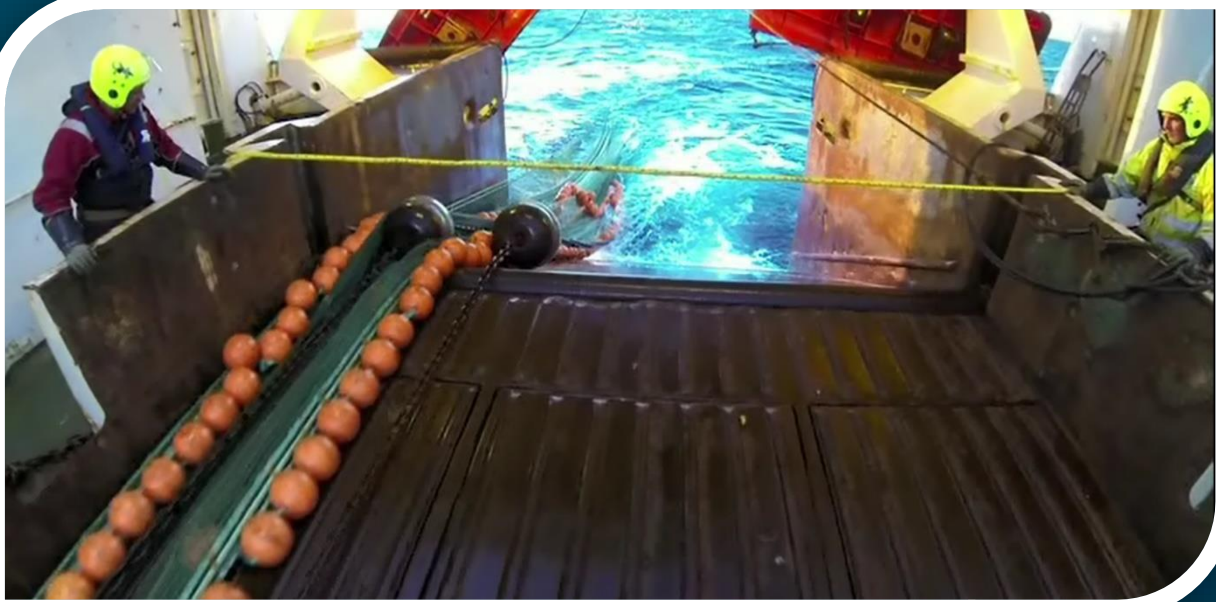
UiT The Arctic University of Norway

Faculty of Biosciences, Fisheries and Economics. The Norwegian College of Fishery Science.

Labour in fisheries: Task analysis of fishing operations on a Norwegian trawler

Viktoriia Kuz

Master Thesis in International Fisheries Management. FSK-3910. November 2019.



Abstract

This study investigates the labour on a Norwegian trawler through the study of tasks that are performed under the trawling operation. Study of tasks is one of the fundamental approaches to studying labour, and in this thesis, it is carried out using the technique of Hierarchical Task Analysis. This task analysis technique has been broadly and universally used in different industries for over 60 years. Hierarchical Task Analysis represents the system of labour tasks and goals that are achieved by performing the tasks, creating an objective picture of labour on a fishing vessel, and visually represents them as a hierarchical system of plans of tasks. After identifying and describing the tasks, each of these tasks is investigated further in terms of talk allocation, character of performance, and number of performers required to complete a task. Hierarchal task analysis contributes significantly to the system description, system investigation and system design. It discovers the tasks and human-machinery interventions, risks for operators' mistakes.

This approach is seen as translational and fundamental for disciplines that concern labour in direct or indirect way, therefore the findings of the study are discussed from the perspective of complementing present labour research and further utilization in safety studies, autonomation and other topics.

Keywords**:** *labour in fisheries, trawling operation, task analysis, hierarchal task analysis, safety in fisheries, autonomation in fisheries.*

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Glossary

Automation - process of converting the controlling of a machine or device to a more automatic system, such as computer or electronic controls (Adlemo and Andréasson 1995).

Automatization – made automatic (Adlemo and Andréasson 1995).

Automatized task – task that is performed automatically (Adlemo and Andréasson 1995).

Autonomation - the highest degree of automation – as an autonomous process is not only performing a task, but as well monitors and controls itself (Adlemo and Andréasson 1995)

Goal - an overall aim which can be achieved by wearing range of tasks based on the set objectives to achieve the goal (Kirwan and Ainsworth 1992).

Labour - a process that is independent on any social formation, and has three main attributes: purposeful activity of man, directed to work, and object on which work is performed in the form of natural or raw materials, instruments of the work, most often tools or more complex technology (Thompson 1983).

Manual labour –labour that consists of tasks that are performed by hand or by using simple tools (Khan 2001).

Mechanization - an introduction of the machines into a certain process (Jerome 1934).

Mechanized labour – labour performed using machines and power tools (Jerome 1934).

Operation –what is actually done in a situation and is usually a description of the behaviour or cognitive activity carried out to achieve the task objective (Kirwan and Ainsworth 1992).

Performance – the way in which people complete their tasks (Kirwan and Ainsworth 1992).

System – the formal interaction of different items in order to produce a specific product or service (Kirwan and Ainsworth 1992).

Sub task – a part of task that when performed with one or more additional sub tasks will result in successful task completion (Kirwan and Ainsworth 1992).

Task – a set pattern of operations which alone, or together with other tasks, may be used to achieve a goal (Kirwan and Ainsworth 1992).

Task allocation – division of individual tasks between members of an organization and between people and machines (Kirwan and Ainsworth 1992)

Task analysis – method of describing what an operator is required to do, in terms of actions and/or cognitive processes to achieve a system goal. It is a method of describing how an operator interacts with a system and with the personnel in that system (Kirwan and Ainsworth 1992).

Task analysis process – a process of collecting information on how a task is carried out and representing such information such that the task can be analysed to see if it can be improved, or to assess its task design adequacy. The task analysis process is most useful when properly integrated into the system life cycle (Kirwan and Ainsworth 1992).

Trawling – fishing with using the trawl gear (Gabriel *et al.* 2005).

Weak point – an area of weakness, characteristic that makes something vulnerable (Collins Dictionary).

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1 Introduction

One famous motivational quote, which is often assigned to Mark Twain and Agatha Christie, says: “The secret of getting ahead is getting started. The secret of getting started is breaking your complex overwhelming tasks into manageable tasks, and then starting on the first one”. While this wisdom bears some emotional load, in its literal reading, it explains the core idea of this labour research.

Labour is a fundamental social creation, and it exists as long as humans started to realize their activity and the benefit of it. Over time, the way people performed their work has changed significantly from simple and completely manual work to creative or highly-intellectual labour of an operator of an automated system. Now there is place for all types of labour in the modern world (World Bank Group 2019).

The process of labour has become a subject to a study in early 20th century, when Fredrick Winslow Taylor systematized and analysed all knowledge about labour and started to use it to design management decisions by coordinating personal benefits of workers (Taylor 1919). This approach has become revolutionary at the time, and caused a long discussion about workers, work and working conditions. Since then, study and research of labour has become an inseparable part of all dimensions of technological and social progress and evolved into many branches and methodological approaches.

This thesis perceives labour process as the process of completing certain tasks, as it is the understanding of what a worker is required to do and how, and successful completing it, that makes a process of work efficient and beneficial. Tasks act as the directions and goals for performance. Thus, this thesis takes the direction of the task analysis (Shepherd 2001).

In its variety of techniques, task analysis contributes significantly to industry, society and science, as it creates the prerequisite to the organization of work, the design of workplaces, work practices and equipment, and in helping people to master their tasks. Task analysis methods therefore should be of direct interest to managers and engineers concerned with setting up an organizing system; to designers concerned with making sure people can use equipment properly; to managers and supervisors concerned with making sure the system works according to design; to human factors and other management support staff concerned with prescribing conditions to enable people to work effectively; to human resources staff concerned with personnel and training issues, and to safety staff concerned to ensure that safe practices are followed. Furthermore, tasks analysis contributes significantly to balancing the human factor in the system and automation, and autonomation of the system (Shepherd 2001).

Task analysis carried out on a fishing vessel is a challenging project, due to variety of unpredictable factors that may affect fishing operation – weather conditions, technical issues, presence of target species and search for them, damage of the fishing gear, human factor and human mistake, but an extremely important one, due to the grand social and economic role of fisheries.

Relevance of studying labour is mostly based on the fact that fishing is one of the most dangerous occupations, with the highest ranks of the occupational casualties (ILO 2007). It is mainly the issues of safety in the fishing fleet that indicate the challenges of labour and performance on board of a fishing vessel and create interest for looking for further studies and search for solutions. However, this is not the only driver for such a study, as optimisation of labour for other purposes (e.g. increase crew comfort) can benefit from task analysis.

If we study the most recent trends, the number of shipwrecks of fishing vessels and causalities peaked in 2015, and after a decrease, started to increase again in the most recent years (Figure 1)

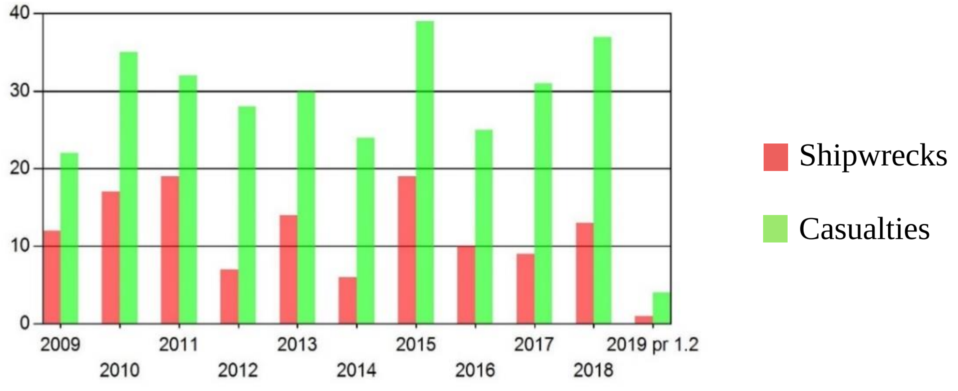


Figure 1: Shipwrecks and casualties of fishing vessels 2009 – 1.02.2019 (Norwegian Maritime Authority 2019).

As for the non-fatal and not critical accidents, it is possible to notice in the Figure 2 that most accidents that happen on the fishing vessels are personal accidents. These statistics rise interest to investigate why is it so and what specific activity led to an accident.

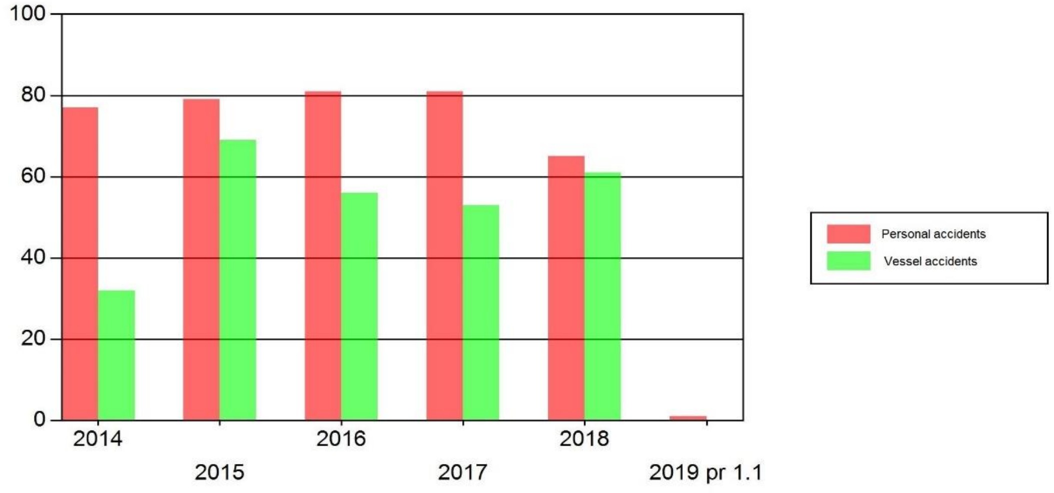


Figure 2: Personal and ship accidents on the fishing vessels 2014-1.01.2019 (Norwegian Maritime Authority 2019).

An accident may occur on a vessel of any size; however, the types of accidents may differ. To identify which group of the vessels by size bear higher potential danger, it is important to study Figure 3, which provides statistics of shipwrecks and casualties by the size of the vessels.

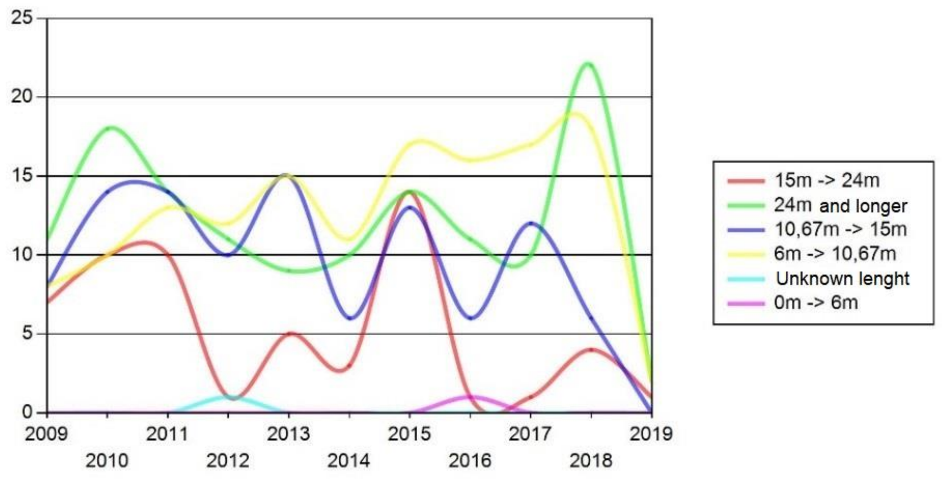


Figure 3: Shipwrecks and casualties of fishing vessels 2009 – 1.01.2019 by size of the vessels (Norwegian Maritime Authority 2019).

There are two trend lines that reach most peaks – of green and yellow colour, which correspond to vessels of length over 24 metres and vessels of size between 6 and 10.67 metres respectively. This means that vessels of these sizes had reported highest amount of the accidents and injuries reported to the Norwegian Maritime Authority.

By studying Figures 1, 2 and 3 thoroughly, we may observe the following trends:

- Most injuries take place on the larger fishing vessels;
- Most injuries reported are personal injuries, not the ship accidents;
- Trend line for personal injuries is strong and tends to increase.

Lower number of ship wrecks among larger vessels and higher number of personal injuries indicates that larger vessels are less sensitive to challenges, but the crew faces potential danger at their work – by performing the tasks that are required by the working process.

This creates extra motivation for the study of labour and tasks on a fishing vessel, as the results of this study may contribute to future improvement of the fishing methods, routines and safety on board, improvement of the machinery on the vessels, and evolution for the new approaches to fishing through new fishing gears and vessel design. One of the greatest benefits of the task analysis is that with the correctly chosen technique, it may serve all the mentioned purposes.

The goal of the thesis is to describe labour tasks on a fishing vessel, produce an empiric study of investigative-descriptive character and create a basis for future studies by answering the following research questions:

1. What tasks does crew perform under fishing?
2. How are the fishing labour tasks performed and where?
3. How can findings of Task analysis contribute to different fields of study? Example of the Occupational Safety Studies in Fisheries.

By carrying out Task analysis on a fishing vessel, it is possible to create an objective and real picture of the processes that happen on a vessel under fishing, which many contribute to different fields of study.

The study of the safety is becoming an integrated part of fisheries management (Petursdottir *et al.* 2001). Same time, among all the reported injuries that required a 72 hour stay from work, main reasons for injuries is related to working process – being caught in the machinery or trampling over objects (Aasjord *et al.* 2012). And it is the deck and factory work that are associated with higher risks for injuries and traumas, and the reason for that is hard and moderate work load (Thorvaldsen *et al.* 2018).

Even though the study of the labour on a fishing vessel often goes hand-by-hand with the safety studies, this thesis is dedicated to study of labour tasks on a fishing vessel, which later can be translated into different fields and projects, complement safety studies and inspire new engineering solutions for more efficient fishing.

This master thesis consists of 7 chapters – Introduction, Previous research of labour tasks relevant to this study, Conceptual Framework, Materials and Methods, Results, Discussion and Conclusion and includes 21 figures, 7 tables and 2 pictures.

1.1 Peculiarity of the research

This study utilizes a methodology that require specific set of data concerning the object of study - labour tasks. This sets several important peculiarities and limitations to the research:

- this research is oriented towards the large-scale fisheries – industrial trawlers specifically, as the category of vessels with the highest catch, stronger dependency on the crew, and most injuries (Norwegian Maritime Directorate 2011);
- this research is performed on the R/V Helmer Hanssen, which is a former shrimp trawler, that has been rebuilt to a research vessel, keeping the trawl deck layout and systems for trawl operations unchanged;
- this research focuses only on the trawling operation, as the most complex and challenging operation that consists of largest number of tasks;
- this research is meant as a translational (Drolet and Lorenzi 2011), as the methodology has been adjusted from other industries and can be translated and applied further into different types of fishing vessels, and other operations;
- this research does not consider conditions that can interrupt work on a vessel – such as weather conditions, machinery malfunction caused by exploitation, etc, but rather explores the interactions between human operators and machinery;

- project is carried about by one person at one vessel, but the data has been validated with an expert in the field, and the task analysis is proven to demonstrate the tasks – which are performed on a vessel, despite some of them are being replaced by equipment.

2 Previous research of labour tasks relevant to this study

2.1 Task analysis in industry

Task analysis is a commonly used tool in industry, and it serves multiple purposes. Several examples of task analysis are described in the “A Guide to Task Analysis” by B. Kirwan and L.K. Ainsworth (1992). The guide includes a chapter of different case studies, and examples on how findings of the task analysis can be utilized further. This provides a good idea of both how Task analysis can be conducted and how it can be utilized further.

