The software tool Storybuilder and the analysis of the horrible stories of occupational accidents

Bellamy, L.J.[1 *], Ale, B.J.M.[2], Whiston, J.W.[4], Mud, M.L.[5], Baksteen, H.[6], Hale, A.,[2] Papazoglou, I.A.[7], Bloemhoff, A.[8] Damen, M.[9], Oh, J.I.H.[3]

1 White Queen safety strategies, Postbus 712, 2130 AS Hoofddorp, Netherlands. linda.bellamy@whitequeen.nl, www.whitequeen.nl
2 Safety Science Group, Delft University of Technology, Netherlands
3 Ministry of Social Affairs & Employment, The Hague, Netherlands
4 Whiston Computers Ltd, UK
5 RPS Advies, Delft, Netherlands
6 National Institute for Public Health and the Environment, Bilthoven, Netherlands
7 National Centre for Scientific Research Demokritos, Athens, Greece
8 Consumer Safety Institute, Amsterdam, Netherlands
9 RIGO Research and Consultancy, Amsterdam, Netherlands

Abstract

To construct models for quantifying occupational risk for the Workgroup Occupational Risk Model (WORM) project for the Ministry SZW in The Netherlands, scenarios had to be built from accident histories. For this purpose the Storybuilder has been developed, tailor-made software that provides a totally new way of analysing and presenting accident data. It enables details of hundreds of accidents to be captured on a single screen by building event structures and accident pathways through the structure. The mode of presentation combines graphics similar to fault and event trees with text boxes and lines which follow the individual accident pathways ("horrible stories"). The data are quantified by counting the number of pathways through a node (box) or combinations of nodes. The results make facts and figures information available about occupational accidents from a database of around 9500 analysed investigation reports from the Dutch Labour Inspectorate 1998-2004 presented in 36 storybuilds, one for each type of occupational accident e.g. struck by moving vehicle, fall from ladder, contact with moving parts of a fixed machine. Some examples are presented.

* Corresponding author. Tel.: +31 23 56 51 353; fax: +31 23 56 51 353.
Email address: linda.bellamy@whitequeen.nl

1. Introduction

The Workgroup Occupational Risk Model (WORM) project in the Netherlands began in 2003 with limited data for analysis of causes of accidents. Data on occupational accident statistics are plentiful but these data do not describe causes and effects in sufficient detail for the quantitative risk modelling proposed for the WORM project (Ale et al, 2006).

The best data for examining causes and effects are as close and as detailed as possible to the origin of the accident. In WORM these sought after data are called "horrible stories". The issue with horrible stories from the WORM perspective is how well they are told. The use of language as a summary or explanation of what has happened filters and interprets what actually happened. It was decided early on in the project that instead of the analysts making an allocation of each accident to a set of predefined categories for statistical analysis, they would record as objectively as possible what happened in each accident as a sequence of cause and effect events as they appeared to occur, including any other incidental information. When analysts are developing scenarios from many accidents they need a grammar so that analyses are comparable. To this end a set of rules were developed alongside a piece of software that allowed the data from "horrible stories" to be recorded as efficiently as possible and enabling frequency counting of occurrences of scenario events with common nodes.

The work of analysing the accident data and the building in Storybuilder was completed in 2006. The database used was that of the Dutch Labour Inspectorate (Arbeidsinspectie) who electronically store all accidents reported to them since 1998 in a database called GISAI (Geïntegreerd InformatieSysteem ArbeidsInspectie). Employers are obliged to report serious occupational accidents. Sometimes this does not happen and the accident is either not notified at all or brought to the attention of the Labour Inspectorate by police, insurance companies or victims. Accidents are reportable according to article 9 of the Dutch Working Conditions Act (Arbowet 1998) if they are occupational accidents resulting in serious physical or mental injury or death within one year. A physical injury is considered to be serious if the victim is hospitalised within 24 hours and for at least 24 hours or the injury is permanent whether or not the victim is hospitalised. A reportable accident has to be reported within 24 hours. Then there are also criteria concerning whether an injury is permanent or not (physically or mentally).

