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Information flow and knowledge transfer of accident investigation results in the Norwegian construction industry

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ABSTRACT: This paper examines the information flow of accident investigation results in the construction industry, and how this affects learning processes. The aim is to document the state-of-the art in the industry on information flow that follow accident investigations, and to find how accident investigation results better can be learned from and used as input for proactive safety management. A literature review was undertaken on the relation between accidents and learning. An interview study was undertaken with different actors (clients, contractors and consulting engineers) in the construction industry on accident investigations and information flow of accident investigation results. The preliminary results from the interviews are presented. Mostly, results after accident investigations are shared within a company, and there is no systematic sharing of information between companies, other than occasional sharing. Further research needs on information sharing after accident investigations are discussed.

1 INTRODUCTION

The construction industry is a complex industry, with constantly changing processes and activities, several actors involved that depend on each other, and external factors, such as state of the market, that affect construction projects.

Just as the industry varies a lot in terms of company sizes, sizes of construction sites, resources available, and competence and experience of managers and workers, so are accident investigations and the results of them influenced by these characteristics and conditions.

The aim of this research is to look closer at safety in the construction industry, by studying the processes after accident investigations, which are meant to accommodate for learning processes and prevention of future accidents.

This paper presents preliminary results of research concerning the results of and the information flow after accident investigations, as it is a prerequisite for the learning processes.

2 BACKGROUND

2.1 *The complexity of the construction industry*

A construction project can be many things; a small cottage to be built, a highway, a tunnel or a skyscraper. "The construction of a building can be regarded as a complex, information dependent, prototype production process were conception, design and production phases are compressed, concurrent and highly interdepended in an environment where there exists a usually large number of internal and external uncertainties" (Pryke, 2012, p.64). This shows how the construction industry varies with regards to project size and durability, company size, contract models and so on. According to Lingard and Rowlinson (2005, p. 3) the project structure which companies in the construction industry operate in, is an important characteristic that challenges the safety work in the industry. Each project site is different, forming a new, temporary organisation. There are large circulations of personnel; some come in for as shorts as a day, others stay for the whole project period. Further, construction projects are operating in an ever-changing environment largely influenced by the state of the marked. All these variations are influencing how safety work is being implemented and executed in the daily life of construction projects.

The socio-technical system involved in risk management by Rasmussen (1997), illustrates the different levels that will influence the safety in the sharp end. The model includes environmental stressors that can influence the different levels that again can influence the overall safety.

Further early project phases can affect the next phases, i.e. decisions in early phases of projects can influence the safety during construction. Therefore, it is important to look at the whole range of actors involved in the project not only during the construction phase, but also in earlier phases.

2.2 *The construction industry in Norway*

The Norwegian construction industry was employing almost 235 000 people in 2016, and the industry comprised of more than 57 000 enterprises, of which approximately 90% had 0–9 employees, and around 1% had more than 50 employees (SSB, 2017a).

The industry is one of the industries with the highest number of work related fatalities and injuries on mainland Norway. Between 2010–2015, there was in total 69 fatalities related to construction work, i.e. close to 12 fatalities per year (NLIA, 2016). Most of the fatal accidents involve falls, followed by collisions, being hit by an object or being crushed or trapped.

In 2016, there were 9 fatalities and more than 2700 reported injuries in the construction industry (SSB, 2017b). More than half of these resulted in long term absence (more than three days' absence from work). The most frequent types of accidents resulting in serious injuries were: fall from roof/ floor/ platform, fall from scaffolding, contact with a falling object, contact with moving parts of machine, being hit by an object in a lifting operation, fall from ladder, and fall from height when unsecured (NLIA, 2017).

2.3 *Incident reporting and accident investigations*

Incident and accident reporting is an important tool for accident understanding, and thus learning and future accident prevention. Incidents and accidents should be reported and investigated internally to prevent them from reoccurring (Lingard & Rowlinson, 2005, p.163–164), and in some cases also investigated externally (e.g. incident with high or potentially high consequences).

According to the Working Environment Act §5–2 (2005) in Norway, employers are obligated to report accidents with fatal or serious outcome to the Norwegian Labour Inspection Authority (NLIA) or the Police. Nearly all fatalities are reported, however in the "serious injury" category there are still unrecorded numbers (NLIA, 2015a). NLIA conduct inspections after all fatal accidents (NLIA, 2015b), but less severe accidents are not examined as closely as accidents with severe outcome.

2.4 *Learning from accidents*

Learning from accidents is one of the goals with accident investigations, both to prevent similar accidents to reoccur, and to prevent other accidents.

