stimulus has been perceptually categorized. The operator makes decision on "what to do" depending on the time available the decision might be thoughtful one or rapid nearly automatic. This is also the components where the individual can attempt to store the information and action to permanently in the long-term memory i.e. learn it (skill).

Response Execution is the products of decision i.e. consider that DPO has made a decision to steer the vessel from rig's port to starboard side by help of joystick control it is necessary for him to use muscle commands to carry out the action (press a button, adding thrust by help of moving joystick etc.).

Feedback and Information Flow is monitoring the consequences of actions i.e. DPO applies 30 % of thrust from the joystick and he is observing that the vessel is responding adequately. The operator and the vessel and its system are forming a closed-loop feedback structure. DPO is receiving visual feedback (vessel is moving relatively to the platform), auditory (by the increased demand to the engines), and tactile (vessel might be vibrating due to high forces acting). Wickens (1992) highlights the fact that information flow does not have to start from stimulus i.e. decision to maneuver the vessel to other side of the rig might be triggered by "thoughts" in working memory from earlier experienced e.g. optimizing the vessel position for approaching bad weather etc.

Processing following STSS requires attention resources to function efficiently. The human brain has information sources which process the stimulus and allocates resources to processes i.e. consider that you're once more maneuvering the vessel, you're well-skilled and vessel handling in a port feels comfortable and you're not using more than 25 % of your working capacity. Now consider that the port is packed with vessel, Northern wind is gusting at 60 to 80 knots and one of your thruster has failed to start; now resources are allocated differently and the process might even require more resources than you have, you're most likely able to do the maneuver but the performance was deteriorated (let's say that in normal conditions 1/10 000 attempts fail, while in deteriorated conditions 1 / 100). Furthermore Wickens (1992) states that stress may result from breakdowns of any of the processing components ultimately leading to human error.

4.1.4 Situation Awareness

In Dynamic Positioning mode, maintaining a situational awareness is one of the most critical features of operator's task. When the operational status changes from Normal to Degraded or directly to Emergency State fast and effective response from the DPO(s) is required. In order to respond effectively one need to be aware of the situation and apply countermeasures to retain the situation from developing to worse and restore the system status to 'Normal'. The time allowance to take counteractions is based on the "tightness" of coupling based on operational conditions.

DP system work stations along with other visual displays units on the bridge are used to share and display critical information to the operators. From the information the operators can build real-time operational picture i.e. they have situation awareness (SA). Endsley (2011) defines SA as an internalized mental model of the current operational environment and the projection of the system status in the near future. Furthermore Endsley recognizes three levels of SA: Level 1 SA, Perception of the elements in the environment; Level 2 SA, comprehension of the current situation; and Level 3 SA, projection of future status (Endsley & Jones, 2011). In order to be able to react and function in a timely and effective manner the DPO's SA have to be on higher levels i.e. from reactive to proactive approach to the dynamic operational environment.

To build and sustain situational awareness the system operator have to have knowledge. Knowledge is subjective to human knowing, and information has to be observed and interpreted against existing store of knowledge (Nonaka & Von Krogh, 2009). Furthermore knowledge is divided into two types: explicit knowledge, and tacit knowledge. This view is supported by Kahneman (2011) who argues that human mind and mental processes i.e. explicit and tacit knowledge can be divided into two systems.

System 1 (old, intuitive, reflexive, unconscious) works based on experiences and heuristics making it biased by its nature where knowledge in tacit, while System 2 (new, intentional, reflective, conscious) processes require working memory and effort from the human (Kahneman, 2011). The theory of human mind and mental processes is comparable with the Rasmussen's SRK framework i.e. skill-based action are System 1 and rule- and knowledge based actions under System 2. The main issue is that human brain by nature tries to minimize the System 2 processes because they are slow and consumes lot of energy while System 1 processes are automated (fast and energy efficient) (Baumeister & Tierney, 2012). Thus both Baumeister and Tierney & Kahneman states that the System 2 is to monitor System 1 and stop it from making bad decisions there is a constant risk of ending up in a situation where system monitoring is solely based on System 1 mental processes and we end up in a situation where both the technology and operator are on the "automation" mode. In such case we can barely speak of SA Level 1 if at all.

4.2 Technology Component

Perrow's Normal Accident Theory labels organizations "High Risk" if they combine complexity and tight coupling, and in addition have catastrophic accident potential. In high risk organizations manager face irreconcilable structural paradoxes. To deal with tightly coupled system centralization is required, and for being able to manage the complexity delegation is needed (Bierly & Spender, 1995). Weick on the other hand analysed aircraft carriers and air traffic control systems arguing that those complex and tightly coupled systems could be managed with strong organizational culture. According to Weick (2007) the strong organizational culture which modern safety literature distinguishes as collective mindfulness provide a centralized and focused cognitive system (see 4.3.2) within which delegated and loosely coupled systems can function successfully (Bierly & Spender, 1995). 'High Risk' Organization theory became known as the principles of 'High Reliability' Organizations (HRO). Before going into detail in organization theory we have to understand what we are dealing with in terms of systems theory i.e. what is the difference between complex and linear system, and tight and loosely coupled one. Technology per se is not interesting. The interesting part is to discover the interacting variables which characterizes accidents (coupling and interactions). The 'DP operation pyramid' proposed by Verhoeven at al. (2004) is not complete, but it is the most comprehensive visualization of the complexity and interactive nature of the work system i.e. relationships between components and subsystems in multiple layers (see picture 2, DP Operations Pyramide). In practice, it means that small input can produce large output e.g. pressing wrong button can cause the whole system to collapse. Complexity and non-linearity guarantees resonance, due to amplification and multiplication of the small beginnings. This phenomena is known, and widely studied in chaos theory, commonly known as the butterfly effect. For the very same reason barriers are added in all system levels.

4.2.1 Complex and Linear Systems

In order to be able to address problems and phenomena's related to the work system accident and incident events specific to complex organizations, it is vital to distinguish and define the terms complexity and coupling. Perrow (1999) defines accident as unintentional damage to people or substances that affects the functions of the system, as well as a number of factors like procedures, rules & regulations, communication patterns, and legitimacy. Perrow (1999) proposes four levels of system analyses and disruption on levels three and four would be called an accident, and first and second level disruptions incidents. The industrial world is dependent on systems with baffling interactions. Systems have grown in size and in the number of purposes they serve which in the other hand increases the vulnerability to unavoidable system accidents. This argument rests on three principles stated by Perrow (1999): (1) individuals make mistakes, (2) big accidents escalate from small beginnings, and (3) failures are related to organizations more than technology.

The size and interactions makes the system complex. Existence of many components is no great trouble itself if the interactions are obvious and people operating the systems get obvious outcomes and results i.e. the system can be enormous in size and highly sophisticated, still linear (e.g. automobile assembly line). When it is complex with parts, units and subsystems serving multiple functions involving complex interactions (like offshore drilling rig) the combinations can rise outcomes that are merely impossible to foresee (Dekker S. , 2011).

Perrow (1999) defines the properties of linear interactions as “expected and familiar production or maintenance sequence, and those that are quite visible even if unplanned” (direct – known in advance – familiar – pre-defined – predictable – visible) and complex interactions as “unfamiliar sequences, or unplanned and unexpected sequences, and either not visible or not immediately comprehensible” (indirect – not well known in advance – unfamiliar – impossible to predefine – unpredictable – hidden). Furthermore Perrow (1999) suggest that terms complex shall read “interactions in an unexpected sequence” and linear “interactions in an expected sequence”. The differences between complex and linear systems by Perrow (1999):

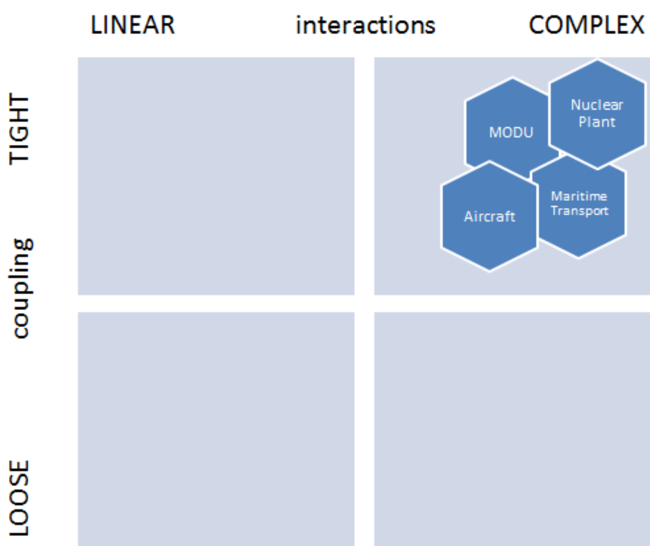
Complex vs. Linear Systems	
Complex Systems	**Linear Systems**
Tight spacing of equipment	Equipment spread out
Proximate production steps	Segregated production steps
Many common-mode connections of components not in production sequence	Common-mode connections limited to power supply and environment
Limited isolation of failed components	Easy isolation of failed components
Personnel specialization limits awareness of interdependencies	Less personnel specialization
Limited substitution of supplies and materials	Extensive substitution of supplies and materials
Unfamiliar or unintended feedback loops	Few unfamiliar or unintended feedback loops
Many control parameters with potential interactions	Control parameters few, direct, and segregated
Indirect or inferential information sources	Direct, on-line information sources
Limited understanding of some process (associated with transformation processes}	Extensive understanding of all processes (typically fabrication or assembly processes)

Interactions on high risk systems whether the systems design are complex or linear, shall be evaluated on the design and operating phase. If we ably the four levels of system analysis proposed by Perrow (1999) into offshore vessel example a part will be the first level: say a cargo pump. A cargo pump (or propeller, valve, joystick etc.) is the smallest component of the system that can be identified in analyzing process of an accident. A collection of parts that are functionally related like for those that make up main engine is called unit which is the second level. An array of units, for example: main engine, bunker oil system, and electric generators will make up a subsystem i.e. level three. Finally level four, the ship has several subsystems for different purposes, for power generating it has commonly a layout consisting of four main engines with all utilities resulting the power management system of the vessel beyond this PMS is the environment. An offshore vessel is a high risk and complex system where components serve multiple functions and an accident can cause harm to people and environment.

Redundancy e.g. parallel systems serving the same function, has traditionally seen as solution for managing risk in systems labelled "high risk". The redundancy is added in order to prevent common mode failures, on the other hand research shows ironically that common-mode failures are the result of added system complexity introduced by redundancy. Consequently increased complexity has made it difficult to identify, and quantify causal links between a multitude of potential causal agents and specific effects that are the source of variance, hence instability of the work system (Aven & Renn, 2010). Furthermore Dekker (2011) stresses that the current trend of creating interactive complexity to work systems has resulted new kind of accidents, so called 'system accident', where the accident is a result of interactions, no single component have to be broken. By studying IMCA incident reports we can find that these "bullet-proof" systems called offshore specialized vessels equipped with six azimuth thrusters, supplied independently from three separate switchboards can trip simultaneously. No reason is found and they work without problem after reset. Five separate and independent position reference systems can be lost all together without any pre-warning, this is the new normal in offshore shipping, "good luck" for those trying to manage complexity by adding procedures.

4.2.2 Tight and Loose System

The second variable that characterizes accidents is coupling. Coupling is a term used to describe the interconnection or interactivity of two or more systems. Maritime systems, especially units engaged in offshore operations are tightly coupled (Perrow, 1999). Interactions are the joint actions among parts, units and subsystems of the system. These interactions can be tightly or loosely coupled. A tightly coupled interaction does not tolerate delay (more time-dependent processes) and have invariant sequences and negligible slack i.e. what happens in one directly affects what happens in the other like pressing the brake pedal on a car which result negative acceleration. Loosely coupled interactions on the other hand have the opposite characteristics i.e. there is slack or buffer between two items e.g. traffic situations where cars are accelerating, slowing down and changing lines.



19 Interaction/Coupling Chart by Perrow (1999)

Perrow (1999) states that "human-made catastrophes appear to have increased with industrialization as we built devices that could crash, sink, burn or explode". Furthermore Perrow argues that this is due to a phenomenon called "interactive complexity in the presence of tight coupling", these views are supported by Dekker (2011), and Hollnagel (2006). The recovery of failure is strictly coupled with the degree of coupling. Loosely coupled systems have longer time or buffer between the system failure and accident or incident while tightly coupled systems the buffers and redundancies and substitutions must be designed in advance to react in the case of failure without significant delay e.g. shear rams of drilling rig in case of blowout or when rig is out of the position. The differences between tight and loose coupled systems by Perrow (1999):

Tight and Loose Coupling Tendencies	
Tight Coupling	**Loose Coupling**
Delays in processing not possible	Processing delays possible
Invariant sequences	Order of sequences can be changed
Only one method to achieve goal	Alternative methods available
Little slack possible in supplies, equipment, personnel	Slack in resources possible
Buffers and redundancies are designed-in, deliberate	Buffers and redundancies fortuitously available
Substitutions of supplies, equipment, personnel limited and designed-in	Substitutions fortuitously available

Couplings tendency affect failures and recoveries by the degree of coupling, especially in high-risk system the effects shall be thoroughly examined. For example, tight coupling in a high-risk system is appraisal drilling which needs to have many functioning parts lined up ready to be placed into the drilling sequence in the correct order and with a minimum time delay. The process is linear in nature with no flexibility to adapt and has only one method of achieving the prescribed goal of producing a well but if we analyze the whole system around it the complexity can be revealed. The rig has to keep position and be able to produce the power needed for the drilling process. All the tools, machines and subsystems have to the operational in order to be able to provide support to the drilling operation. Furthermore the process needs the right tools and personnel in the right place at the right time with little or no room for adaptation. On the other hand the recovery time is dependent on the system design let's say that the needed power for this type of drilling operation is 25'000 kW and you have six times 8'000 kW engines (in total 48'000 kW) where of four are online producing 32'000 kW. If one out the four running engines would fail the rig could not support the needed amount of power and it could result an incident or accident in the worst case. If the system is designed in a way that the startup time for the engines offline is low enough many of the crew members would not even recognize the shortage of power though the PMS is tightly coupled with operations.

4.3 Organization

4.3.1 High Reliability Organization and Interactive Complexity

High Reliability Organizations (HROs) refers to sophisticated organizations using complex technologies and works with tasks that is labelled "high risk" in the sense that errors may lead to employee death or in extreme cases to catastrophic consequences of such magnitude that it well effect the whole society (Perrow, 1999); (Weick & Sutcliffe, 2007). According to Roberts & Gargano (1990) reliability rather than productivity is the core of the HRO's business strategy. Furthermore the "high-reliability" function shall be present in all activities in all organization levels from management to hands-on workers. In comparison High Performance Organization concentrates on high effectiveness that can be characterized by "culture of winning", or getting the job done rather than on error-free, flawless way.

High reliability organizations tend to have complex system network of highly interdependent components which pose problems of co-ordination and integration. For example, a failure on machinery onboard a Mobil Offshore Drilling Unit can bring down the whole system or substantial parts of it because of the interactions e.g. between power generation, propulsion units and control system which ultimately terminates the success of the drilling operations among other critical activities.

Complex interactions occur when components are packed on top of another in overlapping and thick networks. These networks create environments where complex interactions between components and subcomponents and it necessitate significant efforts for teamwork, cooperation, and co-dependency to ensure safe high reliability operations. Rorty (1987) stresses the fact that “interdependent entities for a system whose members or parts cannot be identified except by the process of their interactive functioning”. For example, drilling fluids (referred to mud) used by rig in offshore drilling process are premixed onshore by service company, and transported to the working site with supply vessel. When the mud is used offshore it (the remaining’s and cuttings at least) will be transported back onshore where it will be further processed and components separated, consequently none of the companies in the value chain could operate without each other.

Illustration of different types of interdependencies that can be seen on complex systems can also be demonstrated by help of a Mobil Offshore Drilling Unit (MODU). MODU is not just one system but rather a host for complex systems and subsystems. Focusing on the interdependence between rigs maritime department and drilling department. The sole purpose on the maritime department is to provide working platform for the drilling crew in order to be able to satisfy customers need “hole in to the ground”. The drilling department is highly dependent on the abilities and cooperation of maritime personnel who will be providing them all the services needed for commencing drilling operations this includes stability, supply operations, crane operations to mention a few. Neither the drilling personnel, nor the maritime crew can do their jobs providing services for the client i.e. oil company without the other. From the example it can clearly be seen that their functions are defined in relationship with each other. For instance when the rig is on transit the drilling crew will prepare the unit for mobilization or de-mob while the maritime personnel ensure that the rig will be safely navigated to the next location whether it is another drilling site or shipyard. The maritime crew cannot realize its function without the rig, neither can the rig and drilling crew without the MODU.

If we add the six specific dimensions to the analysis it focuses the interdependence of the departments onboard the MODU. MODU’s are characterized by dynamic interdependence since it is not possible to create cash flow for the owner, neither can you provide service for the client if these parties are not cooperating with each other. The interaction is consensual, since it is not possible to reach the common goal without consensus of how the rig shall be operated. Onboard a MODU there is mechanism for checks and balances. Many activities carried out on the unit can be vetoed by anyone, regardless of rank, who believes that there is a reason to cease the operations in order to prevent a near miss or an accident. The interdependence can be symmetrical or asymmetrical; in this case neither the drilling or maritime personnel have the ultimate power to define the direction of the system, that power is on offshore installation manager (legal) and ultimately on the “company man” (pays the bill’s). As a conclusion we can say that all personnel take steps toward ensuring high reliability operations, in order to succeed they have to understand the interdependencies of a highly advanced and complex system like MODU.

High Reliability operations, like the MODU described above, are the result of Organizational Culture, or collective mindfulness to be exact, so what is it?

4.3.2 Relation between Organizational Culture and Safety

Organizational culture is seen as the reason why major accidents happen (Dekker, 2011; Hudson, 2007; Hollnagel, 2006; Reason, 1990). The concept of safety as a key component in organizational culture theory was introduced into wider world after the Chernobyl disaster in 1986. Organizational culture ties together the individuals and all stakeholders under the socio-technical envelope. In highly regulated industries like Offshore O&G and Offshore Specialized Shipping the culture is strongly shaped by multiple factors. The multinational teams forming the micro-culture onboard the asset is influenced by regional and cultural differences of the individuals (internal), and by the charterer and regulatory framework (external). Organizational culture is influencing rather than determining the actions individuals take. Actions are based on individual's perceptions and competencies determining the success of the system (Antonsen, 2009) since the outcome of the culture is eventually a pattern of observable behaviour.

Pidgeon and O'Leary (1994) defines safety culture as "set of beliefs, norms, attitudes, roles, and social and technical practices within an organization which are concerned with minimizing the exposure of individuals, both within and outside an organization, to conditions considered to be dangerous".

Another definition of organizational culture, which highlights the importance of knowledge sharing is the definition proposed by Schein (1992): "a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems."

Safety culture is one aspect of organizational culture which according to Reason (1997) is an informed culture i.e. the organization collects and analyses relevant data, and actively disseminates safety information across all organizational levels. Furthermore Reason argues that safety culture consists of five elements: (1) an informed culture i.e. collect and analyze data, disseminates the findings actively; (2) a reporting culture i.e. create atmosphere that confidences people to report deviations from the normal and act upon reported findings; (3) a learning culture i.e. individuals understand the Safety Management System processes, and the organization learn from its mistakes, continuous improvement (e.g. PDCA); (4) a just culture i.e. people are accountable but not punished if the error was unintentional; (5) a flexible culture i.e. organization and the individuals are capable of adapting to varying conditions upon demand.

Westrum (1991) have categorized organizations into three types, depending on how they treat information: pathological, bureaucratic, and generative. A pathological organization chooses to hide information, and if defaults are reported the messenger is blamed. Failures are covered up and responsibilities are dodged, and there is no room for new ideas or improved proposals. Such organizational culture creates latent conditions (or errors) (Reason J. , 1990). Bureaucratic organizations are good with routine operations. Latent errors are created, but not at the same level as pathological organizations do. Latent errors results since information may be ignored, they might be good at fixing the errors reactively but root causes are not investigated, and new ideas create problems. The main issue with bureaucratic organizations are that they can manage the everyday, but when system resonates they find themselves unable to react proactively, becoming a passenger and victim of the unfamiliar situation. Finally the generative organizations encourages information flow and self-organization i.e. it is an informed culture. Information is actively sought and people are trained to report detected conditions. New ideas makes the fundament for organizational learning, hence improvement. Latent errors created by system are likely to be quickly spotted and repaired i.e. putting back the missing "Jenga" blocks to stabilize the system, and making it more tolerable for greater variation.

The International Atomic Energy Agency provides similar three levels of organizational culture model like Westrum. On IAEA's model the organizations are categorized by organizational maturity into: rule-, goal-, or improvement based. The rule based safety culture is a blaming culture where people are punished from mistakes, and the safety is solely based on obeying rules and regulations. Goal based organizations has safety as an organizational value and goal to strive for. Management response to mistakes is applying barriers in forms of procedures, training the individuals. On goal based level safety improvement is based on adding defenses without thorough root cause analysis or basis for the changes. Finally improvement based organizations sees mistakes as process variability with emphasis on understanding the reason for variance from multiple underlying factors without blaming any individuals, similar to resilience engineering concept proposed by Hollnagel. (IAEA, 2002).

The modern interpretation of informed culture is based on the principles of collective mindfulness i.e. the theory of High Reliability Organization (Weick & Sutcliffe, 2007). The collective mindfulness according to Weick is the means of discovering and managing the unexpected events i.e. the system becomes reliable. The five processes underlying high reliability organizations success proposed by Weick:

Preoccupation with failure. Focus should be on reporting and analyses of the reported issues. Near-misses, safety observations, and non-conformities send by the offshore asset should be treated as (pre-) accidents that revealed the potential danger or condition. In practice the crew should evaluate every action or operation accomplished e.g. every manoeuvre is revived and graded. Even smallest errors despite how unimportant or inconsequential it feels for the observer are treated as system problem.

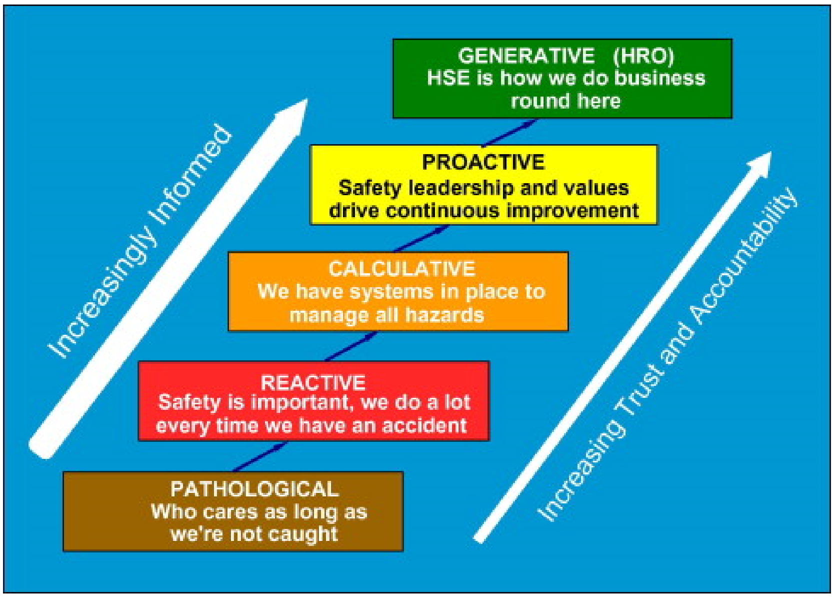
Reluctance to simplify interpretations. The people operating the system takes nothing for granted i.e. we don't satisfy ourselves with referring only to historical records or ways to solve a problem we face, but we try to establish a comprehensive picture of the scenario we are experiencing, highlighting uncertainties and looking into the future, avoiding assumptions. People should also be encouraged to express different points of view. In practice this means that we don't take nothing for granted e.g. when a new propulsion unit is enabled it have to be tested, we cannot presume that it works based on the background knowledge that it worked fine yesterday. Individual's expectations help to simplify the world he is experiencing, and it steers away from disconfirming evidence. We are, after all destined to fall on 'system 1' cognition and our thinking is biased by nature i.e. we see what we expect to see (Kahneman, 2011). To create more varied and differentiated predictions we have to understand how we function as "intellectual", this is essential in order to be able to understand what we face.

Sensitivity to operations. Individuals on all levels involved in the operations should come into contact with each other and create a clear picture of the prevailing situation and the future events. In practice people should be able to detect early warning signals and share their concerns e.g. worsening of the environmental state should be monitored and proactive decision taken to ensure that operations are seized before point of no return is reached (e.g. disconnecting or emergency disconnecting of marine riser, the other takes the magnitude of tens of minutes while the other seconds, the later can cause significant damage). To achieve 'sensitivity to operations' people should be familiar with operations beyond own work tasks and any weak signals are taken seriously. In the maritime context it means that the distributed situation awareness cannot be limited to bridge team, it have to include all stakeholders (e.g. control room operators, deck crew, clients etc.). As stated earlier the system knowledge and communication plays a key role on being 'sensitive to operations'.

Cultivation of resilience. The individual and organization is prepared and it tolerates unexpected events and surprises. The individuals can only achieve resilience by training (competence level) and having response repertoires to novel scenarios. Despite the fact that the systems we operate hides unknowable, unpredictable, and incomprehensible processes that might, or might not ever be concretised the individuals have to have a set of skills to manage the not foreseeable. To be resilient the individual have to have deep system knowledge to be able to improvise when needed, avoid overconfidence and over caution with respect to automation and the underlying processes i.e. adapt attitude of wisdom, and practice respectful interaction with all stakeholders (e.g. provide trustworthy reports). For example, in practice being resilient can be as simple thing as knowing (have the mental model) what counteractions one should take in a case of losing one main propulsion unit, very unlikely, but possible.

Willingness to organize around expertise. Individuals in the high reliability organization value expertise over hierarchical position. HROs understand that judgements or assumptions cannot be done outside one's expertise. In practice this means that decision making structures are flexible and decision making shifts from formal authority towards experience and expertise. For example, offshore installation manager is not the person to determine what actions a driller should, or should not take, in response for wellbore error due to accumulated solids, nevertheless his hierarchical rank permits to do so.

Since organizational culture is evolving over time, recognizing the current stage and understanding which direction it is developing is essential to be able to start the improvement process. Hudson (2007) has analysed how to implement an advanced safety culture into a major multi-national. Hudson proposes a five step evolutionary model, since building a safety culture have to be done in manageable steps allowing intermediate stages rather than jumping into the unknown. The 'HSE culture ladder' proposed by Hudson has similar component with Westrum's concept but the additional steps provides easier, less painful steps.



20 The HSE Culture Ladder by Hudson (2007)

Maritime operations conducted with DP application are complex and dynamic operations. To be able to understand the risk the individuals and organization is facing a comprehensive risk picture have to be drawn. The concept of collective mindfulness by Weick is supported by Aven & Krohn (2014) who argues that an integrated risk perspective is consisting of four pillars. In addition to collective mindfulness the organization have to have (1) suitable risk conceptualization (see Chapter 3), (2) theory, principles and methods for risk assessment and management in line with this conceptualization, and (3) concepts and ideas from the quality management, continuous improvement (e.g. Deming’s PDCA wheel).

Finally, Patrick Lagadec (1993) states on the importance of organizational strength, that work systems “ability to deal with crisis is largely dependent on the structures that have been developed before chaos arrives”, similar to Hollnagel who argues that the more resilient the system is the greater variance of its processes it can tolerate (see figure 6.). A loss of production integrity, or well integrity might never happen to some organization (asset/individual) but if it happens it can “be considered as an abrupt and brutal audit: at a moment's notice, everything that was left unprepared becomes a complex problem, and every weakness comes rushing to the forefront” (Lagadec, 1993). Only a generative and mindful high reliability organization can withstand the impact of unforeseen, in some cases not even them.

5. Results and Analysis

The questionnaire indicates that there are several risk influencing factors (RIF) arising from the human, technology, and organizational contributors. These RIFs are affecting ultimately the human performance and furthermore to the total performance of the system. The complexity of marine operations demands that we recognize the factors creating variance to the system processes. Both tangible and intangible, and identify the missing "Jenga" blocks that create constant instability in the first place. This chapter present the results from survey, analysis of the results, and suggestions for improvement.

The personnel taken part to the questionnaire are representing a wide group of industry professionals working for the major vessel operators in Norway. The detailed background information can be found on 'Appendix 1'. In general the individuals who has taken part on the survey have high level of expertise and pooled knowledge from the field of offshore specialized shipping and advanced marine operations. They have been operating various vessel types equipped with numerous diverse combinations of technical solutions, giving them the possibility to evaluate the differences: pros and cons they have experienced while operating the work systems. This high level of experience combined with understanding the nature of the marine operations has positive contributions to the quality of the survey data. Furthermore I give high credit to the people on their openness and willingness to share the issues they are experiencing in the field.

The results are presented in various ways. Firstly with index number meaning that from the scale minimum 1.00 and scale maximum 5.00 values the reported average value is divided by 100. Secondly the proportion of people i.e. one-third, two-third etc.

Example: "How reliable/unreliable do you feel with regards to Dynamic Positioning System in general?

The result is reported as: two-thirds of people experiences that the system is reliable and one-third perception is that the system is very reliable. The same result with scale gives an average value of 4.25 hence the index is 81.25 hereafter reported as (81). In the example above one out of 36 respondents rated the some to be somewhat reliable i.e. three percent, or 3%.

Note that the results are not reported item by item. An analysis of a highly sophisticated works system cannot be based on the belief that identifying and "fixing" a single broken component could fix the problem i.e. a single parameter has no practical value without understanding the interrelated nature of them. One category of questions and its sub-questions represents potential risk influencing factor, or factors that influences the performance of the barrier system, consequently creating variance to the process. Therefore the set of 5 to 15 questions are firstly handled as an possible attribute affecting the complex system, secondly the comments provided by respondents are applied to the set, thirdly I have had informal discussions with selected industry professional in senior positions to provide hindsight's and reflection, and finally my own experience from the past five years; nine offshore specialized vessels, and a great number of oil companies with their company specific rules & regulations has been added to analyses in order to be able to form conclusions. Additionally the results and theory is applied into some selected cases and scenarios that has been experienced by me or my fellow colleagues, to provide the reader possibility to grasp on real-life scenarios.

The questionnaires numerical results can be found in 'Appendix 3'. Majority of the comments included company and asset names, hence censored completely. Company and asset names are used only in cases where an official accident or incident investigation report has been made available for the public, and/or the companies are presented in the texts (books, or papers etc.), for example BP has "earned" its place on safety related literature.

5.1 Technology Component

The rapid development in software and hardware have provided us the possibility to develop highly complex work systems. An unfortunate by-product of this development is highly interconnected components and subsystems in multiple system layers. Although this development has allowed us to conduct marine operations that was not possible before due to the technical restrictions of the work system it creates instability and variance to the performance of the total system. Normal Accident Theory by Perrow (1999) argues that highly complex work systems are inherently unstable with disposition toward massive failure, this view is supported by Hollnagel (2006) and Dekker (2011). The following analysis of questionnaire part one draws attention to the technical risk influencing factors that create variance to the system dynamics and have the potential to start the drift into degraded system status.

5.1.1 Hardware Evaluation

The respondent's perception of the technical systems reliability of the vessel is at high level in general. The reliability of the DP system, power management system, and propulsion system scored an index 80 or more. The sub-systems for the DP resulted greater variation. Respondents rated the DGPS as the most reliable position reference system (74) closely followed by microwave based system (71). The microwave based system should be compared with laser based (60) since the vessels are typically equipped with one or the other not both.

The heading and rate of turn can be determined from two different heading reference units: gyro or GPS compass. The vessels are commonly fitted the combination of these two i.e. minimum requirement of three gyros are fulfilled with two gyros and one GPS compass. GPS compass is used to compensate for the high cost of gyros. The results indicates a significant reliability difference between these two systems: gyro index (82) while GPS compass index (52). One-third of the respondents reported the GPS compass to be unreliable and two respondents (out of 37) commented that "it should not be used at all". GPS compass performs well when the vessel is moving since the alterations on heading are determined by position changes on the GPS receiver antenna. The problem is that DP application is commonly used for station keeping i.e. the less movement in surge, sway, and yaw axis the better.

In addition to the DGPS system, the vessel owners and managers should choose the most applicable combination of position reference system in the construction phase and the DPO's in operational phase to create stability to the system. According to the survey for determine the relative distances on surface microwave based system is recommended instead of laser based system. However it is notable that the advantage on using the laser based system is that there is no need for fixed arrangements meaning that it is more suitable for SPOT work where the vessel can be operating on numerous locations. One respondent commented that "I wouldn't use any optic system if acoustic is available, because it is too sensitive to environmental conditions and reflectors".

[Case 1] The reflection issue is widely known by the vessel crews but somehow it has not reached the platforms or it is not seen important since deck crews on PLT's are commonly using reflective boiler suits where the laser based system can "jump" and be "locked". On the other hand this is a good example of

competing interest: the visibility of the rig crew if felt overboard (safety issue for the drilling contractor), and the vessels position keeping capability while working alongside unit (safety issue for the vessel) etc.

At first sight the solution for creating a stable work system might be seen as combining as many system as possible to fill out the empty slots of the 'Jenga' tower to make the coupling looser i.e. adding technical barriers to the system by help redundancy to avoid degraded system status. This approach is problematic since adding more PRS's increases the complexity (a source of instability).

[Case 2] The second issue derives from my own experience while working onboard and OSCV for an oil major in UKCS. The marine operation was to ensure production integrity by help of ROV survey (video footage and non-destructive testing of the subsea pipelines and risers) from subsea templates to the production platform and furthermore to the terminal onshore. While we worked inside the 500 meter safety zone, the requirement was to use four PRS's. In practice it meant that the work: entering safety zone, vessel maintained approximately 150 meters from the platform (the ROVs had a physical limit of 200 meters from the cage lowered to the seabed from the vessel), complete the survey of a specific pipeline, and continue with the next pipeline. This mission inside the platforms safety zone would have been done in 20 minutes (coarse estimate). Now instead of running the survey smoothly we were forced to lower the taut wire for additional redundancy. The process of using taut wire is time consuming since ROV has to verify the landing zone, the system has to stabilize before added to the DP, and the retrieval of the weight is monitored by ROV to ensure that it is not damaging anything while lifted. We did not only increase the complexity of well performing work system but we increased the exposure time (risk of collision) of the system from minutes to hours. One respondent commented that "lost a taut wire clump weight during DP3 diving operation" thus it is not directly applicable for my subjective experience it highlights the fact that the subsystems are also subject to mechanical failures.

Note that the discussion above does not mean that fulfilling the minimal requirements would always be the best solution, and adding systems would just cause more instability. For example, vessel engaged in saturation diving operation using DGPS as PRS, it is justified to count all the reference systems that uses same constellation as one PRS, while a minimum of three PRS's are required. The operators has to apply system thinking and professional judgement into the risk considerations when the decisions are made, but instead of having "more is better" philosophy evaluate the interactions between systems and subsystems, the coupling, and exposure time for increased risk level.

The current trend is to build vessels by help of advanced technologies more flexible design that are able to carry out a larger scope of work i.e. "hedge" against a unstable market conditions for a specific type of operation. Vessel with enhanced operational "capability" serves the commercial flexibility of the company but increases the instability that have to be managed by the vessels crew. Ironically the multi-purpose vessel are called multi-useless by the crews. The fundamental principle of work system design should be to ensure vessels or units capability to perform safely its industrial mission i.e. intended operation (e.g. anchor handling, or drilling etc.) not to create complexity by operational "flexibility".

5.1.2 Alarm system

On the first part of the 'alarm system' evaluation the highest index values was reported to be: too many alarms activated during a typical shift (55), alarms can be reset, do they just keep coming back (50), experiencing a lot of false and or inadequate alarms (44), hard for operators to decide which alarm to deal with first when a lot of alarms come in at once (43), and in case of multiple alarms it is not easy to decide which alarms has priority (43). On the other the operators were satisfied with the alarm volume level (26) i.e. it was easy to determine what system is at degraded state. Furthermore the alarm listing has its own box in the system meaning that active alarms are easy to monitor (32). The severity of the alarms are typically displayed by “traffic lights” concept red indicating alarm and yellow warning, green normal status.