Data were available on 22,892 occupational accidents that were reported between 1 January 1998 and end February 2004. 10,237 of these had no offence or investigation report and were not analysed. The main reason why there was no report was that they were not reportable (82% of the accidents without report). The other cases were waiting to be investigated or were under investigation or too sensitive to be made available.

Only accidents with reports could be used for detailed analysis of causes. There are different kinds of reports and only if a breach has been found is the report complete with respect to witness statements and injury classes. If there is no breach report then there is a summary of the investigation findings and the reason why it is not a breach. The latter were also analysed but contain less information. If the conclusion is that the accident was not an occupational accident e.g. natural death or suicide then these were not included in the analysis.

In total 9142 reportable occupational accidents were analysed in 36 storybuilds. To achieve this task took 5 person years of effort. This involved not only analysis but also quality checks on structure and content of the scenario storybuilds and adaptation of rules and structures. Bookkeeping was also important and required that all results could be traced to source and no double counting could occur. Due to time constraints only 2 years of data were analysed for *Falling Objects* and *Contact moving parts of a machine*, two of the biggest classes of accidents.

2. Analysis

One of the purposes of accident investigation is to enable a better understanding of how an accident happened and if necessary take action to protect other workers from a repetition (Arbeidsinspectie, 2005). Analysing the report data as described here provides hitherto unavailable statistics and insights. The analysis required the interpretation of the information by the analysts who were supplied with building rules and a structure template consisting of coded structures based on existing or developed classification systems. Where no applicable classification existed the analyst was allowed to use their own description system which would later be harmonised with those of other storybuilders.

Many of the structural components were based on European classifications such as ESAW (European Commission, 2001). Others were based on previous work in the I-Risk project (Bellamy et al, 1999) from which the WORM team was primarily configured. I-Risk developed a management system classification of 8 delivery systems: Plans and procedures, Availability, Competence, Communication and collaboration, Motivation and commitment, Conflict resolution, Ergonomics, Equipment. These deliver the resources and criteria for the tasks carried out in the workplace. During the WORM project these tasks were defined as Provide, Use, Maintain and Monitor and applied to workplace measures which prevent failure events. These measures were named "barriers" based on principles of loss prevention defined by Haddon (1973)

The GISAI data had not originally been coded according to accident type, causal factors or activity being undertaken at the time of the accident. They were coded for things such as the branch of industry in which the accident occurred and the inspection points, which are related closely to potential breaches of the law, which were considered to have occurred. Other data such as age, sex and year of the accident were also available.

The first task of the project was to devise a mutually exclusive coding of the type of accident. In the Data Warehouse (DAVE) developed in an interfacing project with WORM, the reportable GISAI accidents between January 1998 and Feb 2004 were first classified according to what was known as the Stone Bowtie List. This list of definitions was not allowed to change (cast in stone) during the WORM project. GISAI accidents were initially classified using the stone bowtie list according to the initial short report of the accident (1st pass bowtie classification) and then reclassified when the accident had been analysed in Storybuilder.

The bowtie list is actually a set of names for the centre event in a bowtie shaped structure of cause and effect events of occupational accidents. The centre event represents the contact with or release of the hazard "agent", such as "Contact with moving parts of a fixed machine" or "Fall on the same level" or "Loss of containment of hazardous substance". The set of bowties were derived from a comparison of a number of classifications including ESAW (European Commission 2001), the Dutch Labour Inspectorates priorities in reducing exposures to risks (Arbeidsinspectie, 2002), the British Health and Safety Executives RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995) classification, and a summary made by RIGO (Leidelmeijer et al, 2003).

