SEA 2.0 – Systematic analysis of company events – www.eval.at/SEA

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ABSTRACT
Talking about the analysis of accidents at work three challenges must be considered. First: An accident cannot be regarded as merely an event that occurs only at a specific point in time. Second: The fact that an accident occurs within a specific work situation must be considered. In addition, when describing the incident, the analysing team should not reflect the possible reasons for this specific accident. This can be tackled by applying the guideline of the Association of German Engineers (VDI) 4006 Part 3 (2013). Salzmann (2011) re-analysed four near-miss events and accidents under consideration of the requirements of the guideline VDI 4006-3. It can be said that analysing under consideration of the guideline delivers results, which are much better suitable, minimizing a possible recurrence of this unwanted event in the company. In this article the technical demands and features of a web-based tool called SEA (Systematic Event Analysis) will be presented. It was originally developed in 2014 and recently updated to version 2.0 by AUVA (Austrian Workers Compensation Board) for a systematic analysis of company events.

Keywords
Risk assessment – human-machine-function allocation – work science – occupational Psychology – holistic event analysis – man-machine system (MMS) – human reliability – human error – operational level

1 Introduction

Description of the situation

In 2010 the first draft of a guideline, VDI 4006 Part 3 was issued. This standard of the Association of German Engineers (VDI) defines specific principles, considering specific requirements, for a holistic event analysis. Salzmann (2011) described in his master`s thesis the practical application of the standard in an aluminium-processing company.

In 2014 the AUVA (Austrian Workers Compensation Board) developed a web-based tool called SEA (Systematic Event Analysis) in accordance with VDI 4006 Part 3 (2013): „Methods for event analysis regarding human behaviour“ for the operational use in companies of all sizes in any sector. The information collected can be elaborated for not only cause analysis, but also for the purpose of risk assessment, deriving suitable design measures and prevent the recurrence of unwanted events in the company. Einwögerer (2020) used the SEA tool for complaint management. SEA provides a holistic event analysis and a risk assessment including the detection of technical defects, organizational weaknesses, latent errors, definition of preventive measures and explanatory fact sheets.

2 Methods for event analysis regarding human behaviour

Company practice shows that concerning this matter there consist three principal issues in Austrian companies.
First: An accident is regarded to be merely an event that occurs only at a specific point in time.
Second: The fact that an accident occurs within a specific work situation is largely ignored.
Third: While analysing the incident the analysing team draws conclusions about the possible reasons for the specific accident too hastily. Due to this it is not cleared up firstly whether the acting person is the cause or

the source of the near miss or the accident, neither of which is necessarily the case. This can be avoided if certain principles are considered, which are described in the standard VDI 4006 Part 3 (2013) of the Association of German Engineers. The standard VDI 4006 (Part 1, 2015; Part 2, 2017; Part 3, 2013) covers human reliability assessment methods.

First: An accident is considered as an event that occurs only at a specific point in time.
Every near miss or accident is preceded by a chain of events. Hence, there are various causes for it, not only one. We owe Reason (1994, p. 255-256) the finding, that if we look at the operational level, possible explanatory factors for errors in the workplace can be found on various levels: On the execution level, where active errors occur, which result directly in a fault or accident. Also on the maintenance level, where latent errors have an undetected and event-enhancing effect. Under certain circumstances, latent errors remain undetected before an active error occurs. The latent error is a contributing cause in triggering the active error and can occur extremely remote in time and space from the active error (Badke-Schaub, et al., 2012, p. 43). Errors in the workplace can also go hand in hand with technical defects or technical failures on the system design level. Organizational weak points can be considered as the cause or source of the near miss or the accident on the organizational level. Last but not least, on the regulatory level the default of legal requirements has to be considered. Faults at the workplace on these levels can be the lack of a guideline, a non-functioning device, inaccurate or missing information or unqualified personnel. The different levels are in mutual interaction and interdependence.

Second: Ignoring the fact that an accident occurs within a specific work situation.
An employee depends on colleagues, work time, order placement, task and job description, work equipment, internal rules, deadlines etc. Therefore, an employee is always part of the work system. The event analysis must be carried out in consideration of the work system.
„*A human error always exists in a working system. It is characterized by an undesired or faulty state of the entire system. It then leads to a situation where the requirements of the system are not met or met inadequately. The individual is only part of the working system and interacts together with other portions of the working system. All portions within the working system may be dependent upon each other or may interact in a reciprocal way.*“ (Sträter, 2016, p. 47)

Therefore, in addition to an information collection for identifying sub-events on various levels of the operational level, in a holistic event analysis the sub events are registered as individual Man-Machine-Systems (MMS) (cf. VDI 4006 Part 1, 2 and 3: fig.3, p.15): Task, result, order placement, order fulfilment, communication, system, feedback, human being, activity, environment, situation.

