# A preliminary accident investigation on a Norwegian fish farm applying two different accident models

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**Abstract:** The aquaculture industry is one of the most dangerous professions with respect to occupational hazards in Norway. Hazardous operations are carried out daily on fish farms and safe operations are crucial. This paper aims to apply two methods of accident analysis for an accident at a fish farm. Accident analysis is necessary for understanding why accidents happen, helps us understanding the system in which the accident happened, and can provide for improvements for a safer system. The two methods, namely STEP and CAST are based on different assumptions of accident causation, and highlights different mechanisms that contributed to the accident happening. STEP provides a systematic guidance to ask the right questions to get a full view on what happened during the accident sequence, and portrays the accident in an easy accessible flowchart. CAST is a more comprehensive method that models all levels in the sociotechnical system to evaluate if there is inadequate control in any of the feedback loops of the different levels. Using CAST for accident investigation is more resource demanding, but will also give more information on safety problems which can be used to improve the risk management system.

**Keywords: Aquaculture, Fish Farming, Accident models, STEP, CAST**

## 1. INTRODUCTION

Norway has grown to be the world's largest producer of Atlantic salmon [1], and the industry is of great economic importance in Norway. Especially in the coastal districts of Norway the aquaculture industry is important and in addition to traditional fisheries, aquaculture has become a cornerstone of many local communities. Sea based fish farming has great potential in producing healthy food for consumers worldwide, and the Norwegian government had in 2013 an explicit goal of becoming the world's leading seafood nation [2]. Fish farms in Norway have traditionally been situated in sheltered fjords. Due to challenges faced by the industry and prospects of greater value-creation, the industry is increasing the focus on moving the farms into less protected areas.

The prospects of exposed fish farming will impose several challenges and new hazards. Aspects, such as harsher environmental conditions, availability of the facilities and distance will influence safe operation in exposed fish farming. This also implies a more systematic approach to risk management. The industry is already one of the most dangerous professions with respect to occupational hazards in Norway. The work on a sea-based fish farm is characterized by manual labor assisted by heavy machineries like cranes and work boats. The total work force on a fish farm in one shift, on a normal day varies from 2-5 operators, and when special operations are performed extra personnel can increase the number to 10-15 operators. Many of the demanding operations on fish farms are carried out on work boats moored to the net pens. The forces from wind, currents and waves are making these work platforms unstable relative to each other, and especially tasks involving the use of cranes are difficult. Hazardous operations are carried out daily and ensuring safe operations are crucial. Safety is an issue that needs careful review to prepare the industry for the need for improved health, safety and environment (HSE) performance when moving production to areas with harsher weather conditions, and less accessible sites.

Most research on safety and risks in the aquaculture industry have focused on either food safety, structural safety, and preventing escape of salmon; the latter due to the implications regarding wild salmon [3-5]. Occupational safety has gotten less focus, and a Canadian study on occupational accidents

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concludes that despite the fact that the industry is one of the most injury exposed industries there has only been limited focus on occupational safety management in the aquaculture sector [6]. The aquaculture industry is number two on the statistics when it comes to occupational accidents and fatalities per man-labor year, just after fisheries [7, 8]. In the years 1988-2013 over 1400 injuries have been reported, with the assumption that there is a substantial level of under reporting. From 1980-2013 40 deaths have been reported from the aquaculture industry [9]. Hence, there is positively a potential for improvement regarding safety in the aquaculture industry.

Accident models are used in accident investigations to help understanding causal factors. Accident models can also be seen as a type of risk analysis, when defining risk as the systematic use of methods to identify hazards and to estimate the risk to individuals or populations, property or the environment [10]. Different accident models are based on different assumptions on the functions and structures of the sociotechnical systems, which again can lead us to the conclusion that the outcome of using different models is different results in terms of causes to an accident. As the results from an accident investigation should lead to input for improvements of the system, the choice of accident models for an accident investigation is important for the work on accident prevention. Accident models affect the way people think about safety and how they identify and analyze risk factors, and accident models can be used both in reactive and proactive safety management [11].