Storybuilder files contain scenarios (horrible stories) all of which which pass through this centre event and end up in a reportable accident category (or unknown). A scenario is a sequence (in time) of events represented by a path that goes through a sequence of named boxes in the Storybuild structure starting on the left and ending on the right. Figure 1 gives an example of the bowtie shaped structure of one of the storybuild structures, the centre event being "*Fall from height scaffold*"

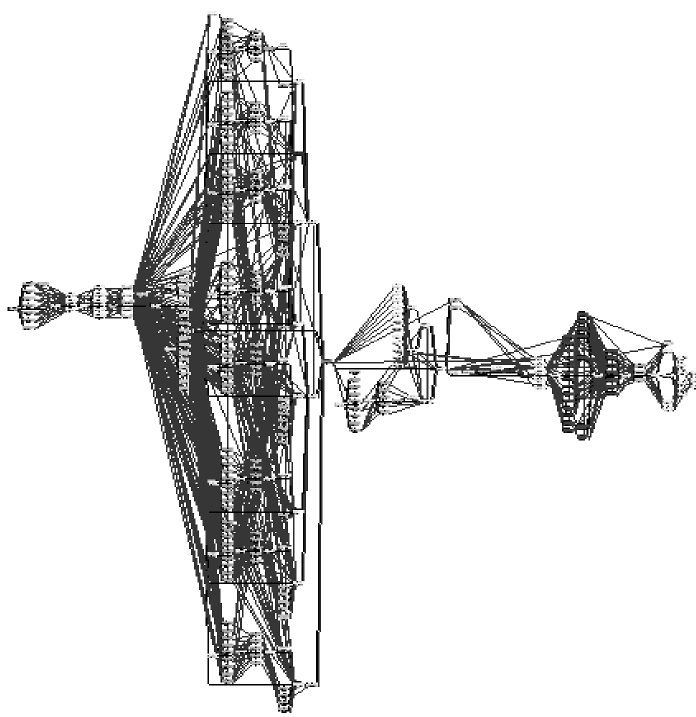

Figure 1 Small scale structure and pathways of 531 accidents of storybuild Fall from height - Scaffold

Figure 2 shows a close up of the same storybuild focusing on the *User stability fails* event and the barrier failures which led to this event, such as the failure *Scaffold floor deficiency*. Under this box is shown the number of paths passing through the event (73) and the number of victims in parethesis (75).

Figure 3 illustrates some of the coded template elements. In the upper part of the figure this shows the structure for analysing a barrier failure mode (BFM) of a safety barrier (B) which is attached to the resulting loss of control event (LCE). The barrier also has a success mode (BSM) BFMs have a task (T) and management delivery system (DS) structure attached to them CE is the centre event. Additional incidental information can always be added (IF) and accident pathways that leave that bowtie for another one (BWT) can also be indicated. The lower part of the figure shows the identical template structure with the actual analysis of accidents.

