The Application and Benefits of Job Safety Analysis

Abstract
The aim of the presented study is to investigate the practices and benefits of Job Safety Analysis (JSA) in construction projects. The study was performed by executing interviews at six construction projects; by observations of JSA meetings; and by a document study of 97 JSA forms. The study demonstrates that too many JSAs are performed for activities in which barriers and procedures should have been established prior to initiating the JSA. Although hazard control can be established on the basis of other methods than JSA, the method has other benefits in terms of safety as well as production. The study identifies six interwoven benefits of the JSA: formalisation of work; retrospective and prospective accountability; worker participation and possibility to influence their own work; organisational learning in communities of practice; improved situational awareness; and loss prevention in dynamic systems. These are benefits both in terms of safe and efficient operations, which underline the link between safety, quality and effectiveness.

Key words: job safety analysis; risk assessment; benefits; construction

Highlights
- Practices and benefits of Job Safety Analysis (JSA) is studied
- Six benefits in terms of safety as well as production are identified
- Too many JSAs are performed for activities that should be handled by other methods

1 Introduction
The construction industry is subject to a higher number of accidents than most other industries (Eurostat, 2016). Sharp-end operations are exposed to sources of high energies, entailing risks that must be managed by the use of appropriate plans, procedures and barriers established and implemented by clients, designers, construction companies and workers. There are several approaches aimed at hazard control in production in all project phases (project development, project design and planning, execution and procurement). Some of these approaches are risk-informed, i.e. insights from risk assessments are considered together with other insights on decision-making and actions. Risk assessments are performed and used for decision-making throughout the whole lifespan of a project. The client performs coarse risk assessments in its business development and feasibility study. During project development and design, designers perform risk assessments and develop construction plans and drawings intended to reduce the risk of accidents for both workers during the construction phase and subsequent users of the building or infrastructure. Before start-up and during production, the construction company performs risk assessments and prepares long-term and short-term plans to reduce risk for workers on the project. Job Safety Analysis (JSA) is a method

employed in the construction phase to assess risk, thereby supporting decisions that lead to safe operations.

A key principle in construction projects is that most risks should be mitigated as early as possible in a project's life span. Figure 1 (based on RIF, 2017) illustrates how risk is ideally reduced during the client, designer and contractor's planning and design processes. Despite employing risk management in the early project phases, there will always be a residual risk that needs to be handled during the construction phase. JSA is one method of dealing with this residual risk. The method should ideally be applied in situations where safety is not ensured by adherence to procedures or plans or by established barriers (Kjellén and Albrechtsen, 2017), i.e. for risks that are not dealt with in earlier stages of the construction project.

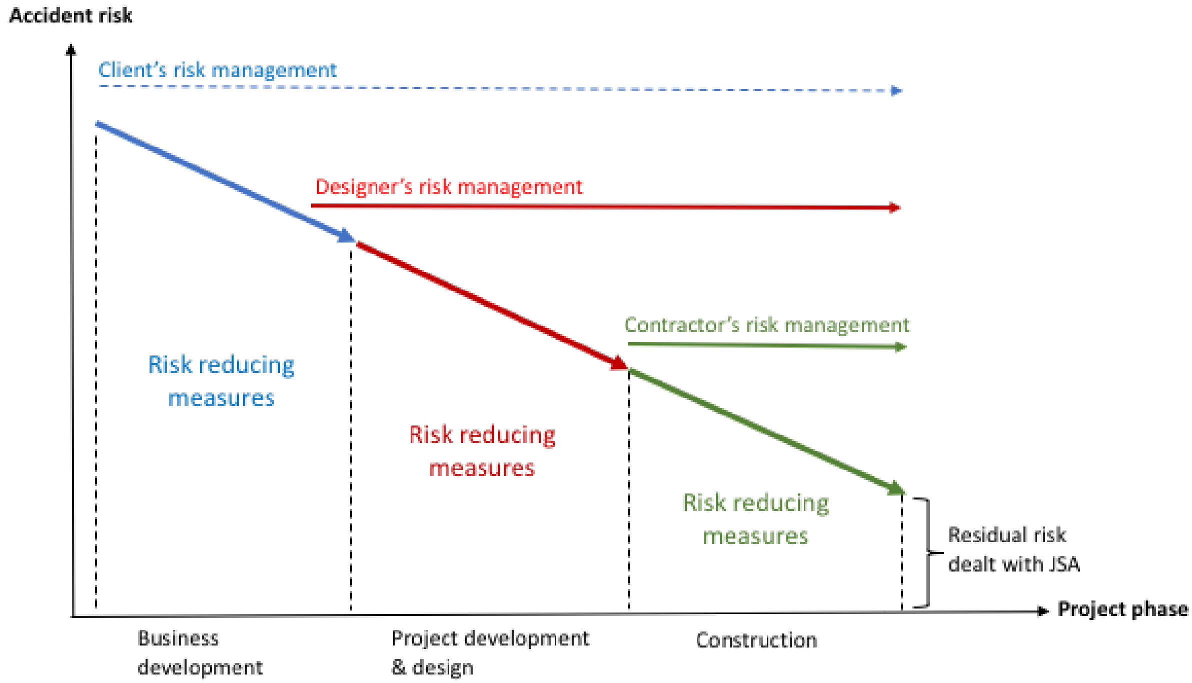

Figure 1: JSA's position in the project's overall risk management (figure based on RIF, 2017)

JSA, also called safe job analysis (SJA), job hazard analysis (JHA) and task hazard analysis (THA), is a qualitative risk assessment method (in some cases limited to hazard identification) for sharp-end operations, which systematically and incrementally considers all risks related to a specific work task. It follows the principles for risk assessment as described in ISO31000 Risk Management (2009) using a more simplified approach. The analysis is conducted in preparation of a defined work task, so that actions to eliminate and/or control the identified hazards can be implemented before the task is executed. The breakdown and analysis of sub-tasks in JSA is rooted in Taylor's (1911) Scientific Management and the principle of analysing, simplifying and optimising work tasks. According to Glenn (2011), Heinrich (1931) was the first author to use the term job safety analysis. The method was used in the American steel industry in the 1920s and 1930s to identify and manage hazards, including to fit the worker to the task (Glenn, 2011). JSA has evolved worldwide and become a popular method of establishing hazard control in many industries, including petroleum (Norwegian Oil and Gas Association, 2011); construction (Zhang et al., 2015); automation (Gopinath and Johansen, 2016); mining (Morrish, 2017) and shipyards (Zheng et al., 2017).

The aim of the study presented in this paper is to investigate the practices and benefits of JSA in a multiple case study of construction projects. Although JSA is embedded in safety practice, little attention is devoted to the rationale, development and use of the method (Glenn, 2011). Two studies are used to examine this issue: firstly, case studies (interviews, observation and document study) of six construction projects and secondly, a document study of a sample of JSAs from a construction company. The study is limited to the assessment process and corresponding results. How the results of the JSA are implemented and the evaluation of the effects of the measures are not included in the study. However, a study of the Australian construction industry shows that there is often a gap between work as imagined on the basis of the JSA results and work as performed in practice (Borys, 2012)

1.1 Job Safety Analysis (JSA)

The purpose of JSA is to identify and assess all risk elements associated with a task so that measures to eliminate and/or control the hazards can be implemented (Kjellén and Albrechtsen, 2017). Guidelines for JSA published by the Norwegian oil and gas industry association (2011) divides the JSA process into five main steps, which are presented briefly subsequently. There are several other similar frameworks for JSA (e.g. Swartz, 2002; OSHA, 2002; Rausand, 2011) that follow the same basic steps but that include different levels of detail in each step.