Learning can refer to either a product or a process, respectively something learned and the activity of learning (Argyris and Schön, 1996, p. 3). In relation to construction safety, the product can be accident understanding, which is one of the products after an accident investigation. To improve the safety and avoid similar accidents from reoccurring, the knowledge obtained needs to be applied. However, taking actions might require major changes (e.g. cultural and behavioural) (Love et al., 2013), which in practice can be challenging and will require designated resources in a company. Correct actions taken after accidents, show the results of learning in practice, by applying the obtained knowledge. This takes learning one step further towards improvement.

Organisational learning can be divided in two types of learning. Single-loop learning refers to learning that results in changes of action so that the outcome is desired. It does not change the "theory of action" (Argyris and Schön, 1996, p.20), meaning that the focus is only on the symptoms of the problem, and not the underlying cause. Therefore, this is a lower level of learning. Double-loop learning on the other hand, focuses on changes "in values in theory in use" (Argyris and Schön, 1996, p.21), meaning that it goes deeper into the root causes of the problem.

Organisation size, complexity, and number of levels in the organisation are factors affecting what type of organisational learning (single or double-loop) learning results in (Argyris and Schön, 1996, p. 25–26).

3 METHODOLOGY

3.1 *Literature review*

A literature review was undertaken to get an overview of literature treating the relation between accidents and learning. The focus was on the construction industry, however papers discussing other industries were also looked at to find good examples and general knowledge about the topics of safety and learning.

Searches for literature were made in the following databases: Scopus, Googles Scholar and Oria. The search strings used were: accidents, learning, and construction. Searches were made both on two of the words at a time, and on all three at the same time.

In Scopus, the review was undertaken in a systematic way, which means it is a replicable, scientific and transparent process (Bryman, 2012, p.102). The search using "accidents" and "learning" as search string resulted in 4,983 results. From the 4,983 documents found from 1930–2017, the majority is published in the 2000s. After round of sorting out, first based on titles and years, then on abstracts, in total 34 articles were found as the most relevant concerning different fields, however not all were accessible.

The aim of the literature review was to get a background for the data collection.

3.2 *Interviews*

The first round of interviews was undertaken with actors in the Norwegian construction industry on information flow and knowledge transfer after accident investigations.

An interview guide was made with the following topics: general introduction, procedures for accident investigations, results of accident investigations, information flow, learning arenas, improvement potential and closing questions. The questions in the interview guide were adjusted to the three different actors (clients, contractors and consulting engineers).

In total 13 interviews with 19 persons responsible for Health, Safety and Environment (HSE) at clients, contractors and consulting engineers were undertaken. Table 1 presents an overview of the interviewees.

All the interviewed companies are large, professional companies that are well established in the Norwegian construction industry.

Interviewees were recruited through convenience selection, through contact persons in the industry. Further selection of interviewees will be done strategically to cover the construction industry widely.

The interviews were conducted between October 2017 and January 2018. Each interview took from 30–80 minutes. Most of the interviews took about an hour. Eight of the interviews were conducted in person, and five over phone. All the interviews except one, were recorded and transcribed. For the one that was not recorded, detailed notes were taken. The interviews were transcribed in NVivo, and coded according to the interview guide. Additionally, new codes were created while going through the data. A first, preliminary review of the data was done, resulting in main topics for discussion.

3.3 *Methodological considerations*

This research only comprises of a smaller sample of interviews and the preliminary results from these. To get a more general picture of the state-of-the art of the whole industry, more interviews will be undertaken, and preferably other methods should be used as well (e.g. questionnaire).

Table 1. Overview of interviewees.

Actors	Interviews	Documentation
Clients	2 interviews	1 company
Contractors	8 interviews^	3 companies
Consulting Eng.	3 interviews*	1 industry association

^one group interview with three interviewees.
*one group interview with representatives from five companies.

4 FINDINGS

4.1 *Accident investigations in practice*

The research shows that there are large variations when it comes to accident investigation practices between companies (within different actors) in the construction industry, and also between different projects within a company. The variations concern both resources available, investigation competence and investigations execution (i.e. methods used). Companies have their own criteria for when and how investigations should be performed, also these vary between the companies.

Mostly the accident investigations are undertaken separately by different actors, however interviews are conducted with persons in different companies during the investigations if it is relevant for the investigation. This results in separate investigations at clients, contractors and sub-contractor if more of the actors are deciding to undertake an investigation.

The consulting engineers reported that they are usually not involved in accident investigations, unless the unwanted event is directly caused by a calculation error performed by them.