Especially during the advanced marine operations the operators have to evaluate constantly the operative capability of the socio-technical system. The alarm system can be seen as a method of communicating the system status to the operators who are otherwise engineered out of the control loop i.e. the role of the DPO is passive monitoring, and variance in the processes is indicated by alarm signal upon exceeding the alarm limits. DP system like any automation system is improving the situation awareness (SA) by reducing the stress, workload, and the complexity of the system for the human component. The alarms from the system activates the human component to evaluate the current situation and updating the individuals SA. A good alarm system provides appropriate information to the operator with regards to the state of system helping them to recognize the deviation (systems, sub-systems, and components creating variance) and taking appropriate counteractions to restore and stabilize the system. The decision making process behind intervention can be rationalized by help of SRK-framework i.e. the operator recognizes the degraded system state and applies counteractions based on the recognized problem. Unfortunately the respondents reported “too many alarm during the shift” (55) and that they are experiencing the very same alarms thus reset (50), this causes the operators to become reluctant to react on alarms and the acknowledgement of alarms is done on skill-based behaviour using tacit ‘system 1’ knowledge without cognitive and structured analysis. This kind of behaviour can lead to situations where warnings and alarms that had importance are acknowledged by mistake since believed to be false (44) or not justified. Three respondents highlighted the fact that every vessel or unit are unique and it is “persons responsibility to learn operate the system” meaning that a number of false alarms have to be tolerated and accepted as a “part of the game” as one mentioned.

The understanding and acting upon alarms and warnings are crucial to the safety. Ignored alarms or incorrect responses can compromise the safety of the unit or vessel resulting catastrophic consequences. The second part of the alarm analysis had three questions: is it sometimes unclear about what to do in response to a particular alarm (29), information is easy to interpret and apply counteractions (61), and company is providing me guidance how to react in different types of alarms (36).

The answers indicate that the operators can interpret the alarms i.e. diagnose the system condition and apply skill-, rule- or knowledge based counteractions to restore the status quo (ante bellum). Chen et al. (2008) reported that based on their analysis there is no operational manuals that had procedures or guidance targeted on DPO’s action to detect deviations and act upon them, the situation has not changed. Acting upon alarms is still seen to base solely upon individual interpretation without standardized procedures, neither solutions to the experienced degraded system state. With respect to the alarm response findings I have to give same recommendations to the vessel owners as Chen et al. (2008) eight years ago: “DP operators shall receive systematic training on actions given various alarms”. The training could not only reduce the time used on detection- and decision stage prior to the execution of intervention but also bring the recovery actions from knowledge to rule based behaviour reducing the probability of misinterpretation of the situation. Errors arising from human computer interactions are often due to misunderstanding during stressful situations, and not system failures (Mills, 2005), the alarm system influences the stress and workload. Based on my interview none of the seven people had seen a procedure that covered ‘when’ and ‘where’ to check ‘what’ in predetermined intervals whilst the vessel or unit is on DP, “it is the operator’s responsibility, that’s what he get paid for” was said.

DP is a complex automated system which operational condition is shown to the operator by means of alarms and warnings. Too little alarms could cause overreliance and vice versa. Alarms increase the subjective workload of DPO's but on the other hand they can be seen as reminder to the operator that that the alarm inducing sub-system or component is causing variation to the process. Based on my survey I cannot say that some systems are more alarm prone than others but based on my own experience there is large differences on the amount of warnings and alarms shown to the operator. As a DPO the warning and alarm limits can be changed into some extent but it does not remove the faulty alarms. Since in practice alarm problems are not reported to the system manufacturers, neither the focus should be put on the design and construction phase of the unit ensuring that sub-systems and components creating the system can communicate and form well-functioning total system. From the humans perspective the focus should be on understanding how automation can deviate from its usual performance and being trained to respond to surprises raising from the automation system, this is paramount to the system safety.

5.1.3 Work System Design

The questions on work system design was divided into two parts: workspace arrangements on existing assets, and system selection preferences on new buildings.

The bridge layout was reported to be "optimal" for work without distraction by two-thirds of the respondents. Furthermore the bridge design typically consisting of DP workstation, Navigation Bridge, and the chart board area which is the workspace for office work done with PC's etc. The use of bridge PC's was not reported to be a problem either (22). What was reported to be a problem was that the crew members like to visit the bridge and socialize with issues and topics non-relevant to the operations (60), and extra personnel on bridge is creating distraction (51).

The second part was focusing on the system selection and suitability for various operations. The results are unanimously suggesting that one system is more suitable for a specific scenario than other (index > 80). Three people have commented that they would choose a DP system by manufacturer 'A' for stationary operations (e.g. subsea, or drilling etc.) and DP system by manufacturer 'B' for operations requiring multiple changes on the operational mode during the work shift i.e. "jumping" between manoeuvring manually and AutoPos mode. The lowest score (61) was given to "arrangement of the visual display units (VDU) provides me relevant parameters without searching" emphasising the importance of sufficient number of displays (of any type) and the correct placing of them.

The crew members like to visit the bridge and socialize with issues and topics non-relevant to the operations (60), and extra personnel on bridge is creating distraction (51) is a recognized issue. The main issue is that DPO's will be distracted by extra personnel and it decreases the situational awareness. Situational Awareness has direct link between the detection and decision time prior to the execution, and the time used between the observation and the execution of recovery tasks determines the success/not success. The time allowed to use is proportional to the coupling (e.g. physical limits of equipment or distance between two object that can collide etc.). The survey indicates that distraction is due to organizational and managerial issues rather than due to the bridge layout. One respondent commented that one DSV/OSCV had the construction supervisors on bridge which had two negative effects on SA of DPO's. Firstly the offshore manager and the project team (generally referred as 'clients') were placed on bridge instead of "client offices" creating distraction. Secondly occasionally the ROV and Crane teams were left outside of the command loop since the project "core" i.e. DPO's and the offshore manager were discussing face to face instead of radios.

Furthermore the respondent comments that “it would be best to have project related workstations totally separated from bridge, although, at times having guys next to you have its advantage, too”.

Any offshore vessel or unit is equipped with vast amount of controls and displays. The digitalization has shifted the workstation from electromechanical to electro-optical devices. The latest models from DP manufacturers are using touch-sensitive overlays i.e. the physical user interface has become multifunctional display that serve both as control and display, blurring the distinction between the two. The workspace arrangements should ensure layout that is optimized for safe and efficient operations. The fact is that bridge layouts on different vessels and units varies significantly. A large bridge allows the vessel management functions (e.g. bridge PC’s used for work planning etc. to be placed further away reducing the possibility of distraction of safety critical activities). Optimal DP workstation consists of graphical user interface (GUI) with visual display units (VDU), joysticks, buttons, and levers arranged in a way that the information is easily available and the information presented provide the DPO information needed for decision support. The DPO’s only possibility to manipulate and interact with the automation is through the workstation. In order to take the advantage of shared situation awareness (SSA) a dual complete and independent operating station design is recommended. In practice this means that instead of having the workstation next to each other on the side of bridge they are divided into two independent but parallel workstation “mirrors” of each other, taking the control by pushing a single button, twice to be exact. A good workstation allows the user to determine what is shown on the “secondary” displays. The majority of DP system manufacturers on the market provides well designed layouts with sufficient number of displays but it is ultimately up to the vessel owner to decide the setup. The risk of having a massive amount of data available is that the DPO’s become swamped. Thus the risk of information over flood and increased system complexity the improved SA and SSA outruns the weaknesses of added complexity. Finally it is important to remind that the operator (human component), not the technology, initiates and controls all actions i.e. the operator has to have the feeling of control (Bjørneseth;Dunlop;& Strand, 2008). Feeling of not controlling the system, or becoming a “passenger” on the process creates stress to the operator and makes the system vulnerable for resonance.

In addition to the multifunctional displays the system manufacturers have released GUI’s that present the operational aspects in 3D. According to Wickens (1992) efficient operation of any work system require mental models. Mental models are individuals understanding of how the system works in the operational context and 3D aspects of the user interface enhances our understanding how we as a unit are related to the bigger picture. Based on my observations the systems that has the possibility to tilt the ‘camera’ view is widely used and operators are trying to match the display with what he or she is experiencing in the real 3D world to conform operators mental model.

[Case 3] I had been using type ‘A’ and ‘B’ DP systems for the last two years. The vessel that I started to work was equipped with manufacturer ‘C’ system and equipment. Upon the arrival to the offshore location we setup the vessel for DP operation i.e. enabling the sub-systems for DP application and prior to the fully automated DP mode (AutoPos) the vessel movements are eased by help of joystick. You start by “locking” the Yaw, when heading control has stabilized the Surge or Sway movement is locked (depending on operational condition, time available, and weather), eventually both but the sequence is up to DPO’s preference. Surge was “locked” without problem but I could not understand why the speed of the vessels Sway movement increased even though I applied propulsion force to compensate the movement. After a short while (10 seconds) I noticed that the screens where on “North Up” mode and the vessels heading was directly to the South. This setup created a condition where all the parameters I was monitoring showed opposite direction compared to the true movements, something that I had never experienced or used before

on type ‘A’ or ‘B’ systems. “Luckily” I recognized the situation and started to compensate the movement. My coarse estimate is that the vessel had moved 50 meters aside from the planned position and we used an extra 30 to 60 seconds on the process. The process was not time dependent in any ways (loose coupling), this event happened in open sea in combination with ROV survey start up ten of nautical miles of closest top surface structure. Scenario could have been very different is the same manoeuvres were done inside the 500 meter zone (tight coupling) like collision of the Seven Atlantic with Gaz de France platform in 2011 on Dutch Sector implies.

[Case 4] Aviation industry has understood that the operators have limited ability to effectively manage the available information using just eyes. As a solution to provide information for a visually saturated operator tactile systems like stick shakers has been applied. I had been using a certain type of manoeuvring handles to control the vessels main propulsion units. One time I was manoeuvring another vessel for the first time and noticed that she was very fast to pick up speed. Speed is not a problem per se (normally better manoeuvrability with good propulsion) but what surprised me was that I had applied approximately 70 % pitch/thrust, what I believed to be around 40, max 50 %. Manoeuvring is a multitask environment and the focus is on observing the vessel movement with respect to fixed structures. The position of the handles comes from “backbone” it is done within ‘system 1’ skill-based behaviour assigning the operators cognitive working capacity to “important” things. In this case the vessel accelerated from 0 to 5 knots in let’s say 40 seconds while if applied a pitch of 40 percent the time would have been 60. After the intended speed was reached the handles was adjusted to a position where the vessel keeps the preferred speed. After the “aggressive” manoeuvre I understood that the system handles was built in a way that 0 to 100 was achieved by applying let’s say 60 degrees angle to the actuator. 0-100 had prior to that system been 90 degrees. Vibro-tactors or similar equipment would have enhanced my SA by informing for example when handles passes an additional 10 percent or by giving resistance the more you order.

[Case 5] The importance work system design and construction supervision process. One vessel that had left handed construction supervisor responsible of placing the joysticks, handles and buttons. The problem of placing equipment to be ergonomic for a left handed person caused operational difficulties to the rest of the operators, in this specific case nine out of ten right-handers had to adapt. One friend of mine has made successful football career by being able to shoot with both legs equally well among other top qualities, thus not convinced that the industry needs DPO’s capable of operating right and left handed systems, if even left handed systems exists. I do highly doubt that the cost of redesigning and constructing a bridge that has shown to have poor ergonomics and layout would be justified by the company management. The issues concerning bridge design should be evaluated in the new-building phase. The role of construction supervision plays crucial part on the product quality in terms of usability.

[Case 6] In year 2011 one of the largest and most advanced subsea construction vessels ever built was launched. The new vessel is equipped with “Triple LLC Redundancy” claimed to be unrivalled and new level of advanced marine operation can be conducted in the future. In an interview the both the vessel owner and manager announced that the system is so advanced that “we could claim it to be DP Class 4, if that class notation exists”. This example highlights fact that the offshore business has always had a long tradition of technical integrity, an intrinsic value to praise and pursue it. I am not stating that it is wrong to be proud of the new state of art equipment but this example shows the irony of people’s beliefs that safety is based on technical redundancy of the work system. If you agree with the concepts of Resilience Engineering and Normal Accident Theory wouldn’t this increased complexity added to the system by redundancy be

ultimately self-defeating feature against safety. We end up building complex non-linear systems since we don't know how to reach and fulfill the purpose of the system with simple and linear interconnections.

5.1.4 System Knowledge

The system knowledge questions included the major systems that influences the vessels performance in terms of reliability and availability. Furthermore the respondent's technical knowledge was questioned with regards to the DP systems sub-systems (e.g. PRS etc.). Respondent's technical knowledge perceptions were on a good level in general. The highest scores was assigned for DP system in general (67), Stability Calculator (65), Cargo Control System (63), Integrated Automation System (61), and Power Management System (60).

The sub-systems for DP had more variation the lowest scores was assigned for the taut wire (43) and hydroacoustic system (44). While respondent's technical perception of microwave based PRS (62) and DGPS (61) scored highest values.

High scores for DP system in general can be explained by the fact that it is the system they use in daily basis. Respondent's perception that they are above average user with Cargo Control System and Stability Management reflects to the fact that two-thirds of the individuals who took part on the questionnaire was on senior position. The vessels or unit's stability and cargo operations are on Chief Officer / stability section leaders' responsibility a rank that the Captain and OIM's have had prior to their promotion. On the other low scores for taut wire and hydroacoustic system can be explained by the fact that there is a limited number of vessels were these applications for position reference is used.

The offshore companies are into large extent knowledge-based organization. People at all levels spend time on managing the complex socio-technical system and holistic understanding of the processes are needed to be able to detect, report, and improve the total quality of the process . Understanding the system and the system interdependencies enhances safety. Situation Awareness (and Distributed SA) in complex collaborative systems is large based on the understanding and communicating of the underlying processes, essential for correct decision-making in real situations that are time constraint. Lack of technical knowledge can influence the risk due to increased use of time on the detection phase and poor decision-making. In addition lack of knowledge increases workload and stress i.e. situation were the operator did not understand what happened he/she tend to describe it by using the metaphor "becoming a passenger" instead of having control over the situation. Furthermore the concept of collective mindfulness arising from High Reliability Organizations theory states that in order to be able to be sensitive to operations it is essential that the operators understand how the system works (see the five processes underlying high reliability organizations success).

5.1.5 Bridge and Work Station Ergonomics

Ergonomics is a scientific discipline to understand the interactions among socio-technical system i.e. the main purpose is to increase the efficiency of the human component hence overall system performance. International Ergonomics Association (2015) defines four main domains of expertise crucial for considering interaction between humans and the socio-technical system: Physical Ergonomics, Cognitive Ergonomics, Neuroergonomics, and Social or Organizational Ergonomics. This Part of the questionnaire is considered mainly with the Physical and Cognitive Ergonomics thus especially Cognitive Ergonomics is discussed later as well as the Organizational Ergonomics on Organizational Factors.

Since DPO's are dependent on the information provided by displays and the manipulation of the system is done with controls the focus on the questionnaire was around these issues and improvement potential.

According to two-thirds of the respondents increasing the number of displays would improve their performance and SA. Identical results were reported for “important parameters are not frequently monitored due to poor positioning of the screens”. Both questions had decent index value 52 and 51 respectively, meaning somewhat good/satisfied but when analyzing the results in terms of individual answers it shows clearly that people are operating with well-designed or poorly designed system not between. This finding can supported with comments: “there is a big difference between new vessels and older vessels where equipment has been retrofitted, but even on newer vessels the placement of gear is usually surprisingly stupid” and “one vessel the chairs for navigation watch was very bad quality but we could not replace them since the vessel was new”. From the results and comments we can conclude that prior to the new vessel order the management of the company should gather information from the operational conditions and evaluate what design has been well accepted by the crew.

The same trend of good or bad layout is continuing on all questions related to ergonomics. It means that it is a management issue and responsibility to provide systems that are optimal for use. Management should act upon reported ergonomics problems by improving working conditions and equipment. According to Hendricks (2002) “ergonomics aims to ensure that human needs for safe and efficient working are met in the design of work systems” this approach to ergonomics attempts to “fit the job to the man” (FJM), alternative approach is the “fit the man to the job” (FMJ). In order to be able to maximize the production of a work system where human component is present the FJM approach has superior features by all measures, most importantly to gain and maintain adequate situation awareness. The human component will adapt to poor ergonomics but the main questions is that how unstable the ‘Jenga’ tower becomes if as fundamental part of the work system as ergonomics is poorly managed. The *[Case 5]* is a good example of managerial issue, the construction supervisor was most likely well satisfied with the ergonomics, probably the best suiting vessel for him, unfortunately not for anyone else. Ergonomics is, after all, largely about finding optimal solution for the typical user. The most modern and well-designed system have the capability of adjusting the seats, screens, and displays according to users preferences. Highly modifiable setups for individual users in terms of what information and how it is presented has definitely a positive effect, but it is worth to mention that there lays pitfalls also. *[Case 3]* is an good example of scenario were the setups had been changed from something that would be considered as standard creating in a way latent (not strictly speaking) condition for the next operator not aware of the different representation of information.

A bit alarming result to question “do management seem to give low priority to doing anything about reported ergonomic problem” was obtained. 50% of the respondents felt that ergonomics has low priority for management “rather, or very often”, nevertheless they felt that it is contributing factors to their successful performance. As stated earlier people are adaptable but if individuals working capacity is used for managing poor working system it will eventually drift into failure.

5.2 Human Component

Human component can be considered as a special case in reliability engineering since it is neither bimodal, nor can we assign it a probability to function or fail, but after all it is the main component, highest contributor to the systems success or failure. This part of the questionnaire focuses on the human’s performance demands and responses. What tools and methods do we have in place to help the operators to manage the complexity and sustain a sufficient performance level throughout the process i.e. the time on duty.

5.2.1 Human Behavioural Safety

Human reliability or capability to response on degraded system state was evaluated by asking how do the individuals cope with system variance and how do they reflect their behaviour in bridge team setup. The respondents felt that their individual competence level is on sufficient level to perform the work in safe manner 40% grading 4, and 60% 5 (90). People's perception on their confidence to handle novel, unfamiliar situation was also on high level (82), but it is notifiable that 40% was confident to handle them very often while other answers were distributed between sometimes (score 3) and rather often (score 4). Applying the results to SRK-framework, proposed by Rasmussen (1983), operators have the perception that they can respond to degraded system states without making a rule- or knowledge-based mistake. Since it is easier to over valuate own performance the respondents were asked how confident are they with respect to colleagues managing novel situation. The question scored an index of (69) and answers were distributed between scores three and four i.e. significantly lower than when evaluating of own performance. One result explaining reason could be that the operators in general value experience (and experience-based learning), and majority of the respondent are in senior position (two-third) i.e. the bridge team has younger operators (in terms of system exposure) whose capability can be scrutinized by the seniors. Furthermore on the question "I doubt my colleagues competence and decision making capability" 50% answered "sometimes", the result could also be explained with respondents seniority, drawing the conclusion into the findings that system exposure time increases the possibility to manage variance.

The second part was to identify how the bridge team does scope with the daily operations. Many research papers and accident investigation reports indicate that multi-national bridge team's hence poor bridge resource management is root cause for accidents. Bridge Resource Management (BRM) has been a widely discussed topic in the maritime communities and new training requirements has been set in force (Table A-III/II/I of the 2010 Manila amendments to the STCW Convention), mandatory for the certificates beyond 2017 (IMO, 2015). BRM course emphases the importance of communication, culture awareness, leadership, team work, situation awareness, and human factors in general. The focus on the course is on lowering the gap between western senior officers and lower ranks with multi-national background (authoritarian leadership style), therefore not applicable to this report. The BRM course is a typical example of IMO's reactive approach to one of the fundamental problems in maritime industry, now officially "fixed" by help of 4 days course. The results from the questionnaire indicates that the risk influencing factors listed above are not felt as issues onboard the vessels. Only the question with regards to language barrier stood out with index (47). Majority of the respondents are working onboard vessel registered to Norwegian Shipping Register (Norsk Ordinært Skipsregister, NOR) flying the Norwegian flag i.e. the crews are from the Nordic Countries sharing Scandinavian language. One respondents commented that using foreign language (English) in emergency situation would have advantage since "people tend to talk less" i.e. the radio channels stay open when the communication is clear and short. Another commented that "I answered "often" since language is problem on flag of convenience vessels", the answer can be interpret to represent vessels with truly international crews excluding the ones discussed earlier.

The cultural aspects is widely studied in the concept '4. Era' of safety but is difficult to determine cultural based differences on behaviour on crews that come from Nordic Countries, hence the findings does not recognize cultural problems on evaluated vessels and units in terms of language, training, or competence.

The respondents was also questioned if they can differentiate the human error source likelihood between engine department, deck department, and service personnel or 3rd parties (i.e. outside of the maritime envelope). Both technical department (36) and deck crew (37) was seen to perform well, but the 3rd parties was seen as more likely to be involved in human error (46). On respondent commented that “due to the limited human resources and time it is not always possible to check what service personnel do” i.e. there is a possibility of latent error left behind. One reason for poor controlling of service work is the time pressure. The time charter terms and conditions used on offshore vessels are generally written in a form that the vessel manager is allowed to use one maintenance day per year without off-hire i.e. loss of cash flow.

The third part of the questions is focusing on the communication within the operational envelope and information exchange between personnel. Information is exchanged by word of mouth, in writing (e.g. checklists, or note etc.), pictures or graphical representation (e.g. weather report, or data card etc.), and by user interfaces, and screens on bridge. In all cases the information should be complete and accurate, fail to do so has been root cause for number of significant accidents, e.g. Piper Alpha, or Texas City Refinery. The information exchange takes places, for example, between shift handovers. In practice this means that there is a large set of underlying processes and one of the most critical component, the human, is replaced. The replacement should not, in theory have any effect on the total system reliability.

The results suggests that the shift handover process has great improvement potential. 70 percent of the respondents answered that they do pass complicated instructions by word of mouth, which would be better put in writing sometimes, often, or very often. And the same result for handover could be better planned and clearer procedure. Operators did not feel that shift handovers are very often rushed with the minimum of information exchanged (33) i.e. the working arrangements allows sufficient time meaning that the focus should be on handover process itself (structure, means etc.).

[Case 7] The intercom phone on my cabin is ringing at 23:30, have slept poorly, deciding to wait until my mobile rings at 23:45. I put some comfortable clothes on, and walk downstairs into mess to find some nutrition. At 23:55 I have a big cup of black coffee on my hand and find myself seating on the operator station. The off-signing crew is exhausted after long and stressful watch, which they claimed to be just like any day in offshore. I see that they have completed all the paper work and filled the handover checklist to reduce my workload, how nice from them. Let’s see what this day brings alone, most likely the unstable position reference systems are causing problems, I hope that I can finish my coffee before the system decides to show her true nature.

Despite the fact that the example presented above is exaggerated there is one important message that everyone has to consider. If you agree that the systems total reliability should not be affected by handover, which factors should be taken into consideration to ensure adequate handover process than. The issue can be divided into organizational and individual level. On the other hand the organization have to ensure that there is a shift handover process in place (clearly defining what information is changed and by what means), and the handover process is audited giving the possibility to improve the process. On individual level the handovers cannot be conducted under time pressure i.e. it is the on-signers responsibility to come on the watch in a sufficient time prior the change of command, and the off-signers to ensure that the on-signer has control.

The key component here is individual’s situation awareness (and bridge teams DSA) after the personnel on the previous shift have left the bridge. Consider the *[Case 7]* would it be justified to argue that the work system is most vulnerable at the times of handover? The automation onboard is prone to fail at any given time, and especially if the performance level of the on-signing officer doesn’t match with the off-signings, despite the fact that some individuals have higher work performance (and less variance) than other in general. In practice, if the handover process was conducted from 23:50 to 00:10, and the information is exchanged by proper means, best suiting for the scenario. The on-signer is exposed to the system information for 20 minutes before left “alone” to ensure adequate understanding of the conditions and processes underlying the work system. On the other hand the operators(s) that are self-collecting and constructing their SA would probably use 30 minutes to do so i.e. to ensure the same performance level than the off-signing officers had. If the work shift arrangement is 6:6 (on-off) would it not be appropriate to claim that the system is prone to increased operational risk 2 hrs a day, or 30 minutes every 6 hours (see the subjectivist interpretation to describe the risk, for further discussion). Before any DP operation the DP system is allowed to build up the mathematical model to ensure sufficient station keeping properties. To fully adapt to the present environment and vessel configurations the system is running collecting data from sensor up to 30 minutes (system dependable) prior to moving into safety critical position with the vessel. Consider building the personal situational awareness the very same way as the system does. You do not operate the system with inadequate mathematical model, neither should you operate the system with inadequate SA. System knowledge, user experience and the level of familiarity to the operational situation can reduce the needed time but never replace the actual process of understanding the prevailing operational envelope.

Final section of the human behaviour analysis is focused on the use of safety critical procedures in operational context i.e. instructions, checklists, and procedures to improve human performance. In addition human error and non-compliance to follow rules and regulations is evaluated.

Three-fourths of the operators assessed that they would be able to react on an active error by corrective measures, although it is process dependable. Corrective action after a manoeuvring error can be applied until point of no return is achieved, opening a wrong valve from cargo system is on the other hand impossible to correct. Furthermore the respondents believe that someone made an error, they would be able to detect the error and apply counteractions (68). According to Perrow (1999) maritime systems are often tightly coupled. I propose that the level of coupling should be drawn to process, not complete work system level as it is normally done (e.g. complexity and coupling is compared between a vessel and aircraft, or between nuclear power plant and a refinery). When analysing the processes we can see that some processes are loosely coupled (manoeuvring), and some tightly coupled like cargo systems etc. In this relation it is also important to understand that there is influencing factors to the level of coupling. Poor weather condition for example reduces the time to respond to loss of position.

[Case 8] Example from supply operations. The winters in the North Sea are stormy, and operating on bad weather and operational limits becomes new normal i.e. working weather considered poor on summer season is normally acceptable in winter. People tend to create approach plans to various fields and rigs they work with regularly, so had I. In practice this means that you arrive to field from the direction directly from ashore. By knowing which crane is used to cargo operations you have a plan how to manoeuvre the vessel safely to locations without any additional roundtrips (i.e. following good seamanship). I, like all other used to turn the vessel to starboard committing a full 180 degrees round and then moved astern to the cargo operation position. Due to the strong winds and current I decided to make the same turn but to port instead of starboard to increase my available space between vessel and rig. The manoeuvre per se was successful and the arrived safely to the dedicated cargo operation position. What makes this example interesting is that even though I differed from the behaviour I normally would have done the vessels stopped a much closer to the rig than I had anticipated on the first place. I have often considered how close we would have ended up if the starboard turn had been done. A complex socio-technical work system that had slack yesterday can turn out to be tightly coupled when circumstances changes.

A report prepared for the Health and Safety Executive UK, ship impacts with offshore installations are regarded as the result of one of three issues, or a combination of human error (e.g., poor judgment or ship handling, inattention, ineffective watch keeping, fatigue, workload etc.); mechanical or system failure; freak, or unplanned environmental conditions (Robson, 2003). The issues presented by Robson (2003) reflects the common understanding of the accidents causation paradigm in offshore specialized vessel domain, and threated as root causes on accident investigation reports. Consider the example on *[Case 8]*, if an accident would have happened the real root cause would have been misunderstanding of the level of coupling, the units with respect to each other. I suggest that the operators build their mental models based on the coupling concept proposed by Perrow (1999). Human error due to poor judgement or ship handling is poor concept to explain why an accident happens. Poor judgement is too abstract concept to rationalize the accident causation. Poor ship handling per se can easily be scrutinized, your driving license is based on the evaluation that you have sufficient capability to drive the car, it does not make sense that accident happens due to operators that cannot handle the vessel but have the "license to drive", operate them.

To avoid poor judgement, inattention, and error inducing by non-compliance there is a set of non-physical controls (barrier) in a form of checklists and procedures. Over 70 percent of the operators acknowledged that some tasks entail remembering complex items of information sometimes, or rather often. In addition lack of suitable training to use the job aids is considered as an issue, and it can be linked with the fact that half of the operators felt that the procedures relevant to the operations they committed are not suitable. The respondents admitted also that: it is often more convenient, less trouble or quicker to break rules, regulations or procedures than to follow them (44), it happens that formal procedures were not followed (37), and that there is conditions that encourage to unsafe or sub-standard behaviour (lack of training, poor feedback, poor procedures) (36). People interviewed does not see themselves as rule breakers, but rather the operational procedures and checklists not applicable.

The reported issues can be seen as management responsibility. Management should ensure that checklist that are on place are used, but most importantly collect information regarding to the usability, and does the job aids support the human behaviour i.e. are the checklist fit for the task. Formal procedures that the operators consider not to have practical value will be abandon despite the risk of losing worthy procedures as well.

5.2.2 Safety Culture

The question on expressing the safety culture was divided into two categories: individual level and organizational level. According to the respondents the operators are aware of the hazards in their work or how to control them (75), and behave as if they are genuinely concerned about their own safety (75). The senior crew involve everyone on safety related matters and issues (77). Operators do actively seek and keep themselves up to date on information and new ideas in safety (62), despite the high score people interviewed could not give any satisfactory answer on the acquisition of safety information. The high score can be explained by the safety bulletins provided by IMCA and Maritime Safety Forum

On the organizational level respondents believe that the management and safety representatives (e.g. HSEQ Manager) generally trust and respect each other (74), and that when incidents and accidents occurs the organisation is interested in solving the problem (78). When an incident or accident has happened are they investigated and given the right level of attention (71), and does the company listen and try to solve problems raised by the people closest to the hazards (68). The question on if the company actively seek and keep up to date on information and new ideas in safety (70), scored high similar to the individual level but no evidence on actions that could prove this conception can be recognized. Finally the lowest score was given to the question on if people who blatantly break rules are generally found out and made accountable (47).

Both on the individual and organizational level the identified issue is the knowledge level and understanding of risk conceptualization, not that they would not care, or consider safety as an important factor. Furthermore several comments on the interviews states that the safety culture is not company but rather vessel dependent. Companies have more or less similar systems to enhance safety, but it is up to the vessels what standards they use. The result can be explained by the fact that the assets widely dispersed and the individuals can decide what safety standards to follow. Hudson (2007) argues that vertically integrated multi-nationals like BP, Shell, and Exxon covers so wide range of activities that those distinct operations have own hazard paradigms, therefore distinct safety cultures. The offshore vessel owners are not facing this kind issues, or at least not in the same level. As simple as the solution may sound, I believe that the most effective way to increase the safety is by correct people selection in combination with shared vision and conceptualization between the asset and supporting organization ashore.

The interviews revealed the fact that the organization and vessels can be seen as both calculative and bureaucratic. The vessels are good with routine operations, but latent errors results since information may be ignored and not handled correctly. Errors are fixed reactively but root causes are not investigated, and new ideas create problems. When raised the questions on how the new ideas are handled I got two types of answers that the operators receive from the office: the first one is “does it cost”, and the second one “we have to check how the other companies do about what you propose”. There is no indication what so ever that the companies would be proactive, generative, or improvement based. Furthermore to take a step up on the HSE culture ladder proposed by Hudson (2007) the support from management, an explicit permission and support. From the interviewed persons it was easy to interpret that the way new ideas are “shot down” by the management onshore can have catastrophic consequences i.e. a certain step on HSE culture ladder is not secured by any means, there is also the risk of slipping down the ladders if people’s concerns are not handled properly.

Besnard & Hollnagel (2014) claims that “Safety First” idiotism is a myth of industrial safety. The statement can be supported with findings from many investigation reports. For example, employees on Texas City refinery were asked for ranking the priorities, the first three were: making money, cost/budget, and production respectively (Besnard & Hollnagel, 2014). Production was ahead of safety and quality, but even more astonishing finding was that the contractors were awarded with 25% bonus tied to production numbers, clear message of priorities some could argue (Dekker S. , 2011). In this context, it is difficult to pass Deepwater Horizon accident on Macondo field in 2011. The findings on investigation report from Deepwater Horizon accident can be interpret by help of car driving. Once you arrive to the traffic lights that are turning to yellow a decision have to be taken: brake or gas. Onboard the rig they pushed gas upon all yellow signals from the process. Safety is largely about understanding the signals from the system and revalidation of the process safety, the overconfidence onboard Deepwater Horizon made them averse to the fundamental concepts of collective mindfulness: *Reluctance to simplify interpretations* and *Sensitivity to operations* (see 4.3.2). Overconfidence might not be the correct word, but the rig was known for breaking records both on time (per drilled well) and measured depth, a dream asset for any company as long as it floated.

Is our cultural background a burden, or why it is so difficult to create an organization where collective mindfulness is our leading principle? No, we who come from the Nordic Countries or Western Europe should have least obstacles on succeeding on it. All maritime crew on officer level has taken courses called Bridge

Resource Management 1 & 2, and later Maritime Crew Resource Management. Maritime trade is one most international business domains and course participants are motivated by referring to the work done by Geert Hofstede. Hofstede is the pioneer of research on cross-cultural groups and organizations. According to Hofstede (1980) four dimension of culture can be identified: (1) Power Distance - individuals acceptance on unequally distributed power i.e. the level of hierarchy; (2) individualism vs. collectivism - to what extent the individuals are integrated to the team; (3) uncertainty avoidance - individuals perceptions on unknown and uncertain conditions, and the need of protocols to manage the uncertainty; (4) masculinity vs. femininity - competitiveness, assertiveness, ambition, power vs relationship, quality i.e. are the individuals on the bridge team more concerned about the achievements than quality of the relationships and life.

Despite the fact that 88% of the respondents answered that the organization is rather hierarchic i.e. large power distances than not the value can be very misleading. Based on my experience and the people interviewed the hierarchy is largely a myth, people answers reflect their belief of what is expected from them to answer, but comments both on questionnaire and interviews tear down the myth of large power distance The question is important since large power distances would harm the 'deference to expertise', and consequently 'sensitivity to operations' and 'reluctance to simplify' since lower ranks would not have anything to say on decisions made by the superior. Individualism can be seen as inversely correlated to power distances. Anglo-speaking countries especially Scandinavians are a stereotypical example of individualistic culture where power distances are low. Helmreich & Merritt (1998) have gathered implications of individualistic culture: communication is direct, concise, and individual (vs. indirect, elaborative, and contextual); emphasis is on resolving issues then being agreeable; the captain on individualist culture "hold the office", while collectivist cultures he "hold the power". Everyone I have discussed with agrees 100% percent on the concepts presented above, but how do we explain the 88%, simple: onboard the assets we practice to be prepared for emergency situation (fire, collision, oil-spill, flooding etc.) despite the fact that during and after the exercises we analyse and discuss the improvement potential while the drill the only way of succeeding within the time limits is by having a clear chain of command. If the asset end up in a "brutal audit" you might have only one attempt to recover and acting is far better than "freezing" i.e. there is a time window and poor decision is better than no decision at all.

5.2.3 Work Demands

The pressure, stress, and workload was evaluated both while operating the system (on-duty), and in general while the operators are on onboard. The workload on-duty was considered manageable. The operators had sufficient time to complete all tasks during the watch (84), also the workload between DPO's was seen to be distributed equally (72). The answers do not indicate big difference between workload demands between offshore (40) and onshore (45). According to one respondent the nature of work differentiates between offshore and onshore locations. Commonly the number of simultaneous operations offshore are limited, while onshore if the vessel is engaged for example in supply operations, it is common that there is many cargo loading and unloading operations simultaneously carried out. The simultaneous operations are potential source of stress since focus is on monitoring several processes.