Third: The acting person is not necessarily the cause or source of the near miss or the accident.
If a person commits an error, possibly the cause for the error lies in the person himself, or the error has an external cause - causes are not known at the time the event occurs.

There is a difference between human behaviour, error and cause for human error. Various scientists make this distinction. Sträter, 2016, p. 46 distinguishes between „behaviour“ and „cause for behaviour“ using the terms „Phenotype“ for the observed behaviour and „Genotype“ for the underlying cause.

Hollnagel, (2019) distinguishes also Safety 1 and Safety 2. Safety 1 means that nothing goes wrong. Safety 2 means that things go well. Safety 1 is defined as the condition where the number of accidents, incidents or near misses is as low as possible. From this point of view, only harmful events attract attention, although they are rare and isolated. Another way to look at safety is Safety 2. When something goes wrong, it usually went well many times before. Therefore, safety concerns should be directed at everyday events, meaning they should be directed at events when „nothing“ happens, when work just goes as it should. It is invisible and we take it for granted. What is called Safety 2 is the ability to succeed under varying conditions.

In the tool SEA 2.0 a contribution to Safety 2 is, that in the tool the user is asked whether the activity was a situation-improving measure or a situation-improving reaction and to document this (chapter 3.1). Since a lot of information is collected and documented during event data acquisition in SEA, also the events going well are documented. This means the events can be within the tolerance or acceptance limits or permitted limits, a regular or optimal operation or performance, work equipment functioning well, the execution, the progress or the course of the task goes as it should.

Sträter, 2016, p. 46 also makes the distinction of behaviour and cause for the behaviour; he distinguishes between an appearance-related and a cause-related analysis of human error.

For this reason during the analysis of the incident the analysing team draws the conclusions about the possible reasons for the specific accident too prematurely. Therefore, it is important to distinguish between event data acquisition and event assessment (cf. VDI 4006 Part 3: occurrence-oriented and cause-oriented analysis). In the tool SEA 2.0, the two analyses are strictly separated: First a detailed analysis of „What has happened?“ afterwards „Why did it happen?“ including the check of the performance shaping factors (chapter 3).

Description of the practical implementation of the guideline

Salzmann described 2011 in his Master`s Thesis the practical application of standard VDI 4006/3 in an aluminium processing company. Four near-miss events and accidents were re-analysed under consideration of the requirements of the guideline VDI 4006-3: unsafe working at height, maintenance work on a press during company vacation, repair of a patronize of junk and a forklift truck tipping-over when transporting goods. In a next step, the specific results were compared. Here are his main results:

As a reminder: At the operational level, five levels have to be considered: execution level, maintenance level, system design level, organizational level and regulatory level.

- Possible explanatory factors for work errors can be found in 3 of the 5 levels in the four examples.
- A further result was, that when comparing the measures derived from the method of the company with those derived from the standard VDI 4006 Part 3 it could be clearly shown that the measures in the first case were more obligations, prohibitions and new instructions, whereas those in the latter case were training courses, explanations and revision of existing rules.
- In addition, this comparison of the derived measures showed that according to the method of the company 13 of the measures were allocated to the behaviour, 4 to the technical and one to the organisation. According to the method of the standard four derived measures were allocated to behaviour, 6 to technical and 13 to the organisation. This is the inverse rank order and corresponds to the STOP principle (substitution before technical before organizational before personal measures) in the Austrian law of safety and health of workers at work (ArbeitnehmerInnenschutzgesetz – ASchG).

The frequency of explanatory factors related to different causes of working errors in this study showed, that task preparation (planning a task) was mentioned most often when applying the standard VDI 4006 Part 3. However, information that is more useful can be obtained by evaluating combinations of causes, as it is often their interplay, which resulted in the event. This is a proposal in the standard VDI 4006 Part 3, p. 22. Interactions can be expressed as the relative frequency of shared mentions of explanatory factors. This matrix was created based on Salzmann's evaluations (Figure1).

Relative Häufigkeit von gemeinsamen Nennungen erklärender Faktoren in %	1 Anordnung	2 Anzeigengenauigkeit	3 Aufgabenvorbereitung	4 Auslegung	5 Bedienbarkeit	6 Deutlichkeit	7 Gestaltung	8 Handhabbarkeit	9 Inhalt	10 Kennzeichnung	11 Komplexität	12 Konstruktion	13 Monotonie	14 Vollständigkeit	15 Vorhandensein	16 Zeitdruck	17 Zuverlässigkeit
Relative Häufigkeit der Nennungen pro erkl.Faktor →	3%		33%	15%	15%	6%			3%		3%	3%			12%	6%	
↓ Prozentanteil pro Faktor																	
A Anordnung	x																
B Anzeigengenauigkeit		x															
C Aufgabenvorbereitung			x														
D Auslegung/Organisations-gestaltung	9%		15%	x													
E Bedienbarkeit					x												
F Deutlichkeit				9%		x											
G Gestaltung							x										
H Handbarkeit								x									
I Inhalt						3%			x								
J Kennzeichnung										x							
K Komplexität/ situativ. kompliziert			15%		15%				3%		x						
L Konstruktion				3%	15%							x					
M Monotonie													x				
N Vollständigkeit														x			
O Vorhandensein/ Anweisungen fehlen			9%						15%						x		
P Zeitdruck/ Aufgabe unter Zeitdruck			9%		3%				3%							x	
Q Zuverlässigkeit																	x

Figure 1: Dependency analysis of explanatory factors.