The main objective of this paper is to apply two different accident models, i.e., STEP and STAMP/CAST, to one accident on a fish-farm and compare the usability of the models. The aquaculture industry has not been subject to extensive occupational or organizational safety research yet. Hence, it is not evident which accident model will provide the most valuable insights into the causes of an accident on a fish farm as basis for determining relevant mitigating measures. The work in this paper analyzes two different approaches to lay the grounds for further systematic safety work and research in the Norwegian aquaculture industry.

The structure of the paper is as follow; Section 2 presents the main categories of accident models. In Section 3 two different methods for accident investigation based on different accident models are presented and applied for the accident case. In Section 4 the usability of the accident models is discussed, and seen in relation to what we can learn from using the different accident models.

## 2. THREE TYPES OF ACCIDENT MODELS

Accident models can be categorized in many different ways, for example, Hollnagel suggests three main categories of accident models; the sequential models, the epidemiologic models and systemic models [12]. Each accident model has its own characteristics as to the types of 'causal factors' that it highlights [13].

### 2.1. Sequential accident models

Sequential accident models portray accidents in terms of a chain of discrete events which occur in a particular temporal order where an initial unexpected event (root cause) triggers the following events [12, 14, 15]. The initial model was developed by Heinrich in the 1940s and named the Domino theory. This model uses the analogy of domino pieces to demonstrate that different factors/events will contribute to an accident, but if you remove one of these factors, such as an unsafe act, you can also prevent the accident from happening. An assumption for the sequential accident models is that accidents happen in a linear and deterministic manner. Some types of risk analysis can be seen as sequential accident models, like fault tree analysis (FTA), event tree analysis (ETA) and failure mode and effect analysis (FMEA) [14]. Other accident models belonging to this category is the Loss Causation Model, Rasmussen and Svedungs model and the Sequentially Timed Events Plotting (STEP) which will be introduced in detail later in this paper [15].

### 2.2. Epidemiologic accident models

Epidemiologic accident models portrays accidents analogues to the spreading of a disease, i.e. as the outcome of a combination of factors, some manifest and some latent, that happen to exist together in space and time [14]. The Swiss cheese model is an example of an epidemiologic accident event developed by James Reason, where slices of Swiss cheese are used as an analogy to barriers. The Swiss cheese has holes of different sizes at different places, and these holes are referred to as latent failures or latent conditions in the barriers [16]. There can be several layers of barriers (defence in depth) and an accident happens if there are latent failures in all barriers. The theory of man-made disasters by Barry Turner is another epidemiologic accident model consistent with the ideas that accidents happen because of latent failures and conditions in an organization or system. The model suggests that accidents are the result of a long series of events where errors, misconception of hazards and lack of information flow in the end will accumulate into an accident [17].

### 2.3. Systemic accident models

Systemic accident models are based on systems theory. Systems theory assumes that some systems cannot be separated into subsystems without losing information on the systems interaction and relationship between technology and social aspects [18]. Accidents must thus be seen in relation to the system as such, and the thought is that if you single out parts of the system to model how and why an accident happened information will be lost. A basic property of the system is also that it consists of hierarchical levels, and that each level will put constraints on the lower level. A system is held in balance through these constraints and accidents happen when control over these constraints is lost. As Leveson [19] argues, it is in the interaction of system components that safety of a system can be determined, and that accidents occur when component failures, external disturbances, and/or dysfunctional interactions among system components are not adequately handled by the control system. As opposed to sequential and epidemiologic models the focus in a systemic accident model is not on the actors or events. This means that it is to a lesser extent possible to assign blame when using a systemic model, because instead the focus is on context and conditions. Systemic accident models are Rasmussen's hierarchical sociotechnical framework, Hollnagels FRAM (Funtional Resonance Accident Model) based on cognitive systems engineering and Leveson's STAMP (Systems-Theoretic Accident Model and Processes) on which CAST (Causal Analysis based on STAMP) is based, introduced in more detail in the next chapter [12, 14, 20, 21].

## 3. APPLYING ACCIDENT MODELS

### 3.1. The accident case

The accident modeled in this paper involves the capsizing of a workboat at the coast of Norway, fall of 2013. The boat sunk, but was later lifted and moored at quay. The workboat has been out of service since the lifting, as the material damages after the accident were severe. Two operators were involved in the accident. Both operators were exposed to imminent danger as they had to jump from the sinking workboat and swim approximately 250 meters to shore in cold water at night. The air temperature was -3 °C and the sea was calm.