One of such examples is the “Balancing automation and human action through task analysis” for a specific cooling manoeuvre of pressurized water reactor, carried out by A. Fewins, K. Mitchell, and J.C. Williams (Kirwan and Ainsworth 1992). The goal of study was to balance the tasks between human operator and automated system by running the manoeuvre with different number of personnel. Objective of the project was to identify if the manoeuvre could be carried out adequately with the defined minimum of operators – desk operator and a supervisor. Additional goals were to identify important requirements for The Man-machine interface, system design, work organization, training and procedures.

This study was carried out with methods of Hierarchical Task Analysis (HTA), Timeline Analysis and Workload assessment. As the operating procedures did not exist at the time (analysis has been carried out on the stage of design), HTA has been carried out as the operator actions that are necessary to carry out the manoeuvre, and developed in sufficient details to allow assessment of the workload (Kirwan and Ainsworth 1992). Together with the timeline analysis which identified density of tasks and workload assessment, where tasks were evaluated, the results were revealed in two main directions – staffing level and level of possible automation for the performance of the tasks.

There has been identified several tasks of highest priority – tasks that require reducing workload for an operator and which need to be conducted continuously. Based on the findings, there has been suggested several directions for automation of the researched manoeuvre.

Another interesting example of task analysis in the industry was described by H. Rycraft, F. Brown and N. Leckey (Kirwan and Ainsworth 1992). for the operational safety review of a solid waste storage plant. In this project focus was on the safety and the goal was set to identify human potential for industrial hazards, procedures, hardware features and training.

This study included variety of methods such as observations, interviews, walk-throughs, HTA, task decomposition, timeline analysis and interface surveys. As it is stated for the study, main method was the HTA, as it helped to identify tasks with the highest potential for human mistake (in the context of study – passing nitrogen through the storage area). Each task has been broken down to the simple tasks, which created a good basis for future investigation (Kirwan and Ainsworth 1992).

Results of the study revealed mismatches between human capabilities and tasks. These mismatches increased workload and led to an operator failing his/her tasks. Chosen methodology has as well contributed to identifying industrial hazards, procedures – instructions for performance did not reflect the current practice for performance, hardware features – some of the hardware was not adequate to the set tasks and training – potential for improvement for training of the staff (Kirwan and Ainsworth 1992).

2.2 Study of labour tasks on a fishing boat/trawler

Study of labour on a fishing vessel usually occurs in the context of occupational safety in fisheries and takes the dimension of analysis of working conditions, communication, assessment of the work load and study of the accidents. Study of labour on the fishing vessels appears limited to the study of the accidents, which provides a limited [or incomplete] picture of what is happening on board.

Conclusions that on the large fishing vessels, most risks are falling overboard and other fall-related injuries, impact and crush injuries and these incidents typically occur while a worker moves towards the outer edge of the vessel, or engaged in working activities during towing, anchoring, loading and unloading with a crane, being in contact fishing with trawl nets create a picture of danger on a fishing vessel and of how challenging the labour of a crew member is, and a significant work load they operate with (Stange 2018). However, this kind of analysis lacks understanding of what exactly a crew member was doing at the time of an accident and why that action was important for fishing.

Thus, safety studies in fisheries explain how and where crew members get injured, however they do not always provide understanding of a complete picture of the process they are involved in.

In 2005 in Denmark has been published a study of "Classification and Coding of Commercial Fishing Injuries by Work Processes: An Experience in the Danish Fresh Market Fishing Industry" (Jensen *et al.* 2005), which was dedicated to studying the working processes on board of fishing vessels in order to develop a coding of accidents in fisheries. Authors participated in fisheries operations on the vessels of different types – trawler, beam trawler, Danish seiner and netter. There has been developed a classification and description of processes and the injuries were coded according to the developed descriptions.

Authors admit importance of studying of labour processes on board of fishing vessels and used a different technique – time studies. The focus of the research was on all the processes and human performance in regard of time with the goal to investigate processes with highest number of injuries (Jensen *et al.* 2006). Time studies in regard of the odds for the injury during a working process has been investigated in the cross-referent studies of fundamental working processes on board (Jensen 2006).

Not considering the time studies, this research revealed that the majority of injurious accidents occur within the three most active working locations onboard fishing vessels: on deck, in the fish processing area or within the hold (Jensen *et al.* 2003). It has been identified that the most common injuries are the injuries of hands, fingers, chest, abdomen, and upper body in general – which is logical, as the tasks that are performed on the deck, which is often manual work with heavy loads (McGuiness 2016). Preparing, shooting and hauling of the gear and nets on deck accounts for most injuries occurring in the fishing fleet, often representative of the most serious types of injury occurrences (Jensen *et al.* 2005).

Taking the idea of proper coding of accidents, it has been described 17 main working processes and up to 13 sub-categories for each of the working processes (Jensen *et al.* 2003). Thus, according to their study, the main working processes in fishing are:
1 Embarking/disembarking
2 Traffic
3 Bridge watch

4 Watch elsewhere

5 Preparing the gear (nets)

6 Setting the gear

7 Hauling the gear

8 Handling gear on deck

9 Cleaning fish

10 Handling fish others

11 Handling frozen fish

12 Preparing deck gear

13 Working in engine room

14 Mooring

15 Working in galley

16 Off duty

17 Other

18 Unclassifiable

This classification presents the general processes that are performed on a vessel of any type. Speaking from the labour prospective, this classification names the common large task groups that are performed on board of any vessel. During the research, authors went deeper into the process classification and described processes on different types of vessels, including a trawler (Jensen *et al.* 2003). The following processes were observed on a trawler using a pelagic trawl:

5. Preparing the gear (nets)
5.1 Shooting doors in board/outboard
5.2 Working with gear in port
5.3 Repairing gear at sea
6. Shooting the gear
6.1 Shooting nets
6.2 Attaching double wires
6.3 Paying the lazy decky away
6.4 Securing the escallop
6.5 Shooting/putting on nets/floats
6.6 Paying the bridles away

6.7 Clipping up the back straps

6.8 Letting go

6.9 Letting go the doors

6.10 Blocking up

6.11Chain strapping the warps

7. Hauling the gear

7.1 Letting go

7.2 Knocking out

7.3 Heaving up the doors

7.4 Letting the backstraps go

7.5 Heaving on the bridles

7.6 Pulling the turns out

7.7 Moving the garding bars

7.8 Heaving up the trawl

7.9 Taking off the floats

7.10 Heaving up the lazy decky and net sounder

7.11 Bagging (the cod end)

7.12 Watching aft side

7.13 Working with hatches, bunker lids and sorting the catch (Jensen *et al.* 2005).

Based on the description of the processes, this study appears to be created for a pelagic trawl, and, again, it includes general description of the processes. It provides a good image of what is happening on a trawler, however, by improving the coding of the injuries, it lacks depth in term of labour and labour tasks studies.

3 Conceptual frameworks

3.1 Trawling as a fishing method. Trawling system of the R/V Helmer Hanssen

Development of the different types of fishing vessels are mainly caused by the differences between fishing gears, while fishing gears are designed for the targeted species. Construction of a multi-purposed fishing vessel would be possible only by making compromises, construction of a single-gear fishing vessel has the potential of increasing fishing efficiency. (Gabriel *et al.* 2005). That is the reason why now there are different types of fishing vessels of different size.

Trawling is one of most efficient fishing methods by the size of the catch. It is used in the sea-fisheries and to a lesser extend in the fresh-water fisheries, as for the conducting trawling, a larger area is required. Importance of the trawling fishing method resulted into development of different types of trawls. By fishing depths – pelagic (mid-water) and bottom trawls. By towing, the methods are usually divided into: single trawling, pair trawling, twin trawling, multiring trawling and beam trawling. (Oxvig and Hansen 2007). Figure 3 is the visualisation of a trawl and parts of the trawl.

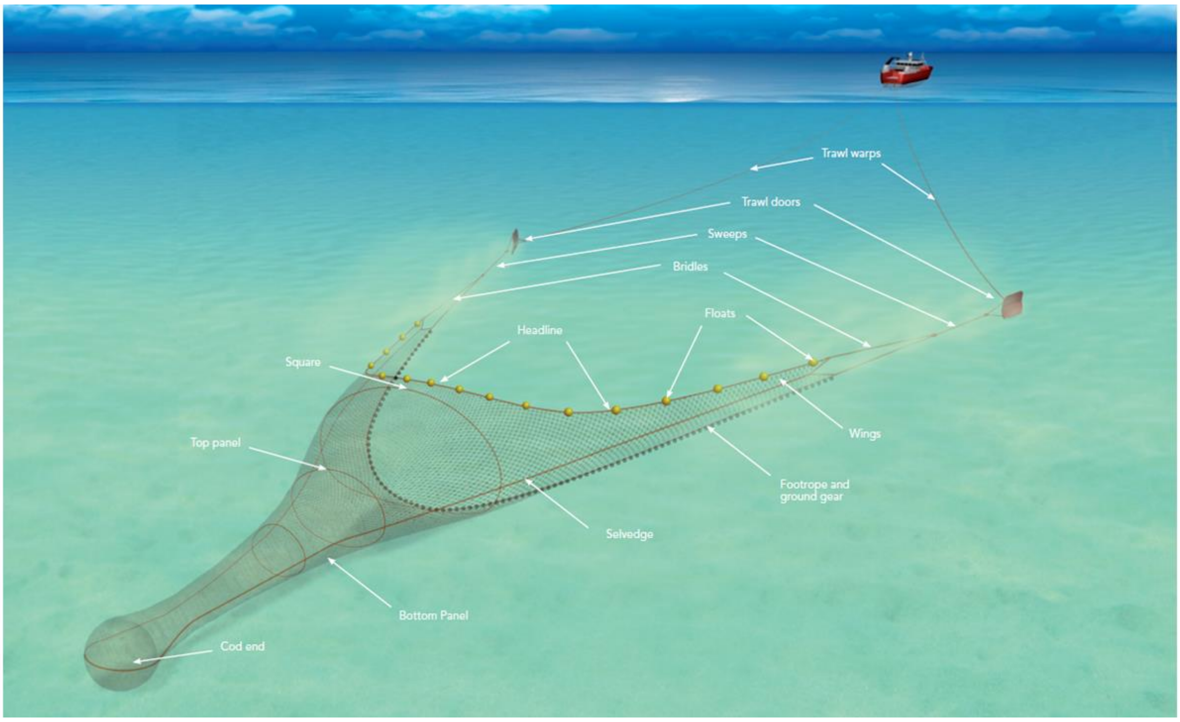


Figure 3: Construction of a trawl. (Sea fish asset bank[1]).

[1] https://seafish.assetbank-server.com/assetbank-seafish/action/viewHome.

Bottom trawls are towed along the sea bed and constructed in the way, that top panel of the net is longer (by a “square”) than the lower one. The square prevents fish to escape upwards. Bottom trawls need to maintain contact with the sea bottom, so it is equipped with additional weights, i.e. the ground rope which also protects the netting from damages (Oxvig and Hansen 2007).

A bottom trawl consists of the following parts with following functions:

- warps – steel wires, 10-30 mm in diameter and of length that is determined by depth of a fishing operation;
- trawl doors – two heavy (over 1000kg) blocks that serve multiple purposes – securing the geometry of the trawl, as the net is flexible, make the trawl net more stable and spread the trawl net, the shape, area, weight and towing speed are important factors for their spreading force. Forces acting on a bottom trawl door, are: -Towing wire forces -Bridle forces -Bottom reaction (friction), -Weight at the sea bed -Hydrodynamic forces. Bottom trawl-doors must have a long shoe to stabilize it, and the height to length relationship is ~ 1:2 (Gabriel et al. 2005);
- sweeps-bridles – steel wires, often double and even triple, the bridles connect the otter board to the trawl net and ground gear. Bridles herd fish towards the mouth of the net and are important in increasing the catch efficiency of bottom fish trawls and in most pelagic trawls. In shrimp trawls and most pelagic trawls, bridles and their configuration are important for opening height of the net (Gabriel et al. 2005);
- ground gear and foot rope – chains, rubber and/or steel bobbins, rubber disks that keeps a bottom trawler on the bottom;
- cod-end – where the catch is collected.

Other parts of the trawl gear that are not included into the working process directly and by the defined routine, are top and bottom panels, headline with floats – that keep the geometry of the trawl and the headline stays up; square, wings, wing lines. Trawl with a headline, floats to keep the trawl open, fishing line with footrope, wing lines and wings, and belly.

The principle of trawl fishing is to herd the targeted species in front of the net by bridles and mud clouds, generated by trawl doors that move against the current. Fish reacts to the trawl and moves in the direction of the tow (Oxvig and Hansen, 2007).

In this study, a trawling system is the system of labour tasks which includes crew members, fishing gear and machinery that is used in the performance of the tasks. Understanding of structure of a trawl gear and machines that are involved in the trawling is essential for understanding of the trawling process and tasks that are performed under it.

R/V Helmer Hanssen was built in 1988 and utilized as a shrimp trawler until 1992, when it was rebuilt into a research vessel. All the trawling equipment was kept, to be able to perform close to real fishing operations. R/V Helmer Hanssen Crew includes: Captain, Captain mate (1. Officer), Chief engineer, Second Engineer, Steward, Galley assistant, 2x trawl boss, 3x seamen[2].

R/V Helmer Hanssen has mechanized hauling system, where trawl winches are installed on deck to control the towing warps (trawling wires) and store them when not in use. Bottom Trawling operations on the R/V Helmer Hanssen are operated by the system of 11 winches, operated by Captain, Captain's Mate and/or the crew:

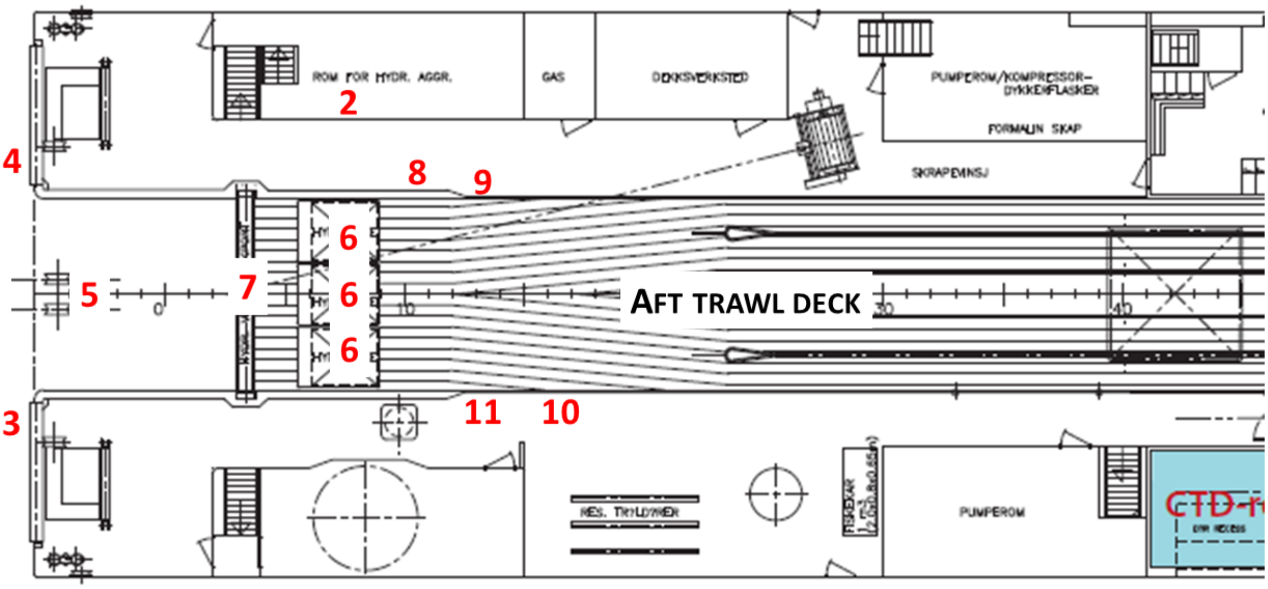
- 2 Trawl winches – two winches that located symmetrically on the port and starboard, top the deck and connected to the trawl doors and sending them out and back in, operated by captain;
- 4 Sweep-line winches – 2 inner sweep winches and 2 outer sweep winches located on port and starboard, used to drag the trawl on both sides individually, operated by Captain and require tension control in hydraulics;
- 2 Gilson winches – two winches located high over the deck, front up (close to the captain bridge), dedicated to pull the trawl sack inside, usually operating one by one, imitating hand movements, operated only by captain;
- pelagic trawl drum – huge drum located in the middle of the deck and operated by Captain while pelagic trawling;
- Timber winch – located over the deck and used to lift the trawl sacks, operated by the deck crew;
- 1 Out-hauling winch, which is used to pull the trawl net out, located back on the deck, in the middle;

[2] During full scale trawl experiments there will be in total 4 seamen.

- 2 helping winches – located on both sides of the deck, they are operated by the deck crew and serve the purpose of minimizing the number of people on the deck and make the crew avoid lifting extremely heavy weights.

As the system of winches is hydraulic, captain releases the tension on the winches after the operation is finished, to be able to keep towing. The deck is as well equipped with 2 cranes, operated by the deck crew members, that should lift the weights and assist to safe performance of the fishing routines.

Trawling operations on R/V Helmer Hanssen take place of the Trawl Deck, where the Deck crew and fishing gear is located and on the Bridge by a Captain or a Captain's Mate. Figure 4 shows the essential locations of the trawl deck on R/V Helmer Hanssen.



2: Console deck-winches - 3: Starbord trawldoor position – 4: Port trawldoor position –
5: Stern ramp - 6: Catch hold hatches - 7: Gate – 8: Outhauler winch hook
9: Port Gilson hook - 10: Starbord Gilson hook - 11: Timber winch hook

Figure 4: Trawl deck layout and important positions on the trawl deck of R/V Helmer Hanssen (Roger B. Larsen, UiT – Arctic University of Norway).

