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EVALUATION OF AN ACCIDENT INVESTIGATION TOOL USING A SAFETY PERCEPTION MATURITY SCALE

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ABSTRACT

Many opportunities for learning from past accidents are lost in practical working life because no systematic approach is used when accidents occur. The Danish Work Environment Authority (DWEA) developed a tool for systematic accident investigation, aimed at inducing a change in attitudes to accident prevention, paying more attention to the root causes and underlying weaknesses of the work system.

It was hypothesised, that companies that used the tool in the intervention period would improve their safety maturity, compared to those companies that did not use the tool.

The tool was introduced to 400 Danish companies via direct delivery and instruction (*few hours*) by a labour inspector. Attitudes towards the causes of injury were measured by using a twelve-item scale immediately before the introduction of the tool at baseline, and again at the one-year follow-up. The respondents were asked what proportion of accidents could be assigned to certain types of causes. 155 companies responded to the baseline questionnaire, 248 companies responded to the follow-up questionnaire and 99 responded to all questions in both questionnaires.

The latter 99 enterprises represented three sub-groups: 35 enterprises had one or more accidents in the follow-up period and used the tool for accident investigation; 47 enterprises had one or more accidents, but did not use the tool, and finally a group of 17 enterprises had no accidents during the period.

The internal consistency of the scale was good (Scale reliability coefficient (Cronbach's alpha): 0.8205). E.g., the Safety Perception Maturity scores for those respondents regarding almost all accidents to be purely accidental (item 1) and for those regarding many, few or none accidents to be purely accidental, were 104 and 97 respectively (difference = 8 [CI: 3 - 12]). The group that used the Accident Investigation Tool experienced a relative increase in Safety Perception Maturity Score of 3.1 points (CI: –2.6 - 8.7).The study could not support the hypothesis, that the accident prevention tool conveyed a change in attitudes towards causes of accidents with only a minimal intervention (few hours instruction). A certain number of accidents are required in order to learn from past accidents. This is also a limitation of the preventive strategy represented by the accident investigation tool.

BACKGROUND

Learning from past accidents is considered to be very important for organisations in order to prevent recurrence. Throughout the safety literature accident investigations are emphasised as a key element in the prevention of accidents – whether it be occupational injuries or disasters (Benner 1975, Kuhlmann 1977, Ferry 1988, Vincoli 1994, Wagenaar and van der Schrier 1997, Kjellén 2000). The aim is to answer the questions “What went wrong?” and “How can this be prevented in future?”. Whenever an accident or

incident occurs, i.e., when a mismatch between an expected and an actual outcome is experienced, there is an opportunity for learning (Harms-Ringdahl 1983, Argyris and Schön 1996).

However, many opportunities for learning from past accidents are lost in practical working life because no investigation or systematic approach is used when accidents occur at the workplace. There can be several explanations for this, but one important factor is whether accidents are regarded as preventable: If accidents are seen as purely accidental, the motivation for prevention obviously will be at a low level. Another important issue is that accident reports and company files often deal with identified causes close to the accident in time and space. This implies that preventive actions often are restricted to the immediate circumstances of the event (Edwards 1981, Wagenaar and van der Schrier 1997), as preceding events to the accidental injury are not reviewed. Prevention will then be limited because the learning process will not affect the root causes, such as the organisational aspects, and activities in other parts of the enterprise (Edwards 1981, Feyer and Williamson 1991).

In 1999 The Danish Work Environment Authority (DWEA) developed a tool for systematic accident investigation The tool was aimed at inducing a change in *attitudes* towards accident prevention, and paying more attention to the root causes and underlying weaknesses of the work system. The Accident Investigation Tool was to provide an aid for the enterprises in their investigation and analysis of occupational injuries in order to reduce accidents at work (Danish Work Environment Authority 1999).