A short description of the accident is as follows: two operators manning the workboat started their shift at 0300 a.m. Their task was to load the workboat with fodder from quay, then leave for the fish farm to start the feeding. When the workboat was 800-1000 meters from the quay, heeling was observed by one of the operators, and shortly thereafter water on deck. The operators turned the workboat to return to the quay, but before they reached land the workboat capsized and eventually sank. One of the operators jumped off the boat when it capsized, while the other operator fell and got hit in the face, nevertheless he managed to swim away from the sinking workboat. The operators swam to shore and were rescued. The material damages after the accident was a sunken workboat and lost fodder sacks. Both operators were chilled and worn out after the long swim in the cold water, and one had a small cut in the lip. The operators tell that they have experienced some psychological after-effects from the capsizing.

The main source of information when analyzing the accident has been the accident investigation documents, provided by the company management. These documents include notes from some interviews with key personnel and a preliminary technical analysis ordered from a consultancy company to analyze the technical causality of the sinking. The labor authorities also initiated a separate investigation and some of the documents related to this investigation were used for information about the accident[†]. In addition, an independent research institute was hired to assist in the company's internal investigation, which is documented in a report describing the event and the most likely causalities. None of these documents states to have been based on a particular accident model.

### 3.2. Sequentially Timed Event Plot (STEP)

[22] gives a thorough description on how to conduct an accident investigation, where guidance on how to collect information through interviews and documents is provided. The book focuses on how to acquire and treat information related to an accident, and how to use this information to reconstruct the events leading to an event. The core of the accident model is the STEP diagram. This is a matrix type diagram where each row is designated one specific actor and each column is one time unit. All actors involved in the accident are identified; these can be both human and technical. The actors relevant for the investigation are those whose actions initiate changes during the accident. The time aspect is also noted as important as it can explain why further actions in the diagram are taken, and it highlights at what times critical actions are made. The STEP building block events are then identified and placed according to actor and time in the matrix. The first and the last event should be identified first. The first event should be the event that initiates the changes that leads to the accident; this is the first event when change is not countered with an adaptive response to keep the expected course of events. The last event should be the event when homeostasis has again been restored and no more harm is occurring. From the first event the consecutive event are then identified by asking “Which actors must do what to produce the next event?” [15] An event is the situation when one actor is performing one action. The events may be physical and observables or they can be mental if the actor is a person. Events can in the model occur at the same time when actuated by different actors, and the method is thus multi-linear. When all events have been identified the events are connected through arrows. The arrows between events can be both converging and diverging showing that several events can lead to one single event and that one single event can trigger multiple other events or actions. The linking of the events also tests the relationship between the identified events as the logical sequence must follow the arrows.

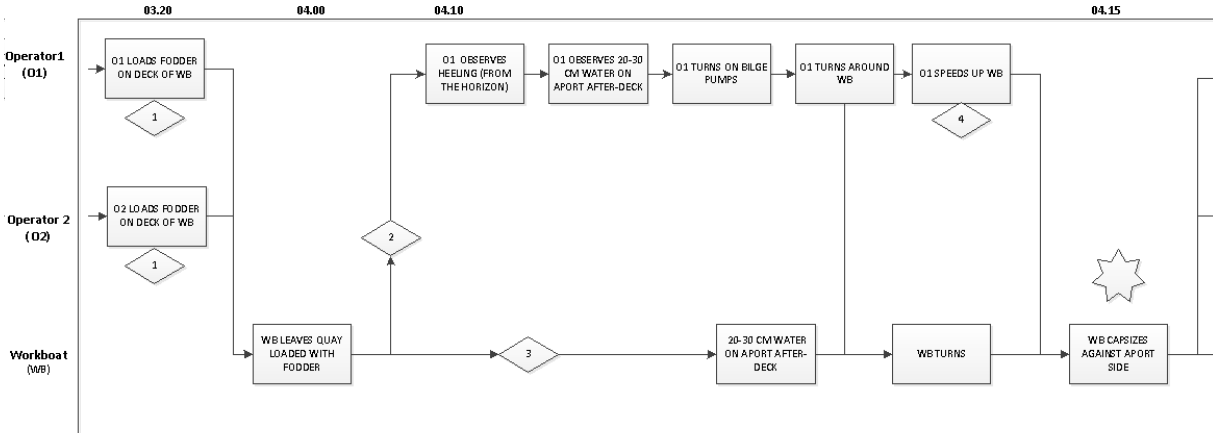
When the STEP matrix diagram is completed, the event sequence can be analyzed for safety flaws. Then each event set and their linking arrows in the flowchart is used to find the effect that one event has on another event. The thought is that it is the flow of the events that will disclose the problems, and that the flow of events that triggers harm must be changed or better controlled [22].