The major source for increased stress and workload according to the respondents are working on the systems operational limits (e.g. poor weather conditions) (66), and working on drift-on / on weather side of any installation (63). The questionnaire does not differentiate between positive and negative stress, but based on the interviews no one mentioned that working on operational limits would improve their performance. Workload can simply be defined as demand on the human component by external means, and the source of stress raising from the miss match between demand and capability. Like the answers indicate the workload have to be considered individually i.e. it is subjective measure. This leads to two problems. Firstly if the operator is very confident about his performance combined with the high trust to vessels capability to manage higher variation, it is justified to claim that his action create higher potential for system resonance. On the other hand if the vessel is "forced" to work on bad weather, and it is a source of stress to the operators, it has a negative impact on the performance, especially on the situation awareness, and reduced human information processing capability (Wickens, 1992), consequently to the response time in a case of intervention.

[Case 9] Working on operational limits (e.g. bad weather) is an important topic to be discussed. Two risk influencing factors can be identified: firstly it makes the coupling between the work systems more tight than it would be within good weather conditions (i.e. loads due to wind, current, and sea to the vessel/unit), and secondly the reduced human performance level due to increased stress and workload, resulting reduced SA. The relation is following; the time window for initiating system recovery is reduced the tighter coupled the systems are, and the human's reaction time is increased due to lower performance level.

There is very limited statistical data for human reaction time in general, for the DP operational context only one can be considered. Based on findings in simulator with operators engaged in shuttle tanker offshore loading operations Chen et al. (2007) argues that it takes a total of 85 s in average for the operator to initiate the recovery actions. Operator observes reduced system state, and makes the decision (evaluation + task formulation) 60 s, and executes the manual intervention in other words start the recovery action 25 s. Combining the findings proposed by Chen et al. (2007) with the *[Case 9]* the relation comes obvious. In weather state 'A/Good' the total time available is (let's say) 100 seconds and in state 'B/adverse' 30 seconds before the accident becomes inevitable. The question every operators should pose is: how tightly coupled the work systems are with respect to each other and what is our response time in a case of degraded system state. The accident of AHTS Bourbon Dolphin while moving the Transocean Rathe is good example of extremely tightly coupled work systems that resulted the capsizing on Bourbon Dolphin after an active error, lowering the inner towing pin (Accident Investigation Board Norway, 2008). The time between pressing the button and capsizing was in a level of a few seconds. Terrible, but good example of "brutal audit" and operator induced system resonance in practice. In this relation it is important to notify that there is disagreement over whether the Tow Master suggested that the DP operators should lower the inner towing pin, holding the anchor chain.

Furthermore the findings on Chen et al. (2007) report are based on simulator observations, and people working on e.g. supply, or anchor handling knows that due to the tight coupling the available time to initiate recovery actions are significantly lower. The setpoint, hence distance between FPSO (or FPU) and shuttle tanker is approximately 100 meters with ± 50 meters allowed movement with respect to the setpoint. PSV operating in cargo handling position alongside platform is normally 10 to 15 meters of the rig superstructure, therefore the coupling can be considered tighter and there is less time to respond on degraded system states. In practice, a 5000 gross register ton vessels movement due to the environmental loads are in the scale of 0,5 – 1,0 knots when moving of the setpoint. Speed of 1 knot equals to 0,514 m/s i.e. vessel 10 meters of the platform leg has 20-40 seconds time to make contact (numbers are rough estimates, based on experience).

The second part of the questions aimed to recognize the pressure, stress, and workload in general i.e. in not time dependable processes. Only the questions: workload is high (41), and work is creating stress (27) in general was identified to effect on the human performance. The interviews revealed the asymmetrical power distribution between stakeholders in operations created stress and increases workload that is not limited to hands-on work on DP desk. “The stress comes from being forced to work on operational limits due to bad planning by third parties”, this comment came up in relation with supply operations. When supply vessel has arrived to offshore location, it is managed by the rig that the vessel is dedicated for.

[Case 10] It is late evening in the North Sea. Supply vessel contacts the semi-submersible drilling rig engaged on drilling campaign on a mature field. A radio conversation is taken prior to the arrival to the offshore location for information exchange. It is agreed that the vessel is taken alongside the rig next morning at 07:00, when day shift starts work. During night the weather has increasing and the sea is picking up. The supply vessel inform the platform about changed weather conditions and expresses the concern of committing the cargo operations safely due to the current weather, and prognoses of the adverse development. The platform informs that there is certain equipment that they simply have to have onboard. Since the crew onboard the supply vessel knows that they are in “service business” options are limited: disturb the drilling operations and cause the platform problems with Oil Company, or deliver the cargo i.e. do the job that we are paid for, and as an reward recommendations from the rig for cooperatives and high quality of service.

The *[Case 10]* can be considered as a classical example of asymmetrical power distribution between stakeholders on operations. One OIM described the situation as following “as long as the top-drive rotates everything is good, hell breaks loose if rotation stops”. Another OIM said that he would “rather jump to sea then be forced to sign the off-hire statement”. In other words the rig feels production pressure from Oil Company, and the vessel from the rig. Nevertheless the vessels are usually chartered by oil company with same principle that the rigs are. It is common that we end up in situation were the vessel is not aware of its “master”. The rig have to be supplied, but can we increase Oil Company’s risk by operating in poor weather conditions (tight coupling). Safety is just one of the competing goals that organizations have (Besnard & Hollnagel, 2014), and it is easy to interpret from the example above. An explanation proposed by Dekker & Suparamaniam (2005) might be one of the reason why productivity has such a high priority on the dispersed drilling rigs: “the less likely that people in decision-making positions are well calibrated to the actual risks and problems facing their operations” i.e. the assets are handled as numbers on the balance sheets and the performance is compared with other assets without understanding what actually is happening.

It is really positive to see that operators in general did not feel that the work creates: feel of tense or anxious, sad and lack of energy, worrying and feeling generally less confident, tired and exhausted, difficulties on sleeping, difficulties on relaxing between the shifts. The only question that is worth to discuss is that operators felt boredom during the work offshore. Boredom or low mental load has similar effects on the human performance than overload. Underload reduces SA due to vigilance problems, low motivation, or general unawareness of what is going on i.e. operators behaviour becomes inactive (proactive vs reactive) (Endsley & Jones, 2011).

5.2.4 Fatigue

Fatigue and issues related to rest between watches play a significant role in the causation of incidents and accidents. The question on fatigue was divided into two categories: during the watch and generally while onboard.

49% of the respondents had 12 h on 12 h off work schedule, 28% had a 6 h on 6 h off, the remaining 14% other arrangements. 12/12 schedule is typical for construction and other vessel engaged on special operations where crew is commonly divided into day and night shifts. 6/6 schedule is also used in many vessels but most commonly on platform supply operations. Many senior positions onboard the asset are type “have to available 24/7” which can explain the remaining five respondents answer.

From the “on duty” related answers highest score was assigned for working overtime regularly (24), followed by being so busy that cannot take a proper brake while working on the shift (19), and being noticeably absent-minded or forgetful at work or find it hard to concentrate (19). Lowest scores was given to questions: have you asked to rest during your watch if you haven’t felt well (10), and have you asked for relief of the duty when you have felt fatigue (12).

Generally while onboard respondents felt that they sleep well between watches (84). The working arrangements ensure sufficient rest (66) divided respondents into two groups, furthermore this topic was widely discussed and various solution has been provided to ensure Watchkeeping arrangements that supports good rest. The same trend continued on questions: adapting to night shift after crew change feel 'rough' for the first few days (64), and changing from night shifts to day shifts they feel ‘rough’ for the first few days (58), seemed to be vessel depended.

Rest and fatigue is an important topic to discuss in terms of health, safety, and efficiency. Monitoring the automation is vigilance task, experiments among nuclear power plant operators suggest that a monotonous and repetitive task will force the activation level to drop and create mental fatigue (Hendrick & Kleiner, 2002). Seafarers in general are exposed to higher stress than general population working ashore due to special mental, psychosocial and psychical stressors (Agterberg & Passschier, 1998). A fatigued operators has reduced situation awareness and reduced information processing capability, hence response time for degraded system state can be largely effected.

A recent study including 157 navigators working onboard offshore vessels measured stress, work pressure, and fatigue found that 30% of the respondents reported unsatisfactory sleep and resting conditions (Håvold, 2015). Furthermore Håvold (2015) stresses out the fact that positive work culture reduces the stress improving the quality of sleep. A coherent definition for fatigue is different to find, hence lacks reliable and valid tool to assess the phenomena.

Fatigue can be considered as management responsibility both from shore by providing adequate manning level to the asset, and offshore by the vessel master. Offshore Specialized vessels are operated in two shifts in 24/7 environment where circadian rhythms (“body clock”) cannot be followed. The number of crew certified to work on bridge is in general four or five people. As a rule of thumb the one 24 hours is divided by two shifts into four Watchkeeping shifts 00:00-06:00, 06:00-12:00, 12:00:18:00, 18:00-24:00, six-twelve being the “Captains watch” and twelve-six “Chief Officers watch”. On drilling the typical work arrangements is day (07:00-19:00) and night (19:00-07:00) shifts. Furthermore on construction vessels has adapted a well function scheme where operators are working 12 hours continuously and one operator is changed every six hours, this overlap can be considered good in terms of knowledge sharing (shift handover). 12 hours watch has pros and cons. According to the operators this allows the 8-9 hours rest that they consider sufficient after monitoring a system for 12 hours. The biggest concern with 12 hours watchkeeping arrangements is when operated in poor weather condition i.e. operators commented that poor weather conditions can be so energy consuming that 12 hours “feels alike a week in good weather”. Theory has recognized the fact that the risk of an accident increase over the course of a 12 hour shift i.e. after 10, 11 and 12 hours of duty, the risk is twice that at two, three and four hours of duty. These findings questions the safety of conducting advanced marine operations in harsh North Sea during the cold and dark winter periods by night shifts between 7 PM and 7 AM. Consider a construction vessel that has been “rolling” at sea for several days waiting for the weather window to be able to lower the subsea template, the normal behaviour for the humans would most likely be “lower the template whatever it takes”. As an matter of fact the nuclear power plants at Three Mile

Island and Chernobyl, the chemical plant Bhopal, and the oil tanker Exxon-Valdez, accidents started during the night hours (at 04:00, 01:25, 00:57, 00:20 respectively). Root cause for all these accidents was as categorized “human error”, provoked by fatigue.

From the literature review it is known that people in general needs about eight hours of sleep per day, errors are more likely between midnight and 6 am, and that adaptation to new shift arrangement takes time a few days (HSE, 2006). Health and Safety Executive (2006) has also recognized the fact that people can find it difficult to admit that they are fatigued. This finding is very relevant to the offshore context since there is no one to replace your service i.e. if your colleague has to work your shift it merely means that you “steal” from his rest and force him to work overtime, this arrangement with already 84 hours work week would also have judicial consequences (for details, see: Maritime Labour Convention, 2006). This can be supported with the results: people simply don’t miss their own watch despite you haven’t felt well (10) or felt fatigued (12) in other terms nine out of ten.

Fatigue can be seen both as variance creating element since it reduces the human performance, or embedded in the ‘Jenga’ concept by missing building block i.e. the human is not capable to substitute the automation in a case of malfunction. The improvement proposal for fatigue related issues raises from comments. Firstly only operations carried out with DP application requires two operators to be on bridge i.e. this allows the operators to split watches. Splitting watches means in practice that the night can be divided into two 00:00-03:00 and 03:00-06:00, and the “Captains watch” in a way that only one operates the vessel 22:00-24:00 while the other takes the following morning 06:00-08:00. One respondent commented that they use the traditional 4:8 system used in conventional merchant vessels when possible i.e. three operators are used to navigate the vessel on 4 hours on duty, 8 hours of duty rotation, and the master is working as a “day man”. The splitting concept presented above is not agreed with everyone, the operators are paid for working 12 hours per day, was commented. My subjective view is that when you analyse the system performance on macro level, eliminating the potential source of variance by having operator’s well rested overrides the significance of serving the agreed amount of hours. An operators not subject to fatigue or reduced cognitive capacity has lower probability to make errors. In practice, for example, the likelihood of pushing a wrong button by person fatigued (performance level ~70%) is 1/100, while well rested person (performance level ~90%) is 1/1000. Furthermore the criticality of pushing a wrong button can be analysed through the concepts of ‘coupling’ and potential ‘resonance’ error would create. In general people do not consider 6 on and 6 off arrangements to ensure sufficient rest if followed slavishly.

Three respondents raised the issues with crew changes, and discussed moreover on the interviews. The common perception by the operator is that the mustering crew is well rested after long holiday, and ready for the refreshing sea adventures from the time of embark. The truth is quite opposite: it is common that on the crew change day for embarking crew starts with earliest flights i.e. the rest at that specific day has been minimal. The charterers on the other hand are relieved that the crew change is done allowing them to operate the unit without restrictions again. In practice vessel that can change onshore are send onto land a day or two before crew change and made ready to sail out when the change of crew has been done. Given that both the theory and respondents answers indicate that it takes time to adapt to shift work, therefore the risk level can be considered to be on increased level until crew has adapted to the new rhythm.

5.2.5 Bridge Team

The bridge team can be seen as the part of the asset to form and determine the organizational culture onboard in terms of values, attitudes, perceptions and competencies (Antonsen, 2009). This part of the questionnaire tried to recognize how the individuals experience their role as a part of the bridge team and furthermore what level of synergy can be found between superior and subordinate. The bridge team is a typical small high-integrity (/high-performance) team that can be characterized by paying attention to the smallest detail, have high working morale, and share same goals, attitudes and perceptions. Successful organizational culture is based on strong leadership and clear communications (Hale & Baram, 1998).

The respondent's perceptions about their role and function as a team member was surprisingly united. Questions on if they know exactly what their responsibilities are scored an index of (94), and if the operators know exactly what is expected of them on duty (91). Furthermore questions on can you influence the amount of work assigned to you (80), are your immediate superior treat the workers fairly and equally (80), your immediate superior encourage you to speak up when opinions differ (70), does your immediate superior encourage you to participate in decisions (68), and your work achievements appreciated by your colleagues (67).

Despite the fact that people interviewed did not know what 'collective mindfulness' is, they recognize the concept when explained. Furthermore it can be derived from the survey results, and especially from the interview findings when the 'sensitivity to operations', and 'willingness to organize around expertise' concepts was explained, they made perfectly sense. The three out the five processes underlying high reliability organizations success proposed by Weick (2007), which applies for the bridge team:

The operators can be considered *sensitivity to operations.* The operators communicate in order to create a clear picture of the prevailing situation and the future events e.g. how would they do the next manoeuvre, or since the departure from port is in 60 minutes what actions has to be taken, roles, and sequence. Operators monitor systems to detect early warning signals, and share their concerns e.g. worsening of the environmental state is communicated and proactive decision taken to ensure that operations are seized before point of no return is reached. For example, in supply operations the operators inform the deck crew and crane operator on platform regarding the changes in weather so that they are able to prioritize cargo if it seems unlikely to able to finish the vessel during that specific operations. The same is done while "waiting on weather", when the weather shows signs of easing the rig is informed proactively allowing them to start planning "when" and "what" marine operations will be done i.e. involving all stakeholders and individuals on all levels. To achieve 'sensitivity to operations' people should be familiar with operations beyond own work tasks. What can be considered a bit unique characteristics in maritime setup is that despite the crew hold a variety of professions and ranks the way has been same for each and every person, there is no master or offshore installation manager that hasn't started as deck hand, or helped out in the engine room. That is the main source of "sensitivity" and the importance cannot be underestimated, hence I do recommend that cadets and junior officers are allowed to gain experience from various vessel types and roles onboard prior to senior position.

The "romanticized" view, raising especially from maritime related literature is that vessels Captain was "next to God", and generally officers do not socialize with rest of the crew. According to Antonsen (2009) this form of hierarchy is hardly ever found onboard Norwegian vessel. Based on my own experience, and experiences among people interviewed, the confrontation between departments and strict hierarchy is not present on any offshore assets manned with crew from Nordic Countries, but multinational crews has this tendency. Low power distances are the key contributor for *willingness to organize around expertise.* Operators do value expertise over hierarchical position, despite the survey shows that 90% of the respondents thinks that the organization is hierarchic. The result can be explained by the fact that their interpretation of being hierarchic means simply that the final decision is always made by the one who must bear the responsibility over actions taken, ultimately the master, or OIM. Furthermore this setup was not seen as a hinder for operating the work system experience and expertise based instead of formal authority, 90% of the respondents stated that there is mutual trust and safety is the guiding principle. This is also supported by the comment from the questionnaire: “hierarchic but everyone can do everything and that’s why we perform so well”, “the command chain is hierarchic but the best bridge teams I have worked with have mutual trust and everybody can do everything, there is no time to alert the one who might be responsible”, and “many vessels have 4 members on bridge crew, captain and chief mate share the same function so both are highest authority when on duty”.

Leaders and managers are surprisingly often mixed. Leadership is influencing and directing others to perform towards the shared goal and vision by means of proactive initiatives. Someone has once told me that leader make the people to climb up the ladders, while manager ensures that the ladders are set against the correct wall. This example encapsulates the fact that managing something like safety can be very reactive i.e. the vessels report (if report) and based on the findings new measures are proposed and implemented to the operations to ensure a “safer” condition. Hale & Baram (1998) argues that strong leadership is essential for successful HSE culture since management approaches act as defensive routines, and change requires always proactive leadership.

[Case 11] In 2012 I attended on a Drilling Campaign Safety Seminar arranged by major multi-national, prior to a field development drilling campaign start on NCS. One of the strongest memories regarding safety management leadership was the story of General Eisenhower and his beliefs about the essence of setting the example. Eisenhower took a chain and stack it in a pile on a table. He would then ask “If I push that chain, which way will it go?” The answer to Eisenhower’s question is that you cannot anticipate. Then Eisenhower takes one end of the chain and ask, “If I take the chain and pulled it as I moved in a specific direction, which way it will go?” The answer is simple, it will follow you. Management can be seen as pushing people (reactive), while leading is the proactive pulling the individual to perform and act towards the norms.

5.3 Organizational Component

5.3.1 Reporting

Reporting is this context does not mean informing the Vessel Traffic Service when entering their monitoring area while approaching the harbour, or sending the daily report to rig/vessel manager for details about the progress in operations. The reporting in this context is sharing of information and lessons-learned. The companies can use various terms for the reported issues, but commonly the lowest criticality is on safety observations that can be either proactive, or reactive measures to improve the safety. Near-miss or incidents reports identified a condition that might have led to an accident. Non-conformities are critical defects on the systems technical integrity i.e. the performance of the work system is reduced until the component or sub-system is repaired (normally in combination of loss of class). And finally accident report or accident investigation reports, that are prepared in co-operation with all stakeholder affected by the adverse event.

Questions on this part was divided into three categories: reporting perception in general, reporting behaviour on individual level, and on the organizational level. Reporting perceptions in general divided the respondents into two: 64% agreed that underreporting is normal if offshore, and that it protects the vessel from added procedures, checklists, rules and regulations. Furthermore (64%) underreporting benefits the shipping owner against client. (See 5.3.4 for more about the procedures and added value)

The second set of questions tried to recognize if there are some specific factors that would cause the observed reporting behaviour. According to the operators they have sufficient time to do the reporting (89), but only surprisingly low number of respondents did believe that the reporting would make any difference (51). Furthermore the operators did report the novel situation internally (88), but sharing the information for the industry in general was not considered beneficial (38). The respondents doubted the confidentiality of the reports provided by them, hence reporting anything outside of the organization was not considered to be beneficial either. The perceptions of what should be reported and what should be considered as normal operations varied largely, the survey indicates that 50% of the respondents report also something that can be considered “minor” deviation from the normal, but the interviews indicate that minor deviations are generally not reported.

[Case 12] From the very same Drilling Campaign Safety Seminar arranged by major multi-national a story of the importance of reporting was told. Consider that you are driving with your car from Bergen to Stavanger after the seminar. Would you do the driving if you had problem with the cars heating causing fogged windows, what if the other driving light was broken, what if the windows wipers stopped working, and the list just continued until we agreed that the driving had to be stopped, and issues solved before the trip could continue. Now the interesting part of the story was that these findings embedded on the car setup was actually findings reported by the drilling unit. The driller cabin had broken fan, and due to poor ventilation the cabins windows fogged, in addition it was reported to be cold inside the cabin. The problem with wipers caused limited visibility since drilling mud was spread over the windows during the drilling process. Four out of the twelve floodlights was reported to be broken causing poor illumination level on the drilling floor. And finally one of the clients had by accident walked into the drilling floor while pipe handling, since the gate to restrict people from entering the area while drilling was left open. Analysing these kind of “minor” findings in isolation do not indicate that there would be a problem in the process, or at least it is manageable and not time critical. Applying these into system thinking reveals the potential resonance creating effect of these reported issues. This is probably the best example of how important it is to understand the interconnected nature of the complex socio-technical systems.

The example above shows that we should treat all reported issues from safety observations, near misses and errors, to accidents as vital information about the health of our work system and most importantly try to learn from them. What was experienced in one of the twenty (or thirty, or even hundred, in the largest drilling contractors and offshore shipping companies) assets we are managing doesn’t have to reoccur just because we could not share information and learn as an organization.

A well function reporting system that is used to large extent can be powerful tool, its potential should be understood and applied to continuous improvement. Consider the HRO example the Aircraft Carrier USS Enterprise and its crew. They were able to change the microculture from distrust and disrespect to a culture of mutual trust and mindfulness. The paradigm shift improved not only the operational capability of the unit itself, but it become an indirect problem solver for the whole fleet. Does the company you work for afford not to do the same?

ISM Code created the fundaments for Safety Management Systems onboard the assets that today provide high quality tool to do reporting efficiently. The modern reporting tools are well structured web-based solution were the people reporting can attach photos and various reports from the systems. If you agree that informed culture is the key to understand the defaults and it creates the fundamentals for continues improvement, hence safe and reliable operations. The consequence of poor reporting culture is that safety managers are unaware of the potential misalignments between beliefs and practices (Besnard & Hollnagel, 2014). On the other hand the increased number of checklists and procedures might be a symptom of these misalignments, the barriers to improve safety seems to evolve further away from what can be called practical or in the worst case not even applicable.

The third part tried to identify organizational factors affecting the reporting perceptions. 90% of the respondents felt that they are encouraged to report all incidents and accidents to the office (83), and that there is a proper system and tools available to do so (81). In general operators felt that the vessel management does not tolerate malfunctioning equipment (31). The identified issue that can be considered to limit the reporting activity is that the operators do not consider that reporting makes difference or benefits the vessel. Furthermore 84% of the respondents believed that a course would help them to write reports. Two operators commented that there is a system in place but “we’re not receiving any feedback on reported issues”.

Reporting provides the basis for informed organizational culture and learning between the units that are spatial dispersed. Since the “trial and error” method of learning is not an option for HRO’s both success and failure need to be communicated (Hudson, 2007). An advanced safety culture is of course more than just a reporting culture, Hudson (2007) argues that well-functioning reporting system is the product of cutting-edge organizational culture focused on safety not the beginning i.e. reporting culture does not make safety culture. Reporting is the outcome of mature safety culture.

Furthermore reporting is one of the elements of mindful organization. *Preoccupation with failure* guides us to focus on reporting and analyses of the reported issues. Near-misses, safety observations, and non-conformities send by the offshore asset should be treated as (pre-) accidents that revealed the potential danger or condition. In practice the crew should evaluate every action or operation accomplished e.g. every manoeuvre is revived and graded. Even smallest errors despite how unimportant or inconsequential it feels for the observer are treated as system problem.

Finally Dekker (2007) argues that the fundamental of reporting culture is trust. Structural arrangements like reporting channels (ISM Code / TQMS) and relationships between parties (power distances, mutual trust) that either lay or reject the basis for trust. Trust is essential if you want people to share their mistakes and problems within the organizations or even to a larger community. Trust hard to build, easy to break, and still and all critical to safety.

From the report to the President: “Sharing information as to what went wrong in offshore operations, regardless of location, is key to avoiding such mistakes” (National Commission on the BP Deepwater Horizon, 2011).

5.3.2 Training

This part of the questionnaire was to investigate into what extent the operators receive training and how could it support them to cope with the daily operations. All operators have to master basic seamanship, operation of maritime system, and navigation according to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), and in addition dynamic positioning system training accredited by Nautical Institute. In addition there is a large set of vessel type specific (and company specific) courses to improve the safety. Training helps the operators to acquire the skills and knowledge enabling them to improve their performance.

Despite the fact that majority of the respondents believe that their colleagues are competent (79), 80% percent of the operators considers that theoretical training would support professional growth on the individual level (73), but only 36% have had some form of technical training after they received their DP certificate. After gaining the DP certificate is interesting since the DP training scheme is built in a way that the operators takes first a familiarization (basic) course, secondly seagoing onboard an Offshore vessel to gain experience (a minimum of 30 days on DP), and finally the simulator (advanced) course. The two courses and six month (+ the one between courses) of training enables the individual to apply for the "full ticket". Now compared to the STCW certificates that takes years of training and sailing the amount of training can be considered low, especially when considered the amount of the daily operations that are conducted by help of the DP application. The training could help to understand and interpret the manuals and procedures provided by system manufacturers, 60% of the respondent felt that the material can be difficult to understand (42). One common solution for system instability and automation malfunction is that the operators disables automation, and operates the vessel manually. In many vessels with large power distances only the master is "allowed" to manoeuvre the vessel manually, this is not an issue among the crews from Nordic Countries. 80% of the respondents answered that the vessel is manually operated by all operators.

The second part was focused on the training possibilities onshore. In general the operators thought that training on simulator centre would support their learning on how to respond on various alarms (68). The training would also give tools to understand and formulate chain of events i.e. recognize the possible sources of instability (63). The quality of current training provided by third parties was examined. A problem recognized with training providers is that 68% of respondents felt that the simulator training fails to scope with real-life scenarios, and furthermore the testing and verification of learning outcomes are fuzzy. Two operators commented that "the training providers would run out of business if someone was send home without the diploma". Quantity over quality is poor approach, HROs has to drive for operational excellence.

What and why should we practice? DP operator's decision making is largely proactive by taking the initiatives to ensure that the system remains on normal state, and reactive on the other hand when acting upon the degraded system state to retain balance. Earlier I stated that situation awareness (and distributed SA) plays a crucial role on the time consumed before counter actions are applied, the other part effecting the time used before action initiation is the recognition of possible failure mode. Psychologist call this process for 'pattern recognition'. Pattern recognition is an attention process where the stimuli (e.g. from DP system) is to be recognized by help of working and long-term memory resources (Wickens, 1992); (Wiener & Nagel, 1988). The DP operators processes the stimuli as either 'typical' or 'atypical' and counteractions are based on the extracted information from long-term memory (Klein, 2000). The decision making process can also be applied to the Skill-Rule-Knowledge Framework (SRK-Framework) to understand DP operators behavior. Rule-based level is similar to the 'typical' stimuli where the problem can be diagnosed and counteractions are based on some stored action pattern. Knowledge-based level is similar to the 'atypical' stimuli where operator need to apply significant conscious effort for recognize and solving the task. In practice, it means that when pattern cannot be recognized the operator applies a knowledge-based solution that he assumes to give best possible outcome. DPO's have to make time-critical decision to protect the system from collapsing. Procedures does not apply for degraded system recovery scenarios, the recovery is based on knowledge and experience that derives from similar events experienced on simulator or in real-life. By help of training the DPO's could broaden their pattern recognition skills meaning that there is higher probability that the operator can apply counteraction based of recognized failure mode and stay on rule-based level. It is important to understand that knowledge-based behavior could also be called "lack of knowledge" based behavior, and the purpose of training is to swift the lack of knowledge to knowledge i.e. into skill-, or rule-based behavior, something that we can restore from working and long-term memory resources. Training is the only “quick fix” I can propose. (See 4.1.2 SRK-framework, and 4.1.4 Human Information Processing)

The training contributes to the principles of collective mindfulness also. The *Cultivation of resilience* means that the operators and organization is prepared for system variance. The DPO’s can only achieve resilience by training i.e. enhancing the individual competence level, and having response repertoires to novel scenarios (being able to apply rule- and knowledge based behaviour). To be resilient the individual have to have deep system knowledge to be able to improvise when needed, avoid overconfidence and over caution with respect to automation and the underlying processes. Being resilient can only be achieved by training to face unfamiliar situation and learning from situation other have experienced.

It is justified to claim that eventually the level of training and competence differentiates the assets that passes the “brutal audit” without severe consequences from those which did not.

5.3.3 Management Commitment for the improvement

In this context management commitment means the organizational source support and control of the running activities. According to Vinnem et al. (2003) management makes strategic choices concerning the technical and operational activities, and defines the operational limits the human component has to follow.

According to the respondents the management ashore encourages attitudes to achieve safety objectives (80), but three people commented that the objectives are rather unclear. The same result was found on the interviews, people want to believe that safety has a high priority but the concept of safety was merely impossible to define. Safety for the operators meant doing things without taking too much risk i.e. being safe from harm. Based on the operator’s comments, and understanding of the safety concept, proposing that the communication should be based on the risk concepts and conceptualization instead of safety. Company acts upon the reports issued by the vessel (76). Despite high index, this question raised a lot of discussion. Majority of the people interviewed stated that it is difficult to determine what to report and what not to report. In addition the operators raised their concern on creating problems for the company if you report too much, or too critical things. On the other hand some comments from the survey highlighted that minor things are not on company’s interest: “safety observations directed on company you don't get any response before pushing”. This is quite alarming, we have ended up in a situation where organizational mindfulness cannot develop since weak signals are not properly managed (‘sensitivity’), and on the other hand when people believes that the company has to be protected from the charterers there has to be issues between the company and oil-major. The offshore vessel managing companies have (based on ISM Code) systems in place to manage hazards i.e. according to the HSE culture ladder proposed by Hudson (2007) the companies and vessels could place somewhere between reactive and calculative organizations, but more importantly it seems that the next step cannot be taken due to the charterers and authorities. The claim is strong, but it can be rationalized. Based on the survey and interviews it is evident that the oil-mayor do not understand the nature of marine operations, or at least they speak other languages, figuratively. This means that when the vessels and managing company is audited the safety management system is gone through to see what kind of incidents and accidents have happened, simply question: if you are working on a procurement division for oil company and had to choose between a vessel/company would you choose the one which has a decent amount of reports but nothing serious (accident etc.), or a one where incident and accident happen regularly. It seems that the offshore companies has to act ‘pathological’ and ‘rule based’ against the charterer, focus on how everything looks instead of how things are in order to ensure contract.

Audits and vetting's are performed for quality assurance, measuring the degree of implementation and effectiveness of arrangements, effectiveness of the Total Quality Management System, and the compliance with procedures, rules & regulations. The quality of auditing was highly criticized by respondents. Audits create value (60) shared opinions, and especially comments and interviews raised the issue and concerns on the process. A good audit would simulate a real-life situation that has the potential for undesired consequences revealing the actual condition of the system with desired, or optimal.

According to the respondents "vessels are audit to death", "due to new contracts you may have 10 audits over a year, on top of the annual FMEA and OVID audit", "Auditing and Vetting don't serve the purpose, inspectors act upon their own preferences", "it is easier to agree than fight despite how meaningless solution they propose", "vetting is done by people who knowledge is limited for certain type of vessels and they as a rule fails to improve anything, normally comes up with list of "ideas" based on their subjective belief", and "vetting is a joke". Stunning response from the operators but maybe it is justified. The document used to support the process are reactive "quick fix" type solutions the repair the broken component as discussed earlier. For offshore specialized vessels the multi-nationals have implemented a Ship Inspection Report (SIRE) programme (mainly for shuttle tankers), and a more general (for all types of offshore vessels) Vessel Inspection Questionnaire (VIQ) that sums up all objects to be checked in a vetting. The problem is that safety and quality is measured with "yes or no" type questionnaire that only sees if system is in place, nothing about the use or quality. According to Hale & Baram (1998) the danger with such schemes are that they just guide for desired behaviour, something imposed from outside, commonly not even seen to belong for the organization. A reward of complying with these type of inspections is contract. This can be considered as a classical example of not only asymmetrical power distribution but also against the principle of 'deference to expertise". In the future, the main question that the inspector should ask himself is "how do I add value to the process?", and the operators "how should we use the 'consultant' to gain hindsight's?" We have to understand the idea proposed Lagadec (1993) "ability to deal with crisis is largely dependent on the structures that have been developed before chaos arrives" i.e. the ultimate test of the success of auditing is reduced frequency of incidents and accidents. Auditing should create value for all stakeholders.

5.3.4 Procedures

The questionnaire has divided the procedure analysis into three categories: procedures used in the organization and vessel specific; procedures use in DP application; and procedures in general. This part of the survey raised most discussion and concerns.

The dominant safety paradigm claims that safety can only be achieved by establishing high reliability systems, and ensuring that the human component operates it inside the boundaries i.e. according to the procedures, rules & regulations (Borys;Else;& Legget, 2009).

Procedures can be divided into several groups i.e. internal and external, official and unofficial. Internal procedures are company and vessel specific to provide help to the operators and crew on daily operations. External are procedures, rules and regulations set by the authorities (IMO, Maritime Directorate, Class etc.) and charterer or a consortium of them (Oil Companies' Industry Marine Forum, International Association of Drilling Contractors, International Marine Contractors Association, Marine Safety Forum etc.). While the unofficial procedures and practices can be considered as the result of overly generic procedures, and left out parts of procedures deemed inapplicable i.e. informal and tacit rule adaptations. The majority of papers that analysis the relationship between safety performance and following the rules, regulation and procedures fails to understand the function of them in the first place. Procedures helps the operators to scope with the complexity and helps to prevent slip & lapses, and mistakes especially in cases where operators have little or no experience, but the idea of that safety is ensured by following them is incorrect.

The first part of questionnaire was analysing the vessel specific procedures. According to the respondents company and vessel specific procedures was used in daily basis (72), but several issues are recognized. Some procedures are too complicated or too detailed, or not detailed enough (53), and on the other hand there is not-written-down knowledge at all (49) meaning that the operators have to apply behaviour be believe is correct. Reasons for acting upon what the operators believed that should be done was: procedures are out-of-date, or just out of step with how the job is actually done (48), poor training on how to use them correctly (46), and because procedures have been developed without any input from the user (40). Based on the answers a cap between procedures and practice can be identified.

Non-compliant behaviour is to be expected, and rule adaptation is considered to be a source of reliability (Hale & Baram, 1998), this view is supported by Besnard & Hollnagel (2014) who states that procedures are inherently underspecified in scope and depth. The operators overcome these limitations of procedures by interpreting and adapting to the scenarios adjusting their behaviour and choosing from the procedures applicable parts. For some reason this is not accepted, or understood by the industry. It has the tendency on creating even more complex and comprehensive checklists, rules and regulations in response for accident to be sure that the incident or accident would not reoccur i.e. buying the myth that safety can be improved by barriers and protection, and being blind to the increased complexity and couplings. Oil companies reactive "quick-fix" approach to increase the pressure on complying with rules and regulations for increased safety can also been seen as a "buffer against prosecution" (Borys;Else;& Legget, 2009). To tackle the real root causes is costly, by adding rules and regulations it is certainly easier to prove that the accident was due to non-compliance i.e. human error by 3rd parties.

The industry should have the focus on understanding the cap between procedures and practice, teaching the operators and organization to be mindful (individual and organizational mindfulness). Dekker (2003) proposes that organizations should resist telling people that procedures has to be followed, and instead help the operators to develop skills to judge when and how to adapt i.e. be resilient, 'sensitive to operations'. The unfortunate result of this compliancy "heat" is that the operators are not only filling checklists and papers that are assigned to the operation but also other documents, just in case something happens "we are able to show that papers are on place" as one commented.

The second part questions are based on the findings by Chen et al. (2008) who analysed the safety DP operations on mobile offshore drilling units, concluding that the instructions did not conclude procedures and guidance targeted for DPO's on how to detect deviations, and when, where, and what to check during the watchkeeping. Based on the questionnaire the operators answered that operations manual gives guidance on how to detect deviations (65),and that procedures covers when and where to check what during the DP watch (60). Despite the average score i.e. more than half claimed that these issues are addressed on the procedures none of the interviewed persons could exactly specify or show these procedures. The conclusion by interviewed persons was that these are the type of things that the operators simply have to know i.e. it is the operators individual decision on what to monitor and how often he does it. I am satisfied with the explanation but the original issue still remains, there is guidance on this which I consider to have much higher contribution to the operational safety than filling out paperwork, a bit extra just in case something happens. By being able to answer to "when, where, what" question the operator would gain the 'sensitivity to operations' and 'commitment to resilience' needed for having sufficient situation awareness and mental model, hence lower reaction. Procedure for allocating the duties between the DPO's (79) comes normally in the form of "Captains Standing Orders" and there is rarely any issues related to this topic. Furthermore the checklists used on DP are prepared by the vessel crew and in case of inapplicability it is the operator's responsibility to correct it, these procedures can be considered to be in place (74).