Eleven locations illustrated on the Figure 4, describe allocation of the deck crew members and certain tasks. Part between the Port and Starboard is referred as "middle" further in the text.

3.2 Definition of labour, types of labour by instruments of work

There are several ways to understand and define labour – as labour is an important part of everyday life, it bears physical, sociological and even philosophical meaning. In this thesis labour is defined as follows: "Labour as a process that is independent on any social formation, and has three main attributes: purposeful activity of man, directed to work, and object on which work is performed in the form of natural or raw materials, instruments of the work, most often tools or more complex technology" (Thompson 1983).

From this definition, we may extract that labour consists of three main elements: purposeful activity, object of work and an instrument of work. The purpose of the activity is to reach a certain goal, in the system thinking this activity is defined as "directed behaviour" and this behaviour reaches a set goal by completing the tasks (Shepherd 2001).

It is the development of different instruments of work that determine how the tasks are performed and based on them it is possible to identify four main types of labour - manual, mechanized, automatized and automated. These types of labour differ not only by the instruments and level of physical work, but by the role of a human operator and level of intervention between a human and machinery, evaluates the human factor in the performance of tasks.

Manual labour

Manual labour is the labour that consists of tasks that are performed by hand or by using simple tools. Even though it is the oldest way to approach work, manual labour is still significant. Processes of mechanization and autonomation had changed the amount of manually performed functions but had not replaced it completely (Khan 2001).
In both manufacturing and not-manufacturing industries, there are tasks that require manual labour for different reasons – from tradition and product image and identity to the operations that are not replaced by machines yet (Khan 2001).

As observed during the field work and in the literature, it is common to use manual labour on large modern vessels – some tasks require manual performance as part of an established system and some tasks may appear under certain conditions - for example for fishing gear damage or malfunction. Manual labour and manually performed tasks do not require formal training, but these skills are obtained by practicing - during the working process and during communication with the colleagues (based on observations).

Mechanization and mechanized labour

Mechanization is an introduction of the machines into a certain process. Mechanization is a transformation of work to increase the units of output in production or displace the labour to cut the cost of production (Jerome 1934). Under mechanization, tasks, that require a huge amount of physical effort of one or several workers are performed by machines, and the efficiency of the work is increased primarily due to two factors – labour savings and time savings. Mechanization influences whole production flow in several ways:

- It eliminates one or more manual operations;
- It increases the speed of the performance;
- it enlarges capacity without corresponding increases in the labour requirements;
- it substitutes one process by a different process, that requires less labour (Jerome 1934).

Tasks that are mechanized are performed with intervention with human operators, and therefore there are several grades and types of mechanization – imitation of the manual operations, construction of new machines, improvement of the existing machines, etc (Jerome 1934). The impact of the mechanization on fisheries is rather broad. Mechanization is the introduction of powered vessels instead of canoes and improvement of tools that are used in fisheries. Regardless how advanced the instrument of work is, it is considered mechanic as long as it is the human operator that has control over the process and uses the instrument.

Automated and Automatized labour, Autonomation

Automated labour, automatized labour and autonomation are much more complex than the manual or mechanized labour, because they integrate a “thinking” element into the instrument (Sheridan and Parasuraman 2005).

Automation - or process of converting the controlling of a machine or device to a more automatic system, such as computer or electronic controls (Boakye-adjei *et al.* 2015). In the fullest contemporary sense, the term automation refers to

- the mechanization and integration of the sensing of environmental variables (by artificial sensors);

- data processing and decision making (by computers);
- mechanical action (by motors or devices that apply forces on the environment);
- "information action" by communication of processed information to people.

Therefore, labour process and task performance in the automated system is happening in four dimensions:

People – processes require human supervision;
Machines – Machines complete cycle until the button is activated;
Quality – defects appear due to machinery malfunction;
Error and diagnosis - Errors are discovered later and root cause analysis is long term (Boakye-adjei *et al.* 2015).

Automation in the industry requires presence of a type of industrial controlling system that operate the machinery, roughly said, replacing a human worker who utilizes a mechanic tool by a program (World Bank Group 2019). As the role of human operator in at automated process is supervisory – in a way it means that human intelligence dominates the computer-mediated process. Human operator intermittently or continually programmes the process and continuously receives the information from a computer. Role of computer is transformation of the received information from human operator into a controlled process (Sheridan and Parasuraman 2005). Modern fisheries utilize automated technologies partially, fishing vessels, for example, are equipped with auto-steering and stabilization systems, auto-pilots that control the vessel and only require a navigator to supervise them and process the outcome of information (from observations on the Captain's Bridge).

An Autonomous system may be designed in the way, that the informational loop is closed without "reporting" to a human operator. Without human supervision, the new program of performance a task is produced by the same computer, it is called the intelligent automation – autonomation (Sheridan and Parasuraman 2005). Autonomation is the highest degree of automation – as an autonomous process is not only performing a task, but as well monitors and controls itself. Under Autonomation the four dimensions of performance change, compared to the automation:

People – supervisors can multitask, and productivity improves
Machines – machine detection of errors and corrections is autonomous

Quality – machine crashes are prevented by auto-stop, hence defects are avoided
Error and diagnosis – errors are discovered and corrected quickly (Boakye-adjei *et al.* 2015).

Automatization is making a process automatic. This term is associated with the automated labour and it reflects on the quality, time, money and flexibility – the parameters and conditions of the manufacturing process. Automatization minimizes interaction of human operator with the machine, however does not replace them (Adlemo and Andréasson 1995). Thus, automatized task is one which starts itself, without a human operator to start it, however a human operator is present to control the process.

3.3 Labour analysis and task analysis

Since the early 20th century, when labour has become a subject of study and the scientific approach to management has emerged, many questions regarding the quality of labour, safety, labour conditions have appeared. This led to the first attempts of labour analysis (Taylor 1919).

Together with the development of technology, one of the branches of labour analysis started to perceive labour as a system of tasks and functions, where a human and a machine, machine and machine, human and human, continuously interact (Kirwan and Ainsworth 1992). This approach evolved into task analysis - description of what a human operator is required to do, in terms of actions and cognitive process, to achieve a system goal. It is a method of describing how an operator interacts with the system and the personnel in that system (Kirwan and Ainsworth 1992).

Analysis of these tasks is the methodology, that consists of number of specific techniques on how to collect information, organize it, and use it adequately to the goal of study. According to Kirwan and Ainsworth: “task analysis provides human perspective of the process and identifies human compatibility between system goals and human capabilities and organization, so that the system goals will be achieved” (Kirwan and Ainsworth 1992).Task analysis can be used in the occasions when:

- Safety is important
- Technology is vulnerable to human error
- System changes have created a high level of uncertainty about system integrity

- Productivity and availability problems occur and a high quality product is required, which depends on human performance (Kirwan and Ainsworth 1992).

In this master thesis, task analysis is used to describe a process of a trawl fishery (fishing with a trawler), investigate the human-machine performance and thus, to contribute to improvement of the system.

As the task analysis can be performed by several distinctive techniques – from the observation to sophisticated computer modelling, this method is quite flexible in opportunities and allows to be adjusted to match the goal of the research. Task analysis can be performed by system designers, operation departments, assessors and managers.

Task analysis techniques

Task analysis is a group of very many techniques, that can be chosen and adjusted according to the goal of the research. Among this huge group, Kirwan and Ainsworth (1992) selected 25 task analysis methods that represent possible task analysis approaches. These techniques are divided into five broad categories:

- Task data collection methods – collecting data about task performance
- Task data description methods – representation of the collected data
- Task simulation methods – task simulation
- Task behaviour assessment methods – scenario assessment
- Task requirements evaluation methods – assessing the adequacy of the task environment and existing facilities available to carry out the task (Kirwan and Ainsworth 1992).

Many of the existing techniques cannot be grouped in one of the categories. The 25 suggested techniques are grouped into five sections, according to their main function and goal and illustrated in Table 1. Each of these sections correspond to their roles within the Task Analysis process.

Table 1: Task analysis techniques.

Name of the section	Goal	Example of techniques
Task data collection methods	Collecting data on actual or proposed task performance	Activity sampling (observation based) Critical incident technique (subject based) Observation (observation based) Questionnaires (subject based) Structured interviews (subject based) Verbal protocols (subject based)
Task description methods	Representing data in a pre-specified format	Charting and network technique Decomposition methods Hierarchical task analysis Link analysis Operational sequence diagrams Timeline analysis
Task simulation methods	Creating simulations of the task	Computer modelling and simulation. Simulators/mock-ups. Table-tops analysis. Walk-thoughts and talk-throughs.
Task behaviour assessment methods	Assessing what can go wrong in task performance	Barrier and work safety analysis. Event trees. Failure modes and effects analysis. Fault trees. Hazard and operability analysis. Influence diagrams. Management oversight risk tree technique (MORT)
Task requirements evaluation methods	Assessing the adequacy of the task environment and existing facilities available to carry out the task	Ergonomics checklists. Interface surveys.

3.4 Hierarchical Task Analysis

Hierarchical task analysis (HTA) is the task analysis technique which has been used in this study. It has been introduced as methodology of examining tasks in the 1960-ies and currently is widely adopted in different studies due to its flexibility and potential to be translated into different fields (Shepherd 2001).

The word "task" refers to human behaviour, the system goals for which people are employed, how context constrains the attainment of goals, or some interaction between these and other factors. `Task analysis' may be treated as an investigatory tool or a method of modelling human behaviour or system (Shepherd 1998).

HTA represents a visual system and a hierarchy of tasks. In a hierarchical control system higher levels in the hierarchy exert influence over the manner in which lower levels behave (Shepherd 1998). It is a common technique for interface design and evaluation, allocation of function, job aid design, error prediction, and workload assessment (Stanton 2006). HTA is dedicated to break down the tasks into their elements, investigate human performance in systems. It is used when there is need to understand both physical and cognitive activity, represent the analysis in a graphical manner, and discover underpinning theory of human behaviour (Stanton 2006).

To ensure the hierarchical structure, discovered tasks are decomposed into the smaller tasks and assigned to the plans, and decomposition stops by the so-called "stopping rule" – level of description that does not require further decomposition (Annett 2003).

HTA is a highly comprehensive technique, which assures its efficiency for different studies (Stanton 2006). HTA is an example of the systematic thinking, re-imagining a process as a grouping of the interrelated parts (Shepherd 2001). This techniques may be used in many different contexts, and is applicable to labour studies on a fishing vessel because it takes into account physical performance of human operator, machinery performance and a process of making decisions (Shepherd 2001). HTA provides the following advantages (Kirwan and Ainsworth 1992):

- it is a relatively economic method – the data collection and analysis has been performed by one person;
- the focus of the HTA performance was on the crucial aspects of the system – tasks and performance of the tasks during the fishing operation;
- HTA itself provides context for other approaches, which in the given project has been transformed into performance analysis
- HTA is built on collaboration between an analyst and operators
- Forms basis for other analysis
- Each task element is broken down into sub-elements, so none of the elements or sub-elements is missed.

HTA acts often as the first step in an overall task analysis, illustrated by the fact that other analyses build on the results of HTA (Adams *et al.* 2012).

4 Materials and Methods

4.1 Research data and context of the field work

This research is an empirical study of the labour tasks on a bottom trawler. Materials for this master thesis consist of the following:

- video materials of trawling operations on a board of R/V Helmer Hanssen and MV Atlantic Viking, provided by thesis supervisor Roger B. Larsen;
- data collected by observation while performing field work on a board of a research vessel Helmer Hanssen in North-East Svalbard Area;
- facts obtained from non-formal interviews with the members of the crew;
- expert opinion on the fishing operation by thesis supervisor Roger B. Larsen.

This study operates with the set of data collected during the field work, which creates certain limitations to it. To ensure validity of the research it is important to understand how the field work was carried out. Field work for the thesis was carried out during the cruise on research vessel Helmer Hanssen in the period between 5th and 21st of January 2019. Data collection for the thesis was carried out under a research project on the R/V Helmer Hanssen, which, due to concept of the project, has been planned and performed as close as possible to a real-life industrial fishing operation, rather than a research trawling.

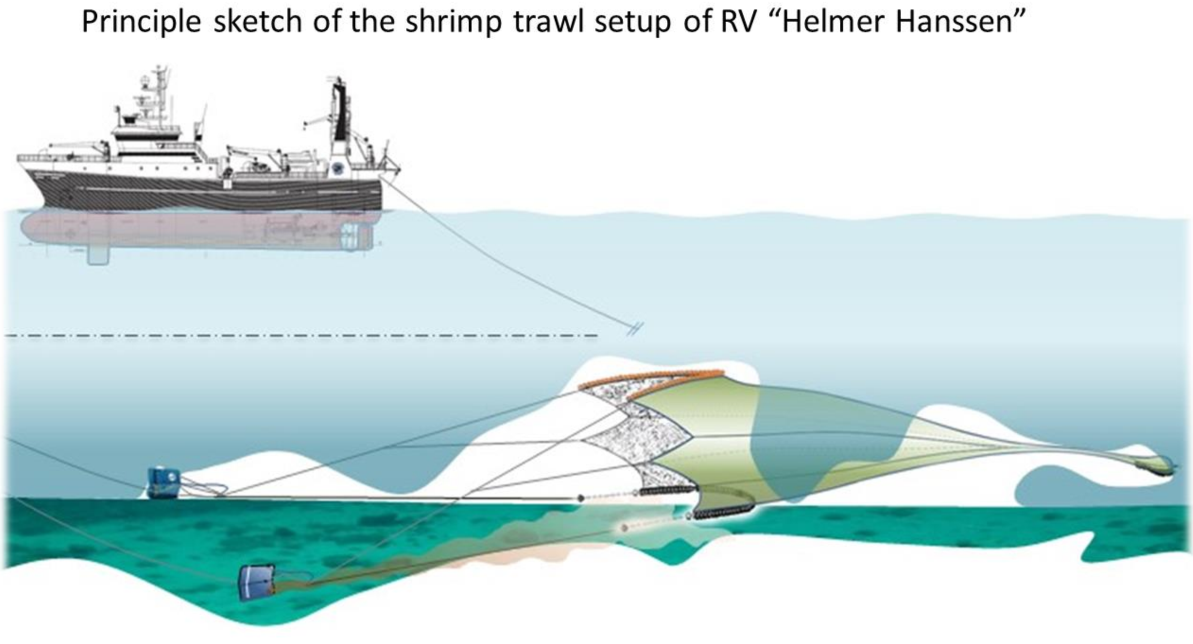


Figure 5: Principle Sketch of the shrimp trawl setup of R/V "Helmer Hanssen" (Roger B. Larsen, UiT – The Arctic University of Norway).

The goal of the research cruise was to measure harvest efficiency and selectivity of the shrimp trawls. It was planned to conduct the experiments in the shrimp fishing grounds of Svalbard area – Isfjorden and on the fishing grounds west and north of Spitzbergen. Primary goal of this research was to minimize catch of undersized shrimp and reduce the bycatch. The project was supported by FHF (the Norwegian Seafood Research Fund) and The Directorate of Fisheries of Norway.

For the research, a commercial size two-body shrimp trawl (one test cod-end + sorting grids and cover, one control cod-end + sorting grids and cover) was used. With towing times for about 2 hours and maximum 6 hauls per day, it could potentially be performed 80 hauls. The catch from each haul was sorted by species, length measured and total weights. Targeted species for the project were deep-water shrimps, redfish, cod, haddock and Greenland halibut. Due to weather and ice conditions, some changes to the plans were made. Nevertheless, in total 78 hauls were performed, operating a trawl net of a large size, which is not typically used on research vessels. The number of operations, conditions and tempo of the conducted experiments of fishing shrimp is similar as to the shrimp fishing fleet.

4.2 Data collection methods

Main method for data collection was a method of observation. Observation is the systematic description of the events, behaviours, and artefacts of a social setting. The method of observation is a hallmark for sociological and anthropological research (Kawulich 2015).

For the task analysis, observational techniques are used to record the complete sequence of the actions and focus on the issue of interest. Method of observation provides data input for analysis and represents a natural performance in unconstrained environment, however it is not efficient for the process dependant on mental activity and communication and in constrained environment (Kirwan and Ainsworth 1992).

Advantages of the observational techniques for the task analysis are:

- can provide information about both physical activities and social interactions, as well as environmental influence;
- reveal potential behaviour patterns;
- observer studies of the process in it is normal environment;

- able to provide explanation of individual differences in performance;
- provides objective data that can be compared to other observations or data collected by any other method (Kirwan and Ainsworth 1992).

To be able to observe labour process and not distract or disturb it, a method of direct (or non-participatory, as referred in some sources) observation was carried out - an observer was not interacting with the object of study (Kothari 2004).

First stage of the observation was preparation, which consisted on the two parts – preparation before the field work and preparation for the observation directly on the vessel. Preparation for the field work included study of the available video materials, which were provided by Roger B. Larsen, and their primary analysis with the technician Ivan Tatone. During this stage, there were made some notes, which contributed to understanding of the working process on a fishing vessel.

Preparation of the routines on board the vessel included study of the vessel's technical equipment, especially the machinery which is used in the trawling operation on the deck and on the Captain's bridge.

To be able to carry out the observation, permission of the Captain of the vessel and consent from each member for the crew was obtained. As the object of the observation was work tasks and their performance, the observations were filmed from different angles – from the Captain's Bridge and from two points on the deck – on the safety zone on the Port and Port quarter on the deck by the trawl doors. All the safety procedures were followed, and the observation was carried out from the points with no intervention with workers and gear. There were carried out observations of the 20 trawling operations, and some of them were filmed, with the goal to be able to increase the accuracy for the observation. The described method of observation has three major aspects:

- the subjective judgement would be eliminated, as the observations would be filmed;
- observations on R/V Helmer Hanssen would be happening simultaneously with the performance of the operations, thus, the data would correspond exactly to the moment it was happening, and camera would be able to capture real time and flow of performance;

- interactions with members of the crew on this stage would be minimized, thus, it would be less demanding for them to respond, and their routine would not be disturbed by participation, as the interest of study is to observe the reality of the performance (Kothari 2004).