As you can see in Figure 1 task preparation, planning a task was used in connection with system design, complexity, lack of instructions or time pressure.

- The evaluation criteria of Fahlbruch (2000) were applied. The evaluation of the used forms of analysis demonstrated that the effectiveness in the evaluation criteria is given when applying the standard. For example, prevention or protection of stopping the analysis prematurely, deducing premature conclusions and hypothesis. The results showed that due to the results obtained in the comparison of the two different event analysis and the empirical assessment one can say that the analysis method according to VDI 4006-3 is suitable for finding appropriate measures and for improving safety at work.

3 Procedure of the development of the tool SEA

In this part the features of the tool SEA will be described. During the development of the tool the requirements were to follow the specific principles and to consider the specific requirements for a holistic event analysis using the standard VDI 4006 Part 3, but also to make SEA practicable, usable, and applicable for companies of all kinds.

SEA 1.0 was developed in 2014 by AUVA (Austrian Workers Compensation Board) for a systematic analysis of company events. SEA 2.0 was released in mid-2020 (Rothmeier-Kubinecz, 2020). It is a revised version and includes a Video Tutorial. The Video Tutorial supports the user to get acquainted with the tool, when finishing the tool the first time a personal password can be generated. The new version is now also available in English for the first time.

SEA makes it possible to split up an event into a sequence of sub-events and offers support for gathering the information (What has happened?) and for the preparation of the detailed information on the work system (MMS). Based on this data SEA provides an automatically created time-person diagram. Subsequently, the user searches for deviations between the actual sequence of events and the specified or normative sequence. Comparisons are made and deviations are analysed (Why did it happen?) with regard to the components of the MMS, based on the information collected in the occurrence-oriented analysis. Tolerance limits, regular or optimal operation or performance, functioning working equipment, correct execution, progress or course are the specifications for the normative sequence of events. The normative sequence can be identified based on operational documentation, procedural rules, manuals, law of safety and health of workers at work or personnel interviews.

Suitable information can be copied from search results, in Austria downloaded from e.g. the website of the AUVA (www.auva.at) or in the English version from the OSHA website (www.osha.europa.eu). Information can be also found in the own operational documents of the company. SEA 2.0 provides some deep links to country-specific information. Subsequently in the tool SEA, performance shaping factors (PSF) and the type of human error are checked. Pictures support the user's choice of the explanatory factors for the sub events, such as working time conditions, machinery design or task-design, which helps them in making a fast decision.

Since data collection and data assessment are strictly separated, it is possible to derive specific measures for a sustainable prevention of accidents. Furthermore, SEA offers the possibility to download photos, plans, protocols, company documents and public information about health and safety in a download area.

3.1 Development of the tool SEA

To follow the standard 4006 Part 3 SEA 2.0 consists of four options for data acquisition, data assessment and data evaluation:

1. An event sequence model with a time-person diagram (chapter 4.3), generated automatically at the end of the occurrence-oriented analysis of sub-events, based on a man-machine system.
2. An interim report, generated automatically at the end of the cause-oriented analysis based on deviations.
3. The full report, generated automatically at the end of finding out performance shaping factors (PSF) and
4. Assessing human reliability.

Deviations from the procedure in the standard 4006 Part 3 are:

- To make SEA applicable for companies of all kinds and for time limitation in SEA it isn`t distinguished between communication between employees (component „communication“ with the components „order placement“ and „order fulfilment“) and communication between operator and machine (components „feedback“ and „result“). Therefore, eight components are checked instead of eleven. To meet the required standard in the tool SEA, the analysis of sub-events is based on a man-machine system with the components „activity“, „task“, „order placement“, „order fulfilment“, „communication“, „technical system“, „environment“ and „specific work situation“.

- The component „Human being“ is taken into account by finding PSF. Factors that influence a person’s ability to perform a task reliably are called performance-shaping factors. Their layout is a precondition for safe action. Because the individual or the operator intervenes in the technical system with their activities or operations (VDI 4006 Part 3; p.18; see also chapter 2), the cognitive loads arising from the task are verified by „Finding out performance shaping factors“.
- The relevance of the different operational levels (chapter 2) is considered in the occurrence-oriented analysis. If the information on the execution level, maintenance level, system design level, organizational level and regulatory level cannot be found, it must be researched. There are two possibilities: To add additional information or copying data from other event modules. The user himself decides at which level the sub-events are to be analysed.