Case [13] Working onboard a supply vessel and received a day-by-day (d/d) job from SPOT market on the British Sector of the North Sea. The beginning is hectic as always: a quick on-hire survey is done, a quay for cargo loading is designated and the vessel should be heading for the field as soon as possible (day-by-day is nowadays the same as hour-by-hour i.e. no time to waste, cost optimization they say). Arriving to the field and agreed with the rig that the cargo operations starts immediately, prior to the entry of 500 m safety zone a pre-entry checklist have to done. In this case the American rig owner and the British Operator are not satisfied by the vessels own checklists, we have to use their specific ones, probably some quality assurance thing:

Rig: "Is the Master truly aware of all procedures?"
Vessel: "Captain is sleeping, but yes I believe so"
Rig: "Both main engines tested ahead and astern?"
Vessel: ""Both" four main engines running and split bus-tie, azimuth thrusters functional"
Rig: "Are rudders tested?"
Vessel: "Still azimuth driven, but let's say yes"
Rig: "I'm sorry, we know that this doesn't make any sense, but you know we have to do this, since the office..."
Vessel: "Yes, off course..."

The third set of questions was used to identify the issues with external procedures, e.g. similar to represented on the *Case [13]*. According to the respondents the rules and regulations was neither considered to be hard to follow, nor do they hinder the process (31). It is also easy to determine what rules applies to specific scenarios (35), but the operators disclosed that it is merely impossible to follow each and every rule in force (47). Two operators commented that "it is depending on the oil company, some use so complicated, and also non-applicable procedures that strictly speaking it is impossible to follow", other commented that "it is better to be unaware of all the non-sense that hinders the safety of operating the unit".

On SPOT market we apply the general rules from GOMO (72), on SPOT market there is no time on reading and understanding the charterer's procedures thoroughly (56), and we feel commitment to the operational excellence in d/d SPOT jobs (55). GOMO, or Guidelines for Offshore and Marine Operations is a standard operational procedure, encouraging good practices and safe vessel operations. The GOMO replaced the publication "Guidelines for the Safe Management of Offshore Supply and Rig Move Operations (NWEA)" 2013 in UKCS, and 2014 in NCS. On charter party it is commonly defined that vessel shall operate according to the GOMO procedures.

Vessels engaged on SPOT market jobs can be considered a special case due to the nature of the contract. Good vessels with good crews can provide high quality of service, but it cannot be guaranteed. Respondents felt that the d/d market is oil companies' way to press down the prices, especially in times of oversupply the vessels goes for less than the operational costs, crews being aware of this. A study by Little et al. (1990) showed that the stress of airline pilots were significantly higher on economically unstable than in stable airlines. Many of the resent air investigation reports (e.g. Colgain Air Flight 3407) have made the same conclusion: people do worry about their own and companies financial state, why would the maritime crews be different. Pressure to deliver can engage the operators to hazardous behaviour, breaking safety rules to deliver and save costs providing temporary help for company, consequently exposing the system for greater risk. Therefore in terms of safety and quality short contract arrangements can be groggy, and should not be considered as permanent solution. In comparison time-charter has the potential of becoming co-operative, mutual enterprise where goals and visions are shared yielding improved safety level (not of course strictly speaking, since it does not effect on the ownership, but operational vision and goals). A long-term time charter gives the shipping company stable cash flow, and possibility to invest on safety, while the field operator has quality assurance in terms of knowing "who" and "how" the vessel is operated in day to day basis. SPOT can be considered as opposite, my personal favourite sentence comes from a marine operations manager in UK who stated that "Safety is paramount, but we have to get the things done", and I'm still unsure how these instructions should be interpret. The sentence above was presented in the context of working in poor weather conditions, unacceptable for safe operations, therefore it is interesting how the respondents have experienced the similar situations where there is clear discrepancy between policy and reality.

The same happens in NCS also of course, the scenario experienced in UK shows so clearly the controversy of the industry that it had to be shared. In NCS the "pushing" is commonly done more gently i.e. the story starts by designating the decision "power" to the vessel but in the same time it is made clear that what are the consequences of not being able to conduct the operations, for example, the time and resources that have to be used if the production or drilling have to be stopped, nonetheless restoring the production. If you doubt this claim consider the following: why would the vessels crews onboard PSV, AHTS, and other attending vessels be aware of this, despite it is totally irrelevant and out of their operational scope. This is in line with the finding from the questionnaire: charterer expects us to operate on the system limits (58), and vessel owner expects us to operate on the limits (40), i.e. in poor weather conditions.

Weather is, of course, not the only external risk influencing factor that can be identified, but it is something that is present in everyday operations and frequently found as a root cause for accident. A number investigation reports suggest that bad weather is not the root cause, but the accident is caused by erroneous judgements and decision with respect to the work systems capacity. If so should not the procedures clearly define what the limiting weather conditions are? The limits (wind, sea, swell, and current) for safe operations are clearly defined by the operations manual (60), charterer (58), and vessel owner (58). The questionnaire does suggest that it is 50/50 if the limits are clear, the interviews on the other hand made it clear that the decision are made by vessel crews since all the vessels. GOMO defines that vessels working on the drift-on position should not exceed the power consumption of 45%, but what is unclear for the operators is that does the value mean, for example, constant thruster utilization, or how should this guideline be interpret. A pragmatic view is of course that significant space for interpretation has to be left since well-defined criterion could result too negative effect on the asset utilization i.e. bad for business, or as one commented "lawyers would run out of business if the procedures were unequivocal".

There is differences between operating practices between the offshore companies (66), and in practice it means the additional operational procedures. The fact that (in theory) the operators are allowed to judge the acceptable weather conditions is a positive sign of 'deference to expertise', but there is still uncertainty whether the oil companies understand where the expertise is. Extraction from one oil-majors checklist package: "…the purpose of this document is to provide standardized global checklist set that will apply to and be used by all vessels working on fields owned or operated by…", this package come into force after an accident, broken component found and fixed.

Actors do not break and by-pass rules because they enjoy doing so (Hale & Baram, 1998). Based on my experience and evaluation, the vessels and rigs have the full potential to grow into mindful organization, but the bureaucratic, procedural, top-down management approach does its best to hinder this process. A mindful high reliability organization that have built-in processes that enable to crews to modify and rules and procedures could tear down the identified gap between procedures and practices. According to Bourrier (1998) patterns of violations are less likely in organization acknowledging the fact that procedural adjustments are unavoidable i.e. an organization which cannot allow itself to fail has to challenge the current routines and procedures constantly. To build these kind of self-correcting organization that are capable of organizing criticism internally the concepts of collective mindfulness has to be applied. I am fully aware that there is many obstacles especially in highly regulated industries but if we are truly concerned about the quality of the marine operations the time is now.

5.3.5 Bridge Team

The bridge team question is divided into three categories: crewing management, working climate, and bridge team evaluation by co-workers. The first one is a company responsibility i.e. ensure that right people are on the right place. The working climate and bridge team evaluation on the other hand evaluates the working atmosphere and behavioural safety. These questions are closely related to the safety culture, but divided into own category since the company is ultimately responsible for human resource management.

The crewing policy provides stable crew (59), clearly space for improvement, since it takes time not only to learn to operate the system but also to be a member of the high performing team. According to the operators the crew changes are managed in a way that it ensures sufficient time to familiarize with the equipment onboard (68), it is especially important when vessels have not unified work systems. By having various work system combinations, the crews have to have sufficient training level and or knowledge from specific work systems (DP, PRS etc.), and signed to vessels that match with their competence. The question on if the operators had sufficient technical training for the systems in use (61) shared the operators into two. Furthermore organization encourages me to develop further in my position (60), and company is willing to support my professional growth (57) was seen to have more symbolic value than practical. The message from the operators were clear: companies are not willing to invest on courses that are not obligatory i.e. the gap between reality and “orations”. One commented that “it is so ironic that HR people posts quotas on LinkedIn: “CFO: What happens if we invest in developing people & they leave us? CEO: What happens if we don't & they stay”, and I don’t get the courses that support my development”. These findings and comments are in line with safety myths argued by Hollnagel (2014): safety is always considered from the financial perspective i.e. important if the company can afford it. Finally promotions are given to the right people (55) scored lower than one could expect. It is an important issue since mutual respect is needed for creating good bridge teams and the team members are sensitive to observe who has the skills and knowledge to take responsibility, and interviewed persons commented that in the maritime industry promotions have to be “earned” not “received”. The investigation analysis on Piper Alpha accident highlighted that the organization had failed on hiring, screening, training, and promotion of personnel which resulted insufficient human resources on the asset that consequently led to the disaster (Gordon, 1998).

The second part of the questions was used to evaluate working climate. The four questions regarding the working climate scored well: relaxed and comfortable (80), encouraging and supportive (76), competitive (48), and distrustful and suspicious (21). The working climate question is important one, and it is the company’s responsibility to man the assets in a way that each and every unit would score similar or better scores. Based on my experience is that a bridge team with mutual respect and good atmosphere creates the climate for cooperation, generative information flow, hence fundamentals for collective mindfulness. Furthermore these results correlates well with the four dimension of culture (see: Safety Culture).

The third section was concerned with behavioural safety among the operators i.e. an operator evaluates colleagues on the bridge team. Some of the bridge crew has lack of motivation (45), tendency to "cut corners" (40), poor attitude to safety (37), and tendency for "cowboy driving" (37). The vessel masters (four) commented that you need to have supportive organization behind you to address the issues related to behavioural safety i.e. solution is to get “cowboys out of your vessel and make sure they don’t continue on the company”. The issue solution seems obvious but problematic if we believe that removing the “bad apples” would be the whole story. The comments are very revealing, they show how strong the belief is that if we get rid of the individual errors the systems become safer.

What should the company do? Company has to provided tools and guidance to the crews which leads to involvement, hence employee empowerment that enables the higher safety norms. Based on the interviews it has become obvious that the issues presented on thesis are difficult to address onboard the units due to the lack on conceptual and theoretical knowledge. Therefore it is the company’s responsibility to provide the skills and knowledge to the crew. Furthermore we know from project management, that project fails without project champions, sports teams have captains to lead and promote for the common goal, so needs the units. Captains, OIM’s are seen as the authority onboard the assets who determine the norms and shapes the cultures. Whether it is the captain or someone else it not important, what is important is to get onboard “safety champions”. These champions shape the culture by setting high standards and can communicate and address the issues, forcing awareness and asking the right questions to promote collective mindfulness.

6. Conclusions

Murphy's Law states that "*Anything that can go wrong, will go wrong*" or more specifically *"If there are two or more ways to do something, and one of those ways can result in a catastrophe, then someone will do it".* The laws author Edward A. Murphy, U.S. Air Force aerospace engineer who was involved in a rocket-sled experiment, during the development he observed that one should always assume worst-case scenarios. This thesis supports the Murphy's Law, and suggests that the industry focuses on creating systems with resilience engineering principles in mind. The errors both active and latent, causes variance to the multi-layered processes i.e. operating an Offshore Specialized Vessel is not a single process, it is a complex set of processes that have the potential of failing one by one or all together. Some processes are more time dependant (tight coupling) than other (loose coupling), but the underlying fact is that the processes continues with or without the human component. An OSV's processes cannot be paused in a way we would do in onshore i.e. take a break and figure out how to continue. This makes the human component the most valuable piece in the "Jenga" tower. A poor system can be compensated with good human component, but poor system and poor people will certainly drift into failure.

One of the most prominent finding was that the companies are all the same, consequently the vessels and crews onboard the units make the difference. There is differences on the safety cultures between the departments, and even between day and night shifts. This indicates that the safety culture and mindset is very individual character, hence the problem to be solved is on creating a shared vision resulting the collective mindfulness i.e. the five processes underlying high reliability organizations success. For example, low power distances indicates that the bridge teams have the tendency to 'deference to expertise', and many of the operators are constantly assessing the situation fulfilling the premise of 'preoccupation with failure' (respondents used "what if" technique i.e. they are constantly asking themselves the question and updating the mental model for being prepared to handle the instability of the works system). But this not enough, the operators cannot improve their performance if they don't know or understand the fundamentals. Therefore I argue that the crews have to be exposed to concepts that are e.g. presented on this thesis.

It was recognized that there is, and always will be a pressure to deliver. The pressure forces the operators to push the work system limits and make decision affecting to the barrier system. Accidents happen when a sufficient number of barriers fail (Hollnagel, 2006); (Perrow, 1999). Controversially barriers add complexity, which the human component have to manage (Dekker S. , 2011). The industries in general seems to apply "quick fixes", barriers after accidents that has occurred i.e. fixing the broken component and continue until next accident happens and new quick-fix is added. This top-down management approach fail to fit for purpose i.e. increasing the safety, hence reducing the risk of similar event to occur. Hollnagel (2006) argues that in order to be able to select the right barrier during system design, it is necessary to assess the efficiency of each barrier system relative to the failure or error modes. The very same principle is applicable on the operational phase also.

We build ever more complex work systems being proud of how technically advanced they are. Increased redundancy and technical advances are used to justify our ever increasing need to drill deeper and in harsher conditions. According to Berg (2013) statistics show that the accident frequency on maritime industry has started to rise from historically low level signing the human element as main contributor. The low level is achieved by technical improvements. I would argue that assigning the human factors as main contributor fails to grasp with the fact that we have engineered so complex work systems that the individuals work performance doesn't comply with the demand the work system requisite i.e. the work systems of the current century are a collection of interconnected complexity, rather than smooth-running systems (Lewis, 2014).

This is an organizational issue that cannot be assigned to the human component. We cannot declare human error to be root cause of an accident if the human component is not trained to match with complexity of the advanced Offshore Specialized Vessel of today.

There seems to be strong consensus, a safety paradigm that the systems are already safe, and they need protection from these disturbance makers, unreliable and unpredictable human component. All we need to do to make the systems safer is to analyse an incident or accident, henceforth provide more procedures, rules & regulations, tighter monitoring and controlling of the activities, more automation. The reality is opposite, the work systems are usually built to the lowest tender, full of inherent imperfection that only the individuals can manage and create safety to the processes in all system levels. Hollnagel (2012) sums nicely why work system can produce the wanted output: "because people learn to overcome or compensate for design shortcomings, because they do not just do what they have been trained to but can adapt or adjust their performance to the demands, because they can interpret and apply procedures to match the conditions, and because they can detect and correct when things go wrong". According to Dekker (2011) we have to invert the perspective of safety, rather than seeing safety as the absence of something (violations, mistakes, and errors), safety should be seen as the presence of something. The something is the human components adaptive capacity, ability to recognize, and absorb variance and resonance. Resonance meaning system states arising from the complexity, and what the system is not even designed to withstand. Only resilient systems can tolerate resonance i.e. system ability to rebound without collapsing (Furuta, 2015); (Hollnagel, 2006).

Technical redundancy should never take intrinsic value on High Reliability Organization, neither can it be treated as a compensator for poor human performance. Recognizing and acknowledging of the problems related to the safety is a necessary first step to genuinely improve the quality of maritime operations.

The current work systems are seen safe and highly reliable due to the technological redundancy and process redundancy. This evolution has made the work system complex causing instability which is to be managed by the human component. To help the human we have added a vast amount of procedures, rules & regulations as a barrier to protect the system for collapsing. What has to be understood is that the procedures do not, neither can they match with the demands of the increasingly complex socio-technical system. To run these complex work-systems successfully we have to acknowledge that there is multiple paths to success. These path are found by the competent operators, and cannot be chosen by the designers or managers. The role of management is to provide the operators tools and knowledge to scope with the varying conditions not trying to limit the system boundaries, it is not possible.

Using resources on understanding the unknowns falls in the category of "academic non-sense" i.e. neither commercial, nor practical value. The industry should emphasis on training the human component by giving the tools needed to be able to analyse and improve the daily actions and processes on micro (individual), meso (unit) and macro (organizational) level. The current level of understanding of the operational practices and work systems characteristics makes the whole discussion about preparing for the unknowns antic, reminds me of the story of a "foolish man who built his house on the sand", in this context sand represent our current understanding of what is "normal". Besnard & Hollnagel (2014) argues that the obsession of understanding what can go wrong consumes the resources on understanding what goes right, purpose of safety is to ensure that normal performance is sustained.

For the companies whose goal is to produce unmanned ships in the coming couple of years i.e. yards and system vendors are the only ones to whom I can propose a "quick fix" based on my findings: take a one week excursion onboard the assets you have built and claimed to be state of the art in terms of performance, and observe the variance in processes and the adaptiveness of the human component to keep the system function. Hopefully the work systems we operate will get stable in the future, and in the meanwhile a huge amount of stock owners' money is saved from R&D activities.

The remaining question is, of course, should the organization invest on safety or not. Investment analysis are based on the fundamental premise of generating more cash flow, than what we would have done without the investment. The Offshore Specialized Vessel owners has one source of cash flow, it is the day rate, paid by the charterer (e.g. Oil Company). If the companies investing on safety are not awarded with time charters with adequate rate enabling stable cash flow, no company can gamble on investors' money by investing on any extra feature, such as safety. Investing in safety is easier said than put into action, understandable since costs involved on improving the safety are tangible whilst the benefits usually distant in time. Based on the previous arguments, I recommend that the companies who really are concerned with safety and sees it as a guiding principle of successful business (generative HRO), should make effort on marketing it to the major multi-nationals.

Kotler et al. (2004) state that a company to be successful it must provide greater customer value and satisfaction than its competitors. This view is supported by Martin (2010) who argues that we are living in 'The Age of Customer Capitalism', where maximizing shareholder value is not top priority, he continues that "evidence suggests that shareholders actually do better when firms put the customer first". 'Blue Ocean Strategy' proposed by Kim & Mauborgne (2006) states that companies strategy should aim on creating uncontested markets i.e. "Blue Oceans" instead being on "Red Oceans" facing fears competition and make value-cost tradeoffs. Despite the fact that the concept is not fully applicable to offshore industry, because the work systems are similar to a large extent, but on the other hand no company was recognized to have adapted the concepts of collective mindfulness. The shipbrokers are stating that "bunker consumption is the key factor in the tender process", let us make the operational excellence the new selling point, a Blue Ocean strategy.

Should we invest on the human component, is it timely or urgent? The current oil crisis, largely due to the increased production capacity derived from shale oil production has shaken the offshore industry. Upstream O&G in offshore environment is even more volatile to crude oil prices than onshore activities due to the high operational expenditure. It have to be acknowledged that safety is only one of the competing objectives, or as Besnard & Hollnagel (2014) argues "safety comes first if the organization can afford it." The fact is that it is not only the complexity of the vessels that has increased but the size also, and if the current trend continues, the operations are moving to harsher environments in addition. Is the size discussion relevant? Yes, in my opinion since data show that risk of collision by attendant vessels has significant risk contribution to the operational safety. It cannot be limited to supply and anchor handling vessels anymore, significant field development is done subsea, meaning that the large construction vessels are also present on the field in increasing numbers. According to Vinnem (2014a) it was considered in the 1980s that general design rules usually provides sufficient resistance for low energy impacts and the "DNV rules", later NORSOK assigned it to be 14 MJ with respect to local damage, the rule is still in force. Much has changed since the 80's, the supply vessel size is in factor on three, and the large construction vessel are reaching the light ship weight of shuttle tankers. According to the current requirements from NORSOK (Design of Steel structures N-004) Regulations the installations should be checked for an impact from a 5000 tonnes vessel at 2 m/s generating impact energy of 14 MJ (40 % added mass) for broad side impact and 11 MJ (10 % added mass) for stern/bow impact. Well stimulation vessel Big Orange collided on Ekofisk Field in 2009 resulting according to investigation report “a collision energy which is up to six times higher than the energy which the exposed facilities are constructed to withstand” i.e. approximately 100 MJ (PSA, 2009).

Given all this one could provocatively ask if the focus should be on human performance improvement or should we start applying physical barriers i.e. metal to the existing offshore structures. The decision have to be made before the systems are taken to even greater depths and harsher environments. Reducing the complexity is a solution as well, but I do highly doubt that considerable emphasis is assigned for reducing it. It has been the growth of technology capacity, applications, and solutions that leveraged our possibility to create and run highly complex system in the first place, and increase the productivity. By help of modern technology for example, the oil companies have been able to push the boundaries by going to deeper and harsher environments as well as squeezing the last drop of oil out of the maturing fields, complexity is to stay and the emphasis has to be on the human component now. “Humans are an asset, without which the proper functioning of modern technological systems would be impossible” (Hollnagel, 2012). Assets cannot be operated on luck, safety is a systematic analysis of facts combined with scientifically verified methods. Lastly a message from the field to the Oil Companies: “Safety is a verb, not a noun!” Stop using the idiotism “Safety is paramount to our operations” if it doesn’t have any meaning in practice.

Finally, from the system operators perspective it feels so absurd that resources are used for preparing for the unknowns, while the current system are “built on sand” and the cures for healing the systems are ineffective, mainly wrong. Fundamentally I am a pessimist who agrees with Rasmussen (1997) stating that complex work system have three types of constraints: economic boundary i.e. the level which beyond it cannot sustain financially, workload boundary i.e. the level which beyond the human and technology component cannot perform anymore, and safety boundary i.e. the level which beyond the system itself will fail. According to Rasmussen (1997) we can only move inside these three boundaries and the only flexibility comes from enhancing some feature for the cost of another. It is inevitable that the work systems are effected by the current oil prices i.e. economic pressure pushes the systems operations closer to the safety and workload boundaries. The migration toward safety and workload boundaries has already started. Let us hope that the human components proves its adaptiveness once more and the industry survives through the stormy seas without major accidents.

6.1 Limitations

This report has several limitations. The sample size of the qualitative data is relatively small. Advantage with the questionnaire data is that I was able to recruit operators from senior positions, and the results gave good structure for the informal interviews. The questionnaire was send to six major vessel operators in Norway. Three of those did not reply on my mail, two appealed on the sensitivity of such data, and the one had to be rejected to avoid biased data i.e. representing one company. There is operators from at least 13 different offshore vessel and rig companies, while the interviewed persons were from four companies. Constructing the questionnaire was challenging. Survey that would had served the purpose of the thesis was not found, hence it had to be made taking into consideration that terminology on literature survey was not applicable (Appendix 2). The interviews confirmed my presumption, even words like proactive and reactive was unfamiliar to some, and hence the questionnaire may look rather simple compared to the concepts presented. Finally my own mindset is biased and slightly on the operators side due to my own experiences and exposure to the problems arising from these work systems. I was not *epoché,* pre-conception-free prior to the study, but I have to say to my own defend that at least this thesis does not include coarse misunderstanding of the marine operations and the work performed onboard. The literature review revealed a great number of papers that included misconceptions about the nature of offshore specialized shipping.

Furthermore Coughlan & Coghlan (2002) argues that pre-understanding is required to understand and externalize the tacit dimensions of the knowledge elicited in action research i.e. "know-how" from the work system analysed is necessity, not a surplus.

6.2 Recommendations for further research

I have been developing a grading system based on my survey findings, to be able to audit the vessel, to verify the variances on the processes, and evaluate the operational culture. Quickly I realized that it would just create another top-down management tool to provide a quick fix. Quick fix is not a solution for improved human and technology performance, neither for operation culture. It is a long, hard path to walk, and the will have to arise from inside the people and organization. By help of this thesis there is a possibility to plant the ideas and concepts i.e. provide the tools for the operators to be able to understand how to describe and communicate their actions and phenome's experienced. The feedback from field has been overwhelmingly positive, and the question I has been answering again and again is "why haven't I been exposed these ideas before."

Therefore I suggest to choose one offshore asset in a specific company, which would be analysed in terms of the five underlying processes of the concept of collective mindfulness in high reliability organizations success. The asset is benchmarked by analysing the level of collective mindfulness, by help of selected key performance indicators e.g. Casler (2013) suggest 10 dimensions relevant with respect to HROs. Hereafter crew on that specific asset and the onshore management engaged to the asset are exposed to concepts like presented on this report i.e. people should be given the right tools (e.g. conceptualisation of the phenomena's). This is the only way that we can difference between benchmarked performance level at times 0 and after a year, or any suitable time span the asset would be audited in terms of quality improvement. If improvement can be verified i.e. the correctness of the hypothesis can be verified, the company could spread the process to cover the all other assets as well. The suggestion is based on the fact that it is actually the assets that differentiate from each other, not the companies.

The image of oil companies I have drawn is rather black and white. Therefore, it would be justified to research the procurement and quality control processes that the oil-majors use, and understand what they value as service i.e. is it reliability, availability, productivity, or perhaps safety?

Another interesting research direction would be similar type analysis where the target group is control room operators (CRO) i.e. the engine department. The CRO's has as safety critical work as DPO's do. They have to scope with the ever increasing complexity, and with high utilization of the asset. There is constant pressure on getting the maintenance work done, without seizing the operations. The drilling unit should in theory be able to produce an output of its processes with minimal variation, despite the CRO's have to intervene on the processes to cope with maintenance programs. The probability of leaving latent conditions to the passive systems by engineers and maintenance personnel is significantly higher than what it is for the deck officer. Most of the systems operated by DPO's are tightly connected and the output of ones actions has immediate result. While engineers have to cross fingers that the system functions error free after it is assembled and enabled online.

Finally, this research was largely about raising the issues and concern from operator's perspective, mainly latent conditions that can cause active errors and hinders the operators from succeeding and scoping with work system demands. What would be even more interesting is to research how the operators build those operating margins to scope with reduced system states that they are expecting to arise. Dekker speaks about cognitive flow of pressures and demands that escalate. How do the operators actually manage the changeable work load demands and have provided them all the tools to remain successful in a range of circumstances.

References

Accident Investigation Board Norway. (2008). *NOU 2008: 8 Bourbon Dolphins forlis den 12. april 2007.* Oslo: Regjeringen, Justis- og beredskapsdepartementet.

Agterberg, G., & Passchier, J. (1998). Stress among seamen. *Psychological reports vol 83*, 708-710.

Ale, B. (2002). Risk assessment practices in The Netherlands. In *Safety Science nr 40* (pp. 105-126).

Antonsen, S. (2009). The relationship between culture and safety on offshore supply vessels. *Safety Science*, 1118-1128.

Aven, T. (1992). *Reliability and Risk Analysis.* UK: Springer.

Aven, T. (2007). A unified framework for risk and vulnerability analysis covering both safety and security. In *Reliability Engineering & System Safety nr 92* (pp. 745-754).

Aven, T. (2008). *Risk analysis: assessing uncertainties beyond expected values and probabilites.* Chichester: John Wiley.

Aven, T. (2009). Perspectives on risk in a decision-making context - Review and discussion. In *Safety Science nr 47* (pp. 798-806).

Aven, T. (2010). *Misconceptions of Risk.* Stavanger: John Wiley & Sons Ltd.

Aven, T. (2010). On how to define, understand and describe risk. In *Reliability Engineering and System Safety nr 95* (pp. 623-631). Elsevier.

Aven, T. (2013). How to define and interpret a probability in a risk and safety setting. *Safety Science (Vol 51)*, 223–231.

Aven, T., & Krohn, B. S. (2014). A new perspective on how to understand, assess and manage risk and the unforeseen. *Reliability Engineering & System Safety vol 121*, 1-10.

Aven, T., & Renn, O. (2010). *Risk Management and Governance: Concepts, Guidelines and Applications.* Berlin: Springer.

Bai, Y., & Bai, Q. (2010). *Subsea Engineering Handbook.* Burlington, MA: Gulf Professional Publishing .

Baumeister, R., & Tierney, J. (2012). *Willpower: Rediscovering the Greatest Human Strenght.* London, UK: Penguin Books.

Bento, J.-P. (2003). *Review from an MTO-perspective of five investigation reports from BP.* Stavanger.

Berg, H. P. (2013). Human Factors and Safety Culture in Maritime Safety. *the International Journal on Maritime Navigation and Safety of Sea Transportation*, 343-352.

Besnard, D., & Hollnagel, E. (2014). I want to believe: some myths about the management of industrial safety. *Cognition, Technology & Work (16)*, 13-23.

Bierly, P., & Spender, J.-C. (1995). Culture and High Reliability Organizations: The Case of the Nuclear Submarine. *Journal of Management vol 21*, 639-656.

Bjørneseth, F. B., Dunlop, M., & Strand, J. P. (2008). Dynamic Positioning Systems – Usability and Interaction Styles. (pp. 43-52). Lund: NordiCHI.

Borys, D., Else, D., & Legget, S. (2009). The fifth age of safety: the adaptive age. *Journal of Health & Safety Reasearch in Practice*, 19-27.

Bourrier, M. (1998). Elements for designing a self-correcting organization: examples from nuclear power plants. In A. Hale, & M. Baram, *Safety Management - The Challange of Change* (pp. 133-147). Oxford, UK: Elsevier.

Bray, D. (2008). *DP Operator's Handbook.* London: The Nautical Institute.

Bridger, R. (1995). *Introduction to Ergonomics.* McGraw-Hill.

Campbell, S. (2005). Determining overall risk. In *Journal of Risk Research, 8* (pp. 569-581).

Casler, J. (2013). Revisiting NASA as a High Reliability Organization. *Public Organization Review vol 14*, 229-244.

Chen, H. (2003). *Probabilistic Evaluation of FPSO-Tanker Collision in Tandem Offloading Operation (Dr.ing. Thesis).* Trondheim: Department of Marine Technology, NTNU.

Chen, H., Moan, T., & Verhoeven, H. (2008). Safety of dynamic positioning operations on mobile offshore drilling units. In *Reliability Engineering and System Safety nr 93* (pp. 1072-1090). Elsevier.

Chen, H., Moan, T., & Verhoeven, H. (2009). Effect of DGPS failures on dynamic positioning of monile drilling units in the North Sea. *Accident Analysis and Prevention 41*, 1164-1171.

Chen, H., Moan, T., & Vinnem, J. E. (2007). Safety of shuttle tanker offshore loading operations with emphasis on the human barrier. In A. &. (eds), *Risk, Reliability and Societal Safety* (pp. 2433-2441). London: Taylor & Francis Group.

Chiuhsiang, J., Tzu-Chung, Y., & Chih-Wei, Y. (2010). Evaluation of operators' performance for automation design in the fully digital control room of nuclear power plants. *Human Factors and Ergonomics in Manufacturing & Service Industries vol 20*, 10-23.

Chiuhsiang, J., Wei-Jung, S., Chun-Yu, C., & Jin-Ling, L. (2013). Applying the Skill-Rule-Knowledge Framework to Understanding Operators' Behaviours and Workload in Advanced Main Control Rooms. *Nuclear Engineering and Design*, 176-184.

Corres, A.-J. E., & Pallis, A. A. (2008). *Flag State Performance: An Empirical Analysis.* Springer; WMU Journal of Maritime Affairs, Vol. 7 (2008), No.1, 241–261.

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. *International Journal of Operations & Production Management vol 22*, 220-240.

Covey, S. R. (1990). *The 7 Habits of Highly Effective People.* New York: Free Press a division of Simon & Schuster Inc.

Dekker, S. (2003). Failure to adapt or adaptations that fail: Constrasting models on procedures and safety. *Applied Ergonomics vol 34*, 233-238.

Dekker, S. (2007). *Just Culture - Balancing Safety and Accountability.* Burlington: Ashgate Publishing Company .

Dekker, S. (2011). *Drift into Failure: From Hunting Broken Components to Understanding Complex Systems.* UK: Ashgate.

Dekker, S., & Suparamaniam, N. (2005). *Divergent images of decision making in international disaster relief work.* Ljungbyhed: Lund University School of Aviation.

del Pozo, F., Dymock, A., Feldt, L., Hebrard, P., & Monteforte, F. S. (2010). *Maritime surveillance in support of CSDP, the wise pen team progress report.* Ixelles, Belgium: European Defence Agency (EDA).

DNV. (2010). *Rules for Certification and Verification of Diving Systems, DNV-OSS-305.* Stavanger: Det Norske Veritas.

DOE. (2012). *Accident and Operational Safety Analysis.* Washington: U.S. Department of Energy.

EMSA. (2015, February 15). *The world merchant fleet in 2013 - statistics from Equasis.* Lisboa, Portugal: European Maritime Safety Agency.

Endsley, M. (1995a). Toward a theory of situation awareness in dynamic systems. *Human Factors vol 37*, 32-64.

Endsley, M. (1995b). Measurement of situation awareness in dynamic systems. *Human Factors vol 37*, 65-84.

Endsley, M., & Jones, D. (2011). *Designing for Situation Awareness: An Approach to User-Centered Desing 2ed.* CRC Press .

Energy Institute. (2015). *Human factors briefing notes*. Retrieved from Energy Institute: www.energyinst.org/hfbriefingnotes

Franklin, J. (2001). *The Science of Conjecture: Evidence and Probability Before Pascal.* Baltimore: Johns Hopkins University Press.

Furuta, K. (2015). Resilience Engineering - A New Horizon of Systems Safety. In J. Ahn, C. Carson, M. Jensen, K. Juraku, S. Nagasaki, & S. Tanaka, *Reflections on the Fukushima Daiichi Nuclear Accident: Toward Social-Scientific Literacy and Engineering Resilience* (pp. 435-454). Springer.

Gordon, R. (1998). The contribution of human factors to accidents in the offshore oil industry. *Reliability Engineering and System Safety vol 61*, 95-108.

Graham, J., & Wiener, J. (1997). *Risk versus risk: Tradeoffs in protecting health and the environment.* Harvard University Press.

Hale, A., & Baram, M. (1998). *Safety Management: The Challenge of Change.* Oxford, UK: Elsevier.

Hassel, M., Asbjørnslett, B. E., & Hole, L. P. (2011). *Underreporting of maritime accidents to vessel accident databases.* Norwegian University of Science and Technology, Department of Marine Technology, Trondheim, Norway: Elsevier.

Heinrich, H. W. (1931). *Industrial Accident Prevention: A Scientific Approach.* New York: McGraw-Hill.

Helmreich, R., & Merritt, A. (1998). *Culture at Work in Aviation and Medicine - National, Organizational and Professional Influences.* Ashgate.

Hendrick, H. (2002). Human factors & Ergonomics: An overview of Macroergonomics. In B. Kleiner, *Macroergonomics: Theory, methods, and applications* (pp. 1-23). Mahwah, NJ: Lawrence Erlbaum Associates.

Hendrick, H. W., & Kleiner, B. M. (2002). *Macroergonomics: Theory, Methods, and Applications .* Mahwah, New Jersey: Lawrence Erlbaum Associates Inc.

Hofstede, G. (1980). Motivation, leadership, and organization: Do American theories apply abroad? *Organizational Dynamics vol 9*, 42–63.

Hofstede, G., & Hofstede, G. J. (2010). *Cultures and Organizations: Software of the Mind 3ed.* McGraw-Hill Education.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics vol 4*, 1-23.

Hollnagel, E. (2004). *Barriers and Accident Prevention.* Farnham, UK: Ashgate Pub Ltd.

Hollnagel, E. (2006). *Resilience Engineering: Concepts and Precepts.* UK: Ashgate.

Hollnagel, E. (2012). Coping with complexity: past, present and future. *Cognition, Technology & Work vol 14*, 199–205.

Holvik, J. (1998). Basics of Dynamic Positioning. *Basics of Dynamic Positioning.* Houston: Dynamic Positioning Commitee.

HSE. (2006). *Managing shiftwork (HSG256), Health and safety guidance.* Health and Safety Executive UK.

Hudson, P. (2007). Implementing safety culture in a major multi-national. *Safety Science Vol 45*, 697-722.

Håvold, J. I. (2015). Stress on the bridge of offshore vessels: Examples from the North Sea. *Safety Science vol 71*, 160-166.