#### 3.2.1 Applying STEP

When analyzing the accident according to the STEP method, the first task is to decide the first and last event in the accident sequence. The first event should be in some proximity in time to the accident. The first event was chosen to be the start of the shift of the two workers, and the end event was the notification of emergency response team (ambulance). The actors in the STEP workflow sheet are identified as the two operators (O1 and O2), and the workboat (WB). An excerpt of the STEP diagram can be seen in Figure 1.

[†] These documents are confidential and the accident has to some extent been generalized to avoid revealing sensitive information. Please contact the authors for more information.

**Figure 1: STEP diagram of the accident**




From the flowchart, safety problems are identified by analyzing the event pairs, which is marked in Figure 1 with diamond-squares. The capsizing is marked with a star. Problems identified:

- The loading of the fodder sacks

It is not obvious from the flow chart that the loading of the fodder sacks was a direct cause to the capsizing of the ship. It is, however, part of the changes leading to capsize, and one cannot neglect the possibility of a relation. In hindsight it has been difficult for the involved operators to identify exactly how many fodder sacks that were loaded onto the boat, and where on the deck they were placed. Only four sacks of fodder were found when heaving the sunken boat, while 12 sacks was claimed to be loaded on board. A preliminary analysis performed by a research institute after the accident identified the amount and the height of the fodder sacks due to stacking as a factor likely to have negatively influenced the stability of the boat. The operators were not sufficiently trained to understand which factors that influence a vessel's stability, and they had no available documentation on how to load the workboat in order to maintain the stability.

- Observation of heeling

The operators had no technical aids onboard that notified the intake of water. The first observation of heeling was made by operator 1 as he looked at the horizon; while operator 2 did not notice this change. Operator 1 explains that he had to climb on top of a fodder sack to see the water on the aft deck. Any technical aid monitoring the heeling of the workboat, or sensors and alarms that can notify water levels on the workboat could have prevented the operators from leaving quay with an unstable boat, or at least alarmed the change in stability earlier.

- Water on deck

The water on deck is the first obvious symptom of the following capsizing event in the accident sequence. The accident sequence in the STEP flowchart cannot identify any technical reason for why the boat started to take in water, however, as stated earlier the accident analysis suggests stability problems due to the placement of fodder sacks and intake of water due to negative trim. This again suggests that the workboat had openings in the hull permitting water to enter.

- Speeds up

After turning the boat, operator 1 speeds up to get faster back to the quay. In hindsight, this has been identified as a reason that might have contributed to the fast capsizing of the boat, as the ship then could have been pressed lower into the sea, and thus taking in water faster. This phenomenon should be taught to workboat operators.

- Capsizing

According to the operators, the time from discovering water on deck until the capsizing was a fact, was very short. The workboat was a catamaran which is a vessel design known to have a good initial stability, but which may lose its stability quickly if there is water below deck and the freeboard is lost. This might implicate that there is a need for some technical safety barriers like safety bulkheads to prevent distribution of water inside the hull.

- Procedures for man over board (MOB)/Personal Protective Equipment (PPE)

Both operators wore thermal suits and life vests, which is company standard for working at sea. None of the operators had time to put on the immersion suits available in the workboat. There was a life raft on top of the wheel house, but this was not released when hitting the water, and was still attached to the boat when it was raised after the accident. Obviously, the routines for regular maintenance and function checks of the safety equipment should be reviewed by the company.

These above safety related issues are not in themselves answers to why the accident happened. They do, however, highlight which areas could be further investigated to find more concrete mitigating solutions into prevention of similar accidents.