For assessing human reliability, the type of human error is asked. To have another look at safety (Safety 2), the user is also asked, whether the activity was a situation-improving measure or reaction within the last course, which often stays unperceived and, as a consequence, is not documented (see also chapter 2).

At the end of the process, SEA generates a report containing a list of factors that cause and explain errors based on information from standards.

The event sequence model (ad 1), the interim report (ad 2), and the full report (ad 3) make up an overall assessment. Based on this assessment the analysis team works out suitable measures. In preparation of deriving the design measures, the analysis team identifies and weights the factors, which are of crucial importance to this specific event.

In SEA version 2, there is, additionally, the possibility to assign the list of explanatory factors to typical cause categories as mentioned in VDI 4006 Part 3. Interactions can be expressed as the relative frequency of shared mentions of explanatory factors within an overall event. A Matrix will be created automatically (Figure 1).

3.2 Technical demands

This chapter will describe the technical side of the tool SEA.

SEA is a web-based tool designed to run in any modern web browser. However, due to its complexity we currently don’t support mobile devices. Since we are aware that this topic touches very sensitive data, privacy is of utmost concern for us. That means we don’t store any user data permanently on our server. After 4 hours of inactivity all data for a given user session is permanently deleted from the server.

This means, obviously, that the user themselves is responsible for their data. Anytime while using the tool, the user can download a file with all their data. We also remind the user after completing crucial steps to download their data file. That file can then be imported the next time they want to continue working with it. Keeping that file confidential is the sole responsibility of the user.

During the phase „Why did it happen?“ we ask the user to compare the actual events as they happened to the „optimal“ outcome and mark any deviations. Hence, the user should compare the events to the company policy, but also to applicable laws and norms. In SEA version 2 we support that task by providing the user with a search feature. They can enter a search term (for example „fork-lift truck“) and we will search several websites and find the search term in their publications. Obviously, laws and norms vary greatly from country to country. Therefore, we let the user choose their preferred country and then look in the respective websites for that country. In Austria, for example, we will search on www.auva.at (the Austrian workers’ compensation board), www.arbeitsinspektion.gv.at (the Austrian labor inspectorate), and a few others. The international version will search on www.osha.europa.eu (which should be applicable across the entire EU). We also aim to add other country-specific websites, which can be done at any time in the future. Whenever new websites that provide suitable information are published, we are happy to collaborate with them and include them in our tool. The goal is that in the future the information provided will become more and more specific and well-tailored.

In SEA version 2 the user can also compare a set of different near-miss events or accidents that they used the tool with. The user can upload several of their data files and the tool will then automatically generate a table like the one in Figure 1. For that to work we need multiple data files, of course.

The values in column x and row y in the table indicate how dependent the two explanatory factors are. It is the number of times both factors are mentioned in the same data set divided by the smaller one of the two frequencies of the two factors being mentioned individually. In math terms it is calculated as follows:

$$h_{x,y} = \frac{h_{\text{both factors } x \text{ and } y \text{ are mentioned in the same data set}}}{\min\left(h_{\text{factor } x \text{ is mentioned}}, h_{\text{factor } y \text{ is mentioned}}\right)}$$

Equation 1: Formula for the entry in column x and row y of the matrix. The letter „h“ denotes the number of times something is mentioned in the given data set. This formula is taken from Sträter’s dissertation (1997).

4 The practical approach to an accident with the tool SEA

This chapter shows how to use SEA, demonstrating it with an exemplary accident, derived from Salzmann's Master Thesis (2011), contractor activity in the construction sector, unsafe working at height.

4.1 Contractor activity in the construction sector, unsafe working at height

On 30.9.2010, the new part of the hall for production and goods transport was opened. The customer P1 gave the opening verbally to his employees P4. Subsequently, the employees began to set up the hall and start production.

On 6.10.2010 at 9:00, the customer P1 gave the list of building defects and the order for repairs to the contractor P2. The order for the contractor P2 was to complete the work within three weeks. One of the work items was to remove the wooden formwork on the crane runways of the new part of the hall. Contractor P2 received the order from the customer P1. On 20.10.2010 at 7:30, the order to remove the wooden formwork on the crane runways was handed over to the contract worker P3 from the construction company on short notice. The contract worker P3 received the order also verbally from the contractor P2. On 20.10.2010 at 8:00, the contract worker/leased employee P3 drove from the external construction company directly to the front of the new hall extension using the minibus, loaded with a ladder and formwork panels. There was no registration.

On 20.10.2010 at 8:00, P1 was busy in other departments with other contractors.

On 20.10.2010 at 8:30, P3 entered the hall with the ladder and formwork panels. The outer door was kept open by a wooden wedge. On 20.10.2010 at 8:45, the ladder was leaned against the crane runway by P3. In order to get a seat on the crane runways, P3 took a formwork panel via the ladder up to the crane runways.