As an independent research institute the National Institute of Occupational health in Denmark was requested to carry out an evaluation of the Accident Investigation Tool. The tool can be seen as a support for a *learning process* – in providing a systematic approach to accident investigation, which implies that not only immediate causes and faultfinding at the level of *workers and foremen* are considered, but also underlying weaknesses and root causes at the *managerial and organisational level* are considered **(**Feyer and Williamson 1991, Reason 1997). However, the critical element in such a tool is the feedback loop, enabling management and safety committee to use the information to reduce subsequent accidents (Edwards 1981, Krause and Russell 1994, Kjellén 2000). The latter level corresponds to the level of double-loop learning in accordance with Argyris and Schön (1996), who consider most learning in enterprises to be only single loop learning. We assume that this also applies to the learning from accidents.

For the evaluation of the effect of the Accident Investigation Tool we have found that the work by Shannon (1998) and the CDC/NIOSH guidelines (Robson et al. 2001) to provide a very useful framework. We did not consider it possible to measure the effect of the Accident Investigation Tool as a reduction in accident frequency. This would have necessitated a long pre-intervention registration period and a very long follow-up period, including a large reduction in the number of accidents in order to measure statistically significant changes. For this reason, only the immediate outcomes, which concern the improvement of attitudes towards accidents and perception of causes and prevention, have been used as output variables in this study (Table 1). However, the implementation outcome has also been measured, by the use of questionnaires (see Table 1 below).

Table 1: Evaluation model used in the study(*)

Objectives, interventions and type of outcomes	OBJECTIVES, INTERVENTIONS AND OUTCOMES INCLUDED IN THE STUDY. ONLY OUTCOMES IN **BOLD** HAVE BEEN MEASURED.
Programme Objectives:	BY USING THE ACCIDENT INVESTIGATION TOOL THE HEALTH AND SAFETY ORGANISATION OF THE ENTERPRISE WILL PUT FOCUS ON ACCIDENT PREVENTION. Attitudes and behaviour in relation to safety and prevention of accidents improve. The frequency of accidents is reduced.
Planned Intervention:	Labour Inspectors will issue enterprises with a copy of the Accident Investigation Tool for accident prevention and an introductory video Labour Inspectors should promote the accident investigation tool to the enterprise.
Implementation Outcomes:	**The enterprise has implemented and used the tool.** **The tool is being used systematically when accidents occur.** **The tool is used in accordance with instructions**.
Immediate Outcomes:	**Improvement of attitudes towards accidents and perception of causes and prevention**. Increased knowledge about risks and safety
Intermediate Outcome:	Improved safety behaviour in enterprise.
Final Outcome:	Reduction in the accident frequency rate of the intervention enterprises.

(*) Model adopted from Shannon (1998)

Objectives

The main objective of the study was to evaluate the effect of the Accident Investigation Tool. As indicated above the study focuses on the immediate outcome of the implementation of the tool, i.e., its potential to induce a more "mature" perception of the causes of accidents and their preventability. We use the term "Safety Perception Maturity" to denote this type of maturity.

It was hypothesised that enterprises using the tool in the intervention period, would improve their *maturity*, compared to those enterprises that did not use the tool. If enterprises already used procedures for accident investigation, or had a practice for implementing preventive measures after accidents, this could modify the effect of the Accident Investigation Tool.

Thus the following hypotheses were tested:

(a) Enterprises that have an accident investigation procedure would have a higher Safety Perception Maturity at baseline compared to those enterprises that did not have such a procedure.

(b) Enterprises implementing preventive measures after accidents would have a higher Safety Perception Maturity at baseline compared to those that did not have such a practice

(c) Enterprises that used the Accident Investigation Tool in the intervention period, would improve their Safety Perception Maturity compared to those enterprises that did not use the tool

The twelve-item scale of Safety Perception Maturity is shown in Table 2 below.

Material and methods

The Accident Investigation Tool was based on a kind of checklist method, which helped the user through the steps of analysing the process of the accident and to implement preventive measures (Danish Work Environment Authority 1999). The method consists of three basic steps:**Step 1**: Survey factors**Step 2**: Analysis of immediate and root causes**Step 3**: Take preventive measures at all levels in the organisation

These steps follow the common procedures for accident investigation, namely, diagnosis, analysis and prevention.