Some companies use external parties to undertake investigations, others mainly perform internal investigations. It was also reported by one interviewee at a client, that they sometimes have to request contractors in order for the contractors to perform accident investigations.

Competence was seen as a success factor for performing good investigations However, the research shows that the knowledge and experience of HSE-managers about accident investigations varies. It was pointed out by the interviewees that methods and tools to be used for accident investigations should be pre-defined, and the methods and tools should be easy to use to ensure that the investigations can start quickly after the accident, and in order to conduct the investigations in a good way to obtain learning. Some of the HSE-mangers found this to be unclear in their company. One of the interviewees stated that it is important to go deeply into the causes to prevent future accidents:

> *"The most important thing is the learning one can get out of accident investigations. That must be the main goal. If you really manage to uncover the root causes, that is when you have the opportunity to prevent the same from happening again. That must be the foremost goal." (HSE-manager, contractor).*

Further, some of the HSE-managers reported that the roles and responsibilities in terms of who is responsible for the accident investigations and follow-up of it in the projects and in the companies, are sometimes unclear.

4.2 *Results of accident investigations*

The results of the accident investigations included investigation reports, learning sheets and changes of procedures. One of the companies had put together experiences from several accidents into a short film. Most companies finalise accident investigation with an investigation report. The reports vary between companies in size and content.

Learning sheets, which are short one page summaries of accidents, have started to become increasingly popular. The drawback that was pointed out with these by some of the interviewees, is that they do not go deeply into the causes and are more like event descriptions. Further, some remarked that the focus on these learning sheets as an answer to the challenge of learning and knowledge transfer is too large.

> *"Generally, I think that there is a large focus on learning sheets and sharing of learning sheets, as if they solve everything. I think perhaps it is somewhat too much focus on only this one solution" (HSE-manager, contractor).*

4.3 *Information flow of the accident investigation results*

The results of the investigations are mainly distributed within the company which undertakes the investigation. Some companies have systems for sharing results after accident investigations within the company, such as management systems, procedures, and best practice databases.

Information sharing across companies is even lesser systematised. There are no automatic mechanisms for sharing results between companies. In one contracting company, it was reported that if the unwanted event happened at a sub-contractor, and the main contractor or client investigated the event, the sub-contractor would have to request the report in order to get it. In the same way, the NLIA can request access to investigation reports from companies. It was also reported that the NLIA sometimes requests companies to make investigation reports. However, it was mentioned that this could affect what the companies put into the report, as they would not want to face additional consequences.

Further, "breakfast-meetings" that some companies hold after accidents, were perceived as very good knowledge sharing arenas across companies. At such breakfast-meetings, a company shares experiences from an accident they think the industry as a whole can learn from. These meetings are held rather seldom, and are suited only for certain types of incidents, e.g. general activities that resulted in an accident or near accident, and where good measures to prevent this type accidents are found.

Another arena for information sharing that was mentioned by several of the interviewees, were workshops held by the NLIA. These workshops were perceived as a good for knowledge sharing. Additionally, HSE-conferences (e.g. SHA-dagene, HMS-konferansen) were other examples of knowledge sharing arenas. These are large conferences that occur yearly, which mostly mangers with exceptions attend. However, not all the interviewees were aware of these arenas, and it was pointed out that the events are occasional.

How information is shared between companies, is in large degree steered by the systems within the companies, and the contracts between companies. It was also mentioned that a client or a main contractor can put requirements regarding incident and accident reporting into contracts to easier obtain safety information from projects.

4.4 *Utilisation of accident investigation results*

Experiences of the interviewees show that investigation competence in the investigation team is important for the outcome of accident investigation. Further, the team compositions regarding the members´ role in the event is also important, so the persons are not too closely related to events or persons affected in the event. The members of the team should not have a conflict of interest with the investigation.

Further, it was mentioned by the interviewees that certain events are better suited to learn and share knowledge from than others. The outcome or consequence of the event (e.g. fatality, serious injury etc.) in large degree influence how the results are used further. In cases where the events result in police investigations and legal proceedings, there can be resistance that will be of disadvantage for the results and for the learning process. Especially, near-misses and high potential incidents (HIPOs) which have not become police cases are good to learn from, as the question of guilt in larger degree is eliminated.

Several of the interviewees mentioned the question of guilt as a factor that impede knowledge sharing, as this concerns the reputation of the company, future projects as well as compensations for injuries.

Further, it was mentioned that it can be challenging to share information in cases of serious

injuries where police investigations are undertaken, as these often take long time. This leads to the company accident investigation report being held back and thus delayed, also delaying the learning processes.