IAEA. (2002). *Safety culture in nuclear installations - Guidance for use in the enhancement of safety culture (IAEA-TECDOC-1329).* Vienna, Austria: International Atomic Energy Agency.

IMCA. (1999). *Guidelines for the Design and Operation of Dynamically Positioned Vessels, IMCA M 103.* London: International Marine Contractors Association.

IMCA. (2003). *Station keeping incidents reported for 2001, IMCA M 169.* International Maritime Contractors Association.

IMCA. (2006). *The Training and Experience of Key DP Personnel, IMCA M 117 Rev. 1.* London: International Marine Contractors Association.

IMCA. (2009). *International Guidelines for The Safe Operations of Dynamically Positioned Offshore Supply Vessels, IMCA M 182 Rev. 1.* London: International Maritime Contractors Association.

IMO. (1994). *Guidelines for Vessels with Dynamic Positioning Systems, IMO MSC Circular 645.* London: International Maritime Organization.

IMO. (2015, February 15). *International Maritime Organization*. Retrieved from http://www.imo.org/About/Pages/Default.aspx

IRGC. (2005). *Risk governance: Towards an integrative approach. White Paper No. 1, Renn, O. with an Annex by Graham, P.* Geneva, Switzerland: International Risk Governance Council.

ISO. (2010). *ISO/TS 29001:2010 - Petroleum, petrochemical and natural gas industries, Sector-specific quality management systems, Requirements for product and service supply organizations.* Geneva: International Organization for Standardization.

Johnsen, S., Bjørkli, C., Steiro, T., Fartum, H., Haukenes, H., Ramberg, J., & Skriver, J. (2011). *CRIOP: A scenario method for Crisis Intervention and Operability analysis.* Trondheim: SINTEF.

Jones, R. B. (1995). *Risk-Based Management: A Reliability Centered Approach.* Gulf Publishing Co.

Kahneman, D. (2011). *Thinking, Fast and Slow.* UK: Penguin Books.

Kaplan, S. (1991). Risk assessment and risk management-Basic concepts and terminology. In *Risk management: Expanding horizons in nuclear power and other industries* (pp. 11-28).

Kaplan, S. (1992). 'Expert information' versus 'expert opinions.' Another approach to the problem of eliciting/combining/using expert knowledge in PRA. *Reliability Engineering and System Safety 35*, 61-72.

Kaplan, S., & Garrick, B. (1981). On the quantitative definition of risk. In *Risk Analysis nr 1* (pp. 11-27).

Kim, W., & Mauborgne, R. (2006). *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant.* Boston: Harvard Business School Press.

Klein, G. (2000). How can we train pilots to make better decisions? In H. O'Neil, D. Andrews, & H. O'Neil Jr., *Aircrew Training and Assessment* (pp. 165-195). CRC Press.

Kotler, P., Wong, V., Saunders, J., & Armstrong, G. (2004). *Principles of Marketing.* Essex: Pearson Education.

Kristiansen, S. (2005). *Maritime Transportation - Safety Management and Risk Analysis.* Burlington: Elsevier.

Lagadec, P. (1993). *Preventing Chaos in a Crisis - Strategies for Prevention, Control and Damage Limitation.* McGraw-Hill.

Lewis, T. G. (2014). *Book of Extremes, Why the 21st Century Isn't Like the 20th Century.* New York, NY: Springer.

Lindley, D. V. (2000). The philosophy of statistics. *The Statistician Vol 49*, 293-337.

Little, L., Gaffney, I. C., Rosen, K. H., & Bender, M. (1990). Corporate instability is related to airline pilots' stress symptoms. *Aviation, Space, and Environmental Medicine vol 61*, 977–982.

Lowrance, W. (1976). *Of Acceptable Risk: Science and the Determination of Safety.* Los Altos, USA: William Kaufmann Inc.

Mankin, D., Cohen, S., & Bikson, T. (1996). Organizations without boundaries: New forms for the twenty-first century. In *Teams & Technology: Fulfilling the promise of the new organization* (pp. 3-17). Harvard Business School Press.

Martin, R. (2010). The Age of Customer Capitalism . *Harvard Business Review*, 58-65.

Mili, A., Jaoua, A., Frias, M., & Helali, R. G. (2014). Semantic metrics for software products . *Innovations in Systems and Software Engineering vol 10*, 203-217.

Mills, S. (2005). Designing Usable Marine Interfaces: Some Issues and Constraints. *The Journal of Navigation (58)*, 67 – 75.

Mullai, A., & Paulsson, U. (2011). A grounded theory model for analysis of marine accidents. *Accident Analysis and Prevention vol 43*, 1590-1603.

National Commission on the BP Deepwater Horizon. (2011). *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling.* New Orleans: National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling.

NMD. (2014). *Excerpts from the Norwegian Passenger and Cargo Ship Legislation etc. 2014, "Vilkår for å føre last mellom norske havner" .* Haugesund, Norway: Norwegian Maritime Authority.

Nonaka, I., & Von Krogh, G. (2009). Tacit knowledge and knowledge conversion: controversy and advancement in organizational knowledge creation theory. *Organization Science vol 20*, 635-652.

Perrow, C. (1999). *Normal Accidents: Living with High-Risk Technologies.* Princeton, New Yersey: Princeton University Press.

Pidgeon, N., & O'Leary, M. (1994). Organizational Safety Culture: implications for aviation practice. *Aviation Psychology in Practive* , 21-43.

Pidgeon, N., & O'Leary, M. (2000). Man-Made Disasters: why technology and organizations (sometimes) fail. *Safety Science 34*, 15-30.

PSA. (2009). *Investigation of Big Orange XVIII's collision with Ekofisk 2/4-W.* Stavanger: The Petroleum Safety Authority Norway. Retrieved from http://www.ptil.no/artikler-i-sikkerhet-status-og-signaler-2012-2013/big-orange-ekofisk-2009-article9105-1094.html

PSA. (2014). *GUIDELINES REGARDING THE MANAGEMENT REGULATIONS.* Stavanger: Petroleum Safety Authority Norway.

Psarros, G., Skjong, R., & Strandmyr Eide, M. (2009). *Under-reporting of maritime accidents.* Høvik, Norway: Det Norske Veritas AS, DNV Research & Innovation.

Rasmussen, J. (1982). Human errors: taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents 4*, 311-333.

Rasmussen, J. (1983). Skills, rules, knowledge: signals, signs and symbols and other distinctions in human performance models. *IEEE Transactions: Systems, Man & Cybernetics, SMC-13*, 257-266.

Rasmussen, J. (1997). Risk Management in a Dynamic Society: A Modelling Problem. *Safety Science vol 27*, 183-213.

Rasmussen, J., & Vicente, K. (1990). The Ecology of Human-Machine Systems: Mediating "Direct Perception" in Complex Work Domains. *Ecological Psychology*, 207-249.

Rausand, M. (2011). *Risk Assessment: Theory, Methods, and Applications.* Wiley and Sons Inc.

Rausand, M., & Høyland, A. (2004). *System Reliability: Theory Models and Statistical Methods (2ed.).* New Jersey: John Wiley & Sons.

Reason, J. (1990). *Human Error.* Cambridge: Cambridge University.

Reason, J. (1997). *Managing the Risks of Organizational Accidents.* Aldershot, UK: Ashgate Publishing Company.

Reason, J., Hollnagel, E., & Paries, J. (2006). *Revisiting the "Swiss Cheese" Model of Accidents (EEC Technical/Scientific Report No. 2006-017).* EUROCONTROL Experimental Centre (EEC).

Redmill, F. (2002). Exploring subjectivity in hazard analysis . *Engineering Management Journal (vol 12, issue 3)*, 139-144.

Redmill, F., & Rajan, J. (1997). *Human factors in Safety Critical Systems.* Butterworth-Heinemann.

Reiman, T., & Oedewald, P. (2009). *Evaluating safety-critical organizations – emphasis on the nuclear industry.* Helsinki: VTT, Technical Research Centre of Finland.

Ritchie, G. (2004). *Practical Introduction to Anchor Handling and Supply Vessel Operations.* London: Oilfield Publications Ltd.

Ritchie, G. (2008). *Offshore Support Vessels: A Practical Guide .* London: The Nautical Institute .

Roberts, K. (1987). *Some characteristics of one type of high reliability organization.* Berkeley, California: Organizational Science Vol 1.

Roberts, K., & Gargano, G. (1990). Managing a high-reliability organization: A case for interdependence. In M. von Glinow, & S. Mohrman, *Managing complexity in high technology organizations.* Oxford University Press.

Robson, J. K. (2003). *Ship/platform collision incident database (2001), Reasearch Report 053.* Culham, UK: Health and Safety Executive (HSE), Offshore Division .

Rosa, E. (1998). Metatheoretical foundations for post-normal risk. In *Journal of Risk Research nr 1* (pp. 15-44).

Rosa, E. (2003). *The logical structure of the Social Amplication of Risk Framework (SARF): Metatheoretical foundations and policy implications.* Cambridge, UK: Cambridge University Press.

Rothblum, A. (2000). Human error and maritime safety. *Maritime Human Factors Conference, MD.* Linthicum, Maryland.

Schein, E. H. (1992). *Organizational culture and leadership.* San Francisco: Jossey-Bass.

Schröder-Hinrichs, J., Baldauf, M., & Ghirxi, K. (2011). Accident investigation reporting deficiencies related to organizational factors in machinery space fires and explosions. *Accident Analysis and Prevention 43*, 1187–1196.

Serck-Hanssen, B. (2013, March 13). *IMR in Subsea 7 for Statoil, past and future, the new IMR vessel "Seven Viking".* (B. Serck-Hanssen, Performer) Stavanger, Norway.

Sklet, S. (2006). Safety barriers: Definition, classification, and performance. *Journal of Loss Prevention in the Process Industries vol 19*, 494-506.

STAMI. (2015). *General Nordic questionnaire for psychological and social factors at work (QPSnordic)*. Retrieved from Statens arbeidsmiljøinstitutt : https://www.qps-nordic.org/en/

Stopford, M. (2009). *Maritime Economics 3ed.* New York, NY 10016: Routledge.

Strand, J. P., & Sørensen, A. J. (2001). Position Control Systems for Offshore Vessels. In F. El-Hawary, *The Ocean Engineering Handbook* (p. Chapter 3). Boca Raton: CRC Press LLC.

SU. (2002). *Risk: Improving government's capability to handle risk and uncertainty.* London, UK: The Strategy Unit.

Sørensen, A. (2011). A survey of dynamic positioning control systems. *Annual Reviews in Control vol 35*, 123-136.

Taleb, N. N. (2001). *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets.* New York, US: Random House.

Taleb, N. N. (2007). *The Black Swan: The Impact of the Highly Improbable .* New York, US: Random House.

Tversky, A., & Kahneman, D. (1974). Judgement under uncertainty: Heuristics and biases. *Science, New Series, Vol. 185, No. 4157*, 1124-1131.

Wallace, B., & Ross, A. (2006). *Beyond Human Error: Taxonomies and Safety Science.* Boca Raton, FL: CRC Taylor & Francis.

Vassalos, D. (1999). Shaping ship safety: the face of future. *Marine Technology, Vol 36(2)*, 61-76.

Weick, K. E., & Sutcliffe, K. M. (2007). *Managing the Unexpected: Resilient Performance in an Age of Uncertainty.* Jon Wiley & Sons.

Verhoeven, H., Chen, H., & Moan, T. (2004). *Safety of DP Operations on MODUs.* Houston, TX, USA: Dynamic Positioning Conference .

Westrum, R. (1991). *Technologies and society: The shaping of people and things.* Belmont, CA: Wadsworth Pub Co .

Westrum, R. A. (2006). Typology of Resilience Situations. In E. W. Hollnagel, *Resilience engineering: Concepts and precepts.* Ashgate Pub Co.

Wickens, C. (1992). *Engineering psychology and human performance.* New Jersey: Harper Collins Publishes Inc.

Wiener, E., & Nagel, D. (1988). *Human Factors in Aviation (Cognition and Perception).* New York: Gulf Professional Publishing.

Willis, H. H. (2007). Guiding resource allocations based on terrorism risk. *Risk Analysis nr 27*, 597-606.

Vinnem, J., Hokstad, P., Dammen, T., Saele, H., Chen, H., Haver, S., . . . Toennessen, L. (2003). Operational safety analysis of FPSO - Shuttle Tanker collision risk reveals areas of improvement. *OTC 15317.* Houston: Offshore Technology Conference.

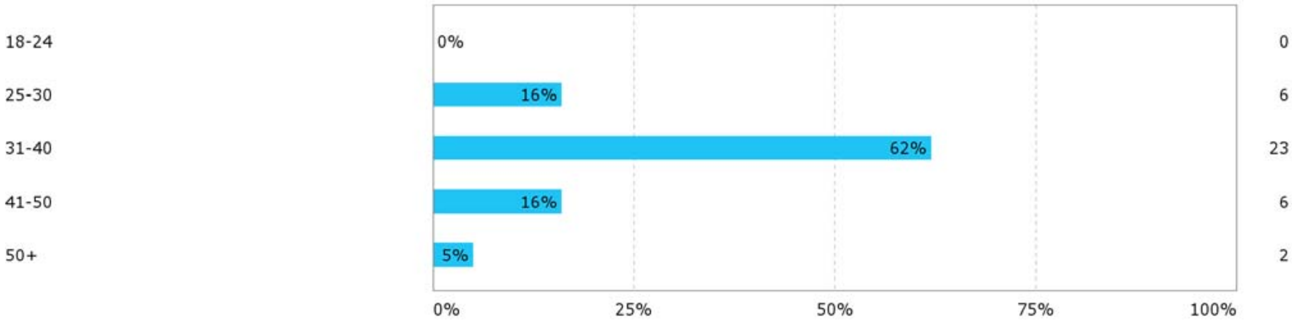
Vinnem, J.-E. (2014a). *Offshore Risk Assessment vol 1 (3ed.).* London: Springer.

Vinnem, J.-E. (2014b). *Offshore Risk Assessment vol 2 (3ed.).* London: Springer.

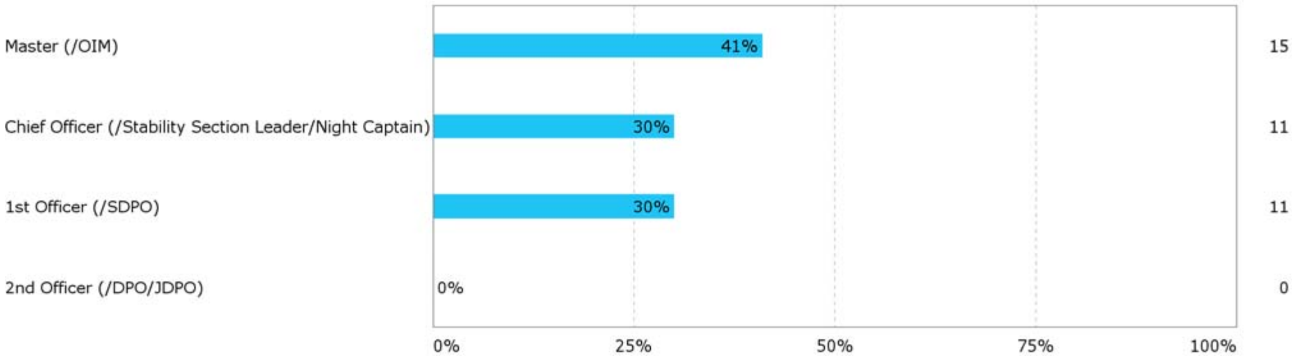
Wong, W. (2002). *How Did It Happen: Engineering Safety and Reliability.* Professional Engineering Publishing.

APPENDIX 1 – Background Information

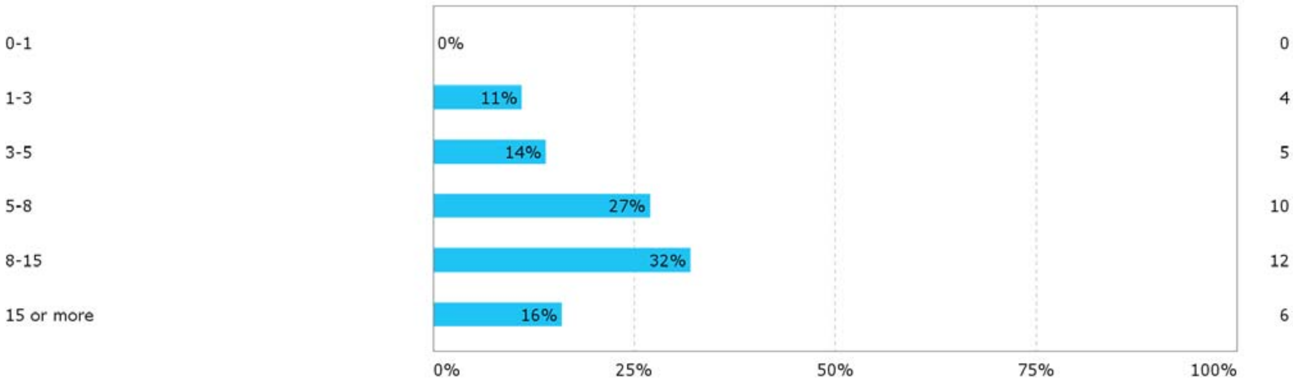
Age



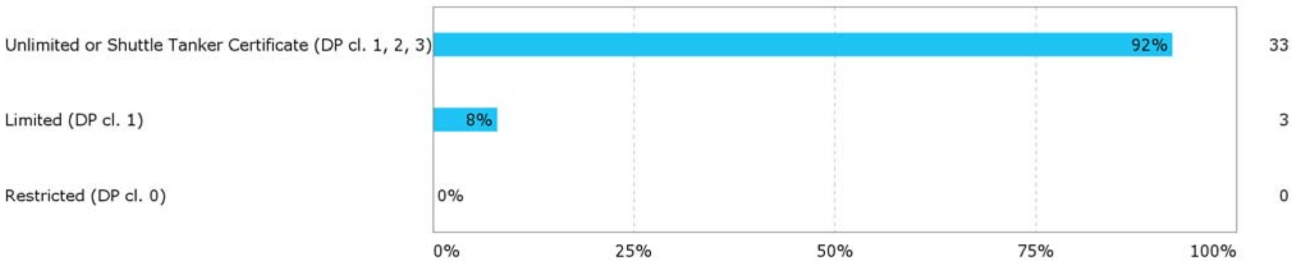
Position



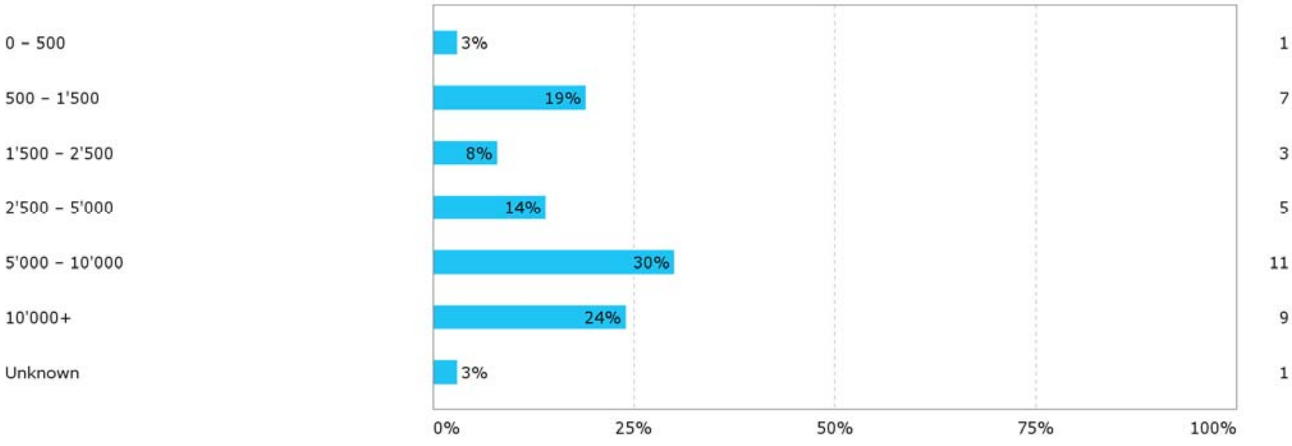
Total number of years in offshore specialized shipping



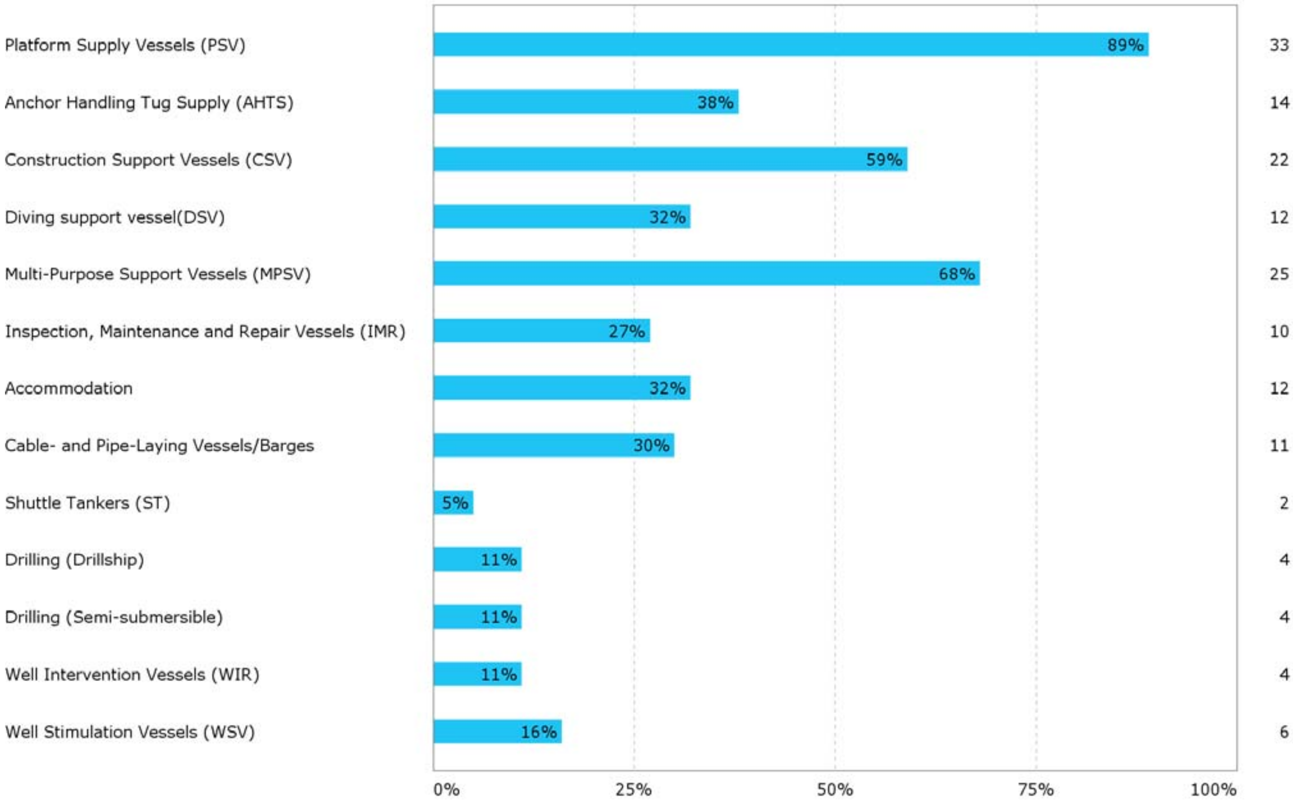
DP Certificate (Nautical Institute Training Scheme)



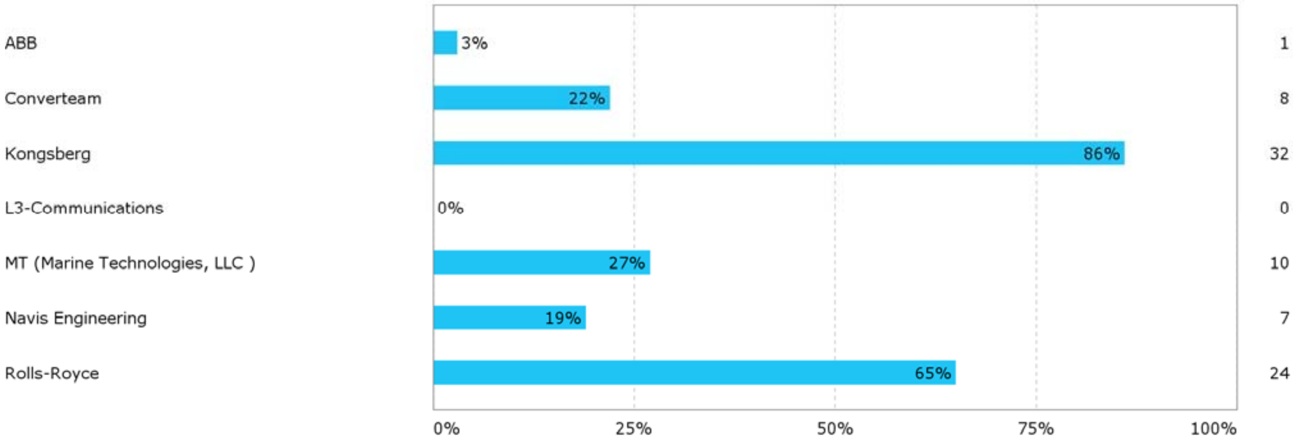
Experience in hours logged to IMCA logbook



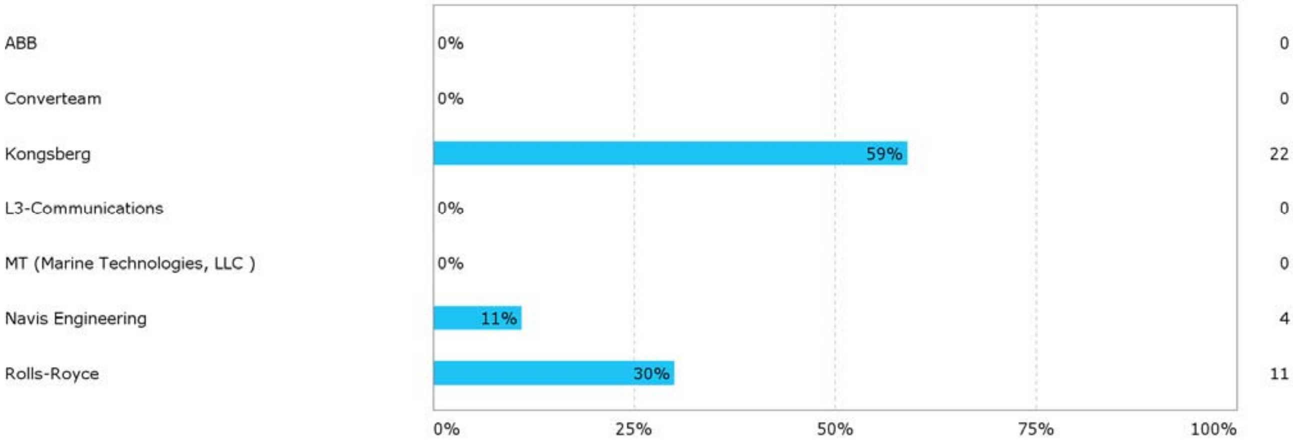
Experience by vessel type



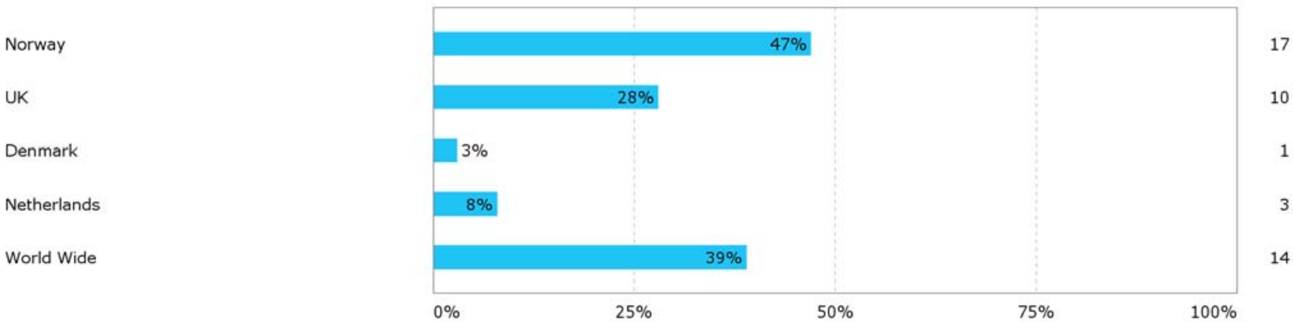
Experience by DP System manufacturer



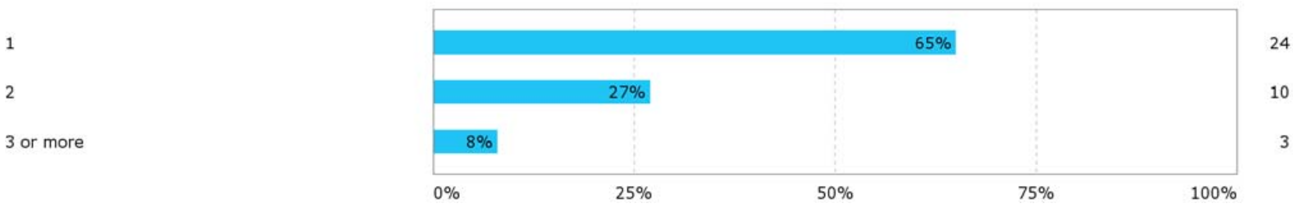
DP System you're currently using



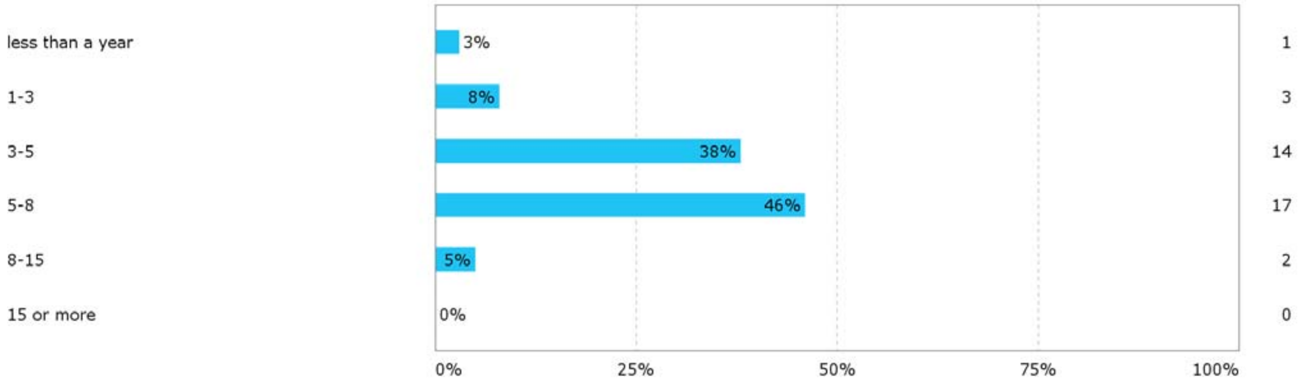
What is your normal working area



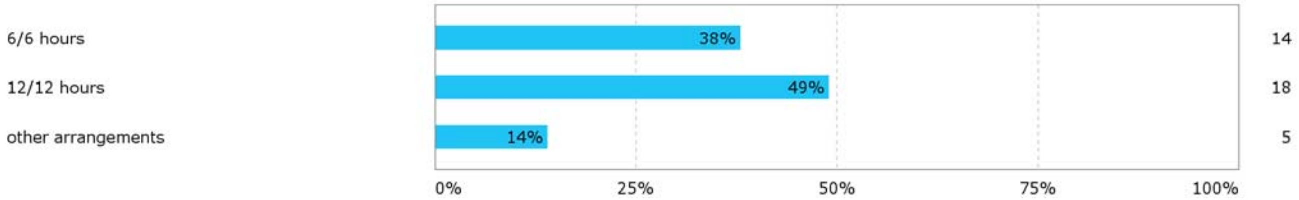
On how many vessels have you worked on during the last 12 months period



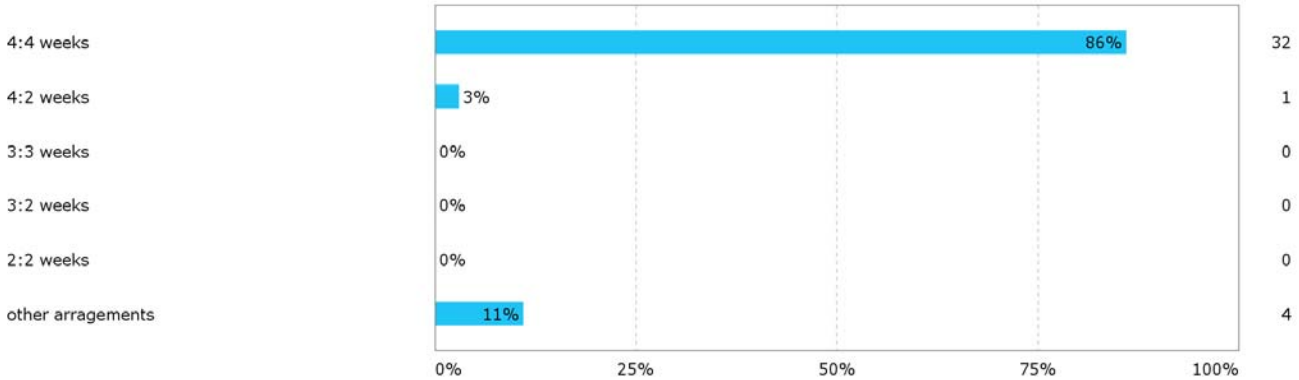
How old is the vessel you're currently working on



What is your work shift schedule when offshore



What offshore rotation do you follow



APPENDIX 2 – Questionnaire

INTRODUCTION to Questionnaire for DPO's and bridge team's onboard dynamically positioned vessels working in the Northwest European Area.

"There can be no greater asset than the people working within an organization" –Chris Charman, Chief Executive of International Maritime Contractors Association (IMCA)

The strengthening of the safety culture in an organization has become an increasingly important issue for High Reliability Organizations. The human performance plays a key role in the safety of the offshore maritime domain and the high safety level is essential for succeeding in the competitive global business environment. The offshore vessels are highly complex socio-technical systems setting high performance requirements for the operators.

In order to understand the human performance and improvement potential onboard offshore specialized vessels, the following questionnaire is made available. The questionnaire assesses factors related to the technology, working culture, perceptions with regards to risk and safety, and managerial issues related to the operator's performance.

The quantitative data is collected by help of web based untraceable survey tool (surveyXact): no individuals nor the companies can be recognised. For the qualitative data everyone involved in a questionnaire are subject to a duty of confidentiality. Both the quantitative and qualitative results will be treated confidentially, and the answers of participants are not available to employers or third parties.

I highly do recommend that you take a part on this survey for the better basis for the companies to implement improvement measures. We cannot compete with the technology anymore, the future of competitive advantage relies on the performance and reliability of the "Human Component".

This research is done for the fulfilment of the Master´s degree in Offshore Technology with specialization in Industrial Asset Management at the University of Stavanger (UiS), Norway.

Your help is greatly appreciated.

Questions regarding to the survey can be directed to:

Juha Kristian Palola jk.palola@stud.uis.no

Thank you for participating!

The survey is using a Likert-type scale question (or ‘item’) technique where respondents select one of several responses that are ranked in order of strength from 1 to 5:

1 characterizes: Bad / Seldom / Never / Poor / Difficult / Not Optimal / Ineffective / Unsatisfying / Mismatch

5 characterizes: Good / Often / Excellent / Easy / Optimal / Effective / Satisfying / Match

On some questions one might feel that the term on the scale does not scope optimally with the question, in case of doubts consult the scaling system presented above.

According to the feedback the questionnaire will approximately 60 minutes to complete but I do highly recommend that you take the complete survey since it benefits all. If you’re not satisfied on answering some of the questions it is made possible to jump to the next page without filling the complete form.

All answers are highly appreciated!