Step 1: Identifying the need for JSA

The first step identifies whether or not the job to be done requires a JSA. This means establishing criteria to determine the necessity of JSA, which will provide grounds for the decision to conduct one. According to Kjellén and Albrechtsen (2017) a JSA should be performed when there are:

- activities where hazards are present and are not adequately controlled by existing work procedures or barriers
- activities that require deviation from work prescribed by procedures or routines
- new work activities unknown to the workers performing them
- activities where the teams of workers are not familiar with each other
- activities that involve equipment with which the workers are unfamiliar
- activities where the preconditions change (e.g. weather conditions, new time schedule, changed order of sub-activities, new interactions with parallel operations)

Step 2: Preparation and planning

If a job requires a JSA, a person responsible for the JSA is elected to manage the process. The JSA manager establishes a JSA analysis team. A JSA team usually consists of a JSA manager, a safety representative, the work team leader and executing personnel (Rausand, 2011). The JSA manager and the team collects data and other relevant information for the analysis as part of the preparation.

Step 3: Performing the JSA

The JSA is performed through the following steps:

1. Decomposition of job: breaking down the job into functions, tasks and steps. The steps are listed and described in order
2. Hazard identification: Potential events and conditions that can lead to dangerous situations are identified for each sub-task identified in 2)

3. Potential consequences of the hazards identified in 3) are assessed
4. Expected frequency of occurrence for the hazards identified in 3) are assessed
5. An assessment of the risk for each sub-task is performed based on the assessed frequency and consequence, which is, in turn, assessed in relation to a risk matrix
6. Risk reduction measures that can help to improve safety for performing the work is identified for those sub-tasks that have an intolerable risk

A JSA form is used to document the JSA. The result of the JSA provides grounds for the decision on whether the risk of carrying out the job in a proper manner is acceptable enough to proceed.

Step 4: Implementation of measures and execution of the work
Before work can be carried out in accordance with the JSA, it is checked whether the prerequisites for the job are met and whether suggested measures have been implemented. If unforeseen factors or substantive changes in the work arise, the JSA must be updated and reassessed.

Step 5: Summary of experience of JSA
Evaluation of the work performed in relation to the JSA, performed by the JSA manager. This evaluation is important in order to make improvements the next time a JSA is conducted, and helps ensure a transfer of experience.

1.2 Literature review: merits and limitations of JSA

There are several merits of JSA as a method in systematic loss prevention (Glenn, 2011; Crutchfield and Rougthon, 2014). The main merit is better hazard control as well as more efficient work if the results of the JSA are appropriately applied. A study carried out by Zheng et al. (2017) demonstrates that a thorough JSA considerably reduces the number of recordable injuries. Roughton and Crutchfield (2008) and Yoon et al. (2011) point out that a major benefit of JSA is that it is a simple tool that helps to highlight the dangers of risky operations. Both managers and employees gain insight into task-specific hazards by performing a JSA. Another advantage of JSA is that the method is simple to use and is directly related to operative job tasks. By including the employees in the preparation of the analysis, their participation will promote greater ownership of the decisions taken, and better understanding of the safety of the work (Swartz, 2002; Rausand, 2011). Worker participation is essential for the quality of the analysis since those performing the job have valuable tacit knowledge about practice relevant to the job to be done. JSA also improves communication about safety between workers and managers (Roughton, 2003; Epstein, 2015). The JSA process gathers the team who are to perform the work activity, and the process thus not only makes plans for safety, but can also function as a planning tool for the efficiency and quality of the task to be performed.

Borys (2012) performed a study of safe work method statements, which are based on the results of a JSA carried out in the Australian construction industry. The study showed that 1) the method statements are important for hazard control, in particular tasks that are out of the ordinary; 2) the social interaction when making the method statement is important for safety; 3) gaps exists between work as imagined in the method statements and the work performed in practice. Saurin et al. (2008) demonstrated that pre-task planning among work team members, which has similarities to the JSA process, creates improved individual knowledge and awareness of hazards. An interview study of experts on construction safety by Hallowell and Gambatese (2009) demonstrates that JSA ranks the fourth most efficient safety management element for mitigation of accident risk. Upper management support, subcontractor selection and management and employee involvement were ranked above JSA. JSA is found to contribute to all three of the top-ranked elements, in particular involvement. Additionally, requiring JSA for certain tasks is an important tool for managing sub-contractors.

For larger and more complex tasks, JSA can become too simplistic (Rausand, 2011). For the construction industry in particular, Rozenfeld et al. (2010) point out that a challenge for the method is that it does not cover the dynamic nature of construction projects, e.g. change of work crews. The use of JSA requires resources in terms of time (Roughton and Crutchfield, 2008). It may thus cause resistance, and arguments such as "our employees know their job", the result being that the JSA is seldom used (Crutchfield and Roughton, 2014). Use of JSA can also meet resistance among managers and employees due to a belief that it is unnecessary to employ the method (Yoon et al., 2011).

2 Method

To investigate practices and benefits of JSA in the construction industry, the study employs a qualitative approach to JSA practices in construction projects. The qualitative study consisted of 23 interviews, 2 observations of JSA processes, and a document study comprising 97 JSA forms.

2.1 Interview study

A total of 23 interviews were conducted with informants working at different levels in the Norwegian construction industry, who could share their personal insights on JSA; see table 1. The interviews were carried out with informants from six different projects, divided equally between two construction companies.

All six projects were building projects, but they differed in relation to complexity, price and stage of the construction phase. JSA is a method applied in most construction projects. The purpose of the interview study was to examine the application and benefits of JSA on a general basis, and not related to the specific project. The characteristics of each individual project should thus not influence the results of the study. Nine of the interviewees represented the sharp end (including safety representatives and supervisors) and 11 interviewees represented the blunt end of projects (HSE managers, site managers and project managers).

Table 1: Studied projects and interview objects

	Construction company A				**Construction company B**				
	Project A	Project B	Project C	Other	Project D	Project E	Project F	Other	Total
Construction worker			1						1
Safety representative	1	1	1		1	1	1		6
Supervisor	1		1						2

HSE project manager						1	1		2
Site manager	1	1	1		1	1			5
Project manager	1	1			1	1			4
HSE manager, company level				2				1	3
Total	4	3	4	2	3	4	2	1	23

On average, the interviews lasted about 45 minutes. An interview guide was created on the basis of literature relating to JSA, examples of JSA forms and input from practitioners in the industry. The interview guide covered topics including experiences with using JSA, practical application of JSA including preparations, reasons for performing the JSA, benefits of JSA, JSA's place in the total risk management of projects, experience transfer, and suggested improvements of JSA. The questions in the interview guide were not necessarily followed in order, since emphasis was placed on promoting an atmosphere in which the informant felt safe to talk openly and honestly about the topics (Kvale, 1996).