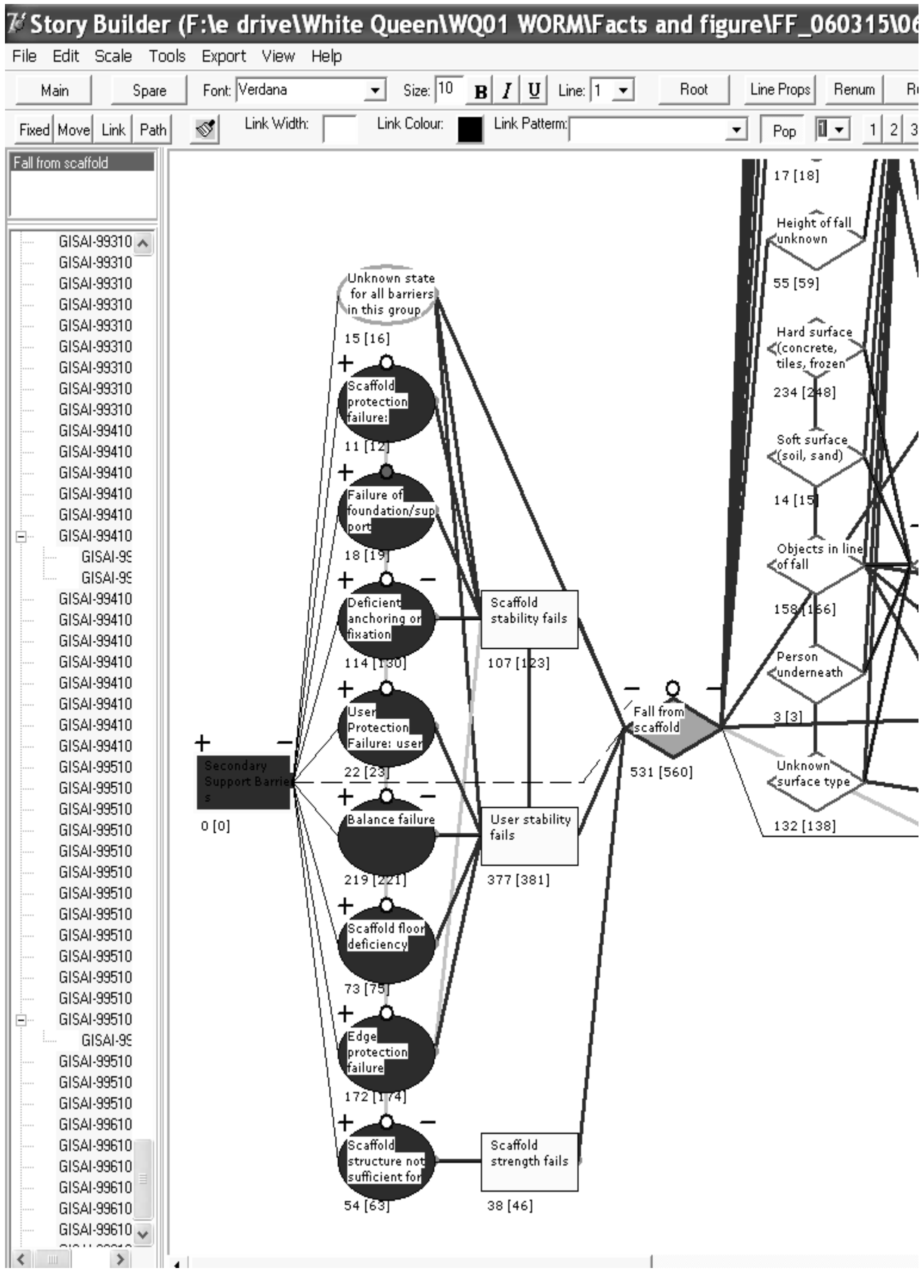

Figure 2 Part of collapsed structure for storybuild: Fall from height scaffold.

Note: Numbers below the boxes indicate accident path counts through the structure with associated number of victims shown in parenthesis [ ]. A path can never go through a box twice