Survey starts with general background information followed by three main categories divided into five subcategories contributing to the total performance and operational excellence from “Operators" point of view:

	VESSEL PERFORMANCE	
1. Technology and equipment	2. Human Component	3. Management
1.1 Reliability Perception	2.1 Human Behaviour	3.1 Reporting
1.2 Alarms	2.2 Risk & Safety Perceptions	3.2 Training
1.3 Design	2.3 Pressure and Stress	3.3 Management Commitment
1.4 System Knowledge	2.4 Rest and Fatigue	3.4 Procedures
1.5 Ergonomics	2.5 Leadership	3.5 Bridge Team

Background Information

Age

(1) ☐ 18-24
(2) ☐ 25-30
(3) ☐ 31-40
(4) ☐ 41-50
(5) ☐ 50+

Position

(1) ☐ Master (/OIM)
(2) ☐ Chief Officer (/Stability Section Leader/Night Captain)
(3) ☐ 1st Officer (/SDPO)
(4) ☐ 2nd Officer (/DPO/JDPO)

Total number of years in offshore specialized shipping

(1) ☐ 0-1
(2) ☐ 1-3
(3) ☐ 3-5

(4) ❑ 5-8
(5) ❑ 8-15
(6) ❑ 15 or more

DP Certificate (Nautical Institute Training Scheme)
(1) ❑ Unlimited or Shuttle Tanker Certificate (DP cl. 1, 2, 3)
(2) ❑ Limited (DP cl. 1)
(3) ❑ Restricted (DP cl. 0)

Experience in hours logged to IMCA logbook
(1) ❑ 0 – 500
(2) ❑ 500 – 1'500
(3) ❑ 1'500 – 2'500
(7) ❑ 2'500 – 5'000
(4) ❑ 5'000 – 10'000
(5) ❑ 10'000+
(6) ❑ Unknown

Experience by vessel type
(1) ❑ Platform Supply Vessels (PSV)
(2) ❑ Anchor Handling Tug Supply (AHTS)
(3) ❑ Construction Support Vessels (CSV)
(4) ❑ Diving support vessel (DSV)
(5) ❑ Multi-Purpose Support Vessels (MPSV)
(6) ❑ Inspection, Maintenance and Repair Vessels (IMR)
(7) ❑ Accommodation
(8) ❑ Cable- and Pipe-Laying Vessels/Barges
(9) ❑ Shuttle Tankers (ST)
(10) ❑ Drilling (Drillship)
(11) ❑ Drilling (Semi-submersible)
(12) ❑ Well Intervention Vessels (WIR)
(13) ❑ Well Stimulation Vessels (WSV)

Experience by DP System manufacturer
(13) ❑ ABB
(14) ❑ Converteam
(15) ❑ Kongsberg
(16) ❑ L3-Communications
(17) ❑ MT (Marine Technologies, LLC)
(18) ❑ Navis Engineering
(19) ❑ Rolls-Royce

DP System you're currently using
(1) ❑ ABB
(2) ❑ Converteam
(3) ❑ Kongsberg
(4) ❑ L3-Communications

(5) ❑ MT (Marine Technologies, LLC)
(6) ❑ Navis Engineering
(7) ❑ Rolls-Royce

What is your normal working area?
(1) ❑ Norway
(2) ❑ UK
(3) ❑ Denmark
(5) ❑ Netherlands
(6) ❑ World Wide

On how many vessels have you worked on during the last 12 months period
(1) ❑ 1
(2) ❑ 2
(3) ❑ 3 or more

How old is the vessel you're currently working on
(1) ❑ less than a year
(2) ❑ 1-3
(3) ❑ 3-5
(4) ❑ 5-8
(5) ❑ 8-15
(6) ❑ 15 or more

What is your work shift schedule when offshore
(1) ❑ 6/6 hours
(2) ❑ 12/12 hours
(3) ❑ other arrangements

What offshore rotation do you follow
(1) ❑ 4:4 weeks
(2) ❑ 4:2 weeks
(3) ❑ 3:3 weeks
(4) ❑ 3:2 weeks
(5) ❑ 2:2 weeks
(6) ❑ other arrangements

TECHNOLOGY and EQUIPMENT

1.1 Reliability Perception

How reliable / unreliable do you feel with regard to

	Unreliable	**Somewhat Unreliable**	**Somewhat Reliable**	**Reliable**	**Very Reliable**
Dynamic Positioning System (DP) in general	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Position Reference System (PRS) in general	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: DGPS	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Laser based system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Hydroacoustic system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: taut wire	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Microwave	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Gyro compass	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
GPS compass	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Wind sensors	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
VRU/MRU	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Power generation / Power management system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Propulsion Units / Thrusters / Rudders	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Mechanical failures of the equipment during critical operations	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

TECHNOLOGY and EQUIPMENT

1.2 Alarms

Alarm system design and response

	Seldom or Never	**Rather Seldom**	**Sometimes**	**Rather Often**	**Very Often**
Are some alarms too quiet compared to background noise?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are too many alarms activated during a typical shift - even if there isn't a major problem?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Are you experiencing a lot of false and or inadequate alarms	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Although alarms can be reset, do they just keep coming back?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do alarm lists seem to be arranged in no obvious logical order or are they confusingly mixed in with other information?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it hard for operators to decide which alarm to deal with first when a lot come in at once?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it often unclear what caused an alarm?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
From the alarm information it is not easy to interpret the severity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The wording of some important alarm messages are unclear?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
It is not easy to determine the severity of the alarm	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
In case of multiple alarms it is not easy to decide which alarms has priority	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it not easy to determine what system is indicating an alarm	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Response to the alarms

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Is it sometimes unclear about what to do in response to a particular alarm?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Alarm information is easy to interpret and apply counteractions	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The company is providing me guidance how to react in different types of alarms	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

TECHNOLOGY and EQUIPMENT

1.3 Design

Workspace arrangements and layout

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
The bridge layout is optimal for work without distraction	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Crew members like to visit the bridge and socialize with issues and topics non-relevant	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
to the operations					
Extra personnel on bridge is creating distraction	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The use of bridge pc's are creating distraction to the operating of the DP system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

System Selection (New Building)

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
I prefer a certain type "A" of radar rather than type "B"	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I prefer a certain type "A" of ECDIS rather than type "B"	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I prefer a certain Dynamic Positioning system by manufacturer "A" rather than from manufacturer "B"	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some DP system fits better for a certain type of operations	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Arrangement of the visual display units (VDU) provides me relevant parameters without searching	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
There is difference between the DP system providers on the readability and availability of the workstations and relevant parameters	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

TECHNOLOGY and EQUIPMENT

1.4 System Knowledge

What is your technical competence with regard to:

	Lacking	Below Average	Average	Above Average	Excellent
Dynamic Positioning System (DP) in general	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Position Reference System (PRS) in general	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: DGPS	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Laser based system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Hydroacoustic system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Taut wire	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
PRS: Microwave	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Lacking	Below Average	Average	Above Average	Excellent
Gyro compass	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
GPS compass	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Wind sensors	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
VRU/MRU	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Power generation / Power management system	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Integrated Automation System	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Cargo Control System	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Stability Calculator / Program	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

TECHNOLOGY and EQUIPMENT

1.5 Ergonomics

Ergonomics

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Increasing the number of displays would improve my performance	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Important parameters are not frequently monitored due to poor positioning of the screens	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it unclear how certain groups of controls and displays relate to each	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are some controls and display devices in the wrong place so that it is difficult to reach	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Could a control be easily operated accidentally - by knocking into it, or through confusion	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are computer systems difficult to use to put information or commands into (ECDIS, AIS, Radar, DP, Fire Panel)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Could the displays used provide more or better quality information	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do management seem to give low priority to doing anything about reported ergonomic problems	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Are the maintenance (or other) jobs made more difficult because of the location and layout of the equipment	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you get pains in the arms, legs, back or neck when operating the vessel on bridge	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

HUMAN COMPONENT / DPO

2.1 Human Behaviour in work context

In general

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
I have the necessary competence to perform my job in a safe manner	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are you confident in your own capability to handle in novel situation (unfamiliar)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are you confident that your colleague would be able to perform satisfactory in novel situation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

People and team

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Working with multinational bridge team increases risk in general	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
due to language barrier	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
due to culture in terms of how to operate the vessel	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
due to training and competence level differences	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I doubt my colleagues: their competence and decision making capability	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Human error by an engineer and or technical department	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Human error by an deck rating	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Human error by an service personnel and or 3rd parties (e.g. client)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Communication and information exchange

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Are there lots of problems with intercoms, phones, radios or other hardware, e.g. poor	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
sound quality, location					
Are noticeboards, leaflets and other written materials full of mainly useless or out-of-date information	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you pass complicated instructions by word of mouth that would be better put in writing	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are shift handovers very often rushed with the minimum of information exchanged	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The handover could be better planned and clearer procedure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
There is a time pressure to get the job started causing poor information exchange (tank washing etc.)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Risk Perception (operations)

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
If someone made an error, would they be able to detect the error	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Would there be little or no time to correct an error before any harm was done	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do some tasks entail remembering complex items of information	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
A lack of suitable training, job aids, competent assistance from other team members are causing problem solving issues	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it difficult to obey all rules and regulations and still get the job done	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
If anyone did break a rule or regulation, is it very unlikely that they would be found out and punished	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it often more convenient, less trouble or quicker to break rules, regulations or procedures than to follow them	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Latent errors are found (wrong setting on DP, valve left open, machinery not switched of etc.)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
It happens that formal procedures were not followed	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Where the procedures relevant to the operations you committed	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Are there conditions that encourage to unsafe or sub-standard behaviour (lack of training, poor feedback, poor procedures)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

HUMAN COMPONENT / DPO

2.2 Risk Perceptions and Safety Culture

Individual Level

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Have you worked with people you would consider incompetent for the given tasks	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have you worked with supervisor or manager you would consider incompetent for the given tasks	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
It is anticipated to push the technology to the limits to get work done (work in poor weather conditions etc.)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does the senior crew involve everyone on safety related matters and issues	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do DPO's avoid risks and behave as if they are genuinely concerned about their own safety	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Horseplay makes the daily operations more interesting	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do DPO's seem aware of the hazards in their work or how to control them	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you actively seek and keep up to date on information and new ideas in safety	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Company Level

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Do management and safety reps (e.g. HSEQ Manager) generally trust and respect each other	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are people who blatantly break rules generally found out and made accountable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does the company listen and try to solve problems raised by the people closest to the hazards	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
If there is an incident or accident, does the organisation seem interested in solving the problem	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Are incidents always investigated and given the right level of attention	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does the company actively seek and keep up to date on information and new ideas in safety	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

HUMAN COMPONENT / DPO

2.3 Pressure, Stress, and Workload

On Duty (time dependent)

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Did you feel any time pressure during the operations offshore	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Did you feel any time pressure during the operations onshore (base etc.)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Did you have sufficient time to complete all your tasks during the watch	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Did the time pressure make it hard to follow all applicable procedures (and rules & regulation's)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you have enough of time to complete work tasks	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The workload is equally distributed between the DPO´s	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Several DP alarms are overloading and distracts the operations	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have you broken the safety procedures in order to get things done	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Working on the operational limits (poor weather conditions) increases stress	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Working on drift-on / on weather side of any installation etc. Increases stress	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Generally while onboard (not time dependent)

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
The workload is high	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
At times, I am forced to work in ways that increases the risk	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Do you feel tense or anxious	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Feeling sad and lack of energy	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Worrying and feeling generally less confident	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Feeling tired and exhausted	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
At times, we brake the safety rules in order to get things done	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Having difficulties on sleeping	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Having difficulties on relaxing between the shifts	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Did you feel boredom during the work offshore	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Having difficulties on concentrating	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The work is creating stress	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

HUMAN COMPONENT / DPO

2.4 Rest and Fatigue

On Duty

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Doze off suddenly during a shift	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Regularly work a lot of overtime	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are noticeably absent-minded or forgetful at work or find it hard to concentrate	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Regularly find so busy that you can't take a proper break	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have you asked for relief of the duty when you have felt fatigue	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have you worried about your own safety during your watch	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have you asked to rest during your watch if you haven't felt well	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Generally Offshore

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Find it difficult to get a good undisturbed sleep between shifts	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have you worried about your own safety during free watch	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Feel generally drowsy a lot of the time	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I have experienced insomnia cause by high work load	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The working arragements ensures sufficient rest	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I have a problem with noise when sleeping offshore	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I sleep well when offshore	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I have a problem with vessel movement when sleeping offshore	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
When changing from night shifts to day shifts they feel ‘rough’ for the first few days	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Adapting to night shift after crew change feel 'rough' for the first few days	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

HUMAN COMPONENT / DPO

2.5 Leadership

Leadership Perceptions, Bridge Team

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Do you have to do things that you feel should be done differently?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are you given assignments without adequate resources to complete them?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Have clear, planned goals and objectives been defined for your job?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you know what your responsibilities are?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you know exactly what is expected of you at work?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Can you influence the amount of work assigned to you?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Can you influence decisions your collegue is making during the watch	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
If there are alternative methods for doing your work, can you choose which method to use?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does your immediate superior encourage you to participate in decisions?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does your immediate superior encourage you to speak up when opinions differ?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does your immediate superior encourage you to develop skills?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does your immediate superior treat the workers fairly and equally?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is the relationship between you and your immediate superior a source of stress to you?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does your immediate leader avoid making decisions?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
If needed, is your immediate superior willing to listen to your work-related problems?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are your work achievements appreciated by your colleagues	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
In work we share our concerns to work-related problems	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Things are done the way they have always been done	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Does your leader

	YES	NO
Respond rapidly and positively to reported problems	(1) ❑	(2) ❑
Give safety top priority	(1) ❑	(2) ❑
Look beyond your own organisation for fresh ideas and information	(1) ❑	(2) ❑
Actively check that safety procedures are being followed	(1) ❑	(2) ❑
Take firm but constructive action if procedures are not being followed	(1) ❑	(2) ❑
Have the trust and respect of the crew	(1) ❑	(2) ❑
The organization is hierarchic	(1) ❑	(2) ❑

MANAGEMENT

3.1 Reporting

Reporting Perception in general

	Agree	Sometimes	Disagree
Underreporting is normal in offshore shipping	(1) ❑	(3) ❑	(2) ❑
Underreporting protects the vessel from added procedures, checklists, rules and regulations	(1) ❑	(3) ❑	(2) ❑
Underreporting benefits the shipping owner against client	(1) ❑	(3) ❑	(2) ❑
During the last 12 months period I have been involved in a novel situation (loss of DP/Engine/Propulsion)	(1) ❑	(3) ❑	(2) ❑

Individual Level

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
The novel situation that has occurred was reported internally	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The novel situation that has occurred was reported externally (IMCA Incident reporting form etc.)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
All non-conformances are reported	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I have sufficient time to do the reporting	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I do report but it is making any difference	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I report deviations from planned procedures	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Minor "things" are not reported due to the unimportance	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Organizational Level

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
I am encouraged to report all accidents and incidents	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
There is a system in place to collect and share information between the vessels	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are the malfunctioning equipment tolerated by the management, rather than being investigated	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Would it be easier to write reports and finding if a course was provided	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you feel that you are incompetent the report i.e. problems with using the correct terms and language	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is there a reluctance to report problems with the operability of the equipment (i.e. we have poor PRS's)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

MANAGEMENT

3.2 Training

Onboard Operations

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Have you had theoretical DP training/course after you have gained your DP certification	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Would theoretical training support your professional growth	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The theoretical material is too difficult to interpret without guidance	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you have thorough technical knowledge of the automation system onboard	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does all bridge crew members manoeuvre the vessel manually	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Do you feel that the people you work with are fully competent	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is there a procedure for the allocation between departments in emergency situation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is there a concise reference guide for various recovery tasks if the DP system fails	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is there agreed practice for emergency recovery of DP system failure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Onshore / Training providers

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Is it easy to apply for and get any training that is needed	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The training covers rare, unusual and emergency events	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Improved simulator training could prepare me for novel situations	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Simulator training supports the learning of how to respond in various DP alarms	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Simulator training fails to scope with the real life scenarios	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The training and education gives me tools to perform failure diagnosis and formulate chain of events	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Does the simulator training provide tools for effective recovery actions during emergency situation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Are trainees tested after training to see if it has been successful	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Is it always clear what the training is trying to achieve	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

MANAGEMENT

3.3 Management Commitment

HSEQ Management

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
The company acts upon the reports submitted by the vessel	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Management ashore encourages attitudes to achieve safety objectives	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
We are improving the practices and procedures by help of audits and vetting i.e. the audits create value	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The company I am working for has identical working systems from vessel to vessel	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Master is responsible for creating the safety culture onboard	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Crewing Management

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
The crewing policy provides stable crew	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Promotions are given to right people	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The organization encourages me to develop further in my position	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The company is willing to support my professional growth	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I have had sufficient technical training for the systems in use	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Competence assessment is based on subject belief of skills done by my manager/superior i.e. it is not based on hard facts	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
There is sufficient time for familiarization of equipment before use (new onboard)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
There is a competence assessment system in place	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

MANAGEMENT

3.4 Procedures

Procedures (internal / vessel specific)

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Jobs that should have a written procedure don’t have one	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
It’s easier to do some jobs without the procedure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some procedures are out-of-date (or just out of step with how the job is actually done)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some procedures are too complicated or too detailed, or not detailed enough	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
There are often problems finding the right procedure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Training in the use of procedures is poor (infrequent, not done at all or done badly)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Procedures have been developed without any input from the user	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The operations procedures are used in daily basis	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Procedures DP

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Is there a procedure for allocating the duties between the DPO's	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The DP operations manual gives guidance on how to detect deviations	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The procedures covers when and where to check what during the DP watch	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
We are using checklists that are not applicable to the operational requirements	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

In General

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
The rules and regulations are hard to follow and hinders the process	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
It is merely impossible to follow each and every rule in force	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
It is difficult to determine what rules applies to this scenario	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
On SPOT market there is no time on reading and understanding the charterers procedures thoroughly	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
On SPOT market we apply the general rules from GOMO	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I feel commitment to the operational excellence in D/D SPOT jobs	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The charterer expects us to operate on the limits (i.e. poor weather conditions)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The shipping company expects us to operate on the limits (i.e. poor weather conditions)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The limits (wind, sea, swell, current) for safe operations are clearly defined by the charterer	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The limits (wind, sea, swell, current) for safe operations are clearly defined by the shipping company	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
The limits (wind, sea, swell, current) for safe operations are clearly defined by the operation manuals	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

MANAGEMENT

3.5 Bridge Team

Working Climate

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Competitive	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Encouraging and supportive	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Distrustful and suspicious	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Relaxed and comfortable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Bridge Team Evaluation

	Seldom or Never	Rather Seldom	Sometimes	Rather Often	Very Often
Some of the bridge crew has lack of motivation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some of the bridge team has poor attitude to safety	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some of the bridge crew has the tendency to "cut corners"	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some of the bridge crew are behaving absentminded	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some of the bridge crew has risk-taking behaviour	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Some of the people have the tendency for "cowboy driving"	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Thank you for your important and highly valued contribution to this research in the field of Reliability Engineering & System Safety.

The information you've provided will help us to better understand how the “Human Component” affects the total safety and reliability of marine operations and how could it be improved resulting operational excellence and competitive advantage.

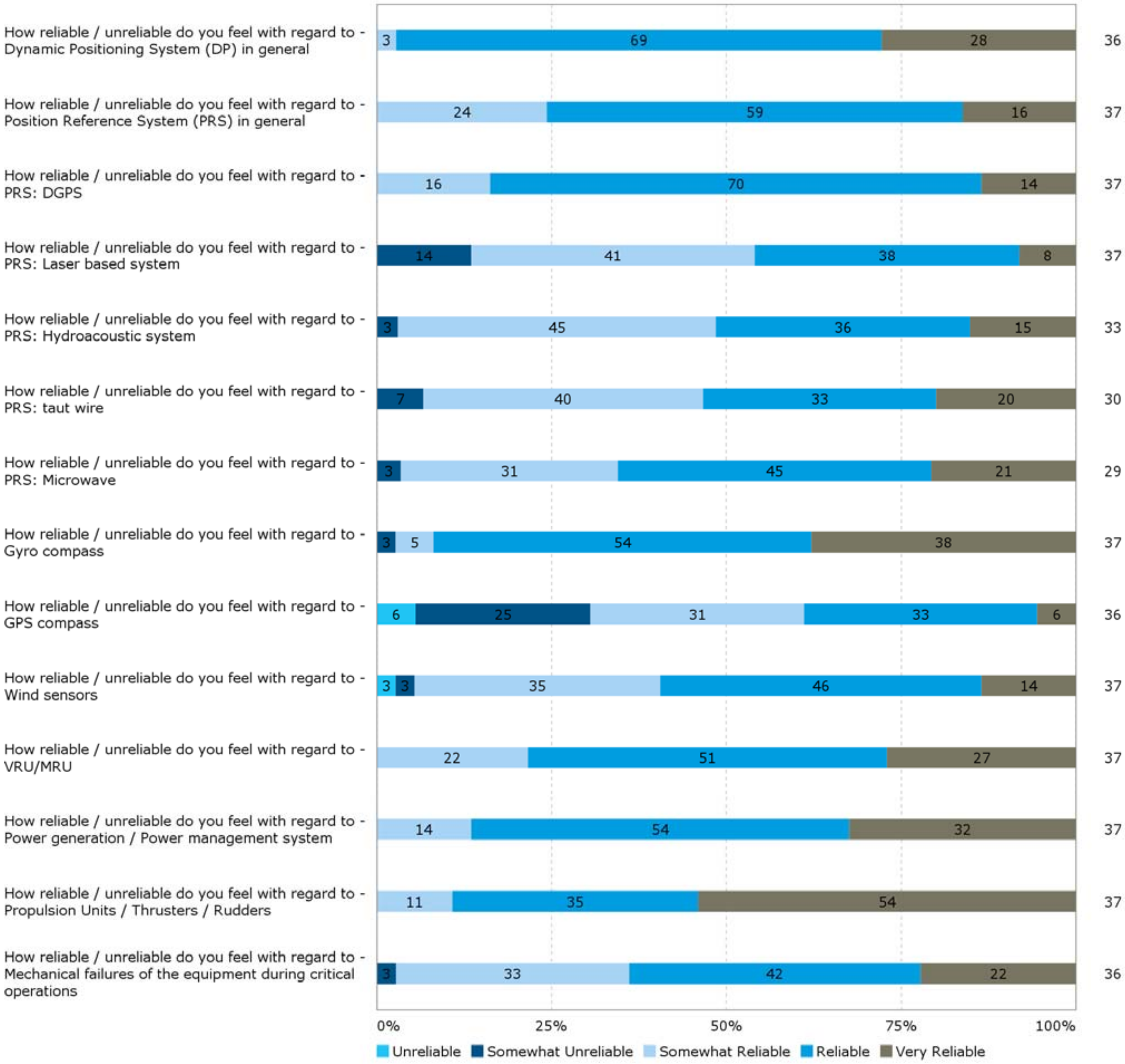
If you have questions about the results or goals of this survey send email to: jk.palola@stud.uis.no

Best Regards,

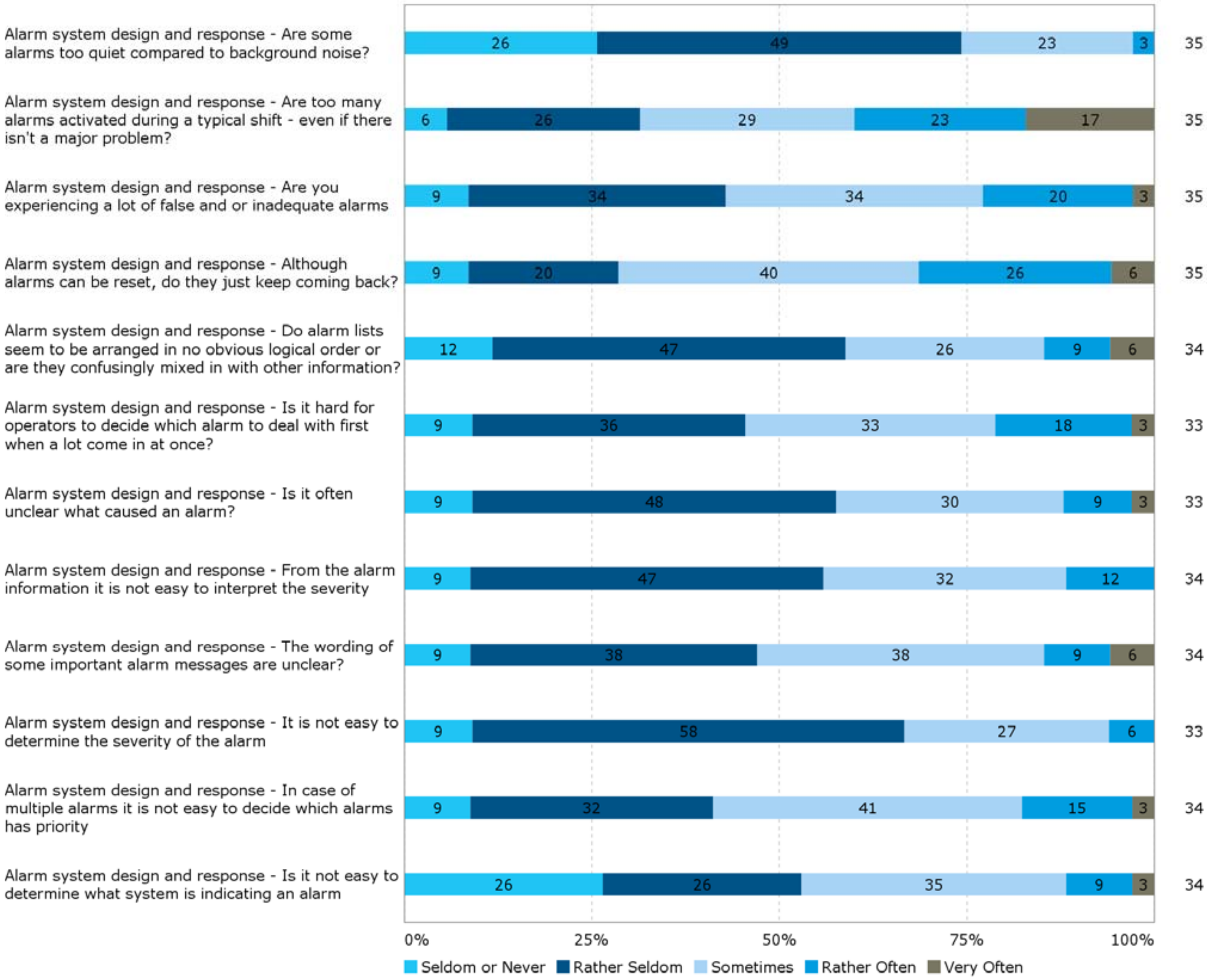
Juha Kristian Palola

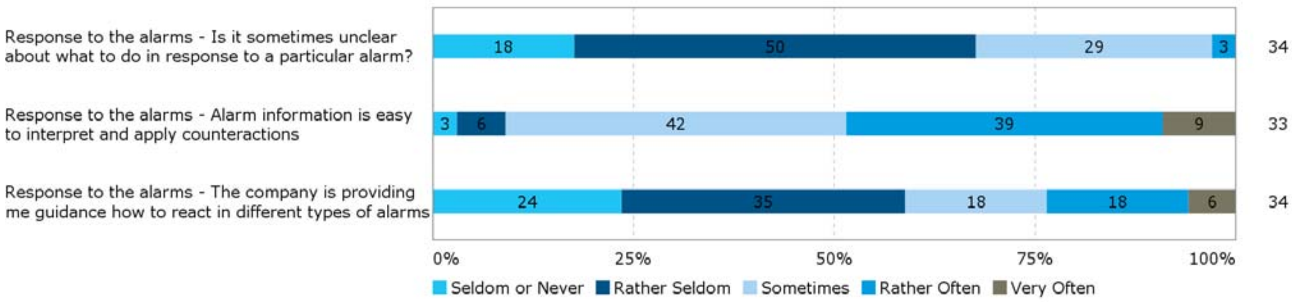
APPENDIX 3 – DATA

TECHNOLOGY and EQUIPMENT - 1.1 Reliability Perception

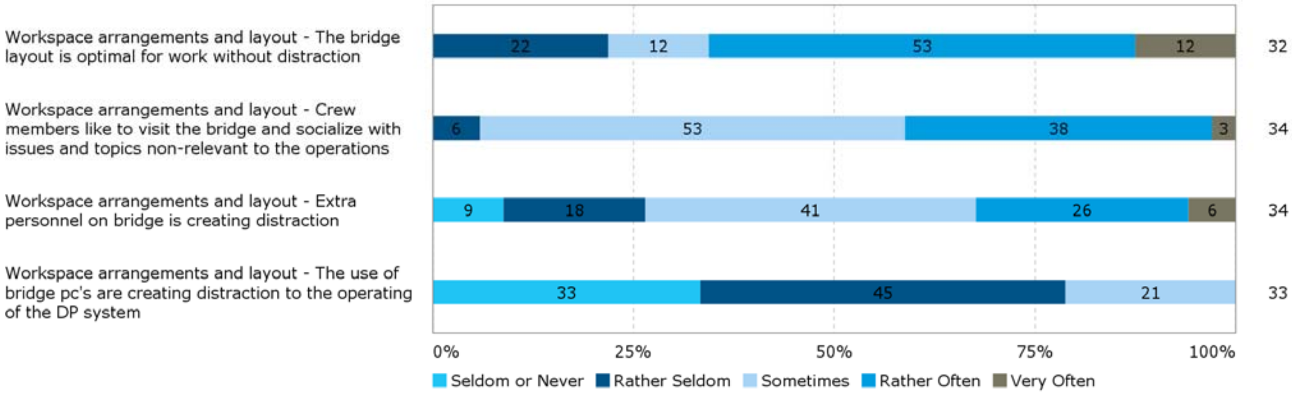


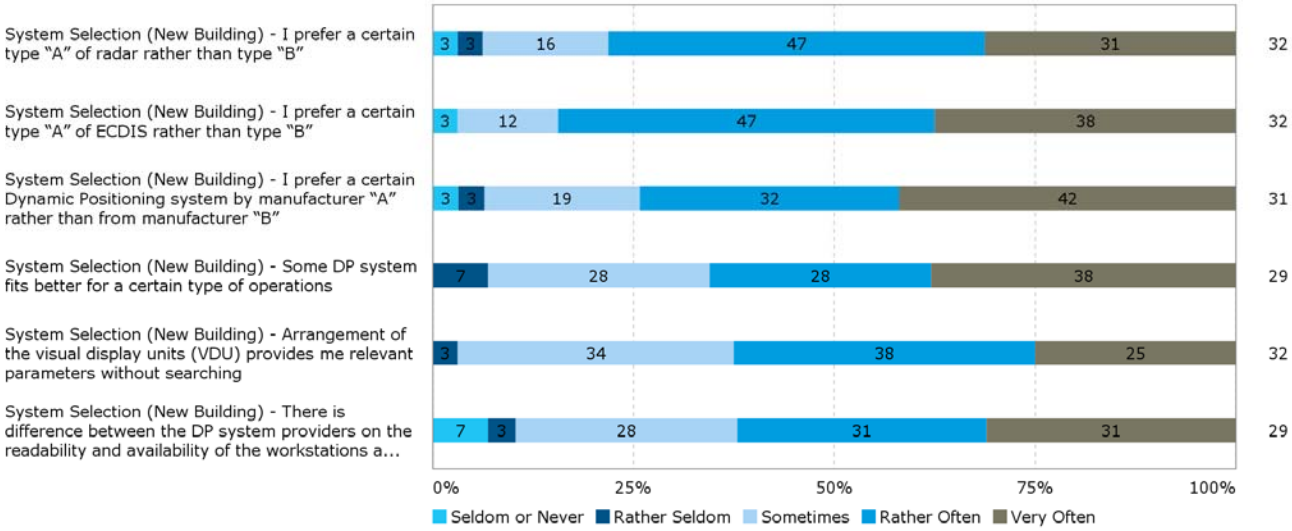
TECHNOLOGY and EQUIPMENT - 1.2 Alarms



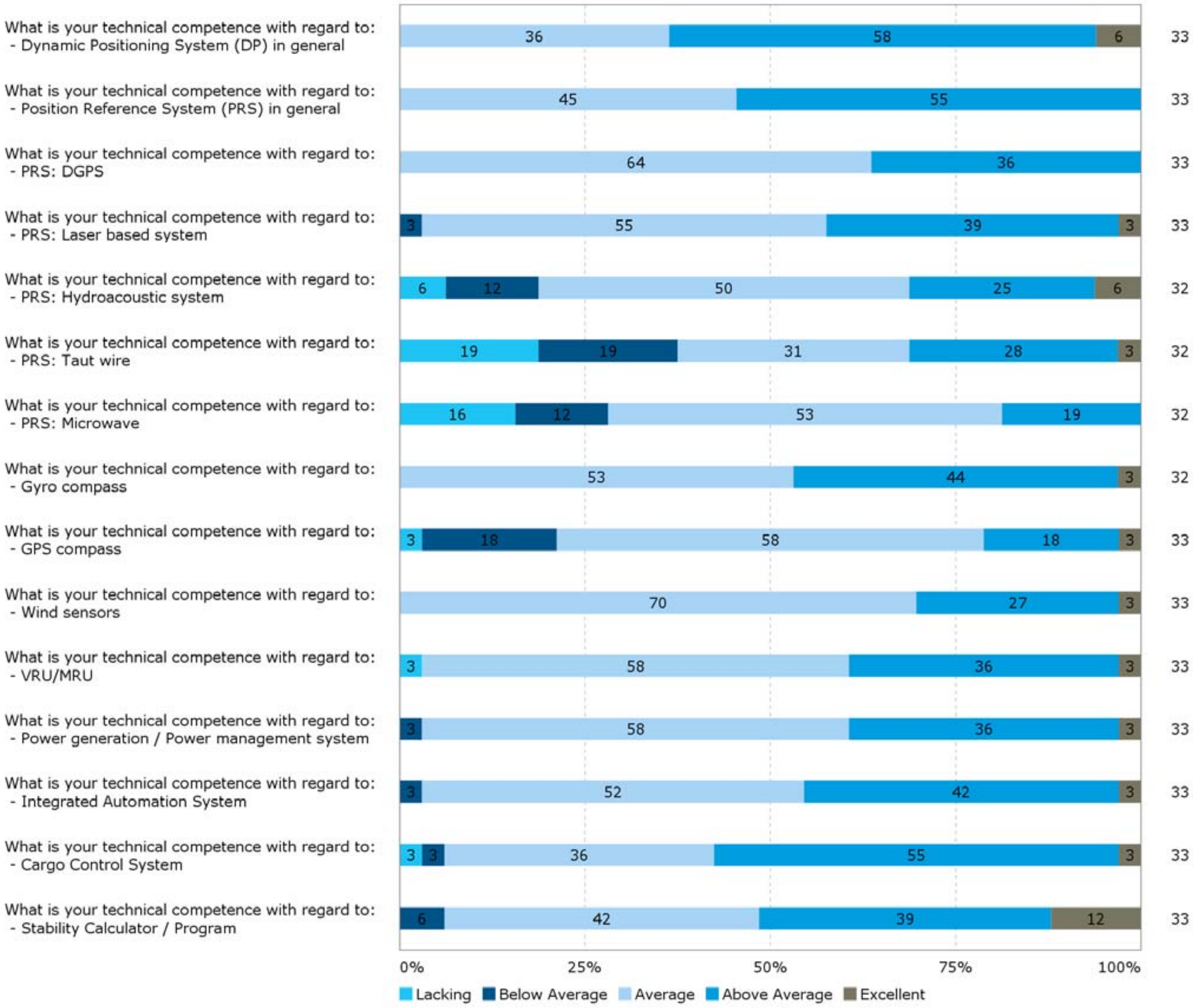


TECHNOLOGY and EQUIPMENT - 1.3 Design

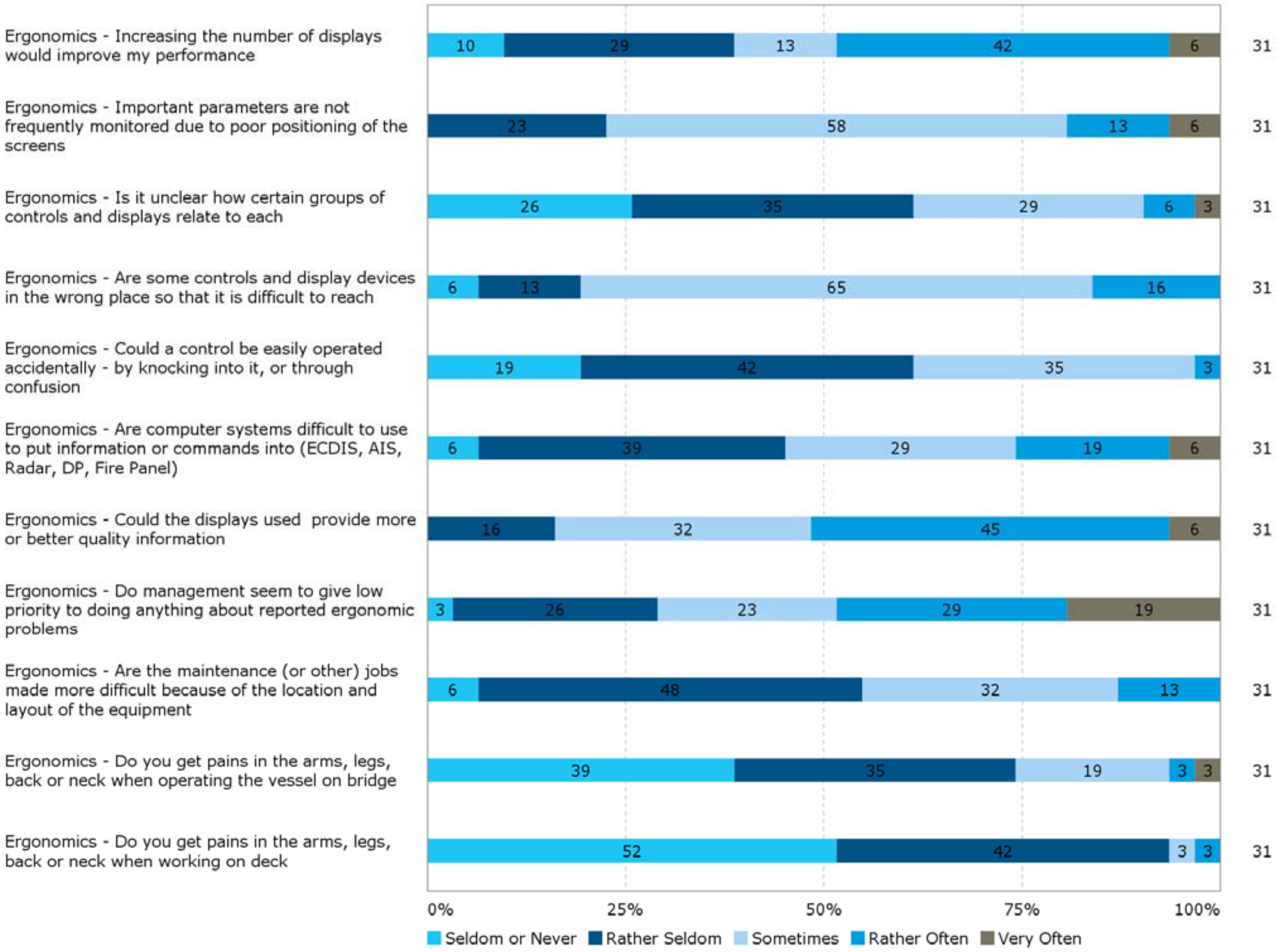




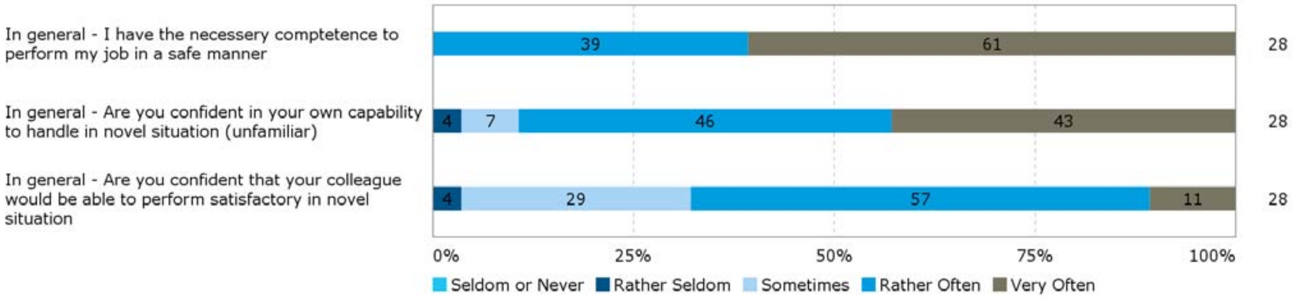
TECHNOLOGY and EQUIPMENT - 1.4 System Knowledge