The interviews were recorded and transcribed. The transcribed interviews were then coded, i.e. phrases were given a label in order to systemise the large amount of information (Bryman, 2012). The transcribed data were analysed on the basis of Straus and Corbin's (1998) principles of grounded theory, by coding and categorising data in order to look for patterns. The categorised data were then analysed by switching between a wider focus on the whole picture to focusing on details (Leiulfsrud and Hvinden, 1996). This was firstly done by testing the ideas noted during data collection, transcription and coding, and secondly, by processing the detailed data material as if they were pieces of a jigsaw puzzle. The aim of this approach was to map and inquire into patterns in the data material, the reasons for these patterns and any contrasts in the patterns.

2.2 Observation study

Two observations of JSA meetings were carried out, one in which two of the authors participated, and one in which one author participated. The observations of the JSA meetings took place in their natural environment in the project construction area and with the people who would usually attend such a JSA meeting. The participants were informed about the observation study in advance. During the observation, the authors took on the role of a participating observer, where they participated in the JSA meetings together with the workers without influencing the actions and decisions made in the meetings. The observation focused on the JSA meeting procedures, the steps of the analysis, leadership, participation and relations. In the observation performed by two of the authors together, one author paid attention to the contents of the process, while the other paid attention to relations and actions. In the second observation, both topics were addressed. Notes were taken by the observers during and just after the meetings. The observer starts analysing the observation data when taking such notes (Fangen, 2004). The authors reflected on and documented key issues from the observations shortly afterwards. The second step of the analysis followed the same procedure as the interview analysis, i.e. coding and categorising the data.

2.3 Document study

In total, 97 completed JSA forms were analysed in order to look for patterns in the use of JSA. The 97 JSAs were coded and categorised into a database under the following categories:

- Project
- Performed by (construction company, sub-contractor or both)
- Date
- Activity description (free text)
- Type of activity (fixed categories)
- Project-specific or recurring activity
- Reason for initiating the JSA (fixed categories)
- Described sub-tasks (free text, if available)
- Identified hazards (fixed categories)
- Measures (free text)
- Categorisation of measures (fixed categories)
- Type of measure (fixed categories)
- Number of measures
- Number of participants in the JSA meeting
- Number of signatures
- Whether hazards and measures are linked to the project's initial rough risk assessment

Due to the low number of forms analysed, a qualitative approach was employed. Data from the categorised JSA forms were analysed using uni- and bivariate statistics and cross tables. In addition, a concentration analysis was performed so as to look for particular types of JSAs, inspired by accident concentration analysis (Kjellén and Albrechtsen, 2017).

Tables 2 and 3 show the distributions describing the JSA form sample. The 97 JSA forms studied are from three different projects. The 40 JSAs from project G were performed in the period September 2017 to April 2018, and were from the start phase of construction where a lot of digging and concrete work took place. Project H (41 JSAs from Jan-Dec 2017) consists of several buildings at different phases from groundwork to commissioning, which means that there are different activities addressed in the JSAs. This project had, in particular, challenges related to several cranes operating in the same areas. Project I (16 JSAs from Jan-Dec 2017) was scheduled to end at the end of 2017.

Table 2: JSA forms, distribution of company and project

		Project		
Performed by		Project G	Project H	Project I
Construction company	42	27	14	1
Construction company and sub-contractor	9	4	3	2
Sub-contractor	46	9	24	13
Total	97	40	41	16

Table 3. Type of activities addressed in the JSAs in the document study

	Performed by	**Project:**

Type of activity:	**Number**	Construction company	Construction company and sub-contractor	Sub-contractor	Project G	Project H	Project I
Concrete (mould and formwork)	26	24	2		23	3	
Crane lifts	21	10	3	8	3	15	3
Slab assembly	10		1	9		9	1
Scaffolding assembly	9			9	2	2	5
Work at height other than scaffolding and slab assembly	7	2	1	4		1	6
Digging	6	1	2	3	3	3	
Carpentry	4	4			2	2	
Assembly crane	3			3	1	2	
Roofing	3	1		2	1	2	
Plumbing	3			3	3		
Paving	1			1		1	
Electrical installations	1			1			1
Blowing	1			1		1	
Traffic control	1			1	1		
Ventilation	1			1	1		
Total:	**97**	**42**	**9**	**46**	**40**	**41**	**16**

2.4 Trustworthiness of results

Lincoln and Guba's (1985) criteria for the trustworthiness of research studies has been used to assess the quality of the qualitative research. Trustworthiness involves establishing four aspects, namely truth value, applicability, consistency and neutrality (Guba, 1981) To establish the truth value of results, credibility is required (Lincoln and Guba, 1985). In the current study, triangulation is used to increase credibility. This triangulation is achieved by using data from a set of interviews, observations and the document study. Applicability means to demonstrate transferability to other contexts. Qualitative research does not aim to produce generalised facts, but rather to produce insight that can be transferred to other settings. JSA is a method rooted in the construction industry, which means that the results should be transferable to other projects as well as other construction companies. By using interviews, observations and a document analysis based on two construction companies and nine construction projects, applicability is strengthened. In addition, the interviewees have provided information about other companies and projects, which makes the findings more applicable. JSA is also rooted in other industries than just the construction industry, and the results of this study should therefore be transferable to other industries as well.

Consistency means demonstrating that the findings are consistent and can be repeated. In the study, justifying the findings has been emphasised in order to enhance its consistency, rather than describing in detail how these conclusions were reached. Consistency also depends on the different observers seeing the same things (Bryman, 2012) and the fact that several authors were involved in data collection and analysis has therefore strengthened consistency. Triangulation has also strengthened the study's consistency, since the results of the interviews, observations and document analysis to a large extent confirm each other. Lincoln and Guba (1985) use confirmability for establishing neutrality in qualitative research results, which is achieved when findings are found in several sources (Guba, 1981).

3 Practical application of JSA

3.1 Performing the analysis

In five of six projects in the interview study, the JSA is carried out in the form of a meeting where a selection of workers is brought together and follow the JSA form structure as a guide to the analysis. In these five projects, the meetings are mainly discussions led by the JSA manager and address three main issues: how the work is supposed to be done, what could go wrong, and what measures are necessary for the work to be carried out safely. Some interviewees indicate that an open JSA form without fixed posts will lead to poorer results as it will not cover all necessary aspects. Open forms also imply that the person chairing the meeting to a greater degree affects what goes on at the meeting.

"The JSA meeting is a conversation between the participants. We discuss around the table in an open-minded manner asking questions like: What do you think the hazards are? What should we do about them? It is problem-solving in collaboration with others." - Construction manager

In the sixth project, the JSA is performed by two persons ahead of the JSA meeting, and then an oral briefing is given to the participants in the JSA meeting. In this project, however, it is indicated that in some cases, the workers only read the already completed JSA form and signed it without having received any information verbally.

The interviews indicate that the process differs between the case projects in terms of who participates in the meetings, who leads the process and how much time is spent on the analysis. This is also reflected in the document analysis, which shows that the number of participants varies from between one and twenty participants. About half of the JSAs in the document study involved between four and six participants. A quarter had between seven and twenty participants and about a quarter had between one and three participants.

Swartz (2002) describes four ways of conducting a JSA: 1) One-to-one observation, 2) Absentee method (Distanced) 3) Group discussion, 4) Recall and check process. The two first approaches are not identified in the companies studied. The third approach (group discussion) was used in five of the six projects. The last method (recall and check) was identified in one project. In 'group discussions', stakeholders in the work operation participate together with their leaders in a JSA meeting. The method relies on open discussion, and that a skilled leader steers the discussion effectively. Almost all interviewees highlight discussions as the most valuable part of a JSA. The discussion creates consensus on what should happen, makes participants more aware of the dangers and creates a common understanding of risk and where the limit for unacceptable risk is set.