Relevance of the observations for the study of labour on a fishing vessel consists of the following facts:

1. Research vessel Helmer Hanssen was originally built as a shrimp trawler, and not a research vessel, only later it has been adjusted for research purposes. Thus, the building of the vessel and engineering of the parts are the same as in a fishing vessel. Therefore, the routines performed by the crew are the same as the routines on the fishing vessel.
2. Field work was carried out in the period between 3 and 21 January 2019 in the Svalbard area, in rather harsh weather conditions, and the plan was to carry out about 80 trawling experiments, thus, the conditions and experiments intensity approach the conditions of the fishing operations.
3. Crew of the vessel has many years' experience in fishing and excessive knowledge, relevant to the topic.
4. Even though the fishing procedure has research purpose, observations and filming followed the usage of a big, commercial size trawl.
5. Task analysis for human-performed elements of the process together with functional analysis of the process does not focus on the entirely human-related labour, neither on the technological parts and technologies used. The process is divided into elements, regardless of the performer, as the idea and process flow are the same for each vessel, same functions and same tasks are performed. Even though, on modern vessels, parts of this process had become more mechanized or automatized, the tasks and functions are the same.

All observations were videotaped, and all the observed tasks were noted in the form of the list and prepared for the analysis.

4.3 Data coding for Hierarchical Task Analysis

Data analysis consists of a huge variety of techniques and is often described as reduction of data to its story and interpretation. Data analysis is the process of reducing a large amount of data into making sense of it (Kawulich 2004). During the data analysis, data goes through the three main stages:

- data is organized;
- data is reduced though summarization and categorization;
- patterns and themes in the data are identified and linked.

Coding starts with the finding the codable; Richard E. Boyatzis highlights that thematic analysis is the way of seeing the process as a whole to be able to recognize the codable moments and transform encode them – see them as something else and proceed to interpretation (Boyatzis 1998). During the performed field work, it has been collected a significant amount of relevant data, represented as the list of the actions performed by each participant of the trawling operation. These lists were formed from the observations by the way decompositions of the observed tasks with a stopping rule “action of a crew member that cannot be further divided” (Annett 2003).

These actions have been realised as the simple tasks (Shepherd 2001). Each element performed by any crew member has a place in the trawling operation, and the goal of coding the data was provide each of them with meaning and context, put each element into its right place in the task hierarchy by assigning them to themes which represent tasks and task groups.

Development of these theme-codes was based on the following principles:

- Reflect the purpose of the research;
- Be exhaustive;
- Be mutually exclusive;
- Be sensitive to the category content;
- Be conceptually congruent (Kawulich 2004).

Thematic analysis goes through three main stages – deciding on sampling the ideas, developing themes and code and validating and using the code. Code development can happen in three ways – theory driven, prior data and research driven, and data driven (Boyatzis 1998).

The first step of the data analysis was to transform the observations into the form of the HTA. HTA consists of plans – how subordinate operations are organized to achieve the set goal. As the context in which each activity takes place affects the performance of the task – there are many situations when a task is contingent in the performing system – it depends on the event within the system, and not on the task that has been performed previously (Shepherd 2001).

The key principle of organisation of hierarchy is "subordination", data coding has been approached, that way that the plans of the HTA are the code themes, which are named after the main tasks that are performed, which later are broken down into simpler and simpler tasks. Observing and understanding of these major and smaller tasks formed a coding scheme for the HTA.

Thus, the design of the coding scheme for the data was inductive, as several distinguished themes from literature can be translated into the case of the labour on a fishing vessel (Boyatzis 1998). HTA technique provides an insight of what coding scheme focus is – the tasks, but the themes of how the tasks are grouped should be derived in the way, that includes the following five elements:

- a label;
- definition of what the theme concerns;
- description of how to know when the theme occurs;
- description of the qualifications of exclusions from the theme;
- listing of examples (Boyatzis 1998).

As described by Boyatzis (1998), criteria of coding tasks may appear during the observational work on board, where the processes were compared to each other and separated – this process is referred as "immersion and crystallization" in literature. It requires excessive note taking during the observation. Data as well can be memorised and split into categories with usage of computer – miming of the raw data and linking it, and then it is possible to assign the data into categories – these are the abstract steps of developing an inductive data-driven coding scheme (Boyatzis 1998).

Coding scheme of the HTA analysis of the trawling subsystem is explained in the Table 2, which represents an inductive and data-driven coding which was happening on board of the R/V Helmer Hanssen. As suggested by Boyatzis (1998), the criteria of coding the data should not include too many factors, as they lead to "multiplication" of the raw data facts, so the coding was performed with the criteria "stage of the trawling operation".

Table 2: Data coding scheme for the large task groups.

Code label	Theme concern	When the theme occurs
Deploy the trawl	Tasks that are performed to send a trawl, until the trawl net is on the correct depth and the trawling operation.	When the hydraulic system on a vessel is activated and ready to send the trawl net to the moment when the net is set on the planned depths at the planned speed.
Tow the trawl	Part of the trawling process when the trawl net is set on the bottom and is pulled by a vessel. Length of this part is determined by a Captain/Cruise leader.	When the trawl (net and door) are completely set on the bottom and dragged by the vessel.
Haul the trawl	Part of a trawling system that concerns tasks that are performed from the point when the trawl net is moved towards the surface to when it fully on the deck.	Theme occurs when the hydraulic system is activated, and the trawl starts to be pulled closer to the vessels and leaves the bottom and until it is fully retrieved to the deck.
Empty the cod-end	Part of the fishing process when the trawl net is retrieved, and the catch is moved to the processing location.	When the trawl net is lifted, it is opened, and the catch is moved into the processing area (factory).
Prepare for the next operation	Tasks that are performed to make the system and the net ready for the next trawling operation.	When the fishing as a process of catching the fish is over, so the catch is sent to the processing site, and the activities are performed to prepare for the next fishing operation.

4.4 Analysis of performance of the tasks

To ensure investigating and descriptive character of the study, it has been decided to investigate the task performance and task allocation. Description of performance of the tasks imitates the HTA structure with the relevant number codes for each operation, but concerns the description of where, who and how the task is performed. By keeping the hierarchical structure and visual representation, it is possible to observe and analyse the following moments – what kind of labour task requires, how many operators a task require and where is the task located.

The following criteria has been chosen as the basic attributes of labour – task is the purposeful activity, character of performance – manual, mechanized, automated or automatized and number of operators required show the role of a human operator in a system and creates a basis for further evaluation of workloads, human factor and human-machinery intervention, allocation of function. Task location reflects on the different parts of the ship which are involved in the trawling operation, and by following the locations plan by plan, it is possible to follow the crew members and tasks allocations.

These criteria are as well relevant for the safety issues on board, and justified by the following findings from the literature:

1. Most accidents happen on the deck while working with the fishing gear and while moving (Jensen *et al.* 2003).
2. The more operators are involved in the task, the lesser the probability of an accident (McGuiness 2016).
3. Manually performed tasks are of higher risks for accidents (Fulmer and Buchholz 2002).

Study of performance of the tasks is important in terms that it completes the picture of task description and creates an opportunity of modelling and simulations, which may be further utilized in different studies.

4.5 Traffic light task performance evaluation

Traffic light Task performance evaluation has been developed by this study to demonstrate one of the examples of how findings of the study may be used in practice. It analyses each of the performed tasks by three safety-related issues found in the literature and described in the previous chapter.

The risk response matrix is a tool designed to easy visualize and systematize potential risks. A risk analysis is based on common sense and the identified factors of risks. The goal of this specifically designed matrix is to evaluate the weak point of the trawling operation by assessing the risk factors that are present in each simple task.

The risk matrix that is applied in the project is a four-stage risk matrix (Aven 2019). The four stages indicate scale of the risk which correspond to four colour-codes. Taking the labour prospective, not the prospective of the labour conditions, we evaluate tasks as following:

GREEN: The green colour indicates no risk or that the risk can be tolerated, and no actions need to be taken.
YELLOW: The yellow colour indicates that the risk is possible to tolerate, and no specific measures are required, but the factor of risk should be monitored.
ORANGE: The orange colour indicates that the risk cannot be foreseen, action is appreciated, and monitoring should be constant.
RED: The red colour indicated that we do not tolerate this risk at all, and immediate action is required (Ræsted 2018).

The rule of evaluation is “General score of a task corresponds to the highest score of the parameter”. This rule is visually presented on the Figure 6.

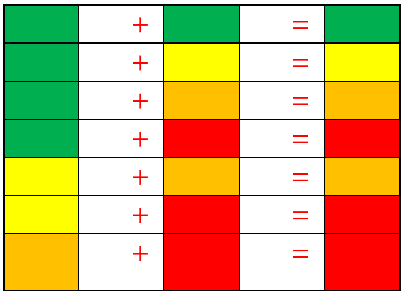


Figure 6: Colour coding scheme for the Tasks evaluation (adapted) (HMS avd. ved NTNU 2013).

Location

Location means “change of location” and is assessed on the movement of a crew member and a location score. It is possible to follow every crew member from the task descriptions by the location of each task they perform, if compared to a previous task their location changes –it means that the crew member had moved and the risk increased to yellow level, if the performer stays at the same location – it is green.

When hauling the trawl – net is dragged by Gilson Winch, so crew members should detach and attach the strapping and winch wire and move to the sides of the deck. Trawl Door positions are marked as yellow, as even though crew members stay there for a certain number of tasks, they are close to the edge and to the heavy trawl doors.

Number of performers

If the task performance, according to the character of performance involves only 1 performer, the danger level will be the highest if a task requires manual work, if 2 – yellow, if three – green. If the task is mechanized, the risk will be lower by the scale – 1 performer of a mechanized task will be marked yellow and 2+ performers will be marked green.

Character of Performance

Character of performance is evaluated in the way that manual operations bear most risk and marked orange. Mechanized operations are of three levels – orange, yellow and green, depending on the tools which are used. As the machines that are used require different levels of the human participation, if a crew member performs a task close to machinery, and a tool is of simple design, – level will be orange, if the machine and operator are in the same location, but have little direct intervention - yellow, and green – if a task performed by a mechanized system from a far distance. Automated and Automatized tasks do not require physical effort, so marked green.

Summarizing the risks happen by the following scheme it is designed this way that the factor with relatively low potential risk does not lower the general risk of the task performance.

5 Results

5.1 Description of the tasks that are performed under fishing with a trawl

Trawling as a process of catching fish using the trawl net takes place on two main locations of the vessel – bridge and trawling deck. Participants of the trawling operation and their main functions under the trawling are visualised in Table 3.

Fishing operation starts with a crew meeting, when an operation is discussed in smallest details and the tasks are divided strictly among the crew members. Efficient communication, adequate commands and correct order of correct actions are the factors that contribute to a fishing operation being executed smoothly and efficiently. During this "box"-meeting Crew members evaluate risks during work on trawl deck and other places, this kind of meetings is required by many operators at sea and compulsory (Roger B. Larsen, pers. comm). During the field work, this kind of meeting was held separately for Crew members and the Research crew members.

Table 3: Main locations and participants in the trawling operation.

Location / Sub- system	Bridge	Deck
Trawling	Control and assistance over trawling	Sending and hauling the trawl net
	Navigator on duty/Auto-trawl software	Trawl boss. 2 crew members: Crew member 1 – crew member who is positioned on the Port side of the vessel, and Crew member 2 – positioned on the Starboard side of the vessel.

Figure 7 illustrates start of a fishing operation, which starts with a decision to fish. This decision is based on echosounder data which is used to check the species that the present in the area, their abundance and the seabed conditions (done to ensure safety of the fishing gear). Decision to trawl can be either positive or negative. If the conditions are satisfactory, the positive decision is taken, and the trawling operation starts.

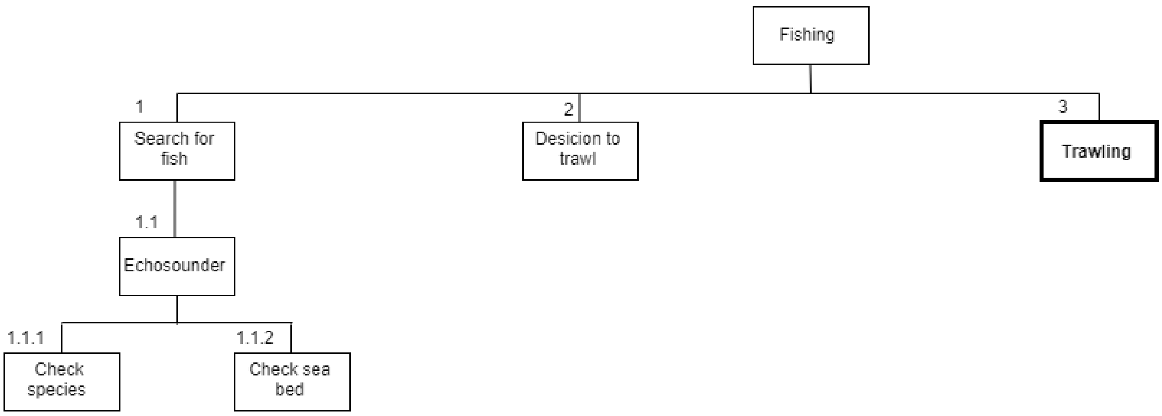


Figure 7: Model of taking a decision to trawl and start of the trawling operation.

Based on the observations made on board of Helmer Hanssen, trawling operation can be divided into 5 main big task groups. These groups are: “Deploy the trawl”, “Tow the trawl”, “Haul the trawl”, “Empty the cod-end” and “Prepare for next operation”, which form Plan 2 of the hierarchical task analysis on the Figure 8.

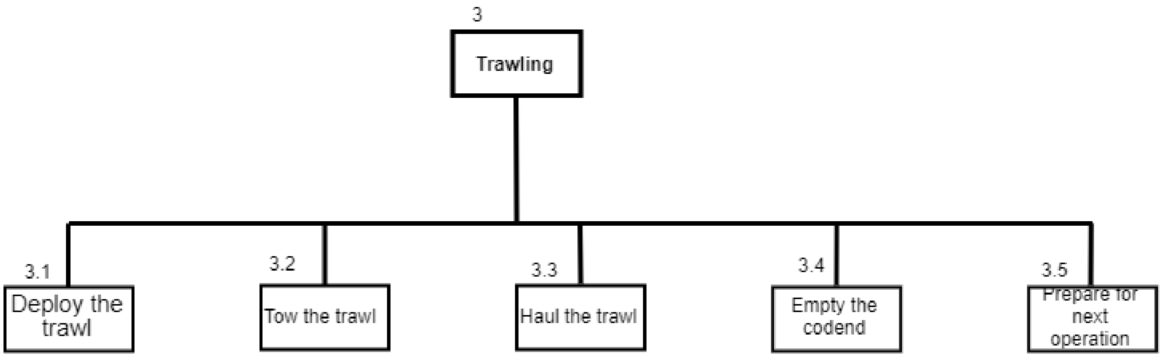


Figure 8: Main task groups of the trawling operation.

“Deploy the trawl” is the large group of 32 tasks which are illustrated on Figure 9. Trawl deployment consists of three major task which are: preparation for deployment, shooting the trawl and finishing the deployment. Each of these groups, as visible on Figure 9, is decomposed into smaller groups, reflecting the real flow of task performance.

Shooting the trawl, in this manner, is divided into two main big tasks – to send the trawl net and sent the trawl door. As trawl net being disconnected from the trawl doors, these tasks are divided into smaller tasks – if we send the net, it should be dragged and lifted to be sent, if it is the trawl door that is sent, the deck crew should attach it first, and then the navigator should take the lead.

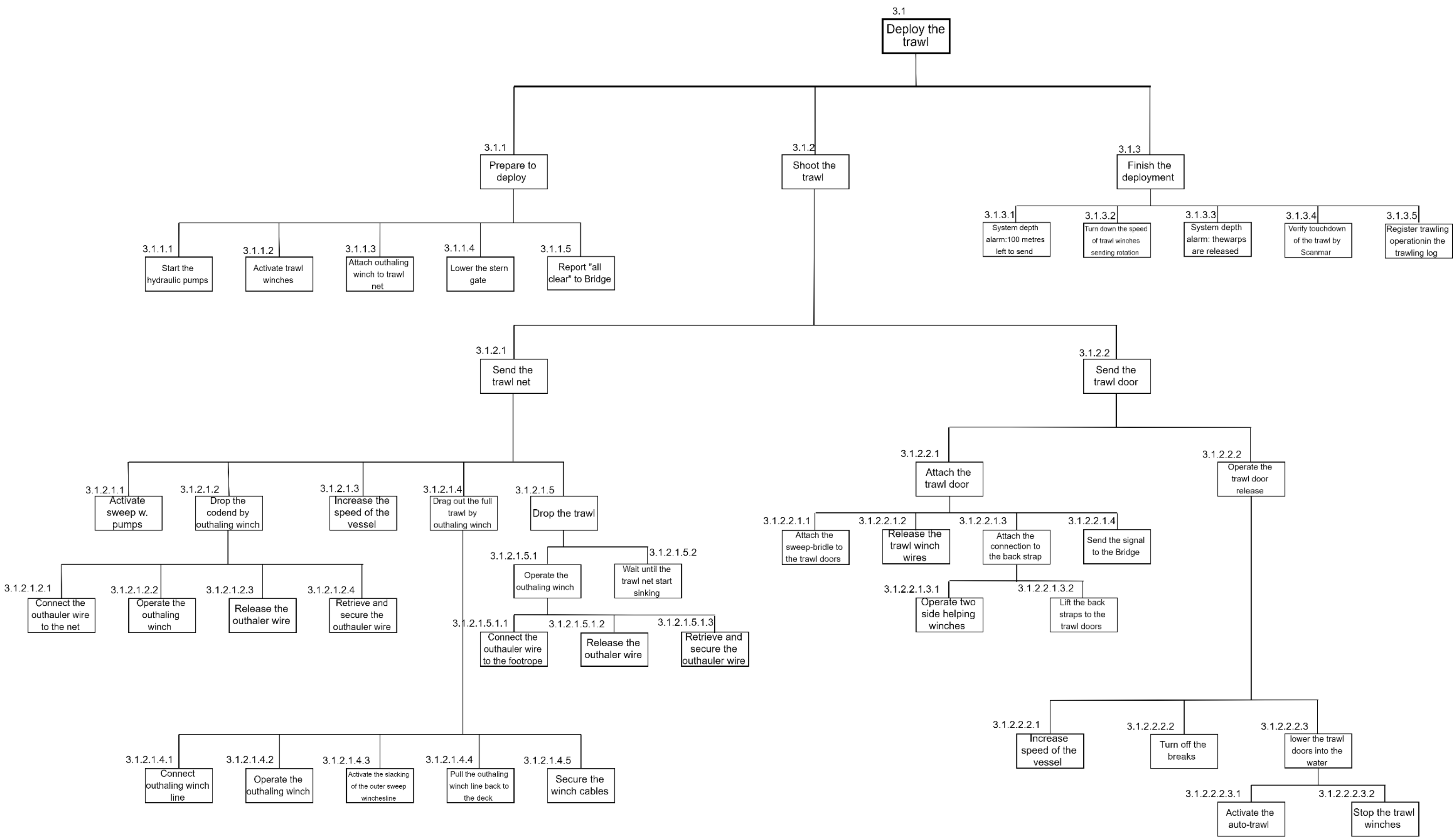


Figure 9: Description of tasks that are performed under the Deployment of the trawl.