The study population included 400 enterprises selected by the local labour inspection authorities on the basis of the following criteria: The enterprise had either had an accident in the preceding year or the enterprise was considered, by the local labour inspection, to be a high-risk enterprise. The tool was introduced in the fall of 1999 to the 400 enterprises via direct delivery, and a few hours' instruction by a labour inspector.

A company's Joint Health and Safety Committee was the target group for implementing the accident investigation tool. During the visit on the enterprise premises the enterprise appointed a member of the Joint Health and Safety Committee to be a contact person, and to be the respondent of the baseline and follow-up questionnaires. The appointed person was either a safety representative (employee) or a safety officer (employer). In total 400 questionnaires at baseline and 400 questionnaires at follow-up were submitted. The same representative who had responded to the baseline questionnaire was also addressed –by name, for the follow-up.

Baseline and follow-up

Attitudes towards the causes of injury were measured by using a twelve-item scale. Additional questions were included about current procedures for accident investigation and prevention (at baseline), and the implementation of the Accident Investigation Tool (at follow-up). The baseline questionnaire was completed by the respondent upon direct delivery by a labour inspector immediately before the introduction of the tool, and the one-year follow-up was completed by mail delivery to the contact person.

The Safety Perception Maturity Scale

Safety Perception Maturity was measured on a twelve-item scale by measuring the attitudes towards different causes of injuries. The respondents were asked what proportion of accidents they would assign to certain types of causes using a 5-point scale from "almost all" to "none". The 12 questions on the scale are shown in an abbreviated version in table 2.

Table 2: Twelve-item scale of Safety Perception Maturity

In your opinion, how many of the accidents in this enterprise could be related to
1 A purely accidental cause?
2 Carelessness …. ?
3 High workload or high-speed work?
4 Missing, defect, or insufficient safety equipment … ?
5 Unorganised or messy workplace … ?
6 Inappropriately planned work procedures … ?
7 Insufficient instructions and training etc… ?
8 Technical faults, poor maintenance etc…. ?
9 Inappropriate physical design of the work-site… ?
10 Personal factors - Sleepiness, excitability, alcohol etc…?
11 Combination of causes…?
12 No specific factors caused the accident?
Answer categories:
Almost all; Many*; Few; None; Don't know*

The scores from the 12 items were summed and rescaled to have a standard deviation of 10 and recentred to a mean of 100. Respondents with low scores represent *Low Safety Perception Maturity,* i.e., accidents are mainly considered to be accidental, whereas, respondents with high scores represent *High Safety Perception Maturity*, i.e., respondents consider that contributing causes can be identified and accidents prevented.

All analyses were made with linear regression, and 95% confidence intervals were calculated throughout using STATA Version 7.

Results

In total 400 respondents, each representing one enterprise, were included in the study. 155 responded to the baseline questionnaire and 248 responded to the follow-up questionnaire. The higher response rate in the follow-up was probably due to a more intensive reminder procedure. Only the 99 respondents who responded to all questions in the baseline and follow-up questionnaires were included in the follow-up study. The responses from the safety representatives (employees) and the safety officers (employers) are treated together in the following, as we found no significant difference in their Safety Perception Maturity (Score 103 and 100 respectively, difference = 3 [CI: –2 - 8]).

The internal consistency of the scale was good (Scale reliability coefficient (Cronbach's alpha): 0.8205). E.g., the Safety Perception Maturity scores for those respondents regarding almost all accidents to be purely accidental (item 1 on the scale) and for those regarding many, few or none accidents to be purely accidental, were 97 and 104 respectively (difference = 7 [CI: 3 - 12]). ***Baseline results***

The group of enterprises (n=55) that implemented preventive measures after nearly all or many of the accidents had higher Safety Perception Maturity Scores, compared to those enterprises (n=62) that only implemented preventive measures after few or no accidents. (Safety Perception Maturity Score 104 and 97, respectively, difference = 7 [CI: 3 - 11]).

On the other hand, there was no significant difference in Safety Perception Maturity score between those enterprises (n=48) having an accident investigation procedure and those enterprises (n=55) that did not have such a procedure (Safety Perception Maturity Score 101 and 99, respectively, difference = 2 [CI: –2 - 6]).