"It is important that we achieve a good dialogue between the participants – that we actually perform the analysis together as a group." - HSE Project Manager

"It is important that those participating in the activity to be analysed actually participate in the JSA meeting. If not, there is no point in doing the analysis." – Site Manager

'Recall and check' differs from group discussion in that a JSA manager prepares a JSA for the work operation, which is then reviewed by another person with knowledge of the work. This method was used in one project, where a JSA was prepared by two people and then discussed with the participants in a JSA meeting. A challenge relating to this method is that the opportunity for input from workers decreases, making them less able to influence their work in comparison to a group discussion. Another disadvantage is that the sense of ownership of the analysis is reduced, and can lead to poorer adherence to the measures.

Most of the interviewees state that they think that those who are going to perform the work operation should attend the JSA meeting. However, whether this expressed ideal is realised in practice seems to vary. Company A to a larger degree attempts to involve all workers who are going to perform the work. For company B, a greater variation is seen, where not everyone is necessarily involved, and rather just those who are available at the time. Worker involvement is seen as important to successful JSAs as it promotes ownership to solutions, work engagement, the ability to influence one's own work and creates a common frame of understanding for the work do be done.

There are clear differences between the best practice procedure for JSA, as described by e.g. the Norwegian Oil and Gas Association (2011), Rausand (2011) and Kjellén and Albrechtsen (2017), and the JSA practices in the projects studied. Best practice for JSA emphasises the importance of preparation and planning prior to performing the JSA, i.e. organising and planning the analysis and understanding the work to be analysed, thus creating a common basis in the analysis group. The interviews indicate that preparations for the JSA vary. For construction company B, it seems that no systematic preparations were made prior to the JSA. However, interviewees in company A indicate that some preparations are made by the JSA manager prior to the analysis meeting. Some interviewees claim that good preparation and planning reduces the time spent on the JSA. Many of the interviewees express that time pressure is a part of everyday work, which may be a hinder for conducting thorough JSAs.

The interviewees have experienced that the person responsible for the JSA and his/her preparations affect the efficiency of the meetings and the quality of the JSA. Typically, the JSA manager is a work team leader or a supervisor. Interviewees from company A state that the persons appointed as JSA manager usually have good knowledge of the work to be done and are experienced with JSA, which are qualities that affect both the quality and efficiency of the analysis. These properties are in line with Crutchfield & Roughton's (2014) observations.

Best practice for JSA described by e.g. the Norwegian Oil and Gas Association (2011), Rausand (2011) and Kjellén and Albrechtsen (2017) underline the importance of breaking down the work to be analysed into sub-tasks. Breaking down the analysis object into smaller parts in a systematic way is recommended for all kinds of risk analysis methods by Rausand (2011) as this will support that the analysis cover as many relevant aspects as possible. However, the practice in the projects studied show that the work is often not broken down in a systemic and sequential way. Separation of sub-tasks is to some extent carried out, but rather done by type of hazard and not sequentially in relation to how the work is to be performed. A demanding part of a JSA is to break down the work into sequences and steps. By simplifying this break down, important hazards may be overlooked during the analysis because adequate coverage of the various job stages is not assured.

Another deviation from best practice is that risk is assessed without expressing frequency and consequences. In some cases, consequences are assessed instead of risk, implying that the criticality of a hazard is only assessed through possible consequences and not how likely it is that it will occur. This could be explained by the fact that the JSA form does not include dedicated columns for assessing frequency and consequences.

3.2 Initiation of the JSA

Some of the workers interviewed claim that JSA is applied to work tasks that are seen as routine tasks, but they are nevertheless obliged to perform a JSA. In such cases, the hazards are already known and should be controlled by complying with already existing work procedures. If workers perceive it to be unnecessary to perform JSA, it will lead to resistance against the method (Yoon et al., 2011).

"If we feel that we have previously performed that specific task several times and there is nothing new to that task, I see no reason to do a JSA." – Construction worker

In the document analysis, the JSAs were categorised to analyse whether the JSA is performed for recurring, known activities or for activities that were specific to the project; see table 4 Project-specific activities are activities and conditions that lead to special sources of hazard for the project. These are not adequately covered by existing requirements in laws and regulations. Recurring routine activities do not lead to specific hazards and are handled by complying with existing legal requirements. In the study, 82 of 97 JSAs were performed for activities that are routine work activities recurring at most construction projects, such as slab assembly, formwork and work at height. However, for 38 of these 82, the assessors have identified conditions that fulfil the construction company's criteria for performing a JSA, i.e. there are special conditions for recurring activities that might lead to loss of control of known hazards; see table 5. The document study thus supports the interview study regarding many JSAs being performed for routine tasks. A total of 15 of the 97 JSAs were performed on activities that are not recurring in other projects, but that were specific to the current project. Many of these JSAs were initiated because of multiple cranes operating in each other's zones in one of the case projects in the document study.

Table 4: number of recurring routine activities and project-specific activities addressed in the JSA

Recurring routine activity	44
Project-specific activity	15
Recurring routine activity with identified conditions that require a JSA	38
Total number of JSAs	**97**

Table 5: Recurring routine activity with identified conditions that require a JSA

Accidents and unwanted occurrences have occurred during similar activities in the past	24
Conditions have changed (change of weather, available time, change of sequence of activities etc.)	15
The work implies a particular danger to life and health	8
People unfamiliar with each other are going to work together	6
The activity is new and unknown to those performing it	4
The workers performing the activity are using equipment they are unfamiliar with	3
The work implies deviations from requirements in procedures/plans	2

Table 6: project-specific activities

Project-specific activities:		Project I	Project II	Project III
Multiple cranes operating in each other's zones	8	1	6	1
Digging near electrical cables	2		2	
Digging proximate to road with heavy traffic	2	1	1	
Digging on steep slope	1		1	
Inadequate stability, slab assembly	1			1
Slab assembly proximate to road with heavy traffic	1	1		
	15	**3**	**10**	**2**

Although many of the JSAs address recurring and common activities, the document study shows that JSA is a well-functioning tool to deal with changes in the conditions for such activities (table 6). Such identification of the need for a JSA is carried out in three ways according to the interviewees. It is firstly identified in early project phases prior to execution of the work as part of the planning process, which is typically included as part of the project's overall safety plan. However, some of the interviewees question why other solutions are not implemented when JSA is indicated at a very early stage, as they believe it would be possible to create other solutions and measures than the JSA. Secondly, the need of a JSA is identified during weekly planning meetings for work over the coming weeks. Thirdly, the need for a JSA is identified just before or during work, mainly due to changes of the conditions for the work. The two latter types of identification are closely related to the nature of the work to be performed and are often related to changing plans or conditions for work.

3.3 Countermeasures and follow-up

Table 7 shows a categorisation of the countermeasures shown in the document study. A total of 393 measures were suggested in the 97 JSAs, averaging about four measures per JSA. Three categories of measures represent about half of all measures. Establishing danger zones is the measure most often suggested (19.6% of all measures), which reflects the type of activities that have been analysed (table 3). Concrete work, crane operation and slab assembly are all activities in which falling objects is an important hazard to control. Describing how work should be performed correctly, which is quite similar to best practice, is the second most popular measure (17.3%), while awareness among workers is the third (13.2%). There is no difference in the distribution of the types of measures between JSAs performed by the construction company and those performed by contractors.