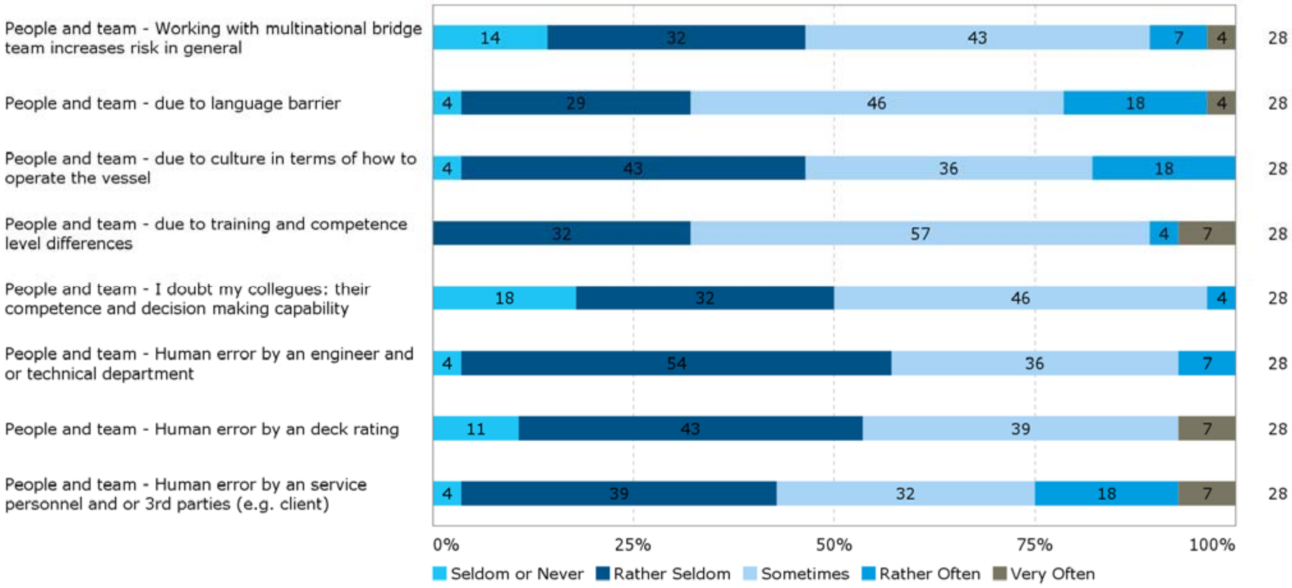


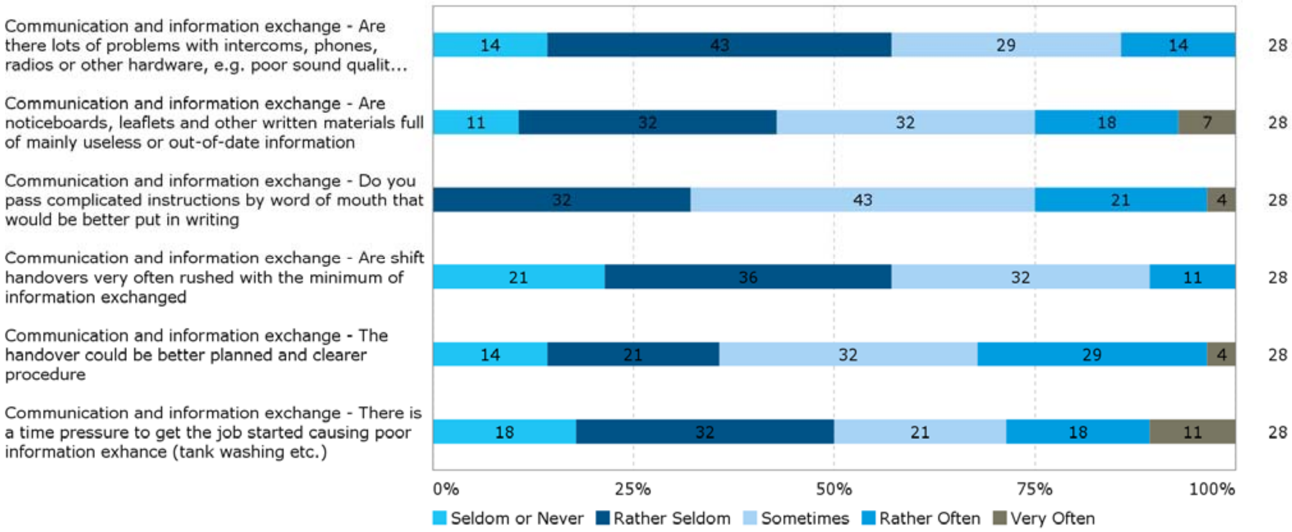
TECHNOLOGY and EQUIPMENT - 1.5 Ergonomics

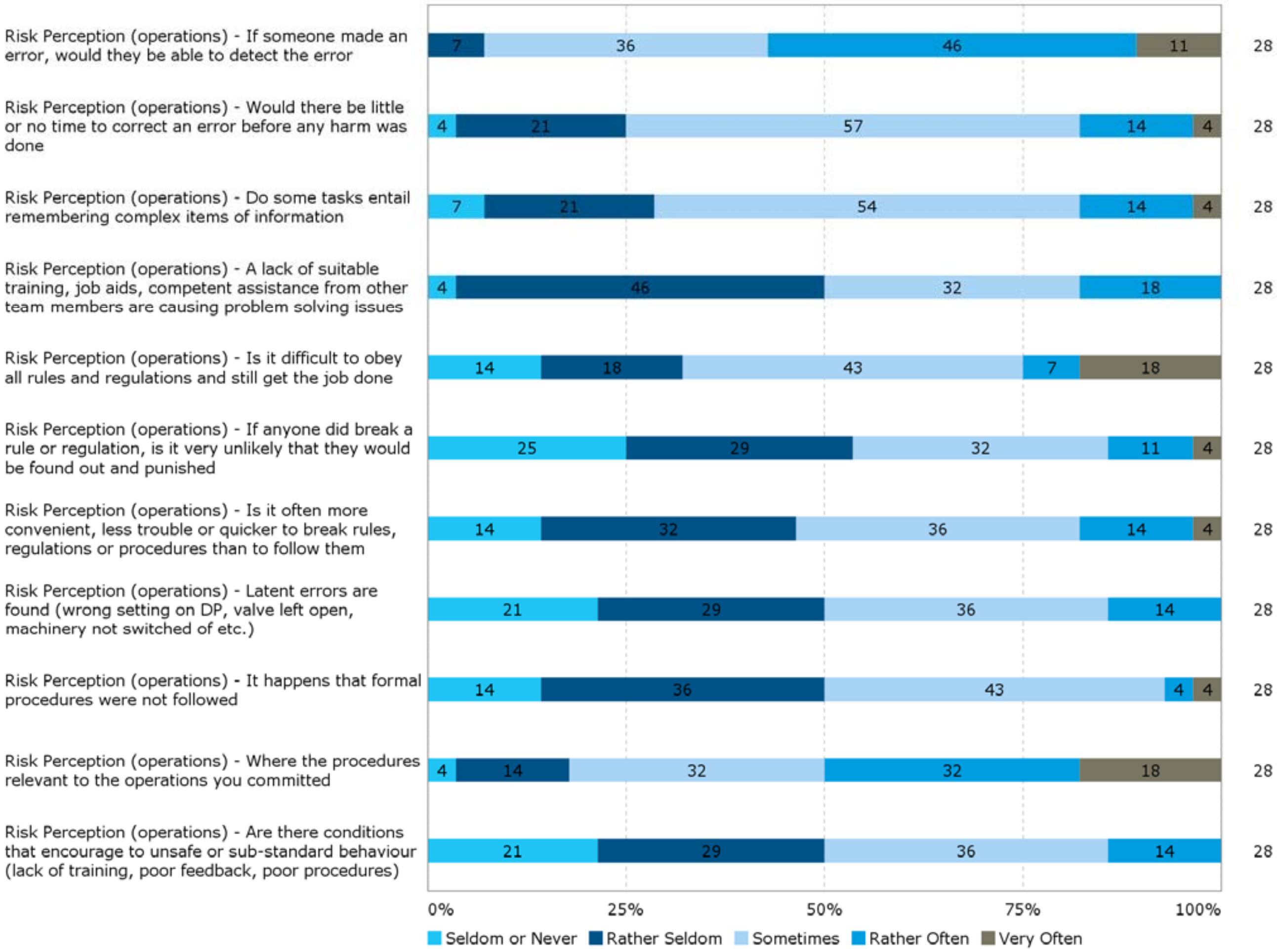


HUMAN COMPONENT / DPO - 2.1 Human Behaviour in work context

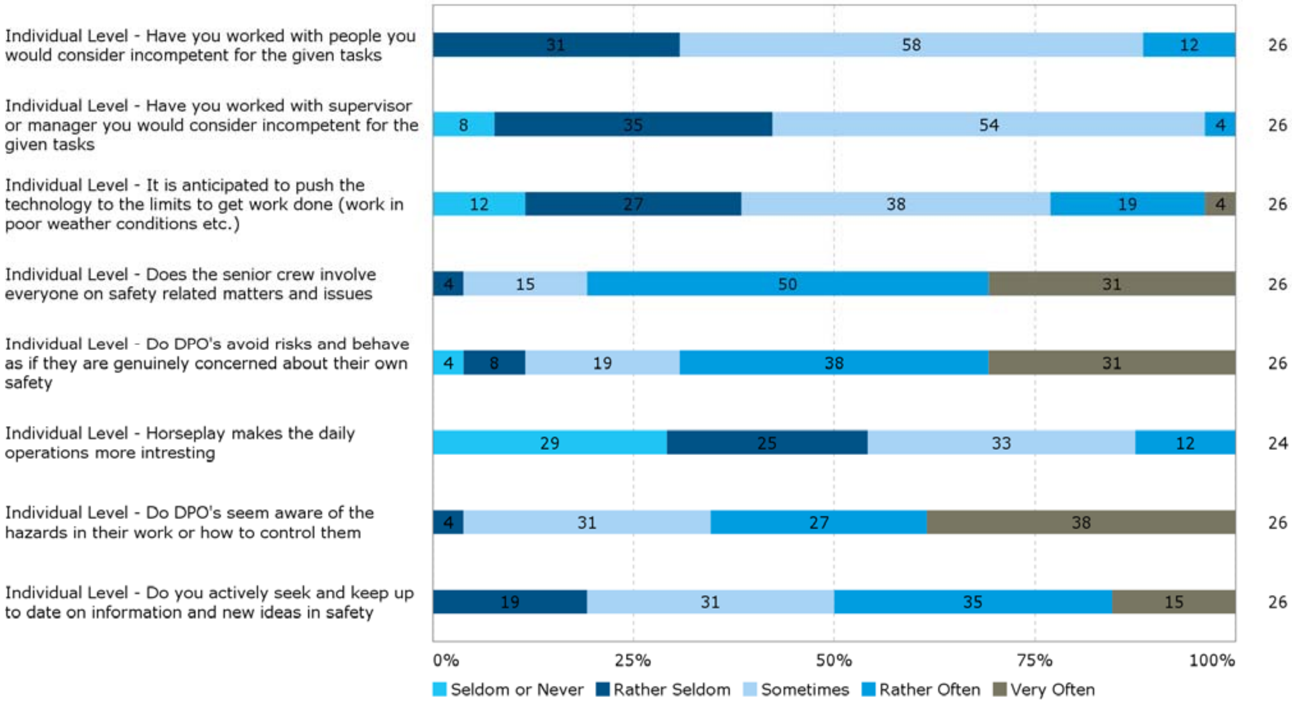


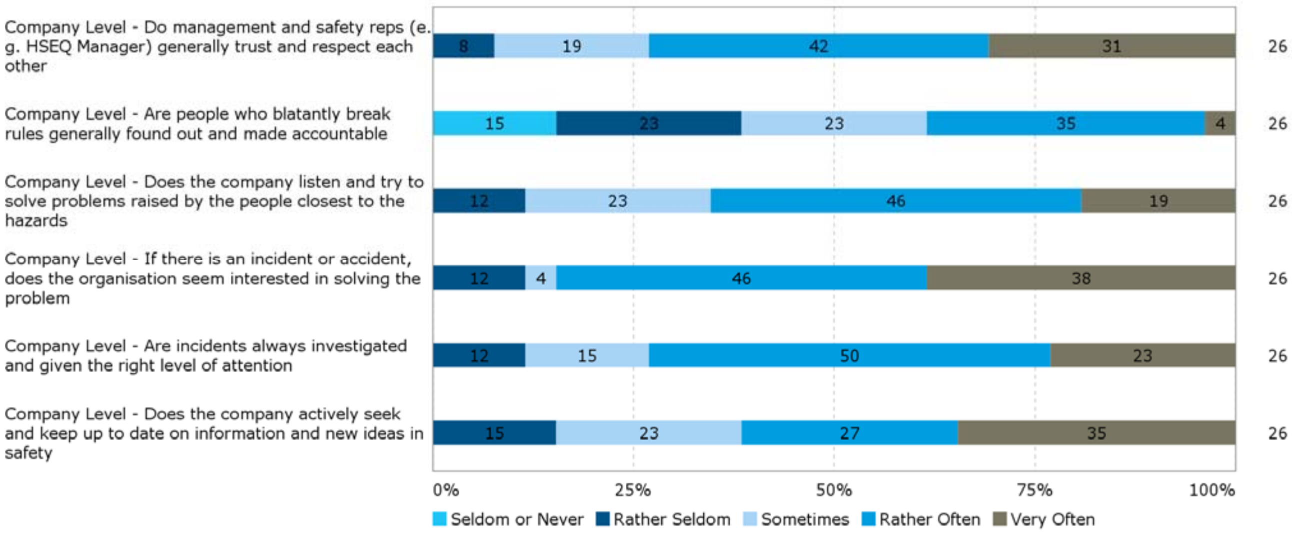




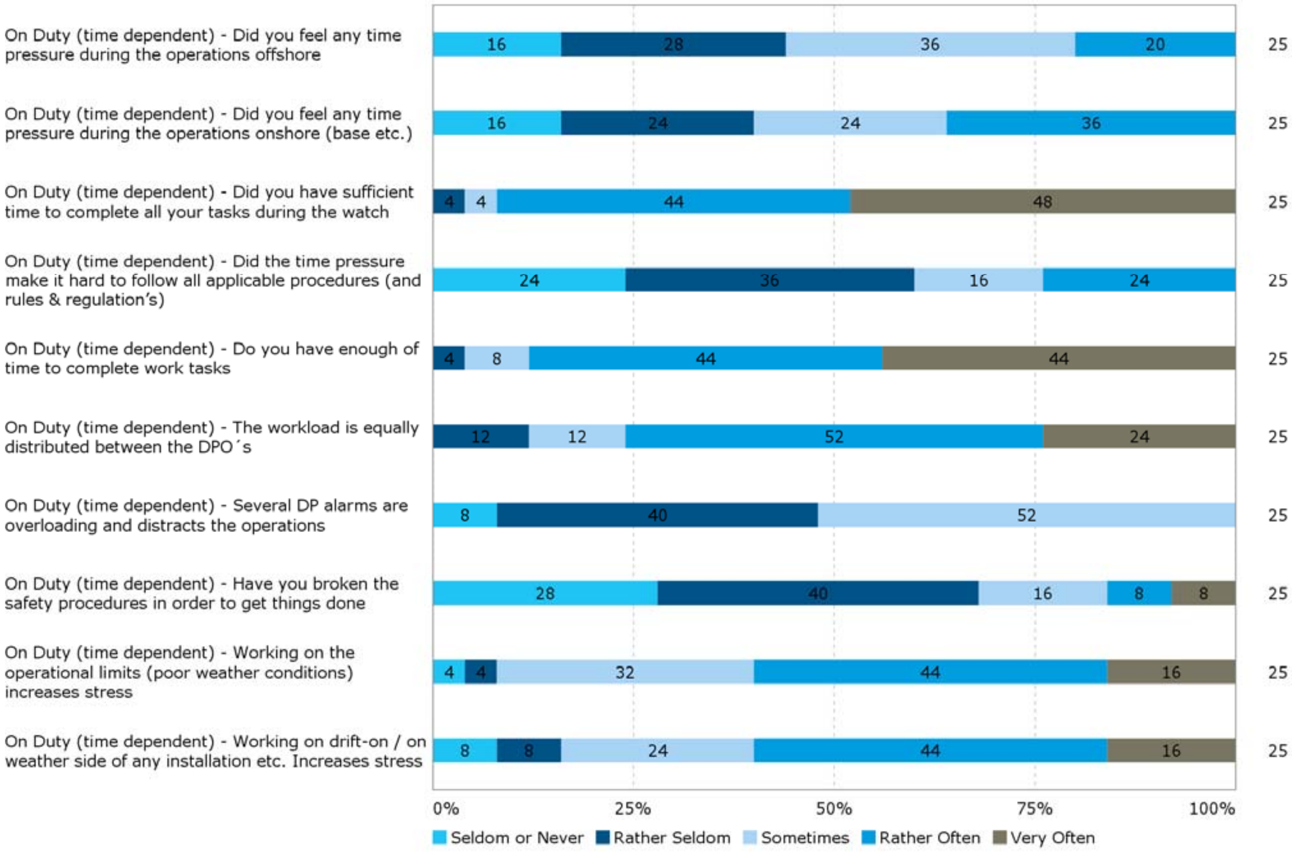

Risk Perception (operations) - If someone made an error, would they be able to detect the error
7 36 46 11 28
Risk Perception (operations) - Would there be little or no time to correct an error before any harm was done
4 21 57 14 4 28
Risk Perception (operations) - Do some tasks entail remembering complex items of information
7 21 54 14 4 28
Risk Perception (operations) - A lack of suitable training, job aids, competent assistance from other team members are causing problem solving issues
4 46 32 18 28
Risk Perception (operations) - Is it difficult to obey all rules and regulations and still get the job done
14 18 43 7 18 28
Risk Perception (operations) - If anyone did break a rule or regulation, is it very unlikely that they would be found out and punished
25 29 32 11 4 28
Risk Perception (operations) - Is it often more convenient, less trouble or quicker to break rules, regulations or procedures than to follow them
14 32 36 14 4 28
Risk Perception (operations) - Latent errors are found (wrong setting on DP, valve left open, machinery not switched of etc.)
21 29 36 14 28
Risk Perception (operations) - It happens that formal procedures were not followed
14 36 43 4 4 28
Risk Perception (operations) - Where the procedures relevant to the operations you committed
4 14 32 32 18 28
Risk Perception (operations) - Are there conditions that encourage to unsafe or sub-standard behaviour (lack of training, poor feedback, poor procedures)
21 29 36 14 28
0% 25% 50% 75% 100%
Seldom or Never
Rather Seldom
Sometimes
Rather Often
Very Often

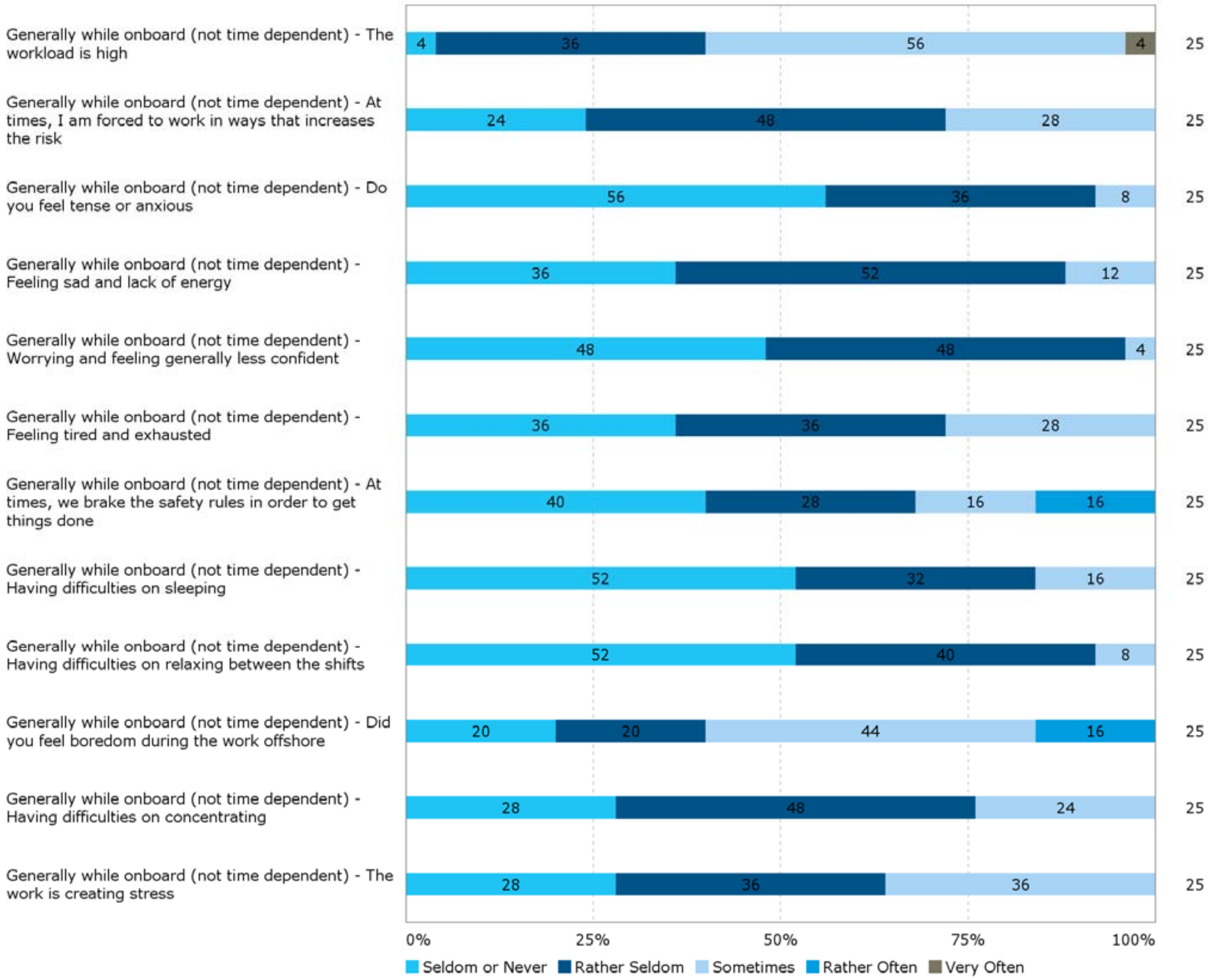
HUMAN COMPONENT / DPO - 2.2 Risk Perceptions and Safety Culture





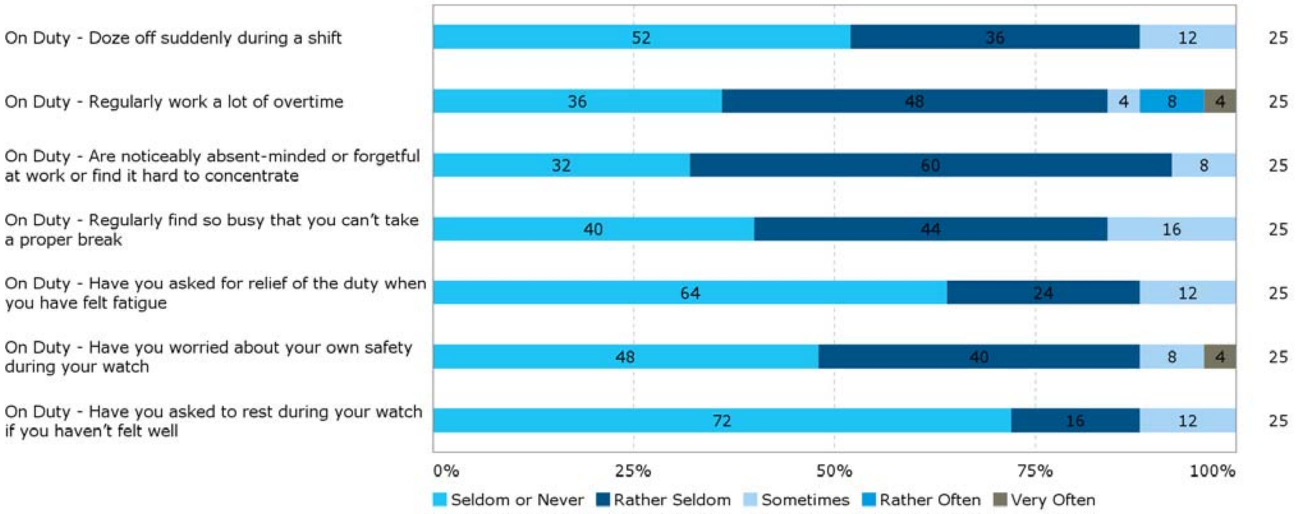
HUMAN COMPONENT / DPO - 2.3 Pressure, Stress, and Workload

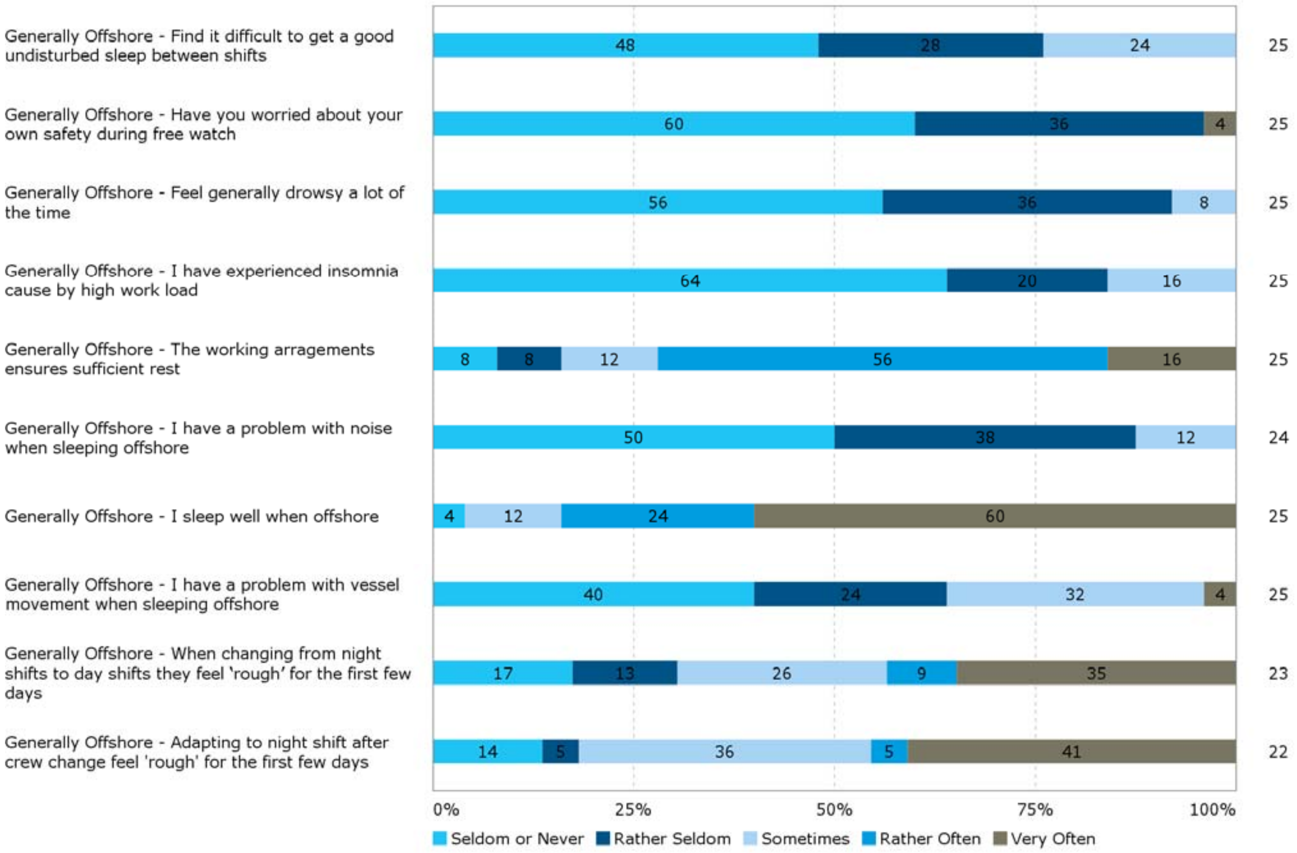




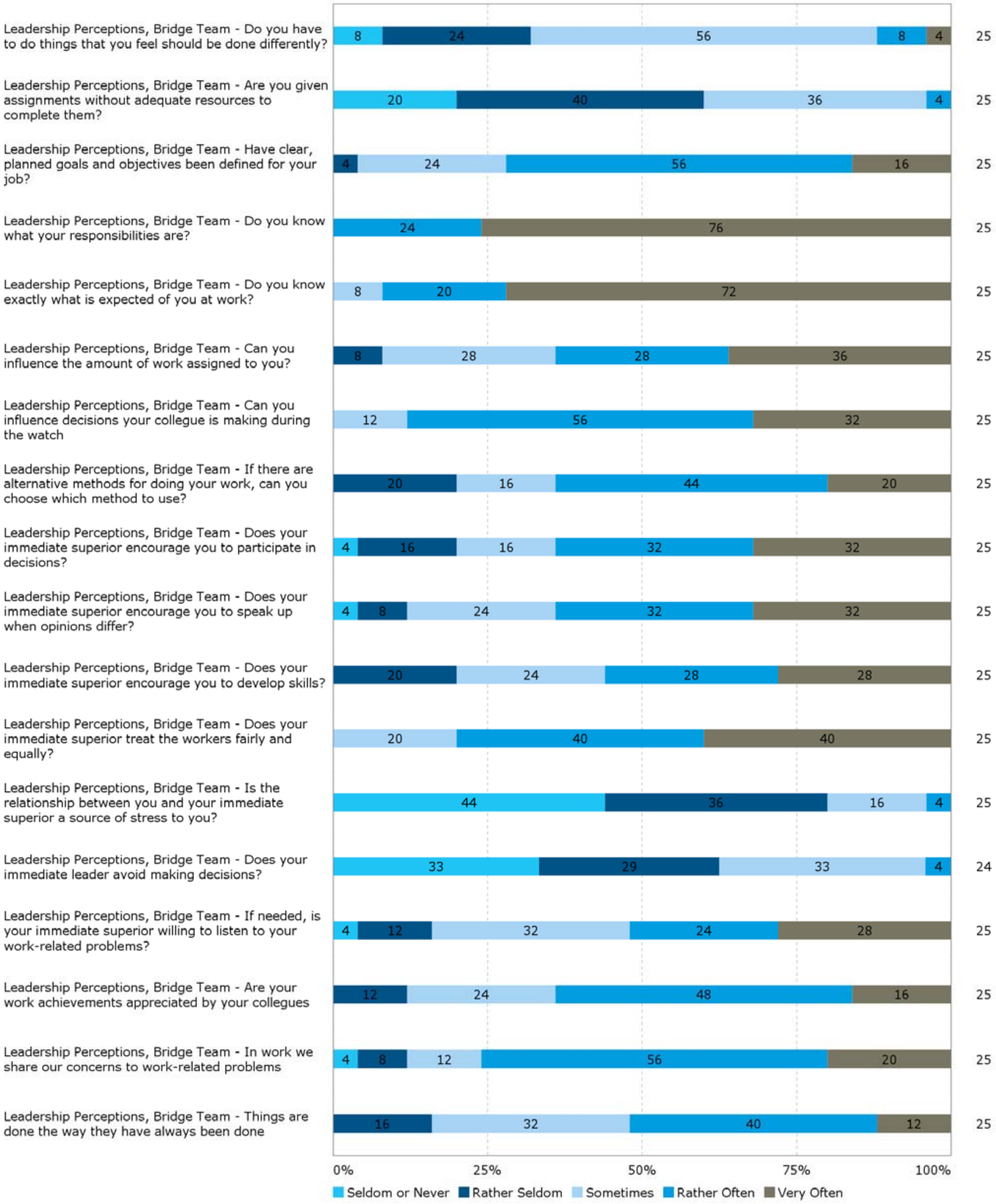
Generally while onboard (not time dependent) - The workload is high
4 36 56 4 25
Generally while onboard (not time dependent) - At times, I am forced to work in ways that increases the risk
24 48 28 25
Generally while onboard (not time dependent) - Do you feel tense or anxious
56 36 8 25
Generally while onboard (not time dependent) - Feeling sad and lack of energy
36 52 12 25
Generally while onboard (not time dependent) - Worrying and feeling generally less confident
48 48 4 25
Generally while onboard (not time dependent) - Feeling tired and exhausted
36 36 28 25
Generally while onboard (not time dependent) - At times, we brake the safety rules in order to get things done
40 28 16 16 25
Generally while onboard (not time dependent) - Having difficulties on sleeping
52 32 16 25
Generally while onboard (not time dependent) - Having difficulties on relaxing between the shifts
52 40 8 25
Generally while onboard (not time dependent) - Did you feel boredom during the work offshore
20 20 44 16 25
Generally while onboard (not time dependent) - Having difficulties on concentrating
28 48 24 25
Generally while onboard (not time dependent) - The work is creating stress
28 36 36 25
0% 25% 50% 75% 100%
Seldom or Never
Rather Seldom
Sometimes
Rather Often
Very Often