The forklift truck driver P4 drove into the hall at 8:45 and saw P3 on the ladder. He climbed down and helped P3 to lift the formwork panels up the ladder onto the crane runways.

The safety engineer P5 entered the hall at 9:10, noticed the process and stopped the work.

4.2 Occurrence-oriented analysis

First an empty field must be opened for the event report.

The first step is the description of the course of the event. The information can be entered in the text field; either copied from a given accident report or typed in manually (Figure 2).

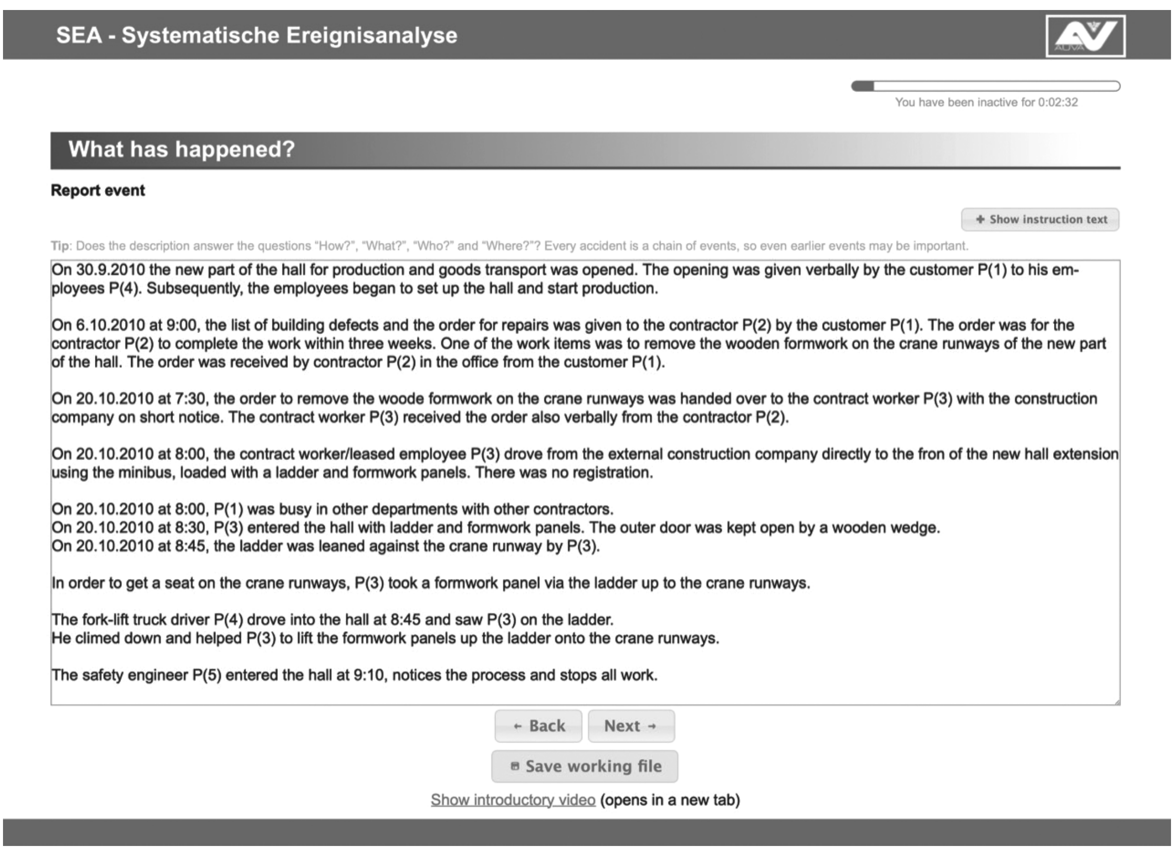

Figure 2: What has happened?

In the next step, the event is split up into event modules, which can be selected separately. The first event module to be selected, is the so called „event occurrence“ (= time of the accident or the near-miss at work). The detailed information will be allocated to the working system with the components „activity“ (1), „task“ (2), „order placement“ (3), „order fulfilment“ (4), „communication“ (5), „technical system“ (6), „environment“ (7), „specific work situation“ (8).

Figure 3 shows a page in the tool SEA 2.0. The first event module is selected, each number represents a component, the first component to analyse is „activity“. To make sure, that the information collection for all components is complete, the basic question is e.g. for the component „activity“, „What could be observed when considering (only) the component activity“. „What activities were the described persons engaged in at the time?“

If the user finds the relevant information in the text, all he needs to do is click on the sentence and it is marked in yellow (Figure 3). In the given example all information needed is in the text. The question can be answered and the answer only has to be marked: on execution level, the contract worker took a formwork panel via the ladder up to the crane runway, the forklift truck driver helped to lift the formwork panels up the ladder.