When talking about measures, the interviewees mainly focused on awareness measures. According to the interviewees, many of the measures are so generic in nature, such as “be careful”, that they can be implemented as measures for most types of work, and will according to Ashby`s (1956) law of requisite variety, not create control of a system. To gain control of the system, in accordance with Ashby`s law of requisite variety, one must be able to do as many actions as the system may exhibit, and measures like "having focus" and "looking out" will not be sufficient to control the system. However, the document study shows a contrasting pattern where the measures are related to specific activities and hazards and should thus provide control if implemented in an adequate manner.

Table 7: categorisation of countermeasures

Category	**Number**	**Percent**	**Comment**
Establish danger zone	77	19.6 %	Separate hazard and victim in time or space or by physical barriers, e.g. prevent access to areas undergoing work at height
Correct work practice	68	17.3 %	Descriptions of how work should be performed correctly, e.g. hoist not removed before beam is welded
Awareness	52	13.2 %	Workers are to be aware. Two different types: 1) general descriptions “be careful”, “be aware”, “use common sense” and 2) specific descriptions, e.g. “eye contact with driver of excavator”
Communication	35	8.9 %	Typically, communication between workers, e.g. two crane drivers. Also includes communication with third parties
Individual fall protection	31	7.9 %	Use of harness, both fall prevention and fall mitigation
Correct equipment	30	7.6 %	Use correct equipment for the activity/use the equipment correctly, e.g. correct lifting device, fix ladder before use
Collective fall protection	21	5.3 %	E.g. railings on slabs
Activity-specific statements of work practices	15	3.8 %	Description on how work should be performed which is related to the particular activity, e.g. identify where water pipes are before digging
Housekeeping	13	3.3 %	Tidy and clean work areas
Take weather conditions into account	12	3.1 %	Measures directly linked to weather conditions, e.g. wind, slippery conditions
Skills requirements	11	2.8 %	Skills requirements for those performing work, e.g. documented slinger skills
Personal safety equipment other than fall protection	10	2.5 %	
Reference to previous plans and organisation of work	7	1.8 %	E.g. in case of a plug in a hose, the concrete supplier’s procedure should be followed
Information in meetings with workers	5	1.3 %	E.g. morning meetings, toolbox talks
Emergency preparedness	3	0.8 %	Typically fire extinguisher available during hot work

Other (blasting mats, guard, access control to equipment)	3	0.8 %	
Total	**393**		

Furthermore, the measures were categorised into different types; see table 8: regulatory requirements (the measure is described in the safety regulations); work procedure (the measure is described in standard work procedures for the current activity); awareness (general descriptions to workers to “be careful”, “be aware”, “use common sense”); communication/information/warning; activity-specific statements of work practices; housekeeping; reference to previous plans and organisation of work adapted to weather conditions; deviation from regulatory requirements; and requirements from the client.

A total of 56% of the measures are identified as regulatory requirements, such as establishing danger zones when working at height, using personal protective equipment etc. One interpretation of this is that many of the identified hazards are known and recur in many projects and should have been dealt with by the construction company, while the sub-contractors’ safety management systems should incorporate the regulatory safety requirements. Another interpretation is that the quality of the measures is good since they fulfil the regulatory requirements. An additional explanation of the high number is that the most frequent activities to be analysed consist of work that is well covered by regulations (work at height, cranes). A total of 16% of the measures are descriptions of standard work procedures, e.g. concerning how to assemble slabs, while 10.9% of the measures are related to awareness in general, such as “pay attention”, “use common sense”.

Table 8: type of measure

	Number	Percent
Regulatory requirements	221	56.2 %
Standard work procedure	62	15.8 %
Awareness	43	10.9 %
Communication/information/warning	25	6.4 %
Activity-specific statements of work practices	15	3.8 %
Housekeeping	11	2.8 %
Reference to previous plans and organisation of work	7	1.8 %
Adaption to weather conditions	7	1.8 %
Deviation from regulatory requirements	1	0.3 %
Requirements from the client	1	0.3 %
Total	**393**	

According to the interviewees, the participants that sign the forms do not receive any feedback on either the quality of the analysis or what happens to the submitted forms. The workers interviewed do not know what happens to the forms they have filled out after they are submitted.

“I don’t know what happens to the forms. We submit them to the safety officer, but I don’t know what she does with the forms.” – Construction worker

"It seems that the aim of the JSA is to perform the task and document it. I don't think anyone uses the JSA for any purpose after it has been submitted." – Site Manager

3.4 JSA's place in the overall safety management system

A JSA is seen as the last step in safety management before an activity is performed, as it deals with residual risk that has not been dealt with by decisions in earlier project phases. Many of the interviewees state that in an ideal world, JSA will be useless, since hazards would be controlled by choices and plans made prior to the execution of the task. However, in practice, JSA is required. Some interviewees explain this in relation to the complex and dynamic conditions of construction projects. There will always be risky conditions that are not uncovered in early project phases since things change along the way. Others state that a JSA is often performed as a kind of 'firefighting' device to compensate for lack of or poor planning or implementation of measures. These patterns in the interview study indicate a lack of attention to safety in the early project phases, which has been identified as one of the biggest challenges in the industry by e.g., Behm (2005); Frijters and Swuste (2008) and Jørgensen (2013).

Managers often view JSA from an overall safety standpoint, and clearly state that the risk linked to a project should be gradually reduced and that JSA should only be used on residual risk. The interviews indicate that many JSAs could have been avoided if other choices had been made at an earlier stage. If safety is better planned from the outset, it appears that the number of JSAs could be reduced.

In his study of how work is performed after job hazard analysis has been carried out, one of Borys' (2012) findings was that such analyses should be reserved for tasks that are out of the ordinary. The document study shows that few JSAs are performed for project-specific tasks (15 of 97). Most of these were related to conflicting cranes involved in one of the projects. The project involved two tower cranes and one large mobile crane that were operating in each other's lifting zones. An initial, coarse risk assessment performed by the construction company before production start-up did not identify this activity. In hindsight, one could claim that this risk should have been dealt with early on in the production phase. However, it is also an example of a well-functioning JSA system that identified the need for JSAs for this activity. One of the reasons why several JSAs were carried out for crane activities was that the mobile crane often changed position.

The document study compared the identified activities and measures included in the construction company's coarse risk assessments before production start-up with the activities and measures indicated in the JSAs. The coarse risk assessment prior to start-up identifies 1) recurring risk activities that are covered by regulatory requirements, such as scaffolding assembly and work at height and 2) project-specific risks. Furthermore, the risk involved in project-specific activities is assessed and dealt with.

- 21% of the JSAs studied are not linked to the coarse risk assessment, i.e. the activity analysed in the JSA is not identified in the coarse risk assessment.
- 23% of the JSAs studied are linked to an activity that is assessed in the coarse risk assessment, i.e. identified as a project-specific risk activity.

- 56% of the JSAs studied cover an activity that is identified as a recurring risk activity in the coarse risk assessment.
- 7% of the all measures in the JSAs are also described as measures in the coarse risk assessment.
- For JSAs addressing activities that are identified as project-specific risk activities in the coarse risk assessment, 43% of the measures in the JSAs are also described in the coarse risk assessment.