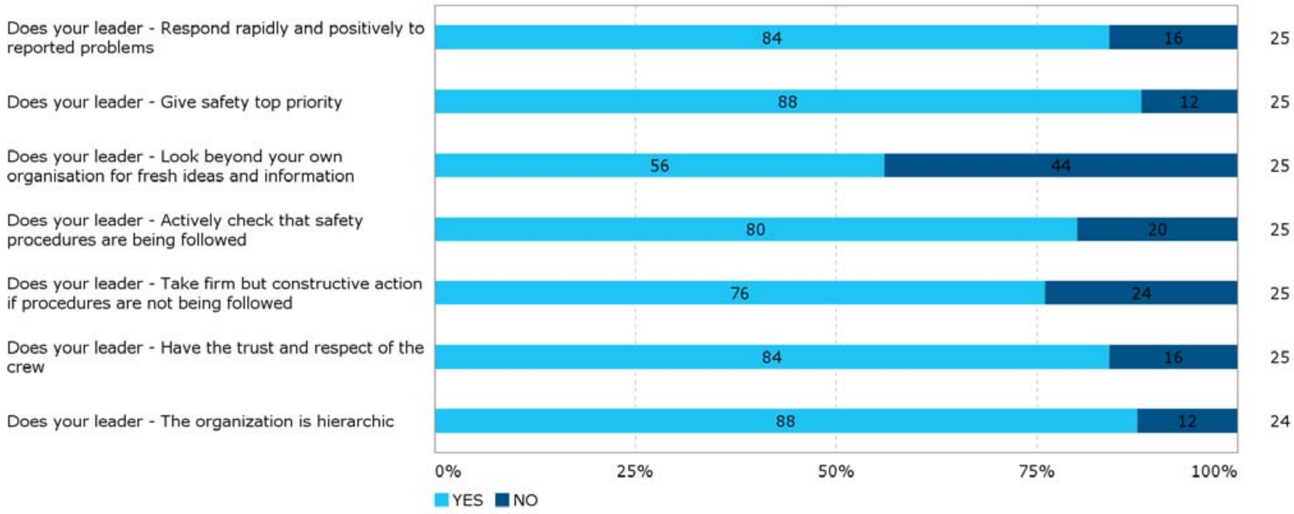
HUMAN COMPONENT / DPO - 2.4 Rest and Fatigue



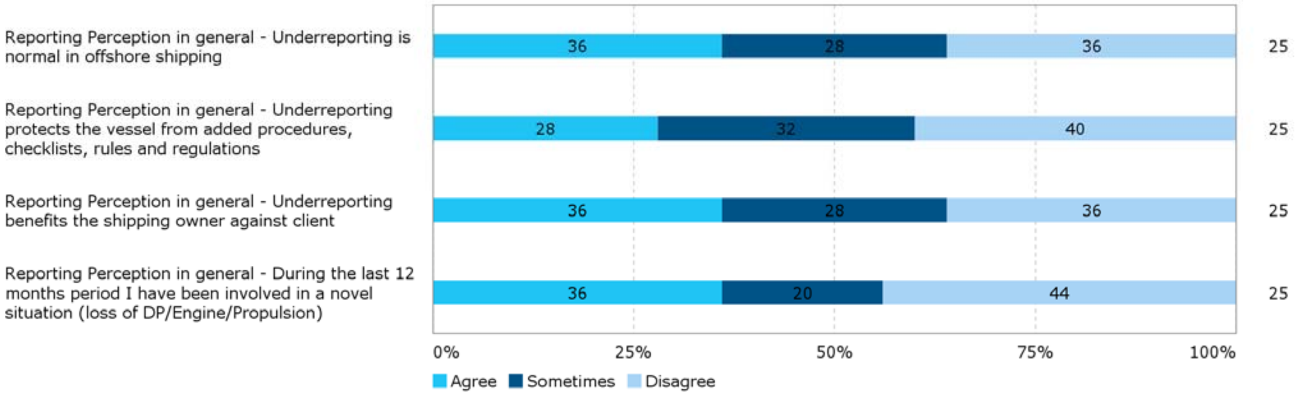


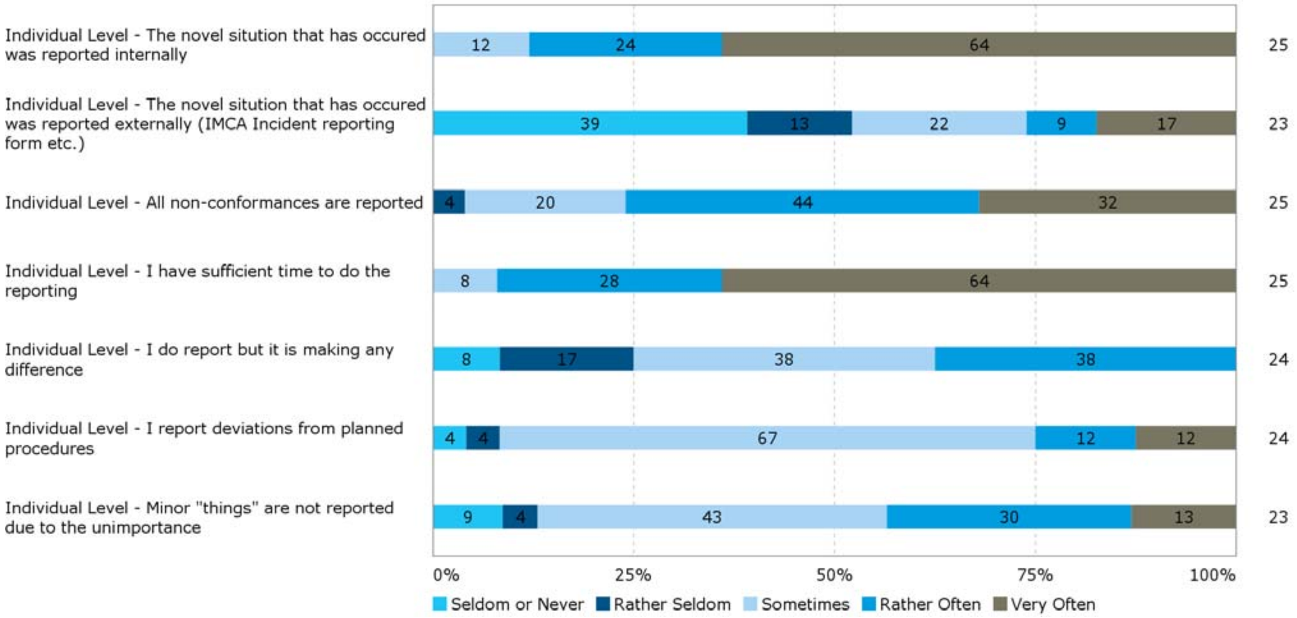
HUMAN COMPONENT / DPO - 2.5 Leadership

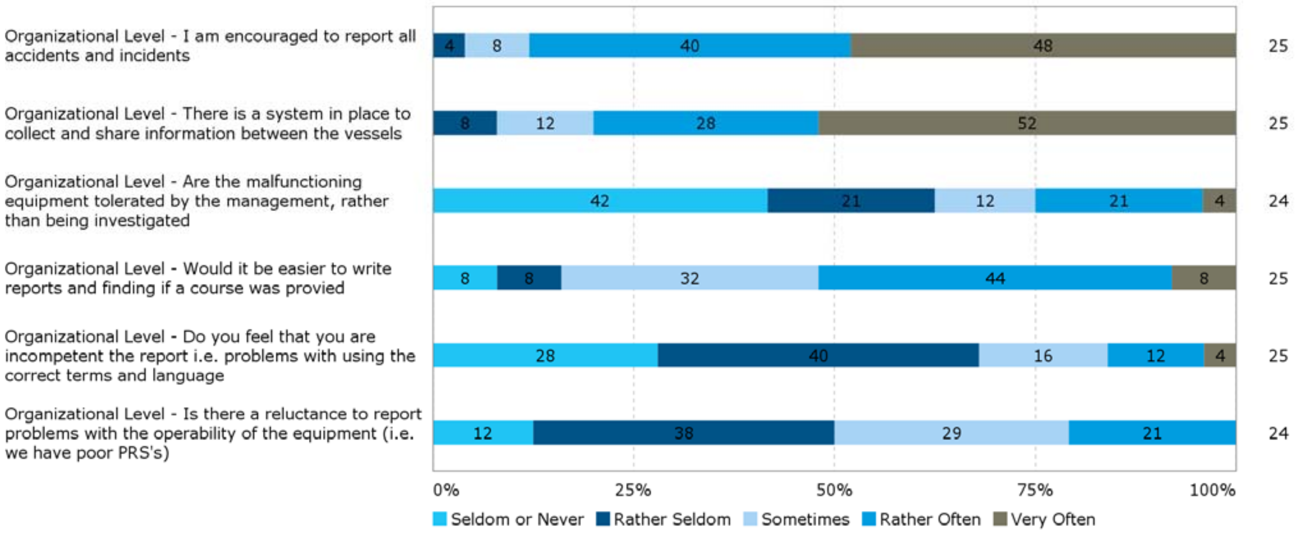



Does your leader - Respond rapidly and positively to reported problems
84
16
25
Does your leader - Give safety top priority
88
12
25
Does your leader - Look beyond your own organisation for fresh ideas and information
56
44
25
Does your leader - Actively check that safety procedures are being followed
80
20
25
Does your leader - Take firm but constructive action if procedures are not being followed
76
24
25
Does your leader - Have the trust and respect of the crew
84
16
25
Does your leader - The organization is hierarchic
88
12
24
0%
25%
50%
75%
100%
YES
NO

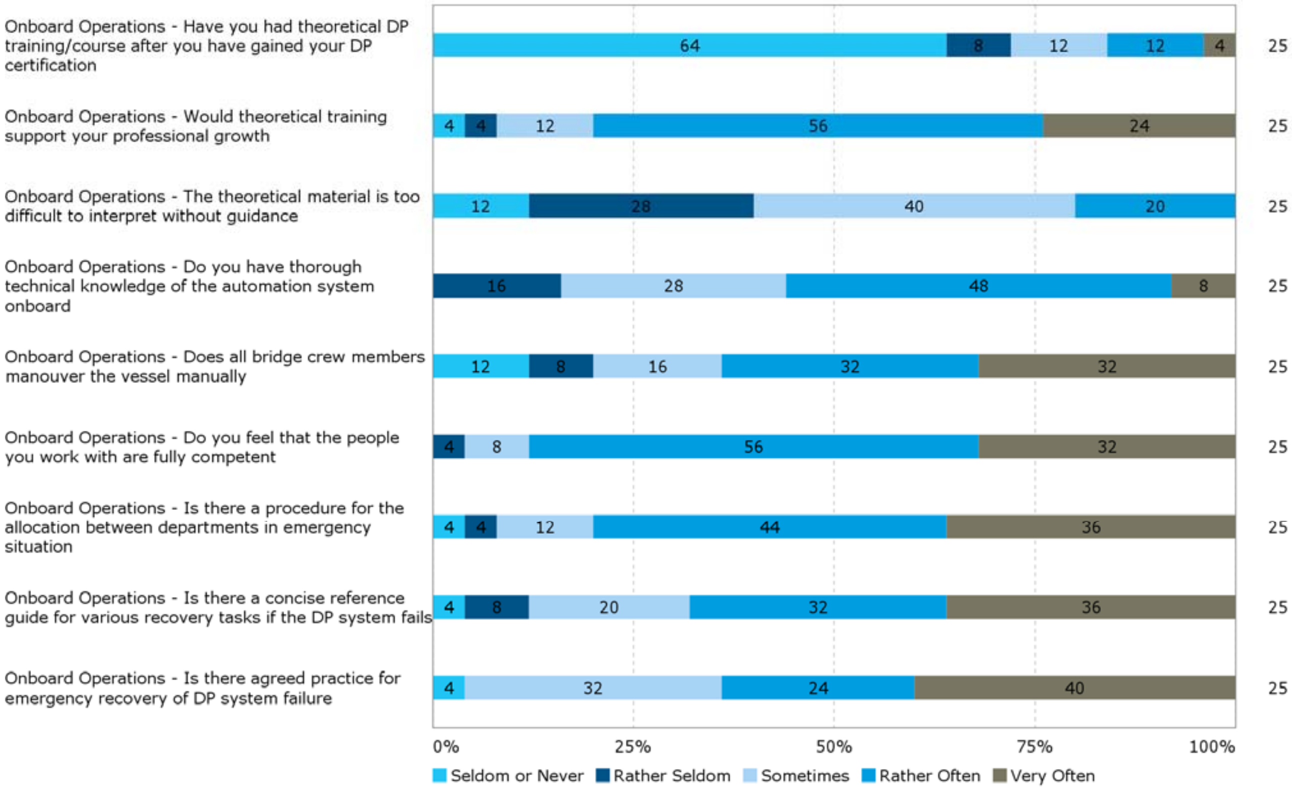
MANAGEMENT - 3.1 Reporting

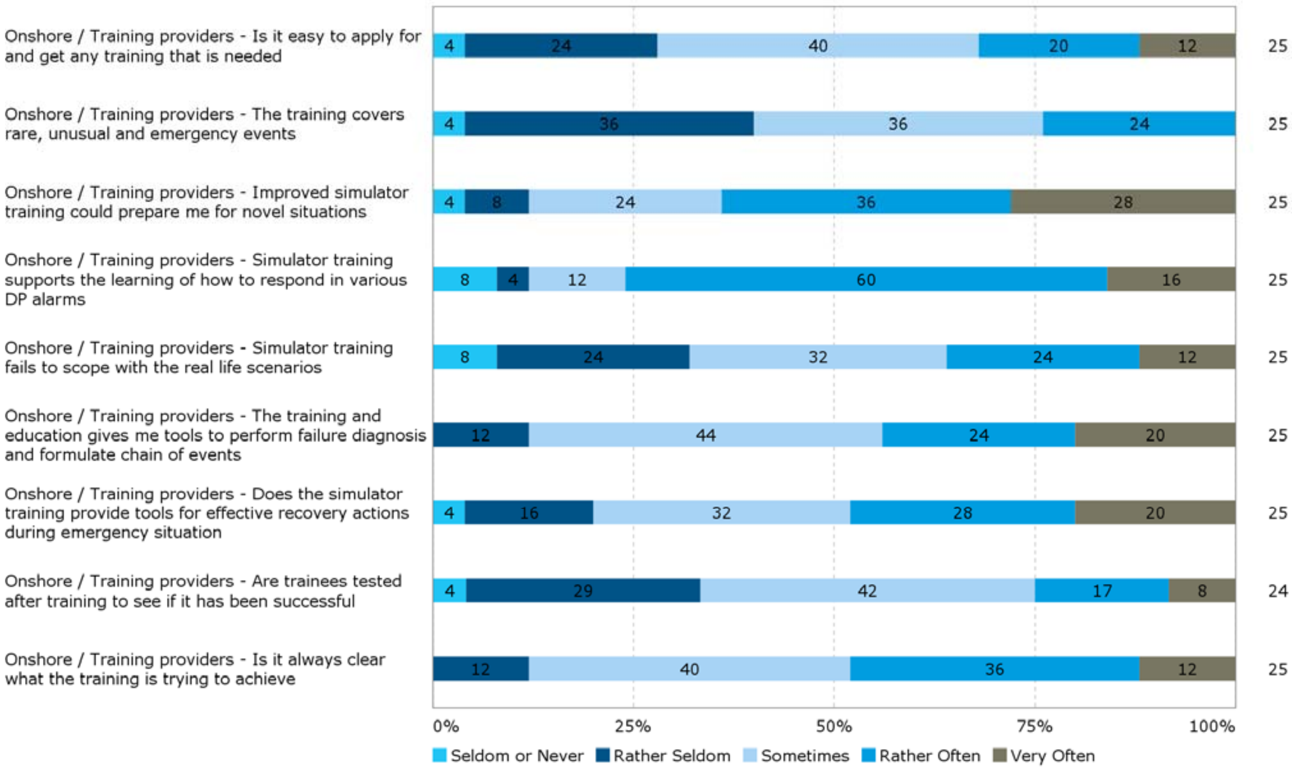




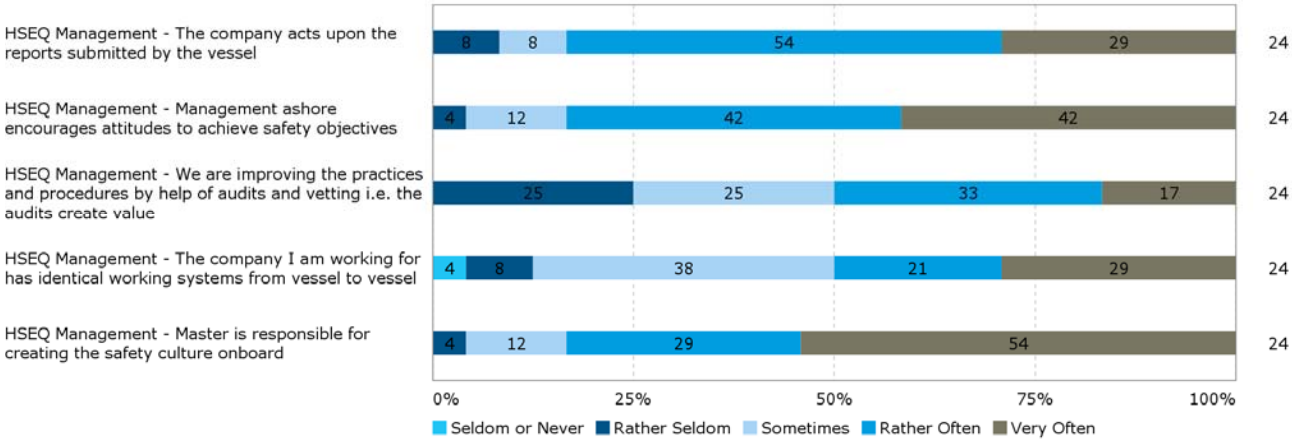


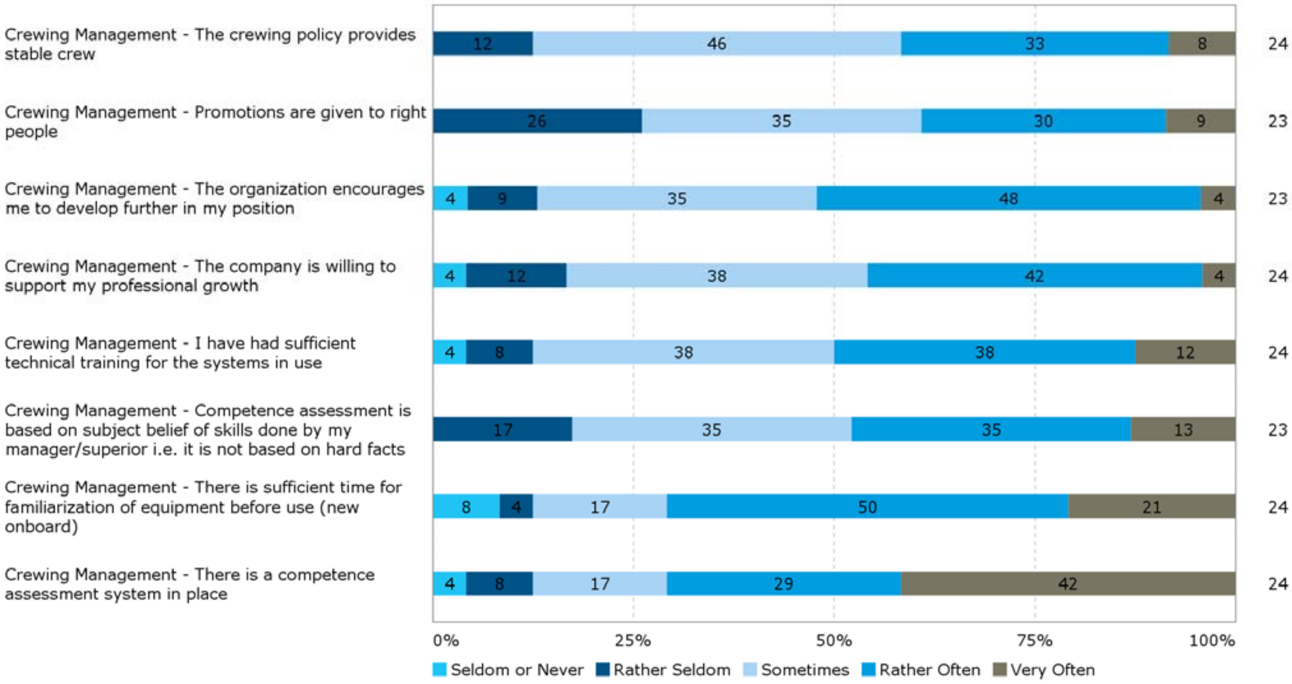
MANAGEMENT - 3.2 Training



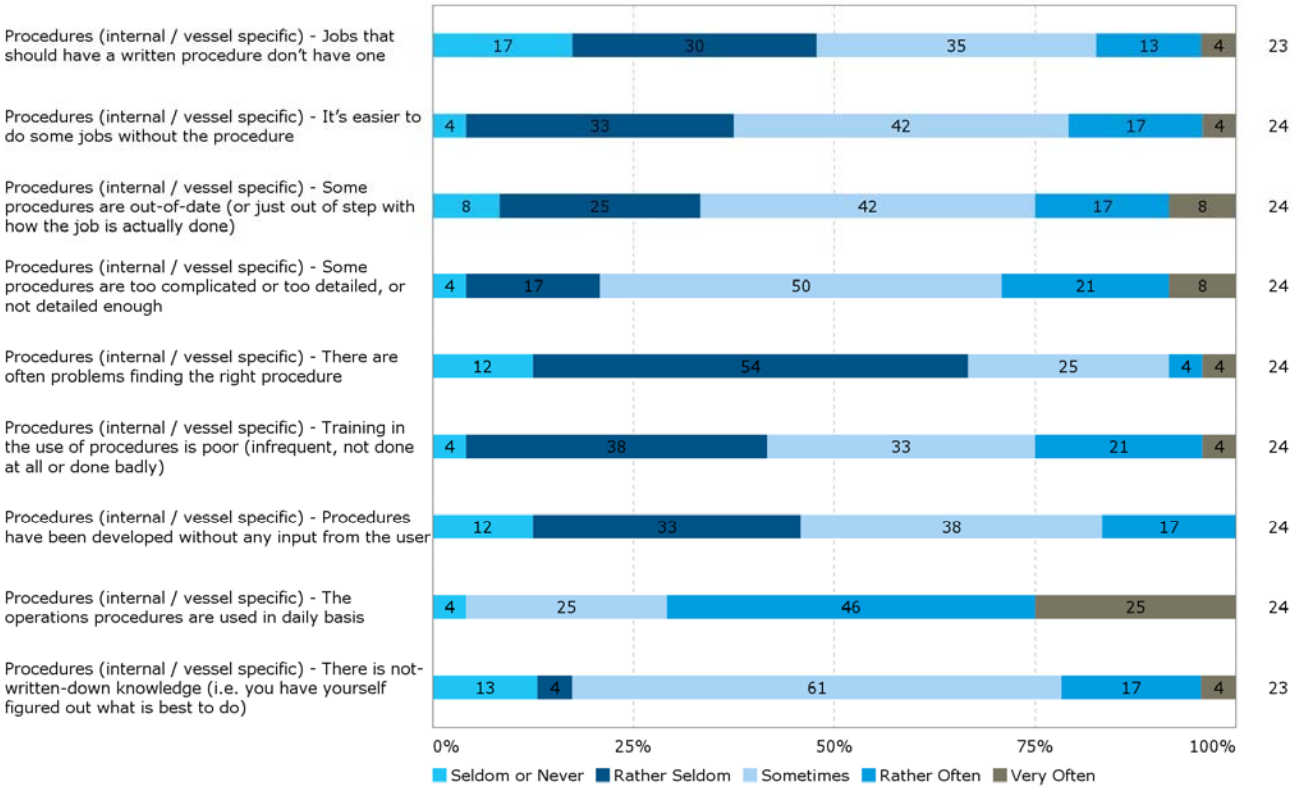


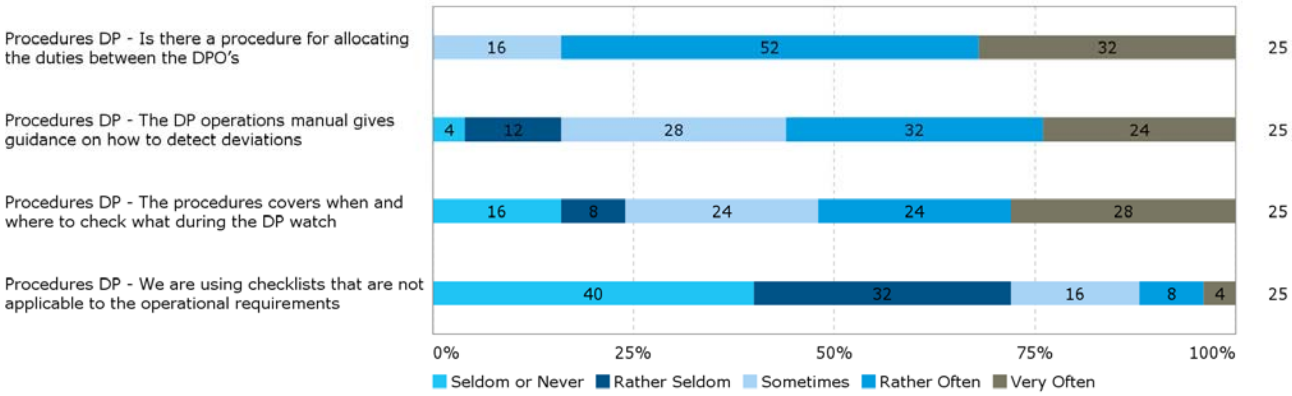
MANAGEMENT - 3.3 Management Commitment

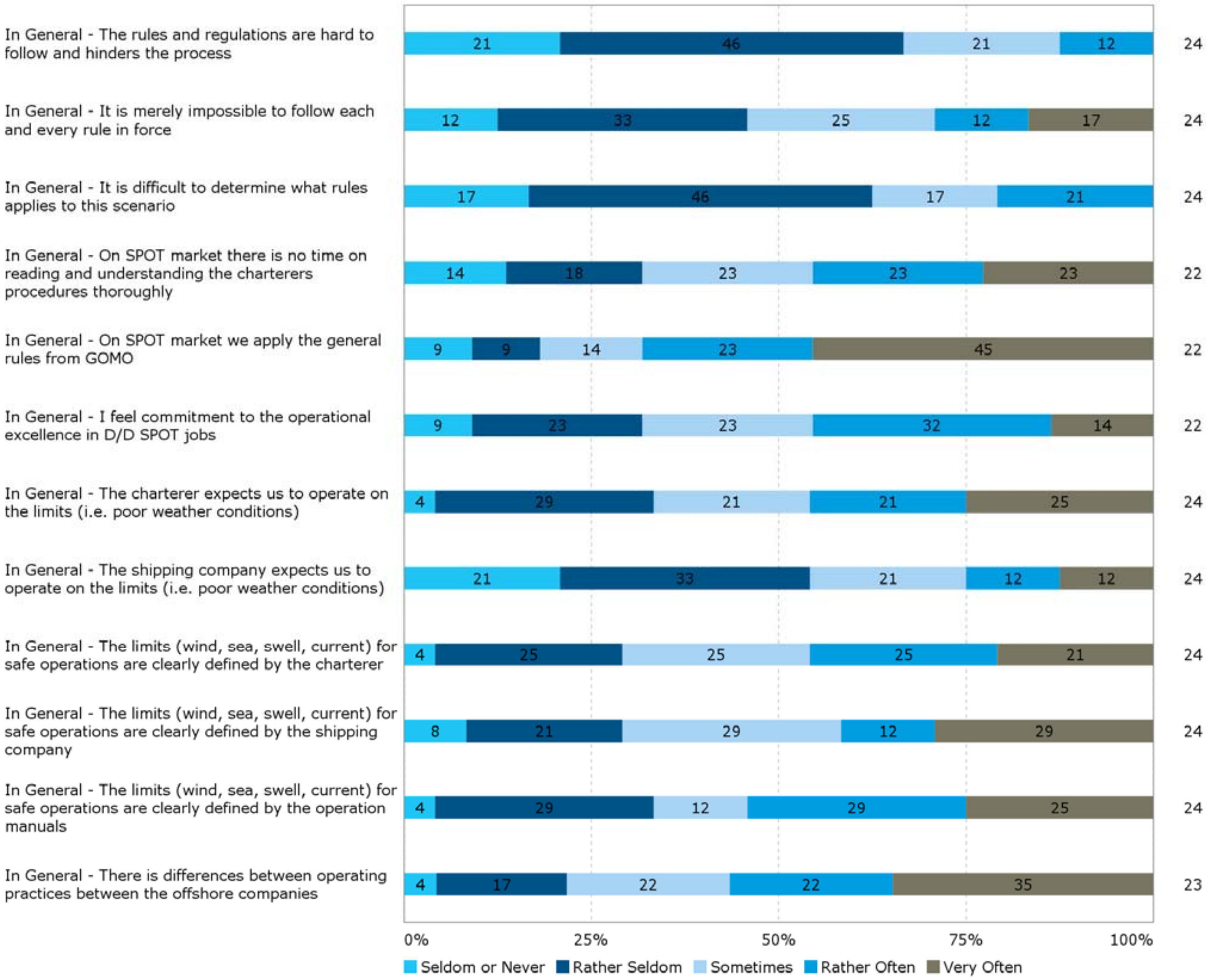




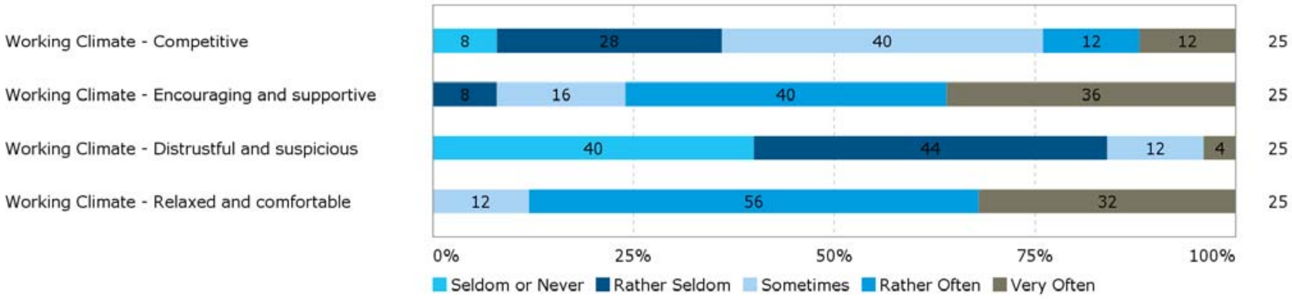
MANAGEMENT - 3.4 Procedures

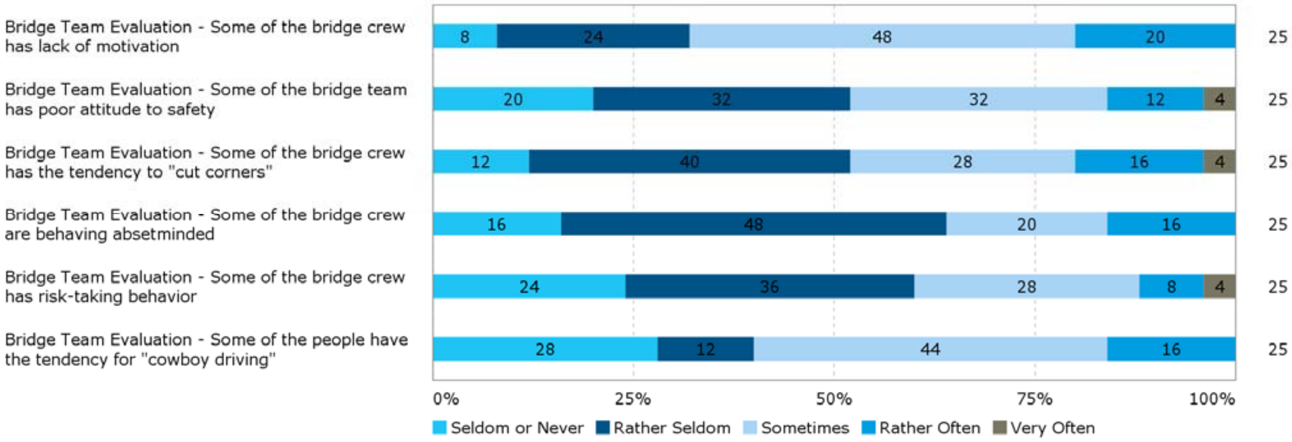





In General - The rules and regulations are hard to follow and hinders the process
21
46
21
12
24
In General - It is merely impossible to follow each and every rule in force
12
33
25
12
17
24
In General - It is difficult to determine what rules applies to this scenario
17
46
17
21
24
In General - On SPOT market there is no time on reading and understanding the charterers procedures thoroughly
14
18
23
23
23
22
In General - On SPOT market we apply the general rules from GOMO
9
9
14
23
45
22
In General - I feel commitment to the operational excellence in D/D SPOT jobs
9
23
23
32
14
22
In General - The charterer expects us to operate on the limits (i.e. poor weather conditions)
4
29
21
21
25
24
In General - The shipping company expects us to operate on the limits (i.e. poor weather conditions)
21
33
21
12
12
24
In General - The limits (wind, sea, swell, current) for safe operations are clearly defined by the charterer
4
25
25
25
21
24
In General - The limits (wind, sea, swell, current) for safe operations are clearly defined by the shipping company
8
21
29
12
29
24
In General - The limits (wind, sea, swell, current) for safe operations are clearly defined by the operation manuals
4
29
12
29
25
24
In General - There is differences between operating practices between the offshore companies
4
17
22
22
35
23
0%
25%
50%
75%
100%
Seldom or Never
Rather Seldom
Sometimes
Rather Often
Very Often

MANAGEMENT - 3.5 Bridge Team





Questionnaire Statistics