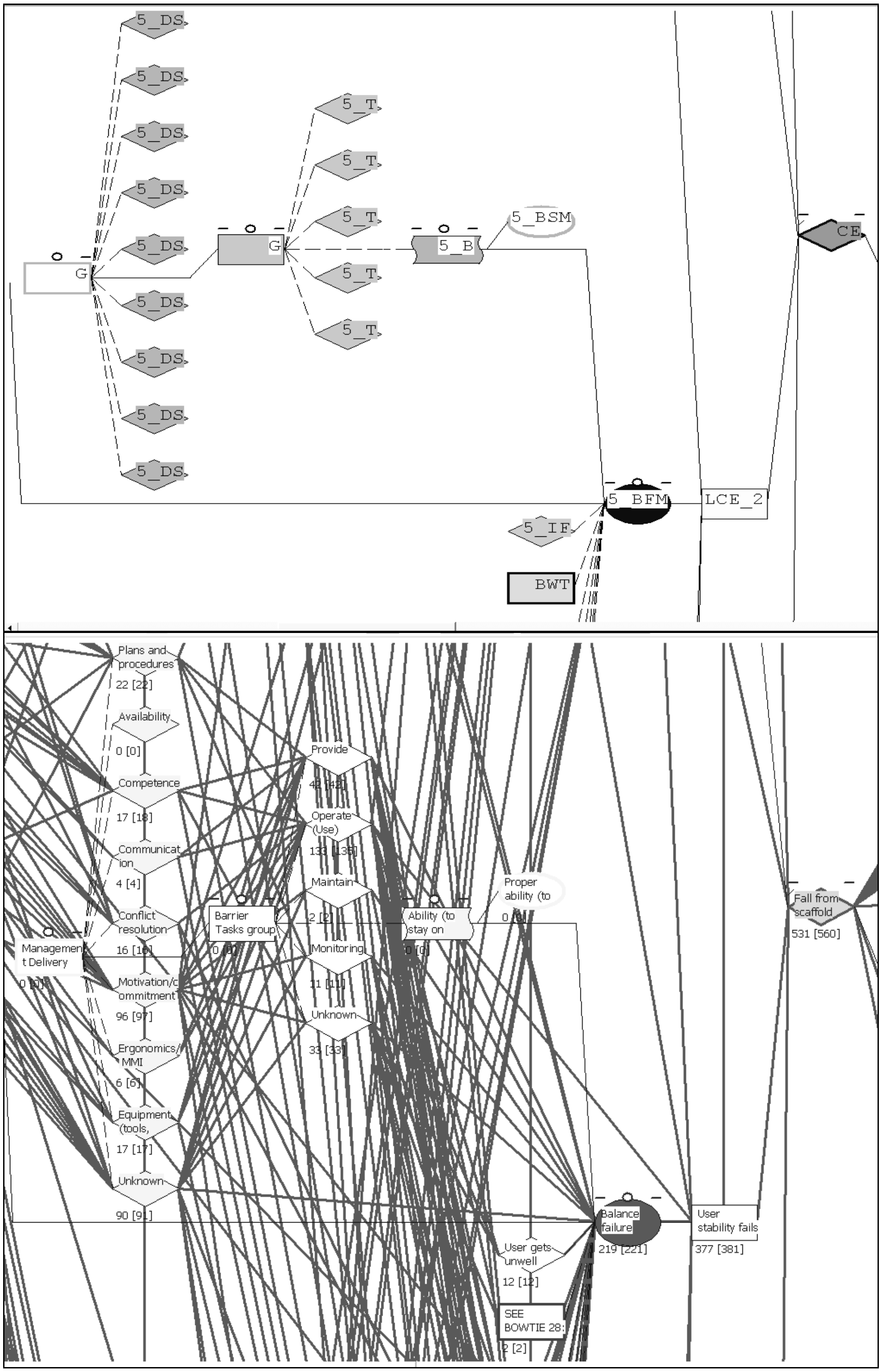

Figure 3 Coded template structure (above) and underlying the analysis (below)

The incidental factor (IF) information can be quite detailed as shown in Figure 4.

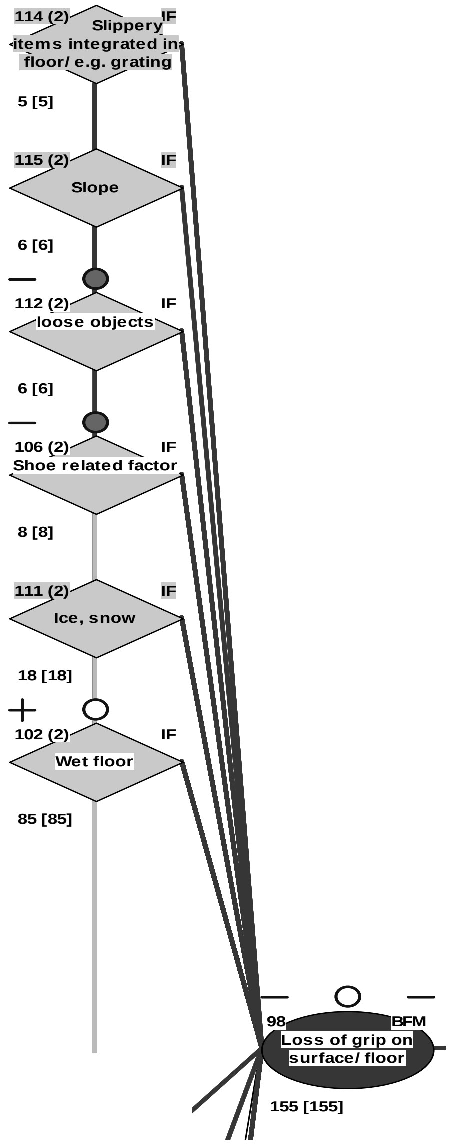

Figure 4 Incidental factors from the storybuild: Fall on same level

The BFM shown is a barrier failure for *Slip* events from storybuild *Fall on the same level*. The incidental factors are about the surface, such a wet floor (85 of the 155 loss of grip scenarios) or ice/snow present (18 scenarios). These data might be important later when modelling the risks that workers are exposed to and identifying ways of reducing the chance of failure.