The analysis shows that JSAs, to a limited degree (21%), address residual risks, i.e. risks that are neither covered by risk management in earlier project phases nor covered by regulatory requirements and internal instructions. Rather, most JSAs are performed for recurring work tasks in which safety should be ensured by complying with existing internal and external requirements.

"Both types of risk assessments [i.e. coarse assessments and JSAs] are required. I wouldn't rank one above the other. You can't run a construction site with only JSAs, and you can't run a construction site with only the coarse analysis." – Project manager

3.5 Three main types of JSAs in the document study

The document study looked for clusters of various types of JSAs. By combining the different parameters of the JSA database, three types of JSAs were identified: 1) planning of in-house tasks; 2) control measures for contractors and 3) project-specific tasks.

The first type of JSAs comprises JSAs carried out for known recurring activities that include many participants (seven or more), and where participants and the JSA manager work for the construction company. A total of 17 of the 97 JSAs in the document study fit this pattern and it seems that this is more a method or meeting intended to plan how tasks are to be performed in an efficient and safe manner. Many of the measures contained in these JSAs are also found as regulatory requirements. In this way, the safe work method statement that is used in Australia (Borys, 2012), among other countries, could constitute a better method. As regards measures, there are fewer awareness measures contained in these JSAs than in the other types.

About half of the JSAs are performed in order to maintain control of contractor activities and appear to be ordered so as to produce a document providing descriptions of how the contractor is performing the work and ensuring safety. A general interpretation of these JSAs is that they are quite short with lean information. The JSAs are performed on recurring tasks involving few participants and with few identified measures. Fifteen of the JSAs are performed on project-specific activities. Collisions with cranes dominate these, and many of the JSAs involve contractors, which is not surprising considering the type of activities involved (e.g. digging, cranes).

Table 9 summarize empirical results from the study for the application of JSA. The results have been categorized according to the steps of a JSA as suggested by the Norwegian Oil and Gas Association (2011).

Table 9: Summary of results, application of JSA

JSA step:	Results:
Step 1: Identifying the need for JSA	- JSAs are often initiated for activities that are dealt with by existing barriers or procedures, but also for project-specific activities or activities with conditions that require a JSA - Conditions that initiate a JSA is typically that accidents have occurred during similar activities in the past or

	that there have been changes of conditions (e.gh. weather, sequence of activities)
Step 2: Preparation and planning	- Some or no preparations prior to performing the JSA
Step 3: Performing the JSA	- JSA executed by a selection of workers to perform the activity to be analysed - JSA forms are used to structure the analysis - The process is led by a JSA manager. The role of the JSA manager has high impact on the quality of the process and the results - Often the activity is not broken down to sub-tasks - Risk is often assessed without expressing frequency and consequences - The studied JSA forms suggest three types of JSA: to control sub-contractors; to plan work or to control hazards for project-specific conditions
Step 4: Implementation of measures and execution of the work	- 4/5 of suggested measures in the studied JSA forms are either measures described in regulatory requirements, measures identified in standard work procedures or awareness measures
Step 5: Summary of experience of JSA	- Learning and experience feedback after JSAs seldom happen

4 Benefits of JSA

This section presents and discusses six interwoven benefits of JSAs as identified in the interview study:

- Formalization of work
- Retrospective and prospective accountability
- Worker participation and possibility to influence their own work
- Organisational learning in communities of practice
- Improved situational awareness and hazard identification
- Loss prevention in dynamic systems

The benefits identified are intertwined and difficult to consider in isolation, since they are influenced by each other. Benefits here are first and foremost related to improved safety. However, there are also benefits relating to the quality and efficiency of work.

4.1 Formalisation of work

Formalisation of work, i.e. "issuing written rules and instructions" (Ellström, 2001:428), is one of the benefits of JSA identified in the interview study. It is beneficial because JSA provides a work method statement that provides instructions on how to perform safe work. This corresponds to the JSA type 'planning of tasks' identified in the document study. The interviews show that it is also beneficial to document countermeasures, who is responsible for the measures, and when the measure should be implemented. The interviewees state that collective planning of the work activity helps to make everyone aware of what tasks are going to be performed, which is also positive for the efficiency and quality of work.

"After the JSA, every participant knows what to do. We become more proactive – things are better planned. There are less questions asked during production which means better flow of activities." - Site Manager

The division of labour and coordination of these tasks is fundamental for accomplishing organised activities (Mintzberg, 1979). Performing a JSA is an approach used to achieve both these requirements, in particular by coordination through standardisation, which "is achieved on the drawing board, so to speak, before the work is undertaken. The workers on the automobile assembly line and the surgeons in the hospital operating room need not worry about coordinating with their colleagues under ordinary circumstances - they know exactly what to expect of them and proceed accordingly" (Mintzberg, 1979:5). Formalisation, i.e. documentation of the steps of a work method, has been an important means of work standardisation since the early 20th century in Tayloristic organisations (Taylor, 1911) and in bureaucratic organisations (Weber, 1971). We still find formalisation of work to be an important mechanism in most organisations. Safety rules requirements, procedures and documentation are important principles in both relevant ISO standards, as well as occupational health and safety regulations. Formalisation of work in addition to specialisation and division of labour and hierarchy has contributed to the bureaucratisation of safety, which has accelerated since the 1970s (Dekker, 2014). Although the bureaucratisation of safety has its benefits (reduction of accidents, standardisation of work tasks, transparency and control), there are also secondary effects, such as the inability to identify unexpected events, the limiting of freedom, diversity and creativity, and safety problems that result from the application of fixed rules (Dekker, 2014).

Adler and Borys (1996) differ between two types of formalisation of work: 1) formalisation designed to enable employees to master their tasks; and 2) formalisation designed to coerce effort and compliance from employees. Attitudes towards these two types of formalisation are likely to vary (Adler and Borys, 1996). The coercive function of the formalisation of work is mainly linked to negative attitudes such as stress, poor job satisfaction, preventing creativity and flexibility, and feelings of powerlessness. However, there are also positive attitudes towards an enabling view of formalisation, since it reduces ambiguity, clarifies responsibility, and improves efficiency if workers see an overlap between their goals and the organisation's goals. The objective of a JSA is to enable workers to master tasks rather than aiming at compliance and coercion. Such formalisation of work that enables workers to master tasks will help these workers to do their jobs more efficiently (Adler and Borys, 1996) and safer. Performing a JSA results in a method statement that the workers have contributed to themselves. Involving workers in the writing of safety rules is seen as one strategy for achieving better compliance with rules (Antonsen, 2009)

Hale and Borys' (2013) review of literature on safety rules and procedures divides rule management into two paradigms. In the first paradigm ('model 1'), compliance with rules is necessary in order to promote safety, while the second paradigm concerns adapting to situations that may include breaching established rules ('model 2'). JSA's contribution to formalisation of work is mainly a model 1 approach. However, initiating a JSA can also be a model 2 approach. A JSA should be performed for activities where hazards are present but not adequately controlled by existing work procedures, or by barriers and activities that require deviation from the work prescribed in procedures or routines (Kjellén and Albrechtsen, 2017). This thereby constitutes a model 2 approach of adapting to situations that are not controlled by a model 1 approach. The JSA process then results in a model 1 approach describing how work should be performed. A study by Borys (2012) shows that there is often a gap between the method statement that the JSA results in (i.e. a model 1 approach) and how work is performed in practice (i.e. model 2). The initiation of the JSA, and its execution and result, as well as the implementation of the planned work, will therefore interchange between model 1 and model 2.