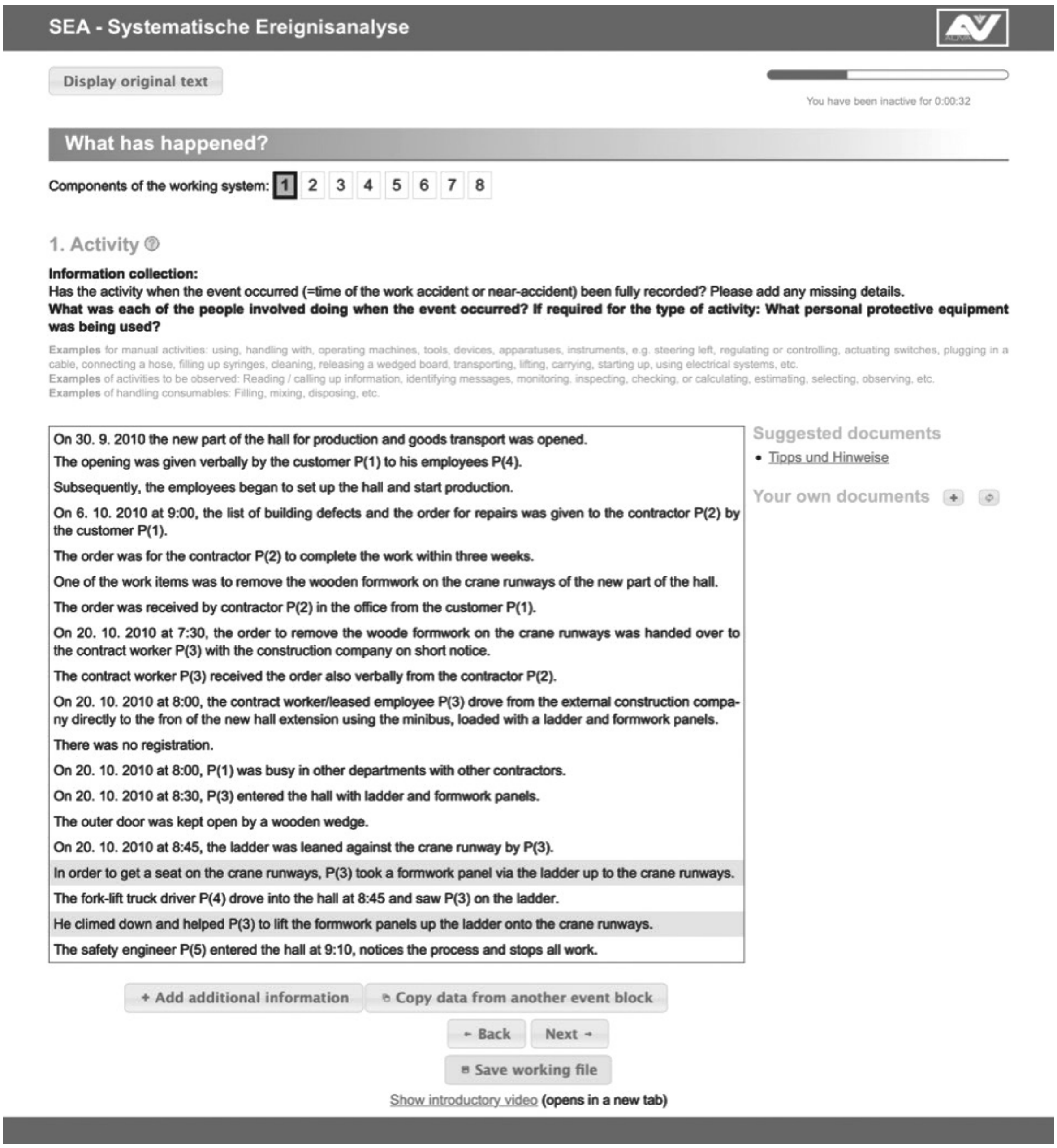

Figure 3: Analysing component 1 „activity“.