As well as box codes there are also pattern codings. BFM, barrier failure mode, is always a red ellipse according to the rules. Figure 5 is the editing box.

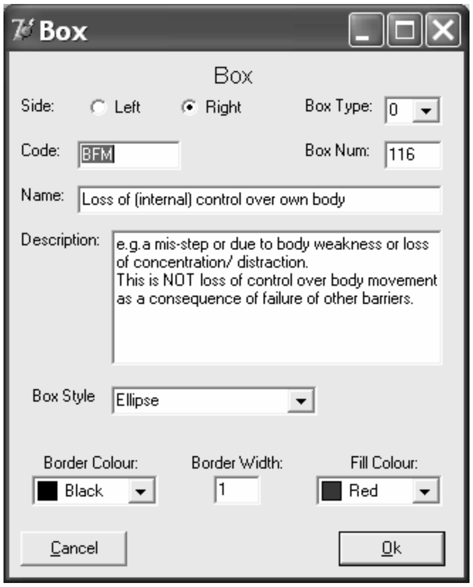

Figure 5 Editing box for BFM event from Storybuild : Fall on same level

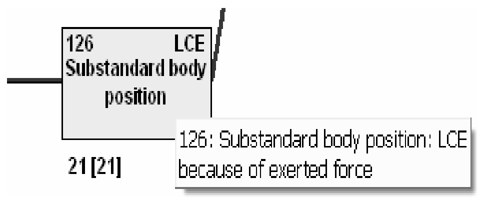

Figure 6 Holding the cursor over a box reveals the more detailed description

As well as defining box properties and entering the box name, further details about the event can be entered. This is important such that the reader of the Storybuild can understand what was meant by the builder. This additional description can be seen when holding the cursor over a box as shown in Figure 6.

Once the analysis is complete, path count queries can be selective based on the interest of the investigator. For example, Figure 7 shows storybuild *Contact with moving parts of a fixed machine* with only the accident paths which resulted in traumatic amputations as one of the injuries. 459 of the 843 accidents analysed involved traumatic amputations of which 439 were fingers.