4.2 Accountability

The interviewees claimed that the documented analysis was beneficial if an accident happened because it is possible to go back to the document to either check that a JSA has been performed or look into what was planned. The purpose of this transparency is twofold. Firstly, it helps to avoid blame for lack of a JSA in the event of an accident and secondly, it is beneficial for accident investigation and learning. In addition, some interviewees point out that their signature on a JSA makes the workers feel more obliged to follow the written plans.

"Today, we must document as much as we can, while earlier, we just made oral agreements and that was it. However, today everything must be documented. This is particular important if something should happen. If it does, the Labour Inspection Authority and the Police will look into our documentation. If they come to investigate us, it won't be sufficient to just tell them that we have made oral agreements." -Project Manager

Additionally, it is claimed that putting their signature on the JSA sheet makes workers feel more obliged to comply with the work plan established in the JSA process. The interviewed workers claim that they are less likely to deviate from what has been decided in the JSA meeting if they sign the completed form.

The results indicate two types of benefits from JSA concerning accountability. This is particularly relevant when JSA is used for control of contractors, as identified in the document study. One benefit concerns accountability in the event of an accident, i.e. retrospective accountability, paying attention to the incidents that have occurred, those responsible for them, and the reimbursement of individuals for their injuries (de Ville, 2010). Another benefit is prospective accountability, generated by involving workers in the JSA process and requiring them to sign the completed JSA form. Prospective accountability is forward-looking because it seeks to establish workers' accountability for future action. This encourages actors and institutions to fulfil their responsibilities towards individual workers so that accident risk is reduced (de Ville, 2010), thus contributing to reporting and learning (McCall and Pruchnicki, 2017). Both retrospective and prospective accountability must be employed, allowing employees to provide an account of the incidents that have occurred, as well as appointing them a role in accident prevention. This broader understanding of accountability relationships encourages the reporting of incidents (McCall and Pruchnicki, 2017). Accountability is seen as both a promoter and disabler for a just culture, i.e. a culture that encourages openness, reporting and learning without fear of reprisal. It is both retrospective and prospective. A just culture means balancing learning from incidents with accountability for their consequences (Dekker, 2009)

One reason for the bureaucratisation of safety and formalisation is liability and accountability for incidents (Dekker, 2014). In the event of an accident, documented rules and instructions can either be a cause of the accident or can free the responsible management from blame. One reaction to such trends is an increasing “responsibilisation” of workers who are assigned more charge of their own safety at work (Dekker, 2014). Gray (Gray, 2009) explains this responsibilisation as a process where workers are assigned a greater responsibility for their own safety at work at the same time as they are held accountable, judged, and sanctioned in the event of an incident. The companies included in the interview study give no indication that such responsibilisation is part of the JSA process.

4.3 Worker participation

A review of literature on workers’ participation in occupational health and safety by Soehod (2008) points out the benefits of worker participation in this field. Accident prevention is improved by workers’ proximity to hazards that enables them to monitor and report hazards. Problem-solving related to safety is improved by utilising workers’ knowledge about sharp-end activities and hazards. Participation in occupational health and safety contributes to democracy in organisations i.e. employees’ right to be associated with decisions affecting them. Improved collaboration between employer and employees will influence safety performance. The successful implementation and application of safety programmes is enabled by workers’ participation in designing and implementing programmes. Participation also improves the ability to adapt to changed conditions.

Employee participation takes on different forms (Cotton et al., 1988), and the application of JSA can be characterised as short-term participation in decision-making. This type of employee participation is formal, direct, concerned with the work itself, and the workers have complete influence in the decision-making process. The effects of short-term participation on performance, satisfaction, goal properties and perceived influence is ambiguous (Cotton et al., 1988). However, participation in decision-making with the same characteristics but with a long-term duration demonstrates consistent and positive effects on productivity.

Another form of employee participation, representative participation, is a legal requirement in many countries. This type of participation is typically in the form of safety representatives and safety committees. There are several studies that demonstrate a relationship between improved safety performance and workplaces where worker representation structures are in place (e.g. Walters and Frick, 2000; Johnstone et al., 2005). However, the use of JSA is not about representative participation, although safety representatives might participate in the JSA process as part of their work tasks. According to Walters and Frick (2000), there are few studies demonstrating the relationship between direct participation such as JSA and safety performance.

Worker participation in occupational health and safety management is in many ways a Nordic construction, closely linked to socio-technical ideas (Hale and Hovden, 1998). The first socio-technical study conducted by Trist and Bamforth (1951) was followed by several other socio-technical studies (Tris, 1981), showing that technical and social systems are closely interlinked. These studies have had a major influence on democratic traditions in Scandinavian organisations, as well as on participative approaches to organisational development (Greenwood and Levin, 1998) and safety management in the Scandinavian countries (Hale and Hovden, 1998). Such participation gives employees a chance to form their own working conditions by utilising local knowledge of the challenges and possibilities that exist in the current state of the organisation. Through worker participation, the implementation of measures should be easier because the workers themselves have taken part in developing the measures and therefore take ownership of the process.

4.4 Organisational learning

An important mechanism of the JSA meeting is the transfer of tacit and explicit knowledge. Such transfer creates organisational knowledge (Nonaka and Takeuchi, 1995). During the meetings, knowledge is shared among the participants. Several of the interviewees say that they acquire new knowledge from the meetings. The JSA process enables sharing of knowledge because everyone is expected to share their thoughts about work tasks and related hazards. A key to conducting a successful JSA is that workers' knowledge of practices is shared. In this way, their tacit knowledge is made available to other workers. Saurin et al. (2008) found similar findings in their study of pre-task safety planning. Such planning improved the members of work team's learning skills by discussing hazards and working strategies and thus made tacit knowledge more explicit.

"During the meetings, we share our points of view. It is a major benefit that we discuss as a group." – Construction Worker

"If there are four people performing the JSA, and everyone has the same amount of experience as me, we will have a total of 40 years of experience. The site manager has about 30 years of experience from this type of work. Together, that will be 70 years of experience in this type of work. There will be lots of knowledge among the participants that will be valuable when we discuss certain tasks." - Construction Worker

There is a great deal of literature about organisational learning after incidents (Drupsteen and Guldenmund, 2014). Learning is often an effect of an unwanted outcome, which makes learning after incidents a natural reaction (Argyris and Schön, 1996). However, the learning related to JSA is not so much about learning after an incident, but rather learning safe work practices to prevent incidents. Such learning is likely to take place in communities of practice (Gherardi and Nicolini, 2000). The team performing the JSA and executing the activity the JSA addresses is a community of practice, which can be defined as groups of people that are bound together by shared expertise and passion for a joint enterprise (Wenger, 2000). Members of a community of practice are bound together by their collective understanding of what their community is about. The members build their community through mutual engagement and interaction. The communities have a shared repertoire of resources – language, routines, artefacts, tools and stories. A community of practice can be viewed as a social learning system (Wenger, 2000), and this learning will affect practices. In communities of practice, "relations are created around activities, and activities take shape through the social relations and experiences of those who perform them so that knowledge and skills become part of individual identity and find their collocation in the community" Gherardi and Nicolini (2000:10).