As the deployment of the trawl is finished the next stage is to tow the trawl. As illustrated on Figure 10, this task group consists of only two main tasks which include the work of the AutoTrawl software and captains watch. Description of this task cannot really be detailed as AutoTrawl system is the computer software which is automated and designed to be able to control the towing process and adjust to some minor changes in depth, etc. This software can perform various tasks from attaching the length of the wires to signalize in the captain if something goes work goes wrong. Main its task for the Navigator is control over the software.

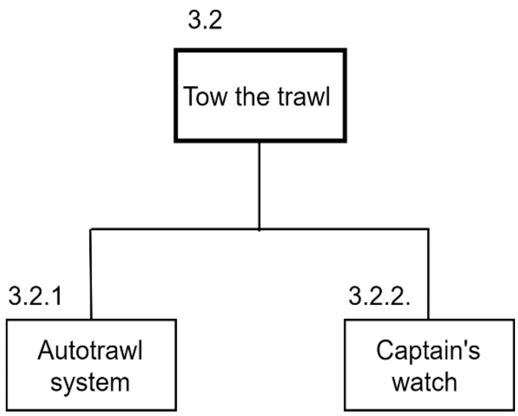


Figure 10: Description of tasks that are performed under the Towing of the trawl.

The next big group of tasks is named “Hauling the trawl”, which is illustrated on the Figure 11. It starts with taking a decision to haul, when the Navigator checks the echosounder and sensors to make sure that the cod-end is filled with the catch. Either way, the gear should be pulled out of the water. As HTA on the Figure 18 depicts, hauling of the trawl starts with preparation to haul, which consists of four main tasks, performed by the Navigator. He activated the hydraulic winches and starts to pull the wires to lift the ground grope from the sea bed and pull the gear closer to the vessel.

By the start of hauling, Deck Crew – trawl boss and 2 crew members take one working clothes and equipment and prepare to go to the trawl deck. As the gear is pulled closer to the vessel, the crew takes position on the Port and Starboard Trawl Doors positions and ready to receive the trawl door, detach the trawl door and haul the net.

Hauling the trawl net consists of hauling the body of the net and retrieving the cod-end (Figure 11). It is necessary to separate these two tasks, as a different machinery is used to perform them. Cod-end is full of catch, it is valuable and heavy, which makes it into a new set of tasks to retrieve it. Finally, the last group of tasks is to finish the hauling.

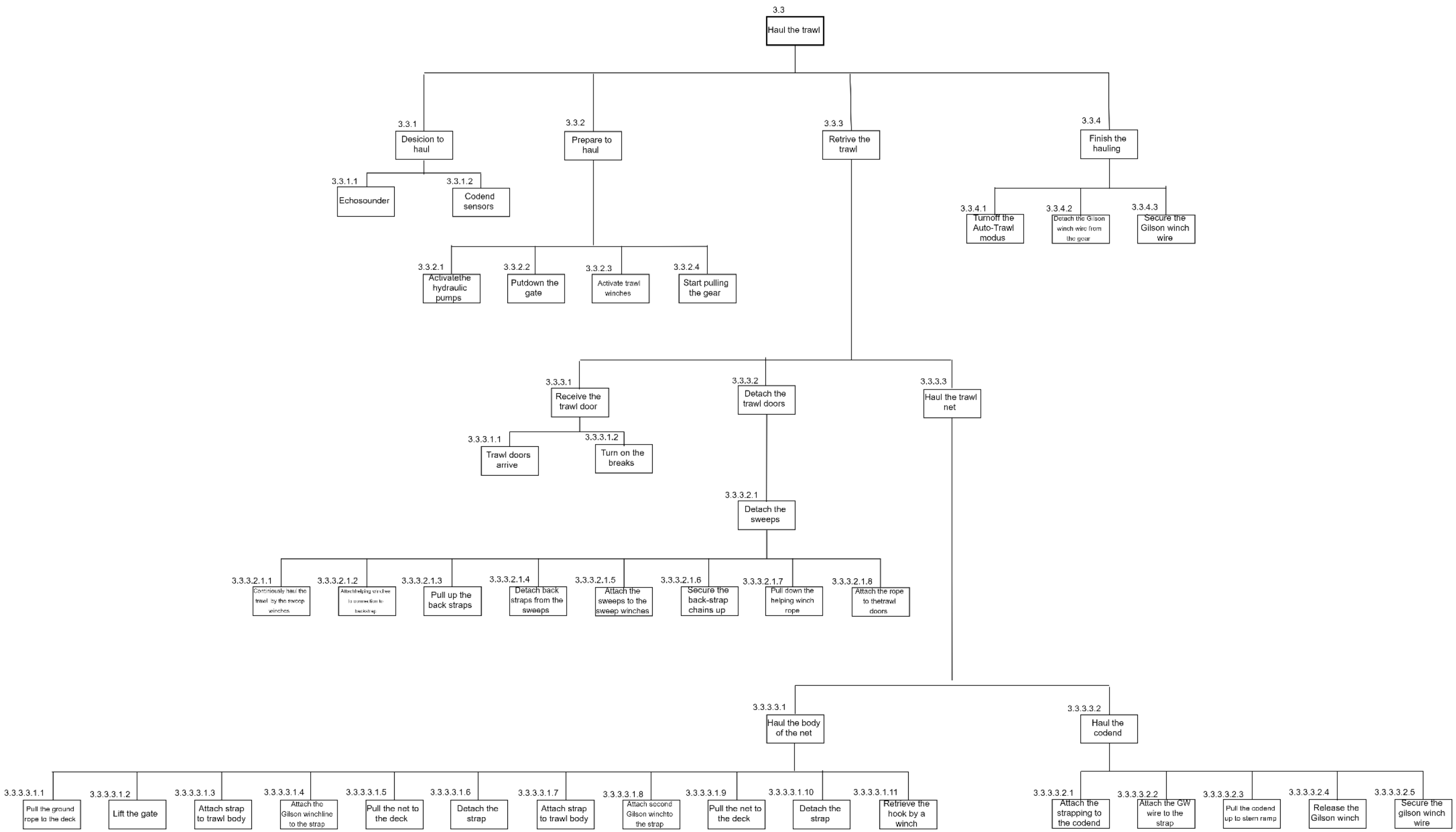


Figure 11: Description of tasks that are performed under the Hauling of the trawl.

Once the net is retrieved it should be emptied and the catch should be retrieved and send further to processing facility, or storage. This process is illustrated on Figure 12.

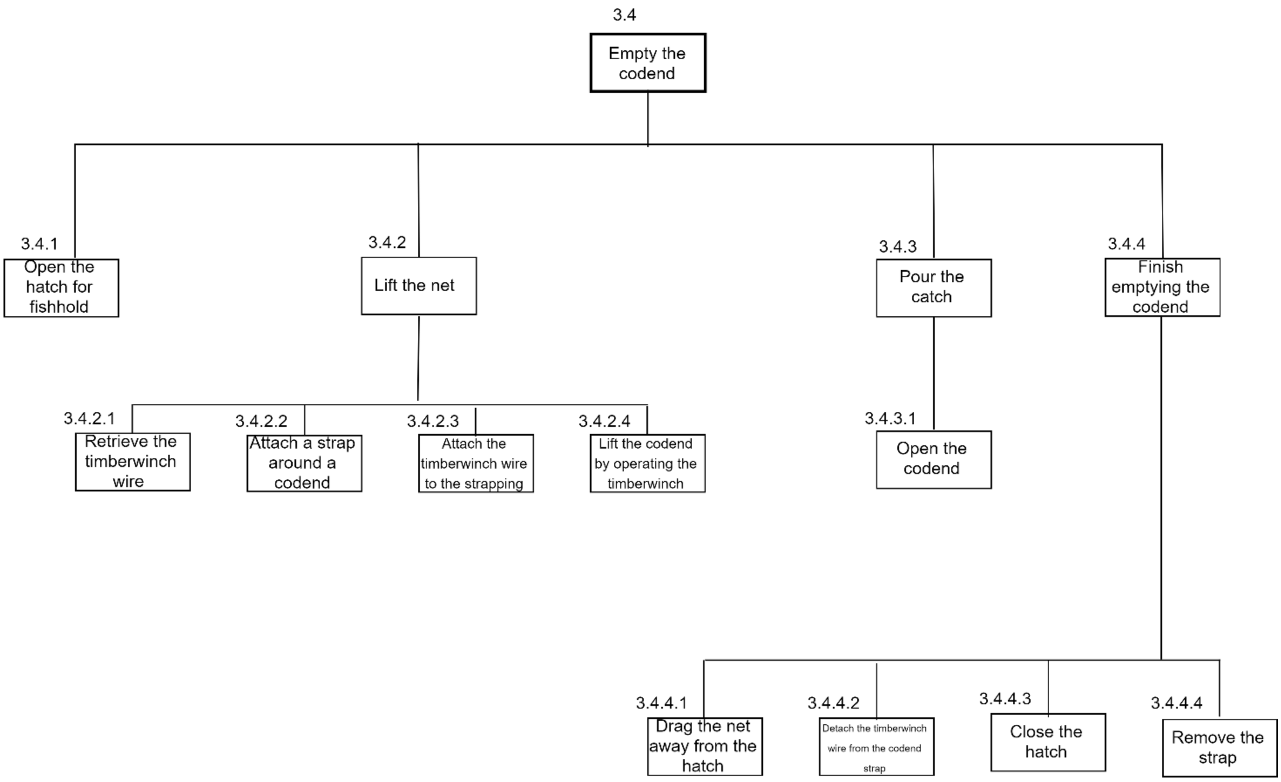


Figure 12: Description of tasks that are performed under the Emptying of the cod-end.

Finally, the last stage of the trawling operation is preparation for the next operation. Figure 13 describes two main tasks - check for net for the damage and check the sensors. If fishing gear or sensor is damaged crew evaluates the damage and looks for a solution. These tasks are not a part of routine and appear depending on the conditions outside the vessel, therefore they cannot be described in detail by the HTA.

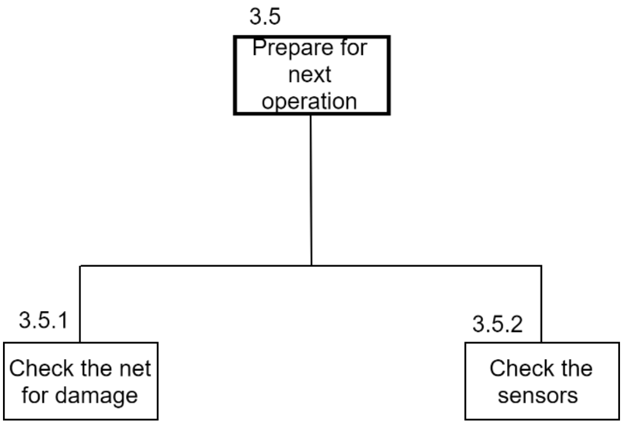


Figure 13: Description of tasks that are performed under the Preparation for the next trawling.

After the preparation for the next operation, trawling starts again with the first task of the Deployment of the Trawl. Commercial fishing is a non-stop process, that consists of the task cycles. Decision to start deploying should be takes several times as well, depending on the data and the catch from the previous haul.

5.2 Analysis of the performance of the tasks

Analysis of the task performance provides a detailed description of the location of the task, the person who is responsible for the task and the type of labour it requires. Decision making is excluded from the Figures, as that is the analytical process based on the collected data, and the prerequisite of the trawling operation to start is that the decision should be positive.

Previous research has working with the fishing gear on the deck is of the highest concern. Based on the previous safety study, it is manually performed operations that are potentially more dangerous. It has as well been revealed that other factors such as movement on the trawling deck and single performance create additional risks.

Task performance visualized on the Figure shows that trawl deployment mainly consists of manually performed operations. Highest number of tasks are performed by a trawl boss, who is responsible for whole operation and is responsible for communication with the Bridge. Two crew members who are located on Port and Starboard sides of the vessel – one on each side, where one of the crew members (referred as Crew member 1) is located on the Port quarter of the deck and operates some of the machinery.

As we follow the allocation of the tasks on Figure 14, it is possible to trace movement of each crew member of the deck. As illustrated, it is the Trawl boss who changes his location most often.

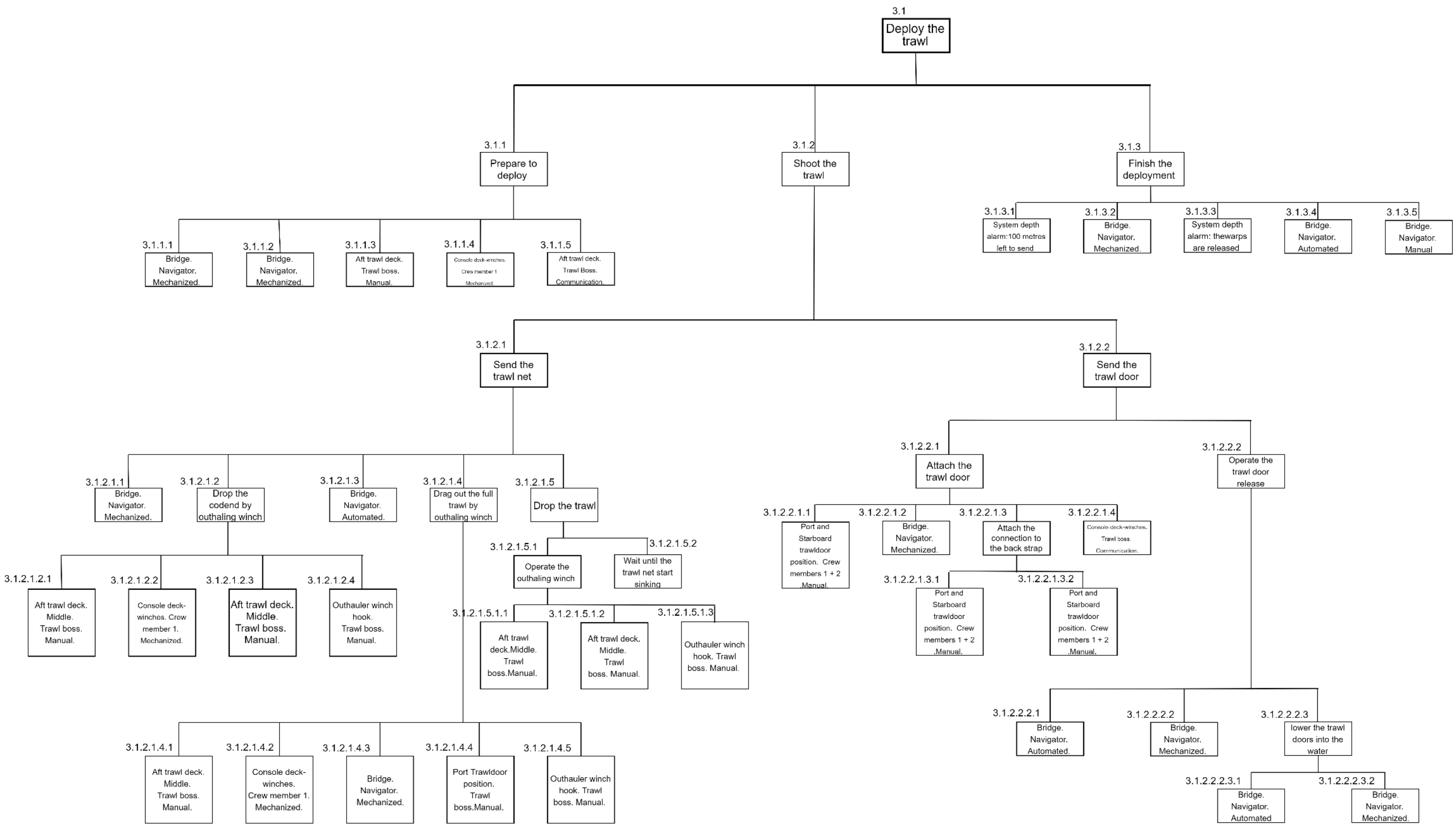


Figure 14: Description of performance of tasks under the Deployment of the trawl.

After the trawl is deployed, Trawl boss and crew member who were working on the trawl deck do not take active part in the trawling operation (however they may perform tasks on the vessel, but they are not a part of trawling).