Results of Follow-up

The follow-up study was completed 1 year after the introduction of the Accident Investigation Tool. Only the 99 respondents that had responded to all questions in the Safety Perception Maturity scale at baseline and at follow-up were included in the follow-up study. These 99 respondents represented three sub-groups of enterprises: 35 enterprises which had one or more accidents in the follow-up period and used the tool for accident investigation; 47 enterprises which had one or more accidents, but did not use the tool; and finally a group of 17 enterprises which had no accidents during the period, and therefore had no occasion to use it.

Respondents from enterprises, which implemented the Accident Investigation Tool, had the highest Safety Perception Maturity at baseline (103.1) and at follow-up (101.1). This group also experienced more accidents during the follow-up period than the other groups. On the other hand, enterprises experiencing no accidents in the follow-up period had the lowest level of Safety Perception Maturity – both before (100.9) and after (96.6) the introduction of the tool (see Table 3 below).

Table 3: Results of the Safety Perception Maturity Scale before (baseline) and after the introduction of the Accident Investigation Tool at the enterprises (follow-up)

	Intervention			
	No accidents and therefore no use of tool	**Had accidents but tool not used**	**Had accidents tool used**	**Total**
Number of enterprises	**17**	**47**	**35**	**99**
Safety Perception Maturity scores:				
• Baseline study	**100.9**	**102.5**	**103.1**	**102.4**
• Follow-up study	**96.6**	**97.3**	**101.0**	**98.5**
• Change in maturity	**–4.3**	**–5.2****	**–2.1**	**–3.9****

**) $p<0.01$

During follow-up the whole study population dropped statistically significant in Safety Perception Maturity Score, on average 3.9 points ($p<0.01$). The largest drop in Safety Perception Maturity Score was in enterprises which had accidents and did not use the tool (5.2 points) The smallest drop in Safety Perception Maturity Score was in the group which had accidents and used the Accident Investigation Tool (2.1 points). Therefore the group that used the Accident Investigation Tool experienced a *relative* increase in Safety Perception Maturity Score of 3.1 points (CI: –2.6 - 8.7), compared to the group of enterprises which had accidents but did not use the tool. We also controlled for existing procedures in the enterprise, by excluding all those enterprises that already had a procedure – ending up with 43 enterprises. This difference in the change in Safety Perception Maturity scores between those using the tool and those not using the tool was then 4.5 points (CI: –5.2 - 14.3).

Respondents representing some of the 79 enterprises in our data material that used the tool claimed it to have a positive effect. 15% of these enterprises reported that they *fully agreed* that the use of the tool was a decisive factor for the implementation of useful preventive measures. 13% *fully agreed* to the statement that the tool was a decisive factor for the drawing up of workplace risk assessment on the worksite where the accident occurred, and 6% agreed that it had a decisive impact on the workplace risk assessment in other parts of the enterprise.

CONCLUSION

The group of enterprises that used the Accident Investigation Tool had a relative, but statistically insignificant improvement in Safety Perception Maturity score, compared to those that did not use the tool.

Consequently, the present study could not support the hypothesis that the enterprises that used the Accident Investigation Tool would improve their Safety Perception Maturity.

It was supported by the findings that those enterprises that often or always took preventive measures after accidents, had higher Safety Perception Maturity compared to those who either never or seldom carried out safety precautions after accidents. However, this study cannot conclude whether this is due to the practice of taking preventive measures, or whether enterprises are taking preventive measures because they have high Safety Perception Maturity.

About half of the companies in the study had a procedure for accident investigation, not including the compulsory notification of accidents. The results in this study do not support the hypothesis that enterprises having an accident investigation procedure have a higher Safety Perception Maturity compared to those that do not have such a procedure. There was only a little non-significant difference between these two groups.

It appears that enterprises experiencing no accidents in the follow-up period had the lowest level of Safety Perception Maturity – both before and after the introduction of the tool. This could support the view that experiences with accidents in itself, induces a more balanced understanding of the causes of accidents.