### 3.3. Causal Analysis based on STAMP

The systemic accident model to be applied in this paper is STAMP (Systems-Theoretic Accident Model and Process) [21]. Systems are here viewed as interrelated components that are kept in a state of dynamic equilibrium by feedback loops of information and control [19]. The most basic component of the model is constraints, as control is always associated with the imposition of constraints. Control loops and process models are essential parts of systems quality functions, and these are also in the core of the STAMP model where different modes of inadequacies will provide for answers as to how a system failed in the path towards an accident. [21] presents a causality model used in accident or incidents analysis named CAST (Causal Analysis based on STAMP). The CAST framework does not aim to appoint blame, but rather to analyze the sociotechnical system design to identify weakness and to find changes that will eliminate not only symptoms but also causal factors. In STAMP there is no root cause, but inadequate safety control structure. The time aspect should be large as adaptions and changes in the system can be a contributing cause for accident.

The first step of using STAMP for accident analysis is to identify the systems and hazards involved in the loss. [22] defines a hazard as a system state or set of conditions that, together with a particular set of worst case environmental conditions, will lead to an accident or loss. Hazards should be identified at systems level first, and then decomposed into lower level hazards if needed. For all of the hazards identified system-level safety requirements and design constraints should be found. With this information as background material, the system safety control structure should be constructed as it was designed to work. The control structures are made up of components and their responsibilities, in addition to the control actions and feedback loops of a standard control loop (controlled process, sensors, controller and actuators*)*. Starting from the physical process and working up the levels of control, a STAMP analysis examines each level for the flaws in the process at the level that provided inadequate control of safety in the process level below. The process flaws at each level are then examined and explained in terms of a potential mismatch in models between the controller's model of the process and the real process, incorrect design of the control algorithm, lack of coordination among the control activities, deficiencies in the reference channel and deficiencies in the feedback of monitoring channel. For human decision making analysis must involve information about the context, information available and not available. When the system have been analyzed for flaws in the control loops, any coordination and communication deficiencies should be examined. Coordination of tasks is especially important whenever there are two or more components or actors with the same responsibility, and conflicting objectives concerning control coordination which is a major risk for unsafe behavior should be considered. When the above mentioned steps have been conducted for all levels of the sociotechnical system, recommendations for improvements can be suggested on the basis of the analysis. There is no algorithm on how to generate recommendations as political and situational factors always will be involved in these decisions [21]

3.3.1 Applying CAST

The first step of applying CAST for accident investigation is defining the system hazard(s) and constraint(s). [22] defines a hazard as a system state or set of conditions that, together with a particular set of worst case environmental conditions, will lead to an accident or loss. In the accident analyzed it is the safety of the fish farming workboat, and its loss of buoyancy that is the hazard to control. Constraints related to this can be identified as keeping sufficient freeboard and prevent water filling.

The control structure is seen in Figure 2, where the analysis stops above company management. It is possible to continue the analysis to the top level of the sociotechnical system, the government. The squares represents components and the arrows between the components represent control actions and feedback loops, an explanation of constraints and feedback of the loops is found in Table 1. Loop 1 illustrates the interaction between the operators and the workboat. Loop 2 portrays the hand-over of the workboat from the fish farm where the workboat previously had been used (Fish Farm 2) to the fish farm where the accident happened. This hand-over happened the day before the accident. Loop 3 is the interaction between the operators and the closest management level, Operations management, and loop 4 is the interaction between the Operations management and the top management level, Company management. Loop 5 portrays the interaction between the acquired companies through which the work boat came into company possession. This happened some years prior to the accident, but is relevant to the control structure as it can contribute to understanding why there was very little knowledge and documentation on loading capacities and stability in the company when the accident happened.

**Table 1: Constraints and feedback of control loops**

| **Control loop** | **Higher level** | **Lower level** | **Constraints/control** | **Feedback** |
|---|---|---|---|---|
| 1 | Operators Fish farm 1 | Workboat | Loading | Response |
| 2 | Operators Fish farm 2 (same level) | Operators Fish farm 1 (same level) | Informal exchange/request of information the workboat changed operators/location | Informal exchange of information when the workboat changed operators/location |
| 3 | Operations management | Operators Fish farm 1 | Procedures, Training requirements, Planning | Deviation reporting, Experience feedback, Change requests |
| 4 | Company management | Operations management | Policy, Resources | Reports |
| 5 | Company management | Acquired company | Information request on acquired workboat | Documentation of workboat history etc. |