Towing of the trawl is performed by the system software – 3.2.1 on the Figure 15 is an automated task. This software has many integrated functions and while it is responsible for towing, it has a function of sending signals if something goes wrong, adjust the wires, control the depth of the gear, etc. During the towing of the vessel, Navigator reads the data from devices and controls the process of towing (Figure 15). Their functions as well include watch and registration of the trawling operation. This makes Towing the trawl and automated process, they perform watch over the conditions outside the vessel, but as these conditions are often unpredictable, but crucial for safety and success of fishing, this task cannot be divided into clearly divided tasks as a routine.

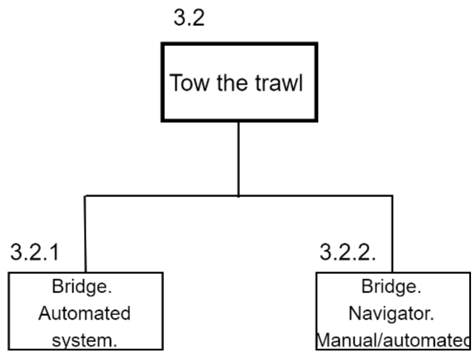


Figure 15: Description of performance of tasks under the Towing of the trawl.

As it is depicted on Figure 16, to start hauling the trawl, Navigator takes a decision to haul by checking the sensors, that are located on the fishing gear.

It is the responsibility of the Navigator to prepare for hauling by taking control over the software and activating the winches. These tasks are performed on the Bridge and belong to the category of automated, as the Captain acts as an advanced software operator and his main function is to control the operation.

During hauling of the trawl, we observe that many operations happened manually, and crew members are often in the physical contact with the gear which is being pulled and moved. Some of the operations are performed simultaneously on the Port and Starboard, while some of them are performed by two deck crew members together.

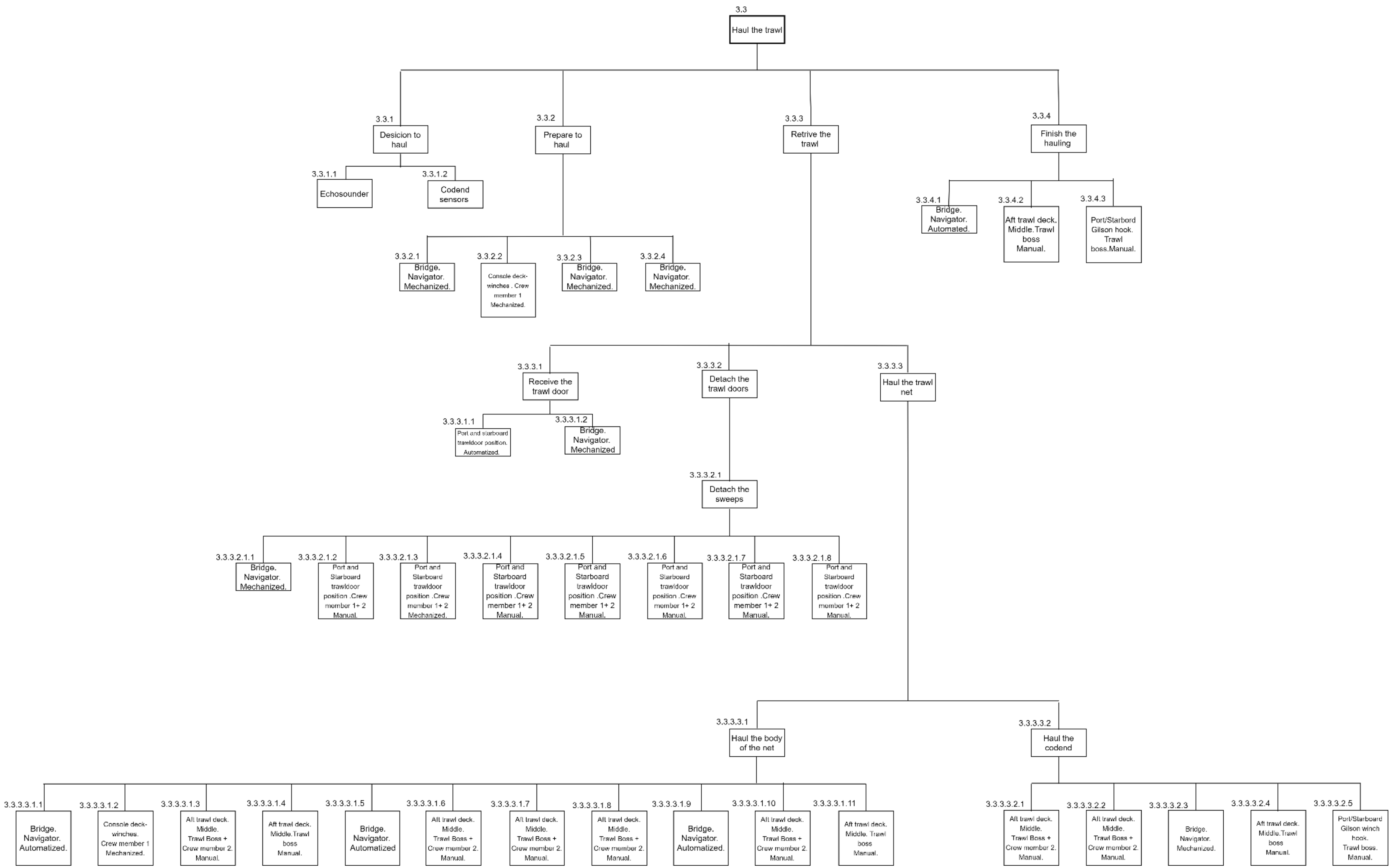


Figure 16: Description of performance of tasks under the Hauling of the trawl.

Emptying the cod-end is the system of tasks that contain most manual operations, as shown on Figure 17 and most of the tasks are performed manually on the trawling deck by the crew members.

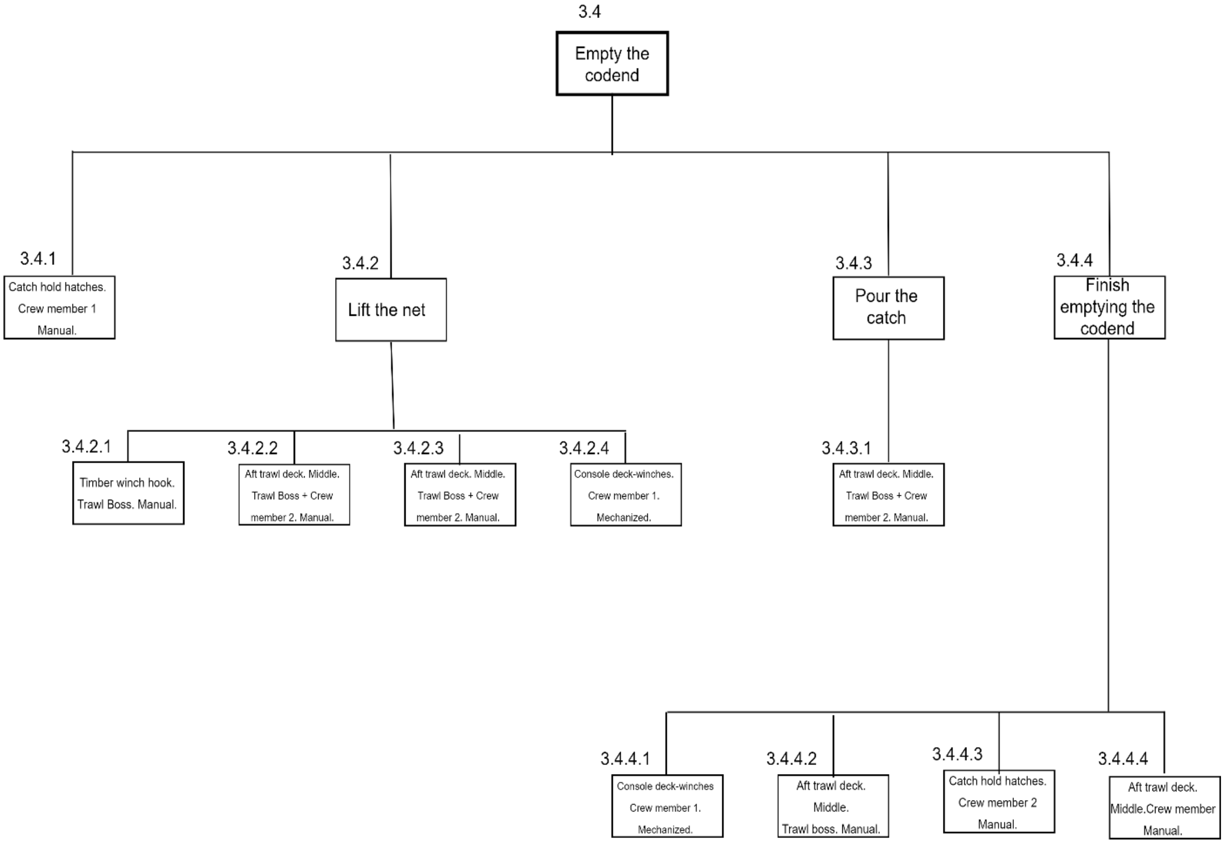


Figure 17: Description of performance of tasks under the Emptying the cod-end.

Preparation of the next operation is mainly performed manually and by all crew members, tasks are separated by the object of work – net and sensors but performed manually as shown on Figure 18. Although, it does not contain any clearly defined and regularly performed tasks which can be systematized, this part of the operation includes being on the deck, lifting the gear, checking the net and sensors.

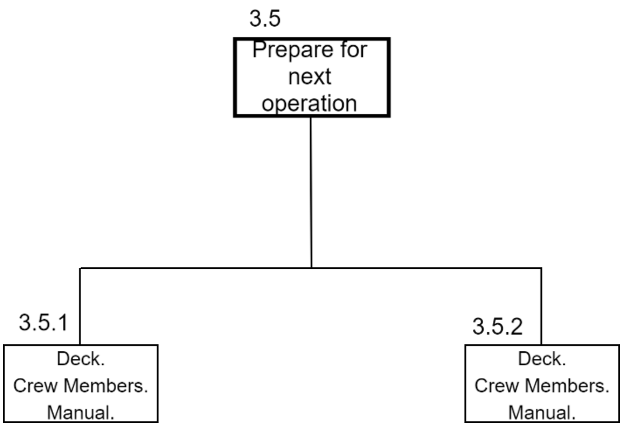


Figure 18: Description of performance of tasks under the Preparation for the next operation.

Figures 14-18 describe how the tasks are allocated and moved from one location to another and between the crew members. This labour flow may be translated in many manners, and the findings of the performance analysis may be translated into statistic data, as presented on Table 4. The main concern for this summary is the operations that are most systematic, form a routine and include interventions between human system and machinery.

During the deployment of the trawl manual labour prevails over mechanized and automated. By the number of tasks performed, Navigator is responsible for 13 tasks, and Trawl Boss is responsible for 10 and Trawl Boss changes location on the Trawl deck 9 times.

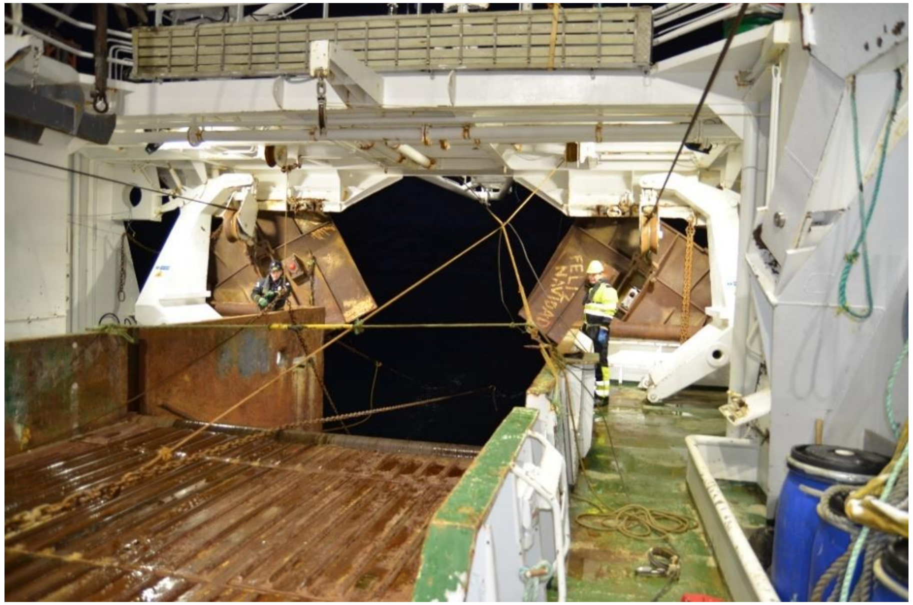
With the total amount of tasks is 34, some tasks are performed by two crew members simultaneously – on the Port and Starboard Trawl Position, while sending the trawl door and attaching the sweep-bridles, and 2 tasks include communication, which are not included into the statistics. Location of the crew members are shown on the Photo 1. Even though crew members are on the deck at the same time, most of the tasks are performed in sequence one after one for the purpose of safety. On Photo 2 it is seen that a Crew Member 1 operates the console and Trawl Boss performs a task manually with the gear. One manually performed task for Navigator is registration of the trawling operation into the log.

Hauling of the trawl consists of 35 tasks, and not all them directly mirror tasks under the deploying of the trawl. Due to the size and the weight of the net, it cannot be dropped or just pulled, but carefully lifted by the strapping that is attached and detached several times. Thus, on the Table 5 it is noticeable the higher number of manual and mechanized operations, and crew members change their location of the trawl deck more often. As the software and the machinery system pulls the sweeps, doors and net, some of the tasks like “Receive the trawl door” falls into the category of automatized – as it is happening automatically while the winches are activated. As it is possible from the Table 5 – many manual operations are performed cooperatively and involve 2 crew members – shown on Photo 1. As follows from the figure 13, these tasks require crew working directly with the fishing gear.

Emptying the cod-end consists of 10 tasks, and it is the part of trawling operation that relies on the manual labour most. From Table 6, it is visual that despite lower number of tasks, crew members like Trawl Boss and one of the Crew Members must change their location on the deck.

Table 4: Summary of the task performance by each participant of a trawling operation.

	Deploying the trawl (34 tasks)				Hauling the trawl (35 tasks)				Emptying the cod-end (10 tasks)				Tasks Total
	Manual	Mechanized	Automated	Location	Manual	Mechanized	Automated	Location	Manual	Mechanized	Automated	Location	
Total	15	11	5		21	9	5		8	2			
Navigator	1	8	5		2	6	5						25
Trawl Boss	10			9	12			12	5			2	27
Crew member 1	3	3		4	6	3		11	1	2		1	18
Crew member 2	3			4	13	1		3	5			2	22



Picture 2: Crew member on the Port and Starboard Trawl door positions under hauling of the trawl (Roger B. Larsen, UiT – The Arctic University of Norway).

Picture 1: Crew member 1 by the Console and Trawl Boss performs a manual operation by the fishing gear (Roger B. Larsen, UiT – The Arctic University of Norway).

5.3 Contribution of the task analysis to the safety studies in the large fishing fleet

As the tasks are evaluated by the three criteria of highest risk, found in the literature (Fulmer and Buchholz 2002; Jensen *et al.* 2006; McGuiness 2016), tasks with the highest rate of potential risks are referred as "weak points". By the definition of the "weak point", it is taken that these tasks were designed in the system in the way that they create unsafe conditions. Tables 5,6,7 demonstrate evaluation of each task by the criteria and the total score of each task.