Limitations

The study population of high-risk enterprises was selected on the judgement of the individual Labour Inspectors. Another limitation of the study is the low response rate, in particular at baseline (39%). The response rate at follow-up was 62%. It is our impression that the low response rate was due to an unclear responsibility for the submission of the questionnaire. In the follow-up the responsible person was identified by name on the questionnaire. The aim of the study was not to generalise to a bigger group of enterprises. For this reason we did not carry out an analysis of the effect of missing data. However, the group of respondents represented both smaller and larger enterprises and enterprises with many, few or no accidents.

The different settings for the completion of the questionnaire, before and after, could possible explain the spurious negative time-effect in the Safety Performance Maturity score. Before the intervention the Labour Inspector delivered the questionnaire personally, and was present while this was completed, whereas after the intervention the contact person received it by mail and completed it by himself. The presence of the Labour Inspector could influence the respondent to give the "correct" answers to the questionnaire. However, we do not think this has biased our results, as this possible effect influenced all groups equally.

It must be assumed that a certain number of accidents are required in order to achieve an effect of the Accident Investigation Tool. Half of the enterprises had 1 to 10 accidents, a quarter had more than 10 accidents and the remaining enterprises had no accidents. The tool has no effect when there are no accidents to investigate.

This has also implications for Safety Perception Maturity questions where respondents were asked what *proportion* of accidents in the company could be assigned to certain types of causes. For enterprises that only encounter few accidents, the experience basis will be very narrow for the respondents. In order to solve this problem in future research, the inquiry should refer to the respondents' perception of the causes of accidents in general.

The present study must be considered a minimal intervention study – both in time and in intensity. When we look at other intervention trials we could not expect large changes in short time. Menckel and Carter (1982) and Menckel, Carter and Hellbom (1993) reported from a case study of two group routines on accident investigation and prevention. They found after an eleven year follow-up, an effect of a 10 percent reduction in accidents. Guastello (1993) found, in a review of studies, that near miss reporting gave a 4% reduction in accident frequency.

We must also expect that necessary changes require a lot of efforts by the enterprises. Edwards (1981) mentioned in relation to the SHEL-model, which is an ergonomic approach to accident investigation, that the adoption of this model by the industry required a radically different orientation. From this perspective accidents tend to be regarded as isolated events, with focus on immediate causes and faultfinding related to the characteristics of the victim – often carelessness. Equally, the DWEA Accident Investigation Tool, which has features and aims similar to the SHEL-procedure, is likely to require major changes in the way enterprises approach accident causation and learning from mismatch.

Harm-Ringdahl (1983) report from a case study of investigation groups at two paper mills that preventive measures have increased considerably, and like Edwards (1981), he emphasises the importance of the organisational aspects of the investigation team if implementation of preventive measurements are to be effective. To ensure double-loop learning the feedback loop must be assured by the design of the tool. In this matter the Accident Investigation Tool could be improved if the organisational aspects of the investigation teams were defined.

These studies indicate that either a much longer intervention period would be needed, or that the intervention must be rather intensive. This will in particular apply to enterprises with relatively few accidents – in order to ensure sufficient learning opportunities.

Implications of the findings

Limited knowledge is available on the effect of safety intervention in general (Guastello 1993), and this applies also to the effect of accident analyses and investigations (Wagenaar and van der Schrier 1997). More research is needed about the effect of accident investigation tools and the extend to which they can support learning processes as described in this study. This is particularly relevant in smaller and medium sized enterprises where the number of accidents is often too small to provide information for an adequate prevention. Investigation of near-accidents in addition to injuries is a suitable solution; even if the effect of near accident investigations is not yet sufficiently evaluated.

These limitations can be seen as a limitation of the preventive strategy represented by the Accident Investigation Tool. The recommendation to Labour Inspectors is that the tool should mainly be introduced to enterprises with a certain number of accidents. However, the model could be expanded to other types of mismatches as a basis for (organisational) learning, e.g., near-misses, safety performance and other deviations from planned outcomes. Finally, taking into consideration that the enterprises need a radically different orientation in the perception of the accidents, as not only isolated events (Edwards 1981), the implementation of the Accident Investigation Tool would require a more intensive implementation than the two hours introduction given by the labour inspectors.

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