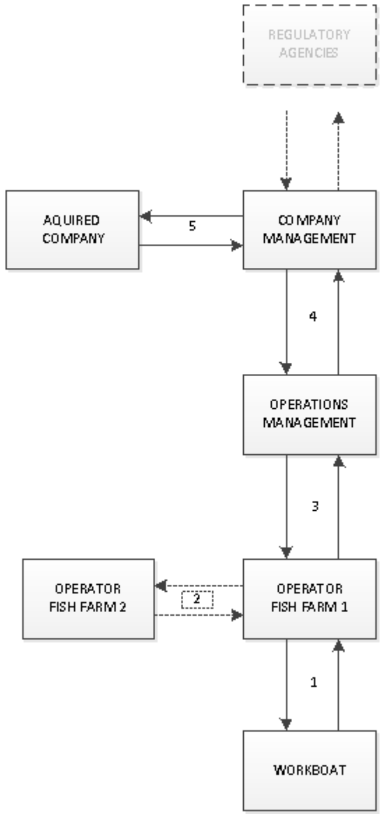
The next step of CAST is to examine the physical process relating to the event. This would comprise of a thorough analysis of the ship and its functions. A preliminary analysis of the workboat have been conducted by a consultancy company, however, as there is no documentation on the workboats capacities and measurements, the boat must be further investigated onshore to understand the physical processes of what happened when the ship sank. Each control loop should then be investigated for flaws in control, as an example control loop 1 will be closer examined, see Table 2. In this loop, two operators have been included at the “Fish farm” level, the shift leader and a new operator working his first shift.

**Table 2: Control flaws of control loop 1**

| | **Control flaws** |
|---|---|
| Safety related responsibility | Keep control over workboat<br>Correctly load the workboat with sacks of fodder<br>Shift leader had the responsibility of guiding the new employee |
| Context | Shift leader had one year of experience working on fish farms<br>Shift leader had only limited knowledge of the workboat<br>Shift leader had more knowledge from a similar work boat with larger capacity<br>New operator had his first day at work, no previous experience from fish farming<br>New operator had some experience from fishing<br>Shift started at 0300 night, dark outside |
| Unsafe Decisions and Control Actions | Loads fodder sacks on workboat without adequate knowledge on how to load the workboat to maintain stability and freeboard<br>Noticed water on deck too late?<br>Sped up workboat to reach quay increases intake of water? |
| Process Model Flaws | There is no formal procedure on how to load the workboat, operators on a neighboring fish farm has through experience learned how the workboat must be loaded<br>There is no technical aids to monitor stability of the workboat<br>Shift leader had no formal training that should allow him to predict the stability loss of the work boat |

Last, the system should be examined for coordination and communication problems. Some communication issues can, be pinpointed by the available information. The history of the workboat in question seems to be adverse as, included the aforesaid accident, four incidents of sinking have been recorded for the workboat. of these events happened when the boat was owned by the current company, and information on the other sinking incident is a part of the very limited documentation that was handed over during takeover. The current company management describes a generally chaotic situation during takeover where very little documentation followed. Furthermore, at the time when the workboat was built this vessel category had no mandatory requirement by the maritime authorities to test and document stability and loading capacities. This is why there was no documentation on loading or stability capacities of the workboat in the current company. This led to a situation where the company relies on informal communication channels to deliver information on loading capacity from operator to operators. This was also what happened when the workboat was handed over from the previous fish farm the day before the accident.