Table 5: Investigation of the labour weak points under the Trawl Deployment

Code	Task	Location	Performer	Character	Total score
3.1.1.1	Start the hydraulic pumps				
3.1.1.2	Activate trawl winches				
3.1.1.3	Attach out-hauling winch to trawl net				
3.1.1.4	Lower the stern gate				
3.1.1.5	Report "all clear" to Bridge				
3.1.2.1.1	Activate sweep w. pumps				
3.1.2.1.2.1	Connect the out-hauler wire to the net				
3.1.2.1.2.2	Operate the out-haling winch				
3.1.2.1.2.3	Release the out-haler wire				
3.1.2.1.2.4	Retrieve and secure the out-hauler wire				
3.1.2.1.3	Increase the speed of the vessel				
3.1.2.1.4.1	Connect out-haling winch line				
3.1.2.1.4.2	Operate the out-hauling winch				
3.1.2.1.4.3	Activate the slacking of the outer sweep winch line				
3.1.2.1.4.4	Pull the out-hauling winch line back to the deck				
3.1.2.1.4.5	Secure the winch wire				
3.1.2.1.5.1.1	Connect the out-hauler wire to the footrope				
3.1.2.1.5.1.2	Release the out-hauler wire				
3.1.2.1.5.1.3	Retrieve and secure the out-hauler wire				
3.1.2.1.5.2	Wait until the trawl net start sinking				
3.1.2.2.1.1	Attach the sweep-bridle to the trawl doors				
3.1.2.2.1.2	Release the trawl winch wires				
3.1.2.2.1.3.1	Operate two side helping winches				
3.1.2.2.1.3.2	Lift the back straps to the trawl doors				
3.1.2.2.1.4	Send the signal to the Bridge				
3.1.2.2.2.1	Increase speed of the vessel				
3.1.2.2.2.2	Turn off the breaks				
3.1.2.2.2.3.1	Activate the auto-trawl				
3.1.2.2.2.3.2	Stop the trawl winches				
3.1.3.1	System depth alarm:100 metres left to send				
3.1.3.2	Turn down the speed of trawl winches sending rotation				
3.1.3.3	System depth alarm: the warps are released				
3.1.3.4	Verify touchdown of the trawl by Scanmar				
3.1.3.5	Register trawling operation in the trawling log				

Table 6: Investigation of the labour weak points under the Trawl Hauling

Code	Task	Location	Performer	Character	Total score
3.3.1.1	Echosounder				
3.3.1.2	Cod-end sensors				
3.3.2.1	Activate the hydraulic pumps				
3.3.2.2	Lower the stern gate				
3.3.2.3	Activate trawl winches				
3.3.2.4	Start pulling the gear				
3.3.3.1.1	Trawl doors arrive				
3.3.3.1.2	Turn on the breaks				
3.3.3.2.1.1	Continuously haul the trawl by the sweep winches				
3.3.3.2.1.2	Attach helping winches to connection to backstrap				
3.3.3.2.1.3	Pull up the back straps				
3.3.3.2.1.4	Detach back straps from the sweeps				
3.3.3.2.1.5	Attach the sweeps to the sweep winches				
3.3.3.2.1.6	Secure the back-strap chains up				
3.3.3.2.1.7	Pull down the helping winch rope				
3.3.3.2.1.8	Attach the rope to the trawl doors				
3.3.3.3.1.1	Pull the ground rope to the deck				
3.3.3.3.1.2	Lift the stern gate				
3.3.3.3.1.3	Attach strap to trawl body				
3.3.3.3.1.4	Attach the Gilson winchline to the strap				
3.3.3.3.1.5	Pull the net to the deck				
3.3.3.3.1.6	Detach the strap				
3.3.3.3.1.7	Attach strap to trawl body				
3.3.3.3.1.8	Attach second Gilson winch to the strap				
3.3.3.3.1.9	Pull the net to the deck				
3.3.3.3.1.10	Detach the strap				
3.3.3.3.1.11	Retrieve the hook by a winch				
3.3.3.3.2.1	Attach the strapping to the cod-end				
3.3.3.3.2.2	Attach the GW wire to the strap				
3.3.3.3.2.3	Pull the cod-end up to stern ramp				
3.3.3.3.2.4	Release the Gilson winch				
3.3.3.3.2.5	Secure the Gilson winch wire				
3.3.4.1	Turnoff the Auto-Trawl modus				
3.3.4.2	Detach the Gilson winch wire from the gear				
3.3.4.3	Secure the Gilson winch wire				

Traffic-light evaluation of each task provides a broader picture of labour under trawling. It indicates the tasks under the trawling that should be addressed first in terms of making labour safer and easier for the crew. At the Table 5 it is visible that tasks that are performed on the deck are of highest concern. Most of them are performed manually. Same picture is noticed on the Table 6, despite the fact that it includes higher number of tasks performed by several crew members. Crew members move more, and this creates extra risk. These tables as well demonstrate that Deploying and Hauling of the trawl and not directly opposite operators but differ in terms of tasks and performance of tasks.

Table 7: Investigation of the labour weak points under the emptying the cod-end

Code	Task	Location	Performer	Character	Total score
3.4.1	Open the hatch for fish hold				
3.4.2.1	Retrieve the timber winch wire				
3.4.2.2	Attach a strap around a cod-end				
3.4.2.3	Attach the timber winch wire to the strapping				
3.4.2.4	Lift the cod-end by operating the timber winch				
3.4.3.1	Open the cod-end				
3.4.4.1	Drag the net away from the hatch				
3.4.4.2	Detach the timber winch wire from the cod-end strap				
3.4.4.3	Close the hatch				
3.4.4.4	Remove the strap				

Table 7 shows that emptying the cod-end is mostly the manual process, and half of the tasks are performed by two crew members together. Out of the context and meaning of the operation – which is retrieving the catch from the fishing gear, it only difficulty of this task – as these manually performed tasks are performed on the catch and with heavy weights.

6 Discussion

6.1. General aspects

Fishing success is not entirely determined by the vessel's technical equipment and fish abundance. There is a huge impact of labour factor on the efficiency of fishing. From the perspective of labour, it is the tasks, task design and task performance that ensure that each trawling operation goes smoothly. This is the reason why fishing starts with a "box" crew meeting, when an operation is discussed in smallest details and the tasks are divided strictly among the crew members.

In this sense, carried out Hierarchical Task Analysis (HTA) creates a model of a trawling operation, with descriptions of the actions of each crew member that are realized and reflected as tasks. This approach ensures better understanding of the routine, workload and labour division not only to an experienced or a new crew member, but to a representative from other fields (for instance ship management, insurance companies etc.).

Methodology of this study has been chosen based on two main criteria – it should provide an objective picture of the labour tasks and answer the research questions in the way that can be universal and translatable into other fields. Examples in the literature, that are mentioned in the Chapter 2 of the thesis provide two examples of how HTA technique serve different goals on the different stages of system design.

In the case described in the literature and Chapter 2.1 "Balancing automation and human action through task analysis", this tool is applied at the stage of system design development and evaluates a specific manoeuvre in nuclear industry, with the goal to balance the level automation. In the second example, carried in the solid waste storage, HTA technique is carried out in the context of safety, in an already established labour system. Goal of it was to investigate labour process for safety issues thought the labour tasks. These examples justify that HTA technique can be used universally, and the findings of this technique may serve different purposes.

Based on Hierarchal task analysis, the further description of performance of the tasks has been evolved. It has been based on three main criteria – location, character of the performance and a performer. These three parameters allow to evaluate work load of each participant of the trawling operation, evaluate level of mechanization and automation on a vessel and identify the priorities of safety and possible mechanical improvement. This approach is based on the observation and excludes opinion and intervention with crew members, which secures the objectivity of the study.

Use of the Hierarchal task analysis in this study justifies its scientific translatability. Translational research concept originates from medicine and means the translation of knowledge between different disciplines with the goal of improving individual and group health and welfare (Drolet and Lorenzi 2011). This approach is often observed in ergonomics and occupational safety studies in fisheries, where safety advice and preventative measures include findings from other disciplines - physics, hygiene, chemistry and others, for example in European Handbook for Prevention of Accidents at Sea and Safety for Fishermen (European Union 2007).

Research of processes on fishing vessels by Jensen is an example of how a labour studies contribute to occupational safety studies by improving the coding scheme for the accidents (Jensen *et al.* 2005). Coding of the processes is based on the studies on the vessels of different types and sizes, and the processes are described generally, and in the way that creates a consistent coding scheme for the accidents, regardless the specific type of the vessel.

Focus of this study was the trawling operation on a large bottom trawler. Due to existence of different fishing gears, there has been designed different types of the vessels, and technically they differ. Although, the processes may have same task groups – shoot the gear, tow the gear and haul the gear, the performance of these tasks will differ depending on the fishing vessel type. In terms of technical equipment, vessels that fish with the same fishing gear will create a more homogeneous group and the processes and the tasks that are performed under each process will be alike.

In this way, this study complements the existent study of the processes on a fishing vessel by providing more detailed description of the steps of the process on a bottom trawler – these steps are essentially the tasks performed by the crew. This study does not separate the processes but provides an objective picture of the flow of the performance, and by this, every action of a Crew Member is put in the system of tasks and provided with a context.

6.2 Necessity of studying labour tasks on fishing vessels

Necessity of studying labour tasks on a fishing vessel is justified by different concerns of different fields. The number of people directly involved in operating trawling as a fishing method are limited to less than 1000 persons in Norway due to more advanced mechanization and structural changes of the fleet. However, this part of the fishing industry is still very important and a focus on safety is necessary because there is a higher demand on efficiency (RB Larsen, pers. comm.).

Despite the different perceptions and challenges that appear in the fisheries, there is always a gap of knowledge that should be filled and there is a constant need for study to complement the existent research. It is believed, that analysis of the tasks may fulfil this role.

On the technological level, marine industries – such as cargo ships and marine vessels have become a subject for the automation and autonomation, and fishing becomes a next marine industry which is studied and evaluated for potential of further automation and autonomation. (Vanhée *et al.* 2018). Task analysis contributes to this by evaluation of human and machinery interventions and studying the tasks that should be performed under fishing.

Thus, previous research of the labour on a fishing vessel left the room for going-in-depth for the labour processes (Jensen *et al.* 2003). With task analysis it is possible to complete the process description with understanding of what a crew member on a fishing vessel experiences during its working process with a fishing gear on the deck.

Another issues revealed in the study of safety in fishing fleet is the lack of reporting of accidents and the reporting forms being too general (McGuiness 2016). In these terms, labour studies, and task analysis specifically can contribute by providing an objective picture of process on a fishing vessel, in this case – on a trawler.

6.3 Integration of task analysis findings into the safety studies and accident prevention

Occupational safety is an issue of high concern in fisheries. There is on-going research of safety issues on the fishing vessels of different scale. As HTA is the tool which is used to safety studies, it would be interesting to discuss how finding of this study can be integrated in to safety research. It is seen two ways how finding of the study may contribute to safety – first one is by complementing the coding scheme of the injuries and identifying the accidents based on the injury type. In SINTEF Report “Work conditions and safety in fishing fleet”, 2018, safety issues were approached by analysis of the statistics of accidents and labour-related injuries, provided by Norwegian Statistics Bureau and Norwegian Labour and Welfare Administration (NAV) and field work on a fishing vessel. It was suggested to make an internal assessment of which workload crew is exposed to during the individual work operations with goal to identify harmful working conditions and potentially dangerous situations with the goal to do the following improvements:

- reduction of unfavourable workload through user-friendly technology and greater degree of automation;
- installation of hydraulic loops;
- avoidance of heavy lifting;
- avoidance of twisting, especially in combination with heavy lifting;
- workplace design that allows worker to stand upright and avoid working with bent back or high shoulders;
- rotation between workstations in the factory to vary the load on each one (Thorvaldsen *et al*. 2018).

HTA provides a picture of the work load of each crew member by assessing number of tasks and changes of location during a trawling operation, and by the realising of the tasks it is possible to identify which of them include tasks that fall into the recommended measures. By combining tasks description and the task performance, it is visual that heavy lifting is present during tasks for attachment of the sweeps and wires under attaching and detaching of the trawl doors. Lifting and twisting are as well present by attaching the strapping while hauling the trawl and by emptying the cod-end. The same tasks require bending.

A 2017 report on safety of fishing vessels “Prevention of accidents at work in Nordic Fisheries – What has worked?” researched the most efficient safety measures, and the analysis of interviews had revealed: “The ten Norwegian fishermen gave the highest scores to aspects related to the everyday work on board the vessels, namely how the work is organised, how tasks are distributed, onboard training (knowledge about what to do), as well as safety equipment for fishermen and vessels. A high average score was also given to safety culture, and several of the fishermen noted that there has been a pronounced change in safety culture during the last ten years.” (Christiansen and Hovmand 2017).

Safety issues that are approached from the prospective of task analysis identifies concrete tasks and actions that need improvement (Tables 5, 6, 7). Dashed line around the analysis of the accident statistics on Figure 19 represents the most common approach for occupational studies in fisheries and the approach to the research that is not used in the thesis. Applying translational research model to the research of labour on a fishing vessel does not only compliments the existing research, but is means to create a basis for transformation of this knowledge into measures of improvement and preventive methods and their application (Lucas *et al.* 2014).

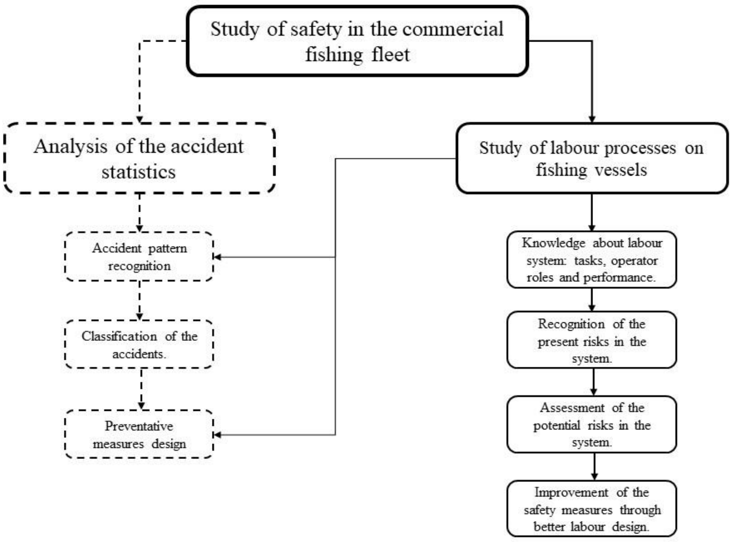


Figure 19: Study of labour on fishing vessel complements safety studies.

As HTA provides an objective picture of labour, it is possible to extract exact work load for each crew member and identify where improvements of automation and reduction the manual work load are required. From the existing safety research, it is fair to assume that working process includes certain tasks that have higher requirement for performance and are heavier to complete, because of the present system design these tasks produce the preconditions for the accidents, visual representation of this idea is Figure 20.

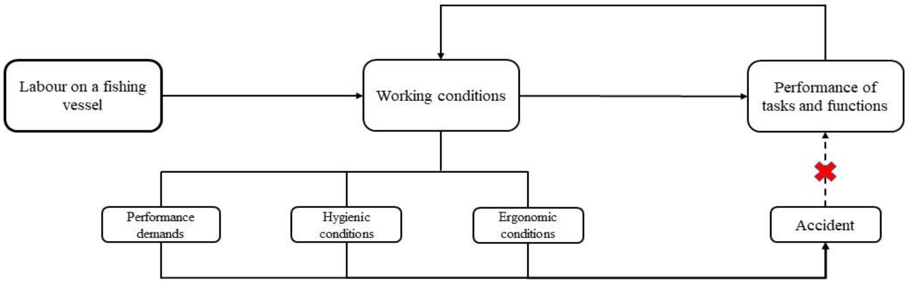


Figure 20: Understanding of an accident from the perspective of labour tasks.

Figure 5 was adapted from labour studies, where working conditions consist of three categories – performance demands, hygienic conditions, ergonomic conditions (García-Herrero *et al.* 2012). From this prospective, it is the working conditions that determine performance of the task, however it is attempted to complement this study by identifying the tasks that are designed in the way that creates potentially higher probability of an accidents.

An example of the this has been introduced in the Chapter 5.3 of the thesis. Each task was listed in the order of the performance and assessed according to the three main labour related safety assumptions – location of the performance, performer and character of the performance.

During a fishing operation, crew members are in the contact and interaction with machinery and each other – efficient communication between crew members and between trawl deck and Bridge is essential for the safety (Thorvaldsen *et al.* 2012). While accidents are complex, it is possible to take a labour perspective on them and narrow accidents down into understanding of them as result of such an interaction.

Thus, an accident appears while a human performs a certain task, using a certain machine or part of machinery, or moves to complete a task. Therefore, primarily addressing the labour on the vessel through the tasks creates potential for the understanding the occurrence of the accidents, helping to report them and possibly to improve the prevention methods. Traffic light risk assessment shed light on which of the tasks are of the highest concern, and by being based on the hierarchical task analysis, it is possible to modify the working process by tracing tasks of each crew member, changing their location and movements and transforming the work load.

As it is visual from the Table 5, tasks 3.3.3.2.1.2 – 3.3.3.2.1.8. – are the series of tasks with highest rate of potential accident, these tasks concern attaching and detaching the backstraps of the Trawl Doors, performed on the Port and Starboard Trawl door positions – small areas by the massive trawl doors which are the least stable if the vessel moves heavily (bad weather and large waves). These tasks of attaching and detaching are performed manually by one crew member on each side and include pulling up and pulling down of the parts of the backstrap chains. HTA provides a concrete flow of how it is done and the meaning behind each action. In this way, it is possible to find a solution for this number of tasks – improve the machinery and tools or increase number of the crew members who perform it. Task analysis may either contribute to replacing manually performed tasks and keeping update about how fishing operation happens.

Education of the crew members is another issue of the safety that may be addressed through the task analysis. It has been identified lack of systematic education of the crew for the large fishing vessels (learning by doing) and safety regulations are vague and general, even though are obligatory (Zwan 2018). HTA may contribute to better education and safety preparations if used as a learning material for education and certification of the fishermen.

In the literature, it has been addressed an issue of reporting of the accidents. Lack of reporting and reporting schemes are the main concerns for the safety. Reporting system has evolved from open end questions and only broad categories of responses to constructed of location, activity, injury type and bodily location. These schemes are seen as satisfactory to define accident patterns (McGuiness 2016). HTA may complete the understanding of the schemes by providing a greater context of each accident – following the scheme, it is possible to trace the concrete task, figure out what exactly and how the situation led to the accident. Description of the tasks may as well contribute to further improvement of the reporting schemes – by having a labour model of a fishing vessel, schemes may be more precise and shorter, and put each accident into a better context.

6.4 Role of task analysis in the automation and autonomation of fishing vessels

Autonomation of navigation is becoming a reality in the shipping industry. Around the world, there are several projects about autonomation of maritime surface ships. For example, in Norway, Masterly, a joint venture of Kongsberg Maritime and Wilhelmsen. Is currently running a self-driving shipping control system, being the world's first autonomous vehicles test bed and holding first contracts for commercial delivery of autonomous vessels (Kongsberg Wilhelmsen joint venture 2019). SINTEF Ocean and Norwegian university of Science and Technology have started several projects on autonomous vessels – cargo vessels, passengers/ferry vessels (Rødseth 2019) which shows that interest for autonomation increases in Norway and there is ongoing research of application of autonomy into different types of vessels.

Challenge of the design of an autonomous system is integration - holistic vision of the system, but not the sum of the parts (Alexander, Ryan, and Casey 2004). Sub-systems in autonomy are integrated in the way, which makes system "think" itself. Based on the rising interest for the autonomous navigation of surface ships, it appeals to discover whether fishing may become autonomous as well. Technological process has been taken the direction of replacing manual work with tools and machines, by the task and functional analysis and replacing essential operations with machines and eliminating as many tasks as possible (Jerome 1934). Therefore, the question of autonomation of a trawler may be narrowed: – to what extend can operations be integrated into one system of machinery that minimises human labour.

Therefore, by designing an autonomous fishing vessel, the systems should be connected into one. Current projects of autonomation demonstrate that it is possible to create an autonomous navigation system, however it is the catching the fish and work with the fishing gear that may be more difficult to autonomate. Current technological level of a fishing vessel is advanced mechanization. As it has been discovered through this study, fishing with a trawl relies on the manual and mechanized tasks, and automation is present only on the Bridge, where a Navigator has control over the software. There is no autonomation as such on the studied vessel.