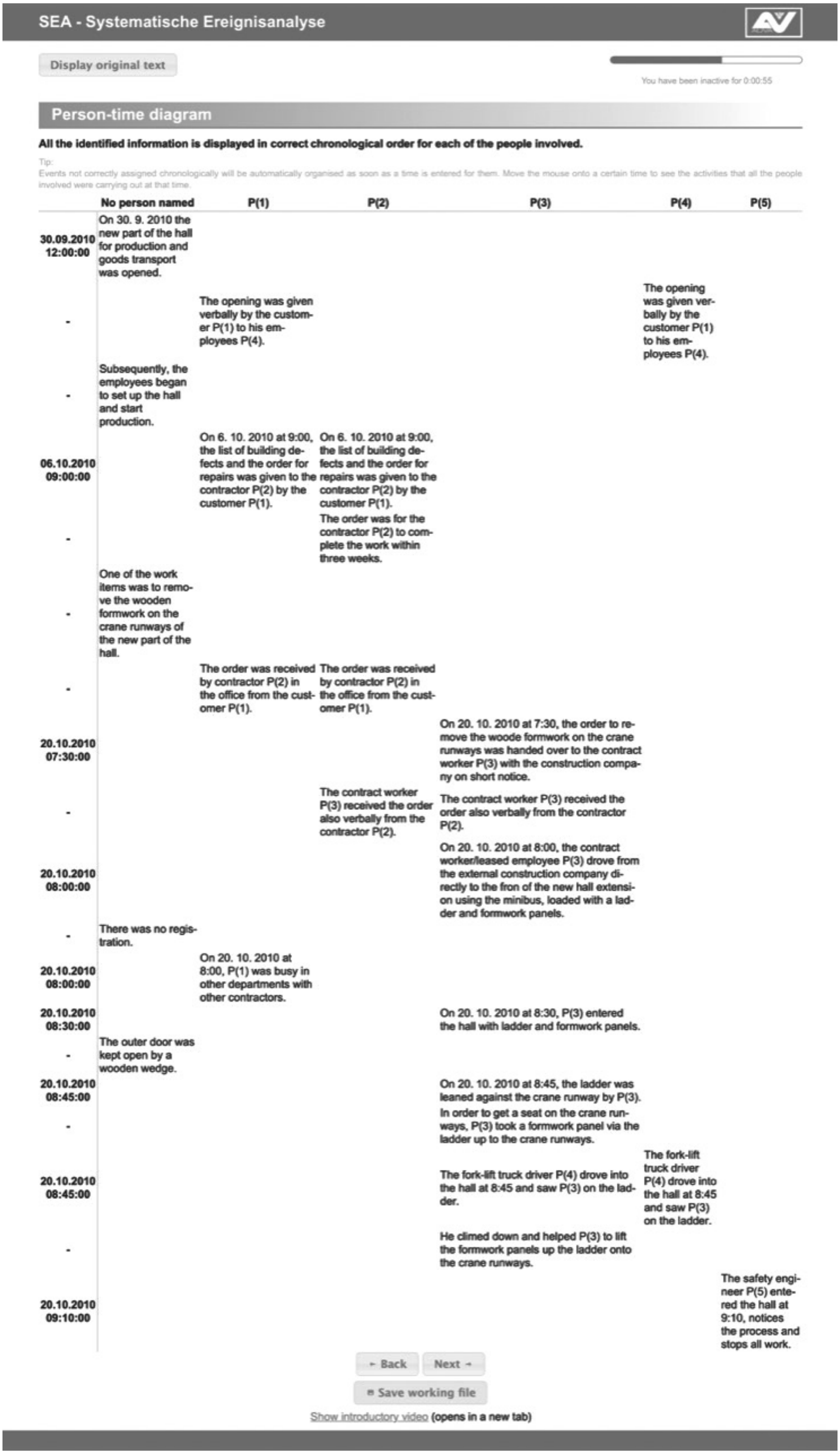

Figure 4: Person-time diagram.

If one cannot find the information, it needs to be researched by asking or looking in the reports or on photos or plans. There are two possibilities: the user can either add additional information or copy data from other event modules. It depends on which operational level is chosen (chapter 3.1). Gerhard Salzmann analysed the component „task“ on organisational level and execution level, the component „technical system“ only on organisational level, but not on maintenance level and so on.

4.3 An event sequence model

All other components are handled as described. At the end of the course a time-person diagram for an event sequence model is generated automatically based on the information collection. All the information gathered is represented here in the correct chronological order for each of the persons involved (Figure 4).

4.4 Cause-oriented analysis

The next step in the tool SEA is to ask „Why did it happen?“. The deviation analysis is carried out based on the information about the actual sequence of events (marked yellow in the SEA Tool) and the specified or normative sequence as well as the tolerance or acceptance limits according to the standard. Comparisons are made and deviations are analysed with regard to the components of the Man Machine System (MMS). Each number stands for a component. All the detected deviations are typed in the text field, or suitable information can be copied from search results (chapter 3).

In the given example, the search result was an information leaflet on the AUVA website under „Publications“ on ladders and contract worker. The appropriate information from the leaflets can be copied in the text field.

Figure 5: Why did it happen?

Within the tool, it looks like Figure 5. The corresponding question is „Was it a perfect execution?“ How is each person's activity (marked in the text) optimally carried out?

The activity actually performed (Figure 5; marked yellow) is compared with the intended, prescribed or ideal activity. The comparisons made by Salzmann and the search result show that ladders are not allowed for this kind of activity, which require high physical strength and constrained postures and for the forklift truck driver it is an activity not related to his work.

All other components are handled as described. At the end of this section an interim report is generated automatically.