5 DISCUSSION

5.1 *Deficits with accident investigations*

To be able to learn from something that has happened, information about what happened and why it happened is needed. Accident investigations are important to gain this information. Gibb et al. (2014) highlight the importance of going in depth into accidents and finding underlying causes of accidents for a good learning outcomes.

In the construction industry in Norway there are no standardised methods to investigate accidents. Accidents largely vary when it comes to type, size and severity, and different accidents may therefore require different types of investigations. One important issue to research in relation to accidents is how accidents are selected for investigation (Lindberg et al., 2010). The criteria for investigating accidents and the degree of investigations vary between companies, and even between projects within a company. This is a challenge when it comes to learning after accidents, as the investigations vary and thus give different foundations for further work with safety.

The quality of accident investigation results is in large degree dependent on the investigation team; their relation to the accident and to the company, knowledge about the industry, investigation knowledge and experience. The knowledge and the experience of the responsible persons in the companies varies as seen in the interviews undertaken, and this affects the outcomes of the investigations. Le Coze (2013) highlights the importance of expertise on accident models, to apply them in proper way. This was also states by some of the interviewees.

Further, as mentioned, the construction industry is characterised by having many actors, many phases, and constant progress and changes in the projects. The cooperation between levels of actors, between different phases of construction projects, between companies in the same phase performing different operations, and between operations within a company is important for good safety. From what is seen in the interviews, there is not much cooperation on accident investigation between companies that are involved in an unwanted event. Mostly, the investigations are performed separately between companies if more companies are undertaking investigations. The weakness with this is that important viewpoints and the causes behind the event can be overseen, due to lack of specialised knowledge (e.g. when consulting engineers are not involved), but also that other involved companies do not get access or ownership of the investigation results and measures suggested in the investigation report to prevent future similar accidents. Lundberg et al. (2009) write in their paper about WYLFIWYF (What You Look For Is What You Find), which shows the importance of using several perspectives in accident investigations, weather it is accident models, methodologies or specialists.

If the aim of the investigation is also to learn from what has happened, the learning perspective should also be integrated into the investigation, to provide for information that will lay the groundwork for learning.

5.2 *Knowledge transfer as a premise for learning*

Nonaka and Takeuchi (1995) describe knowledge as different from information as it is about beliefs, commitment and actions. Both have in common that they are about meaning. Simply said: *"Information is a flow of messages, while knowledge is created by that very flow of information, anchored in the beliefs and commitment of its holder"* (Nonaka and Takeuchi, 1995).

After accident investigations, the knowledge obtained needs to be shared if learning from previous accidents is the goal. The importance of how this knowledge is shared for learning is also highlighted by Lindberg et al. (2010). Drupsteen and Guldenmund (2014) point out that there often are limited processes to follow-up learning after accidents, and that such knowledge is often shared through one-way communication, which does not encourage interaction and thus learning processes. The findings of the current research are similar; uncertainties about who should follow-up the accidents were found, as well as examples of one way dissemination of accident investigation results (e.g. learning-sheets).

Further, the way information is shared is another challenge in the industry seen from the interviews. Internally, companies might have some systems or ways to share information, however they are not necessarily good enough to share information with all levels in the company. Within companies, results are often shared though learning sheets. These are meant as an information sharing arena for all levels in the company; from the top to the sharp end. However, different users require different degrees of details of the information. In example, for other HSE-managers, the information which is on the learning sheets might be too vague to be useful for safety work.

One further deficit as the research shows, is that this information and knowledge is not in large scale shared across companies. A good platform

for sharing information across the industry is missing, even though there are a few conferences and other smaller arenas where some experiences can be shared. A knowledge sharing platform can be one solution for sharing information and experiences across companies in the industry, e.g. a common database. An accident data base could be used to collect all severe accidents in the construction industry. Accidents with a potentially serious outcome also need to be registered. Having set criteria for systemising the accident types, causes and possible use would be useful for the user of such a database.

The knowledge from the investigations can serve several purposes such as input for risk assessments, decision making and to create awareness about important circumstances that can affect safety. To make use of such information companies and the industry need to have certain tools available. Information needs to be shared internally in the company, and externally for the whole industry to improve.

Lingard and Rowlinson (2005, p.366) write that learning from past accidents is important for safety management, and in an organisational context an incident information systems must be available to collect, analyse and create preventive measure. However, only having system is not enough according to them. It is also important to be aware of how the organisation is currently running, and having a vision for the desired safety work and performance, the management's safety focus and safety work being an integrated part of the operations is highlighted.