**Figure 2: CAST control structure**




## 4. DISCUSSION

An advantage of using accident models for investigating accidents is that they provide a systematic approach for collecting and examining information about the accident. It also helps finding relevant questions to pose during an investigation. Using both methods to model this accident raised several questions that were not covered in the original accident investigation. However, where STEP is a method where interview techniques and self-evaluation can be consulted in [22] the CAST framework does not claim to be an accident investigation technique, but only a way to document and analyze the results of an accident investigations process [21]. This might, however, be the only point at which the STEP method takes a more holistic approach than CAST. The main focus of STEP is to portray the close events leading up to the accident; thus, several relevant aspects are lost. For example, the time limit in STEP leads to a focus away from latent conditions in the system that contributed to the accident. There is no integration of these factors in the model, and they must be included separately when analyzing the safety problems through the STEP chart. The latent conditions are, however, not excluded from the analysis, because some of these will naturally come up during an investigation, but there is no guidance provided as to how to find such conditions or how to use them in analysis. Other factors that get less focus in the STEP method are questions aiming to find out why actors acted as they did, higher level decisions, feedback mechanisms, coordination problems and other organizational, social and human factors. These factors can be identified in the STEP model and [23] identifies STEP as an accident model suited for analyzing events influenced by the regulators and the government. However, the inclusion of these factors is more arbitrary than for CAST. Also, when identifying problem areas using STEP, there is a sense of blame in all the identified areas as the problems identified are connected to events, which again are connected to actors. The goal of CAST is to avoid pointing blame, especially to those in the lower part of the hierarchical system and often closest to the actual loss events [21]. CAST enables us to look for reasons why the operators acted as they did, as it gives larger focus to the context in which the decisions are made and to process model flaws on which the operators not necessarily have any influence. An advantage of the STEP model is its simplicity and lucidness. CAST is much more complicated to use, and it does not capture the essence of the model in its graphic form to the same degree as the STEP chart does. The use of these two models support the view that the choice of accident model can to a certain extent determine the results of the investigation. In [24] several accident investigation manuals were analyzed and the author found that since the accident models used in the manuals all took an epidemiologic accident model approach, they all lost certain aspects that would have been covered by a systemic approach. This phenomenon is named "what you look for is what you find" (WYLFIWYF). Also, this will affect any further remedial actions after an investigation as "what you find is what you fix" (WYFIWYF).

The two accident models applied are based on different assumptions for accident mechanisms. Hence, they will provide different feedback for improvement of the system. [13] gives two important theories to a well-functioning safety management system based on feedback; the Van Court Hares hierarchy of order of feedback and Ashbys law of requisite variety. Van Court Hare distinguishes between different orders or levels of feedback, where the lowest level of feedback is no feedback, leading to a "quick fix" of a problem at operator level, with no feedback to higher organizational levels. The level of feedback then goes through foremen, middle management, president and staff and ending with the highest level, the board of directors. These levels consequently leave us with the possibility of changes in the systems according to the decision power of the different organizational levels, where the most fundamental change is possible at the level of board of directors with a change in safety policy and goals [13]. Ashbys law of requisite variety states "For an analyst to gain control over a system, he must be able to take at least as many distinct actions, i.e., as great a variety of countermeasures, as the observed system can exhibit". Kjellén states that one way of increasing variety in possible measures is to" train the organization to conduct more comprehensive accident investigation". These requirements to a safety system could also be applied to the case of accident investigations and accident models; a more in depth and holistic perspective on accident causation could give a more appropriate set of tools in future prevention of accidents.

## 5. CONCLUSION

This paper analyses an accident in the aquaculture industry using two different accident models, namely STEP and CAST. The accident occurred onboard a workboat, where the consequences included loss of the workboat and a potentially fatal situation for two operators having to swim to shore. STEP provides an easy to understand flow chart over the accident sequence and helps pinpoint six areas where further investigation could contribute to understand why the accidents happen, and possibly could have prevented the accident if they had not occurred. The focus of this method was mainly on the workboat itself and the operators manning the workboat. CAST, which is based on a systemic accident model, takes a wider approach to accident modelling and is also more comprehensive. Areas of risk management improvements are thus identified also at higher levels of the sociotechnical system in the company, e.g. the need for procedures assuring that all relevant documentation on old workboats is gathered, and that crucial information in some cases relies on informal distribution channels in the company. Also, in this paper, only a small part of the comprehensive CAST framework have been explored. Further analysis in the higher levels of the sociotechnical system of the accident could provide for even higher level improvements measures.

All industries go through different stages of appointing accident causation to different factors. Technical measures, human factors and organizational factors have all been the focus of causation in different eras and accident models. The three perspectives should not replace each other, but should be seen as complimentary [11]. Accident investigation in the aquaculture industry should reflect this view, and through investigating accidents from several perspectives we can learn more about the accident mechanisms in the industry, but also more about the industry itself, beyond the direct causes of the accident.

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