4.5 Finding performance shaping factors

For event assessment with the aid of the MMS structure, the influencing factors are analysed in a cause-oriented analysis. Possible explanatory factors (PSF) for errors within a MMS may be found in the standard VDI 4006 Part 3, but also in Part 1 and 2 as well as in other standards. The conditions of safe working are checked in a user-friendly solution with pictures (Figure 6). The only thing to do is to click or tap on the appropriate button. Nevertheless, it is also possible to skip some pictures or components.

4.6 Assessing human reliability

Finally, the type of human error, also in a user-friendly solution with pictures is asked for.

Following the general classification these are „habitual error“, „errors from utility“, „error from the situation“, „error of judgement“ and „error, because exceptional situation“. After one is selected, a text field opens to document the explanation. Gerhard Salzmann researched, that is was an error because of the situation. The explanation was, that ladder and formwork panel are inadequate work equipment, there was no coordination and no contact person in the hall and there was no information for the other workers about the unplanned construction work.

5 Summary

Salzmann was able to show that the principles of the standard VDI 4006 Part 3 can be applied in practice. With the SEA Tool, the application of this method is substantially simplified.

As mentioned before, SEA 2.0 offers the possibility for a dependency analysis of explanatory factors, by evaluating combination of causes. Since the interactions between the explanatory factors are evaluated in

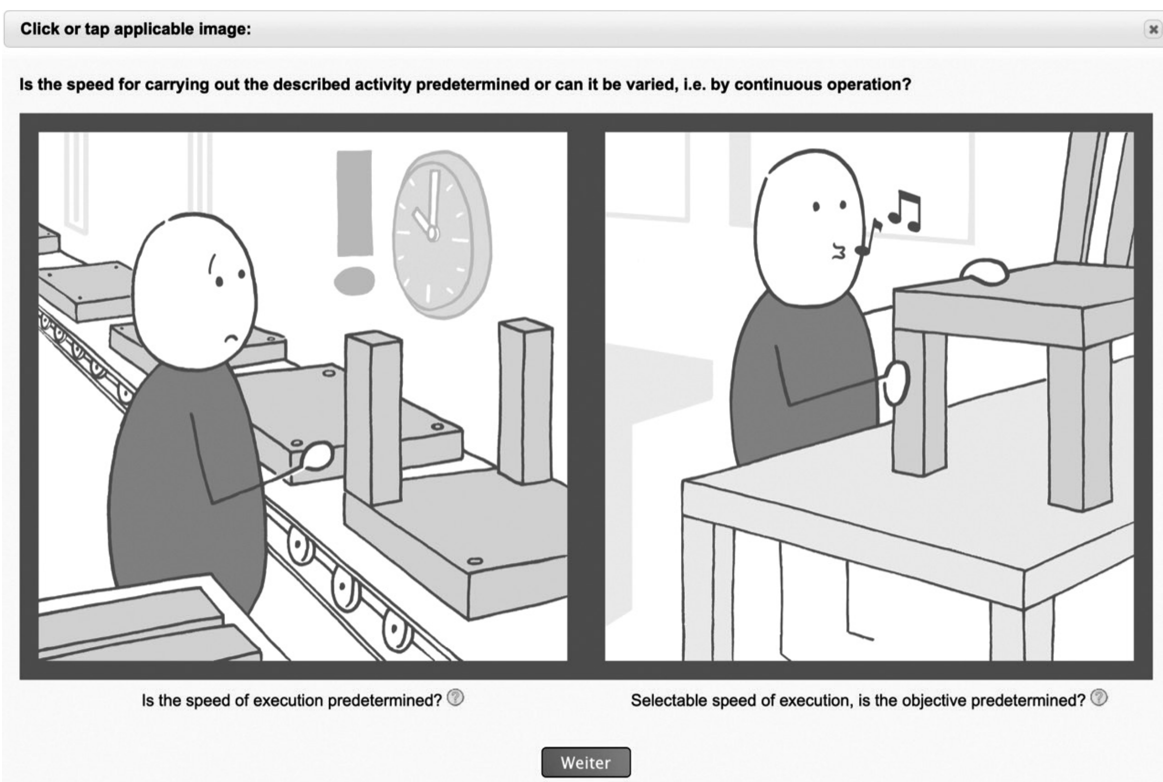

Figure 6: Performance shaping factors (PSF).

SEA 2.0, the effectiveness of improvement measures can be assessed. Higher-level causal areas can be identified in this way.

With SEA 2.0, companies have a free web-based tool at their disposal that can be used in a variety of ways. SEA provides a holistic event analysis AND a risk assessment including the detection of technical defects, organizational weaknesses, latent errors, definition of preventive measures and explanatory fact sheets.

A video tutorial helps to get started. With the English translation, it is now also possible to use this web-based tool in other countries.

Thank you: My gratitude goes to Gerhard Salzmann, who died in a tragic accident on January 28, 2017. In painful memory.

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