Following the trend of the mechanization, it may be possible to design machines that minimize human labour on a fishing vessel. However, when operating the fishing gear there are some critical moments regarding work with the gear – like deployment, which should be performed in the way that does not compromise safety of the crew and respects navigation and fishery regulations. Thus, it might be very difficult to move towards autonomous fishing operations (Vanhée *et al*. 2018). It is believed that it is because of the decisions that often has to be made in "split-second", autonomation of fishing vessels like trawlers and seiners will be introduced in its peripheric systems first (Vanhée *et al*. 2018).

As the HTA technique is often used as the basis for balancing of the automation, description of the task performance in this study has revealed that some of the tasks are performed manually, but mechanically – as a part of a routine; and some of the parts of trawling do not have clearly designed routine – for example preparation for next operation and response for the accidents.

According to the model of autonomation, recognition of risks, being able to stop an operation and restore it after the self-reparation is the main attribute of the autonomous system (Boakye-adjei *et al.* 2015). This can be achieved by programming a level of self-realization and self-adaptation of singular elements and the whole system (Zambonelli *et al.* 2011). Thus, if the fishing gear, a trawl for example, is damaged and tangled – there is a concern of how the system can recognize the damage, analyse and program the reparation.

6.5 Other benefits of task analysis

Being a universal tool, task analysis benefits to other fields that directly or indirectly concerns labour in fisheries and welfare of fishermen.

As the HTA describes tasks and goals of the system, each described task can be evaluated in terms of risks for an operator for the importance for the system. By evaluating the goals and the tasks, it is possible to investigate whether every task is worthy of performance or not. This is a form of cost-benefit analysis, where the cost is the risk which is entitled to the operators and their system intervention. The process of evaluating the tasks is called re-description and results in the innovation of the system design (Shepherd 2001). This provides a second contribution of the task analysis to the cost-benefit, as based on the tasks description it is possible to evaluate the cost of innovations required.

Every task which bears risk for an operator on a fishing vessel is the risk for efficiency of fishing. Fishing is disturbed by an accident, which leads to economic losses. If the potential risks are evaluated and reduced through the system design, fishing is safer and therefore more cost effective. Together with re-description of the tasks it is possible to assess the work load, and depending on it, re-adjust number of operators and cost for personnel. In this way the optimisation of tasks for increase cost efficiency happens by targeting "unworthy" goals and tasks can be changed or eliminated from the process.

There are several benefits for the Crew that may be extracted from the task analysis. By planning the re-assigning tasks, it is possible to balance the work load and increase the crew performance of the trawling by planning their work better and replace movements on the deck for shorter moves or re-design them in the way with the lesser number of movements for each crew member.

On the "box"-meeting before the trawling operation, task analysis may be used for planning of tasks with heavy lifting and re-organize the tasks with heavy load for performance for several crew members would contribute significantly to the human operator comfort on board of the vessels, rises awareness of each crew member about their task's division and tasks of their colleagues, improve organization of labour routine.

6.6 Future work

As illustrated on the Figure 29, findings of this study has covered the following directions – task descriptions, tasks that are performed with a hardware – automatized and automated tasks, tasks that are performed by a human operator – all the tasks which include a human operator, including control, and interaction between a human and a system – all the performed operations, where a human operator is in contact with an instrument or means of labour.

These findings have potential for future studies in safety, ergonomics, mechanization and autonomation of the vessels. Task investigation is dedicated to describing and investigation of the system design flaws, machinery imperfections and assessment of the human factor (Figure 21). And in this way labour-oriented prospective provides a different vision on the labour conditions – ones that are formed not by external factors, but the labour itself – some of the tasks are designed that way, that they require so much effort and risk to be performed.

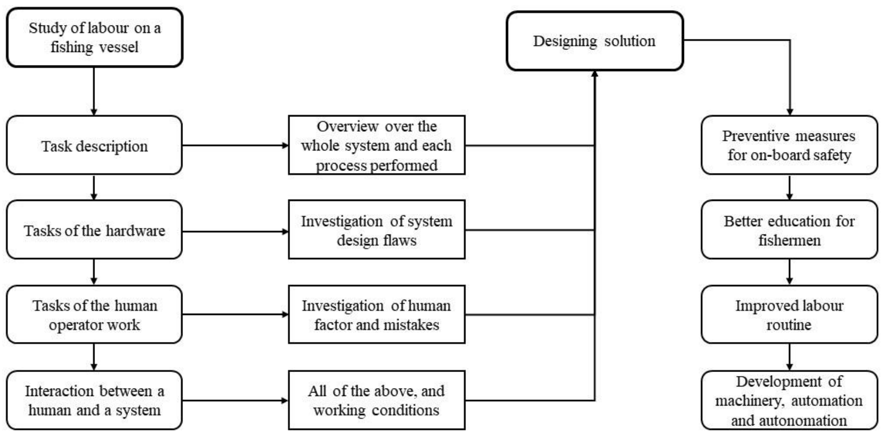


Figure 21: Model of implementation of the study findings and future work.

Based on the findings of this study, future work in the direction of designing preventive measures for on-board safety may be improved through the re-describing the goals and tasks under the trawling operation. Each identified task with the higher risk may be studied thoroughly and together with other approaches to safety studies, preventative measures may be designed in a more objective way.

Better education for fishermen – as it has been discovered during the field work, fishermen are often “learning by doing”, and some researchers express concern about issues of education for fishermen, obsolete advice and the present certification system (Zwan 2018). Task analysis may be evolved further into the studying materials, to provide educational and formal learning background to the fishermen. As the education for fishermen is not present in every country, but the safety training is compulsory, task analysis may be further studied and evolved into safety training routine. In Norway this may be used on the level of High School, where maritime direction is present (Henriksen *et al.* 2014).

Improved labour routine – tasks may be studied further in collaboration with the crew, so the better labour routine may be designed. Labour concerns not only the physical performance, but mental as well, so this direction is interesting to investigate.

Development for machinery, automation and autonomation – by continuous studies and evaluation of the tasks, it is possible to design innovation for supporting and minimising human operators input. In this way, there is a good potential to use the present study to explore the potential of automation and autonomation on a trawl. During the field work observations were made for other sub-systems of the vessel. These may as well be presented as HTA and analysed in terms of automation and autonomation in future studies.

7 Conclusion

Task analysis sheds light onto many aspects and issues of modern and future fisheries and the findings of this analysis may be applied into different fields. Hierarchical Task Analysis technique is a universal tool of labour studies which may be analysed and utilised further according to the research question and point of interest. It provides a model of a trawling operation, which is objective and fully realised in terms of activities and tasks that are performed by these activities.

Trawling operation cycle is a complex system of 83 tasks, which require 4 operators involved and includes manual, mechanized, automatized and automated labour. Trawling operation happens on the trawl deck and on the bridge, with communication between them. Fishing with trawls is a highly mechanized process, but it still relies on manual work, which should be identified, realised and targeted for the improvement.

Findings of the HTA may be applied to complement the occupational safety studies in fisheries and integrated into the future vessel design. HTA can be used as studying materials that may be used for education and certification of fishermen or for researchers who are interested in fisheries.

Thus, task description may contribute to better understanding of accidents by providing a good context of activities when a crew member is hurt, evaluate tasks that are designed in the way that they bear potential danger for an accident. And by further analysis it contributes to preventive measures and improvement of vessel design by diverse changes in machinery system, tasks design and allocation, or automation and autonomation of the fishing related operations on fishing vessels.

References

Aasjord, H. L., I. M. Holmen, and T. Thorvaldsen. 2012. "Fiskerulykker Og Årsaksforhold."

Adams, A. E., W. A. Rogers, and A. D. Fisk. 2012. "Choosing the Right Task Analysis Tool." *Ergonomics in Design* 20 (1): 4–10. https://doi.org/10.1177/1064804611428925.

Adlemo, A, and S.-A. Andréasson. 1995. "Balanced Automatization Levels in Manufacturing Systems." *Balanced Automation Systems*, 393–404. https://doi.org/10.1007/978-0-387-34910-7_37.

Alexander, L., J. F. Ryan, and M. J. Casey. 2004. "Integrated Navigation System: Not a Sum of Its Parts." In *Canadian Hydrographic Conference*, 14. https://scholars.unh.edu/ccomhttps://scholars.unh.edu/ccom/297.

Annett, J. 2003. "Hierarchical Task Analysis." In *Handbook of Cognitive Task Design*, 17–35. https://doi.org/10.1201/9781410607775.ch2.

Aven, T. 2019. "Risikoanalyse." Store Norske Leksikon. 2019. https://snl.no/risikoanalyse.

Boakye-adjei, K., R. Thamma, and E. D. Kirby. 2015. "Autonomation : The Future of Manufacturing." *International Journal of Innovative Science, Engineering & Technology* 2 (10): 214–19.

Boyatzis, R. E. 1998. *Transforming Qualitative Information: Thematic Analysis and Code Development*. Thousand Oaks: SAGE Publications Inc.

Christiansen, J. M., and S. R. Hovmand. 2017. "Prevention of Accidents at Work in Nordic Fisheries – What Has Worked?" *Nordic Council of Ministers*. https://doi.org/10.6027/TN2017-509.

Drolet, B. C., and N. M. Lorenzi. 2011. "Translational Research: Understanding the Continuum from Bench to Bedside." *Translational Research* 157 (1): 1–5. https://doi.org/10.1016/J.TRSL.2010.10.002.

European Union. 2007. "European Handbook for the Prevention of Accidents at Sea and the Safety For Fishermen." European Union.

Fulmer, S., and B. Buchholz. 2002. "Ergonomic Exposure Case Studies in Massachusetts Fishing Vessels." *American Journal of Industrial Medicine Supplement* 2: 10–18. https://doi.org/10.1002/ajim.10086.

Gabriel, O., K. Lange, E. Dahm, and T. Wendt. 2005. *Fish Catching Methods of the World*. Fourth Edi. BlackWell Publishing Ltd.

García-Herrero, S., M. A. Mariscal, J. García-Rodríguez, and D. O. Ritzel. 2012. "Working Conditions , Psychological / Physical Symptoms and Occupational Accidents . Bayesian Network Models." *Safety Science* 50: 1760–74. https://doi.org/10.1016/j.ssci.2012.04.005.

Henriksen, T., and M. Mathisen. 2014. "Utdanning." Fiske Og Fangst. 2014. https://utdanning.no/studiebeskrivelse/fiske_og_fangst.

HMS avd. ved NTNU. 2013. "NTNU." Risikomatrise. 2013. https://www.ntnu.no/hms/retningslinjer/HMSRV2604B.pdf.

ILO. 2007. *The ILO Work in Fishing Convention 2007: A guide for Unions*. London: International Transport Workers' Federation.

Jensen, O. C. 2006. "Injury Risk at the Work Processes in Fishing : A Case-Referent Study." *European Journal of Epidemiology*, no. 21: 521–27. https://doi.org/10.1007/s10654-006-9026-9.

Jensen, O. C., S. Stage, and P. Noer. 2005. "Classification and Coding of Commercial Fishing Injuries by Work Processes : An Experience in the Danish Fresh Market Fishing Industry." *American Journal of Industrial Medicine* 537 (47): 528–37. https://doi.org/10.1002/ajim.20163.

Jensen, O.C., S. Stage, and P. Noer. 2006 "Injury and Time Studies of Working Processes in Fishing." *Safety Science* 44 (4): 349–58. https://doi.org/10.1016/J.SSCI.2005.11.001.

Jensen, O. C, S. Stage, P. Noer, and L. Kaerlev. 2003. "Classification of Working Processes to Facilitate Occupational Hazard Coding on Industrial Trawlers." *American Journal of Industrial Medicine* 430 (44): 424–30. https://doi.org/10.1002/ajim.10292.

Jerome, H. 1934. "Mechanization in Industry." In *Mechanization in Industry*, 523. New York: National Bureau of Economic Research.

Kawulich, B. B. 2004. "Data Analysis Techniques in Qualitative Research." *Journal of Research and Education* 14 (1): 96–113.

Kawulich, B. B. 2015. "Collecting Data through Observation." In *Doing Social Research: A Global Context*, 21. McGraw Hill Higher Education.

Khan, Ali. 2001. "The Dignity of Labor." *Colombia Human Rigths Law Review*, 58. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=936890.

Kirwan, B., and L. K. Ainsworth. 1992. *A Guide to Task Analysis*. Edited by University of Birmingham Kirwan, B. and Synergy Ainsworth, L., K. London: Taylor & Francis.

Kongsberg Wilhelmsen joint venture. 2019. "Massterly." 2019. https://www.massterly.com/news-1.

Kothari, C. R. 2004. *Research Methodology. Methods and Techniques.* Second rev. New Delhi: New Age International (P) Limited, Publishers.

Lucas, D. L., L. D. Kincl, V. E. Bovbjerg, and J. M. Lincoln. 2014. "Application of a Translational Research Model to Assess the Progress of Occupational Safety Research in the International Commercial Fishing Industry." *Safety Science* 64 (April): 71–81. https://doi.org/10.1016/J.SSCI.2013.11.023.

McGuiness, E. 2016. "Safety in the Norwegian Fishing Fleet - Analysis and Measures for Improvement." Norwegian University of Science and Technology.

Norwegian Maritime Authority. 2019. "Ulykker Med Fiskefartøy - 2019 Pr 1.2.2019."

Norwegian Maritime Directorate. 2011. "Marine Casualties 2000 - 2010."

Oxvig, U., and U. J. Hansen. 2007. *Fishing Gears*. Second edi. Fiskericirklen.

Petursdottir, G., O. Hannibalsson, and J. M. M. Turner. 2001. "Safety at Sea as an Integral Part of Fisheries Management." *FAO Fisheries Circular* 966: 49.

Ræsted, S. 2018. "Risk Response Matrix." Lederkilden. 2018. https://www.lederkilden.no/tema/risikomatrisen-risk-response-matrix.

Rødseth, Ø. J. 2019. “NFAS.” Norwegian Forum for Autonomous Ships. 2019. http://nfas.autonomous-ship.org/index-en.html.

Shepherd, A. 1998. “HTA as a Framework for Task Analysis.” *Ergonomics* 41 (11): 1537–52.

Shepherd, A. 2001. *Hierarchical Task Analysis*. London: Taylor & Francis.

Sheridan, T. B., and R. Parasuraman. 2005. “Human-Automation Interaction.” In *Reviews of Human Factors and Ergonomics,* 89–129. SAGE Publications Inc.

Stange, H. 2018. “Focus On Risks 2018.” Haugesund: Norwegian Maritime Authority.

Stanton, N. 2006. “Hierarchical Task Analysis: Developments, Applications and Extensions.” *Applied Ergonomics* 1 (3): 1–56. http://v-scheiner.brunel.ac.uk/bitstream/2438/1733/1/Hierarchical_Task_Analysis_Developments_Applications_and_Extensions_Stanton(postprint).pdf.

Stanton, N. A. 2006. “Hierarchical Task Analysis: Developments, Applications, and Extensions.” *Applied Ergonomics* 37 (1): 55–79. https://doi.org/10.1016/J.APERGO.2005.06.003.

Taylor, F. W. 1919. *The Principles of Scientific Management*. New York and London: Harper and brothers publishers, New York and London.

Thompson, P. 1983. *The Nature of Work: An Introduction to Debates on the Labour Process*. Macmillan International Higher Education.

Thorvaldsen, T., M. Sansund, I. M. Holmen, L. Aasmoe, S. A. Sønvisen, A. Øren, C. T. Heidelberg, and B. Bang. 2018. “Arbeidsmiljø Og Helse i Fiskeflåten.”

Thorvaldsen, Trine, Signe Sønvinsen, and I. M. Holmen. 2012. “Sikker Kommunikasjon Om Bord.”

Vanhée, L., M. Borit, and J. Santos. 2018. “Autonomous Fishing Vessels Roving the Seas: What Multiagent Systems Have Got to Do with It.” *Proceedings of the 17th International Conference on Autonomous Agents and MultiAgent Systems* 34: 1193–97. https://dl.acm.org/citation.cfm?id=3237875#.W5u3jWyNnRA.mendeley.

World Bank Group. 2019. *The Changing Nature of Work*. Broadway, New York: International Bank for Reconstruction and Development/ The World Bank. https://doi.org/10.1596/978-1-4648-1328-3.

Zambonelli, F., N. Bicocchi, G. Cabri, L. Leonardi, and M. Puviani. 2011. “On Self-Adaptation, Self-Expression, and Self-Awareness in Autonomic Service Component Ensembles.” In *Proceedings - 2011 5th IEEE Conference on Self-Adaptive and Self-Organizing Systems Workshops, SASOW 2011*, 7. https://doi.org/10.1109/SASOW.2011.24.

Zwan, M. V. D. 2018. “Training and Certification of Fishermen.” Diemen: European Commission.

Acknowledgments

Firstly, I would like to thank my supervisors Roger Larsen and Melania Borit for their professional help, motivation an inspiration; for supporting my ideas and providing me with all the necessary means and materials to complete this study; for their time, dedication and belief in me.

Thank-you to Ivan Tatone and Jesse Brinkhof for helping me before and during the cruise, for their advice and all the help.

Thank-you to Captain John Almestad and Crew of R/V Helmer Hanssen for cooperation and assistance both on and off shifts and sharing their professional experience and personal insight on my topic. The research cruise was funded by UiT, the Directorate of Fisheries and FHF project 901303 Optimalisering av fiske med reketrål: Nasjonal satsing for å løse utfordringer med bifangst i det norske rekefisket.

I would also like to acknowledge Ane-Marie Hektoen and Administration of The Norwegian College of Fisheries Science for the support and opportunities they provide.

And last, but not least. I would like to thank my family, my husband Aleksander and his family for being with me on this journey.