5.3 *Learning*

According to Nonaka and Takeuchi (1995) learning can be looked at as a dynamic spiral, between the two learning loops that Argyris and Schön (1978) describe. The spiral goes between tacit and explicit knowledge and from explicit to tacit through four phases. The spiral goes on as *"organisational knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge"* (Nonaka and Takeuchi, 1995, p. 70).

Lingard and Rowlinson (2005, p.365) highlight the need for collective learning in the construction industry and the current lack of this. They write that similar accidents reoccur in the industry across countries, and yet the industry does not manage to improve the occupational safety enough.

In relation to the construction industry and safe-ty, it is therefore important to acknowledge the individuals in the organisation when creating and implementing measures for accident prevention. In the same manner, during accident investigations, tacit knowledge should be a part of the information foundation in an investigation, as when it goes back as learning points.

Drupsteen and Guldenmund (2014) point out that it is hard to identify organisational factors and managerial weaknesses that are root causes of events, which limit the possibility of double-loop learning. Le Coze (2013) suggest more cross-disciplinary research on learning from accidents. This shows the need for more research on the topic, and combining different topics together.

5.4 *Input for safety management*

Which results that can be used from an accident investigations for proactive safety management, depend on the type of accident, the outcome of the investigation as well as the way the information it is shared. It is suggested to make specifications and criteria related to characteristics of accidents (e.g. types of accidents, causes, processes) in order to decide what learning purposes they can serve.

Results of accident investigations can in example be used as input for proactive safety management, e.g. in the Safety Management System (SMS) of a company, and as an input in building information models (BIM) which can include early phase actors (i.e. consulting engineers) in the learning loop. One of the challenges for consulting engineers when it comes to occupational safety during construction, is that they in small scale get feedback if their solutions could be executed safely in practice by construction workers. By using new solutions and tools (e.g. digital solutions), these actors could easier be involved in occupational safety work.

The results can also be adapted to serve safety purposes in different processes during a construction project. Procurement processes both in early phases of a project as well during construction put a foundation and boundaries for safety. It is important to transfer knowledge also to these processes from accident investigations, to reduce the safety risks during construction.

5.5 *Coping with the diversity of actors*

The industry is, as mentioned before, diverse and numerous actors are involved in construction projects. This diversity pose a challenge in relation to learning, as different actors have different needs and requirements. This means that adaptation is required when it comes to ways of sharing knowledge and learning. A flow of information is required both between the different levels, and at each of the levels.

To analyse this diversity of actors and activities Pryke (2012) suggests a graphical representation and a social network analysis of how the specific actors and activities are related. Such an analysis

could be linked to safety management. Mapping the relations and information flows after accident investigations might give a better understanding of deficits in communication and knowledge sharing. The different actors in the actor chain in the construction industry, introduce boundaries and conditions that affect safety. A social network analysis can also be used to map other factors such as frame conditions (e.g. contract conditions) and how they affect different actors (Pryke, 2012).

Different actors have different roles in safety management, and this apply also for learning. By mapping relations in the construction network, information flow, finding out who has which needs, and who should facilitate whom, can help in knowledge transfer and learning.

It is suggested to perform a similar analysis as the social network analysis on safety information flow after accident investigations.

6 CONCLUSIONS

Preliminary findings of the research show the importance of coordination and cooperation between actors of construction projects. Accident investigations are important to avoid that similar accident reoccur, however there are elements that hinder knowledge transfer and learning from earlier accidents. Accident investigations in large degree vary between projects, clients and contractors. Often each actor performs individual investigations with limited sharing of the results across companies. Consulting engineers are rarely involved in investigations, unless the problem has clearly been related to calculations.

Having a good knowledge foundation, based on facts including root causes, is crucial to ensure that correct measures are taken after accidents and to enable learning. For this it is important with competence and experience of the investigation team. It was found that experience and knowledge about accident investigations of the HSE responsible persons in companies varies a lot.

To obtain learning after accident investigations, information must be shared. Certain types of accidents are more suitable for sharing and learning purposes, e.g. near misses and high potential incidents. It is suggested to make specifications and criteria related to characteristics of accidents for specific learning purposes.

Information sharing after accident investigations mostly happen within companies. Between companies, knowledge sharing and learning is not systemised and occurs occasionally, and tools to share information between companies are lacking.

The large diversity of actors in the industry challenges practices, information sharing and learning processes. To enable learning in the industry both across organisations and within organisations, there is a need to understand the different relations between actors, processes and needs. A social network analysis of the information flow of the results after accident investigations in the construction industry might help to find the deficits as well as the centre points of communication and relations between actors, that might enable knowledge transfer and learning.

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