The JSA process contributes to factors that, according to Wenger (2000), can generate learning in communities of practice:

- JSA is an event that brings the community together
- Communities of practice depend on internal leadership, and the JSA manager functions as a community coordinator
- JSA strengthens connectivity among members of the community

- The mutual engagement and interaction among members lead to learning that further improves their practice
- All communities produce artefacts. The JSA form will remain useful as the community evolves.

In communities of practice, learning in relation to safety takes place when people take part in conversation across communities of interdependent practices, when changes of organisational order occur and when individuals, communities and organisations cooperate to produce safe work practices (Gherardi and Nicolini, 2000). Such learning occurs by assembling the following intermediaries: human beings (skills and knowledge); artefacts that facilitate performance of a task; text and inscriptions; and institutional authority. The elements involved in performing a JSA can be recognised in these four intermediaries. The skills and knowledge that participants in the JSA meetings bring to the table, the JSA forms, and the criteria for performing a JSA, regulate when the JSA should be conducted.

4.5 Hazard identification and situational awareness

One of the benefits of JSA is to identify hazards involved in the subsequent task. Identifying and understanding hazards is a prerequisite for being able to identify and implement measures to control them. Nevertheless, sufficient coverage of recognised hazards is a challenge in the industry (Albert et al., 2017). Albert et al. (2014) found that construction workers only identified about half of the hazards that were significant to their work tasks. A study of three construction projects in the UK show that only 6.7% of the method statements analysed managed to identify all of the hazards that should have been identified, based on current knowledge (Carter and Smith, 2006).

The interviews indicate that workers gain better insight into the work to be done both during discussions and when documenting the steps of the work ahead. Many of the interviewees feel that their awareness in relation to safety changes after performing a JSA and that they become more aware of hazards. According to many of the interviewees, this improved awareness of hazards is the most important benefit of JSA. The communication that takes place in a JSA meeting creates an awareness of the work to be performed. It is through conversation during a JSA process that attention is focussed on what should be done, and safety is placed on the agenda. Several of the interviewed workers also indicated that they gained a better understanding of hazards related to the work.

"You become more aware of hazards. You have discussed the work tasks and identified hazards for the task. It makes you aware of what dangerous situations might occur. You avoid dangerous actions when you know that there is risk involved." – Construction Worker

There is a clear relationship between hazard control and lack of or poor situational awareness. For example, poor situational awareness is often identified as one of the main causal factors in most aviation accidents (Stanton et al., 2001). According to Kaber and Endsley (2001), poor or lack of situational awareness can lead to critical safety implications such as failure to detect critical cues regarding the state of the system, failure to understand task responsibilities, failure to communicate with other operators in the team, and failure to communicate with other teams. Participation in a JSA process is likely to reduce the likelihood of such failures because it addresses the state of the work system and the tasks to be performed, and is based on communication among work team members.

Situational awareness is a term used to describe an individual's dynamic understanding of what is going on (Endsley, 1995). Many theories and models describing situational awareness have been proposed, the most prominent being Endsley's (1995) three-level model (Salmon et al., 2008). In this, level 1 is the perception of the elements in the environments, level 2 is comprehension of the current situation and level 3 is the ability to project future actions of the elements in the environment of the task. Clearly, JSA contributes to level 3 situational awareness by generating knowledge among the JSA participants as regards what future tasks are going to be performed and the associated accident risks. This is achieved through the participants' knowledge of the current situation at the site (levels 1 and 2).

The main theoretical focus has generally been on individual situational awareness, while team situational awareness has been given less attention (Salmon et al., 2008). Salas et al. (1995) suggest that team situational awareness consists of individual situational awareness and team processes that occur as a result of interaction between individual pre-existing knowledge, available information, information processing, team processes, task characteristics and team characteristics. Team situational awareness is developed through communication among team members, each team member understanding which information is needed by other team members, shared understanding of tasks, and effective team processes for sharing information (Salas et al., 1995), which the JSA process contributes to.

4.6 Loss prevention in a dynamic system

Clearly, a main benefit of performing a JSA is that it creates a basis for establishing measures to control hazards that are not controlled by existing barriers and procedures. The result of a JSA can thus be an important contribution for establishing control of the system we want to control, as described in Ashby's (1956) law on requisite variety: "for an analyst to gain control over a system, he must be able to take at least as many distinct actions as the observed system can exhibit".

A construction project has a dynamic and changing nature with lots of start-up activities, changes in activities, new actors entering the project, changing weather conditions etc. This implies that hazard control must be adapted to these changes. Rozenfeld et al. (2010) claim that JSAs are impractical for the construction industry because of the dynamic and changing nature of construction work. However, it is in such situations that JSA is of particular value as it is a tool that should be used for situations that are not controlled by existing barriers and procedures. This is supported by the JSA study conducted by Borys (2012), which shows that JSA is particularly important for tasks that are out of the ordinary.

JSA is an important tool for dealing with residual risks that are not dealt with by design and planning conducted at different stages of the project prior to execution of work. Ideally, risks are dealt with prior to the work being performed, which implies that JSA should only deal with abnormal situations. However, we can see from the document study of JSA that the method is used for other situations as well, and entails other benefits than just controlling residual risk.

5 Conclusion

Although JSA is a risk assessment method intended to contribute to risk-informed decisions and ensure safe operations, it also has several other benefits in terms of both safe and efficient operations, see table 10. Planning and formalisation of work, accountability and control of contractors, and worker participation not only promote safety but also efficiency and quality. The benefits of JSA underline the link between safety and production. Good project management leads to good safety management and thus good safety performance (Saurin et al., 2004; Sandberg and Albrechtsen, 2018). The current study demonstrates that this relationship is mutual, since good safety management, in this case JSA, results in efficiency and quality and thus contributes to project management.

Accident risk management in projects is a combination of different types of risk assessment. The current study has focused on operative risk assessment, and demonstrates that too many JSAs are performed for activities that should have been dealt with either in the coarse risk assessment prior to start-up or by complying with regulatory requirements. Although hazard control can be established on the basis of other methods than JSA, the method has other benefits in terms of safety as well as production. JSA could therefore also be promoted as a method of planning safe operations rather than merely a risk assessment method.

Table 10: Benefits of JSA

Benefit:	**Description**
Formalization of work	- Method statements of work activity to be performed - Written rules and instructions - Standardization of work has positive (and negative) effects on safety - Benefical for control and follow-up of sub-contractors and for planning of work
Retrospective and prospective accountability	- In case of an accident: avoid blame for lack of a JSA, and as input accident investigation and learning. - Workers are more obliged to comply with the work plan established if they sign the JSA
Worker participation and possibility to influence their own work	- Formal, direct worker participation related to work - Workers can influence decision-making related to their working situations - Involvement of workers improves safety - Ownership to measures - Facilitation of organisational learning and improved situational awareness
Organisational learning in communities of practice	- Transition of tacit and explicit knowledge leads to organisational learning - Learning processes in communities - Organisational learning is long-lasting and more robust than individual learning

	- Organisational learning lead to improvements of both safety and production of practice
Improved situational awareness & hazard identification	- Knowledge about hazards on future activities, which support decision-making on risk reducing measures - Situational risk understanding among participations - Individual and group situational awareness to anticipate future actions and consequences
Loss prevention in dynamic systems	- Control hazards that are not controlled by existing barriers and procedures which is important for the dynamic nature of construction projects

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