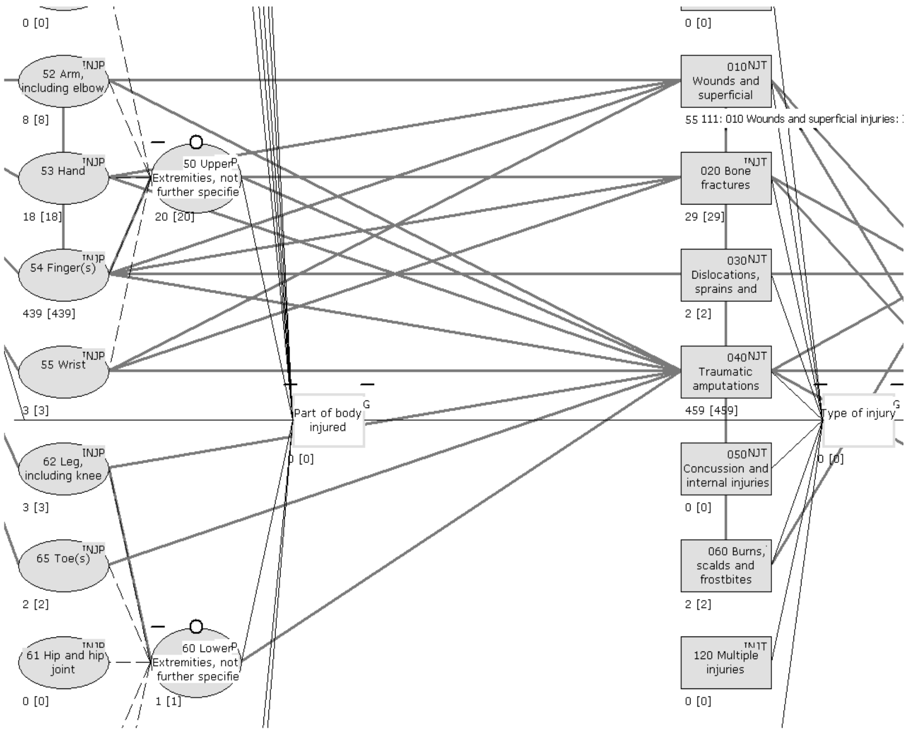

Figure 7 Example of use of ESAW classification for type of injury and body part injured for storybuild 8.1 Contact with moving parts of fixed machine showing only accidents with traumatic amputations and showing large number of amputations to fingers.

3. Facts and figures results

Figure 8 gives a top 20 list of the most frequent accident types. For example, *Fall on the same level* is in 8th place with 416 accidents.

Storybuilder data can be easily accessed using a function which gives the statistics for selected paths. An example is shown in Figure 9. Using these sources of data, Figure 10 gives some examples of accident triangles, after the famous work of Heinrich (1931) who indicated ratios of 1:29:300 for major:minor:no injury accidents. Our triangles show the ratios of deaths:permanent injury:recoverable injury.

Frequency order	StoryBuild Name	Years analysed: 1998-Feb 2004	Years analysed: 2002-2003	% of total per year	Total Accidents analysed	Accidents per year
1	Contact with moving parts of machine		x	**20.96%**	797	399
2	Fall from height - roof/platform/floor	x		**9.36%**	1099	178
3	Fall from height ladders	x		**9.10%**	1069	173
4	Contact with falling objects NOT cranes		x	**8.89%**	337	169
5	Struck by moving vehicle	x		**4.68%**	550	89
6	Fall from height scaffold	x		**4.52%**	530	86
7	In or on moving vehicle with loss of control	x		**4.47%**	522	85
8	Fall on same level	x		**3.52%**	416	67
9	Contact with flying/ ejected objects	x		**3.31%**	390	63
10	Contact with falling objects - cranes		x	**2.68%**	102	51
11	Trapped between/ against	x		**2.68%**	312	51
12	Fall from height - working on height unprotected	x		**2.42%**	286	46
13	Contact with object used/ carried	x		**2.10%**	247	40
14	Loss of Containment from normally closed	x		**2.10%**	244	40
15	Contact with handheld tools	x		**2.00%**	234	38
16	Contact with swinging/hanging objects	x		**2.00%**	232	38
17	Fall from height - non-moving vehicle	x		**1.74%**	205	33
18	Fall from height - moveable platform	x		**1.63%**	191	31
19	Contact with electricity	x		**1.63%**	190	31
20	Explosion	x		**1.32%**	157	25

Figure 8 Top 20 most frequent accident types between 1998 and February 2004

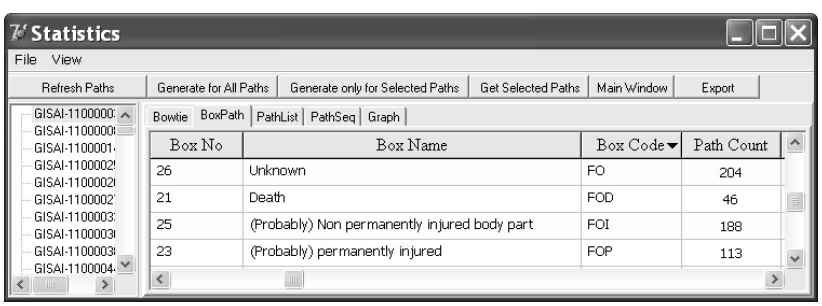

Figure 9 Section of the statistics screen for storybuild 2 Struck by moving vehicle (Path count of victims for 1998 - Feb 2004)

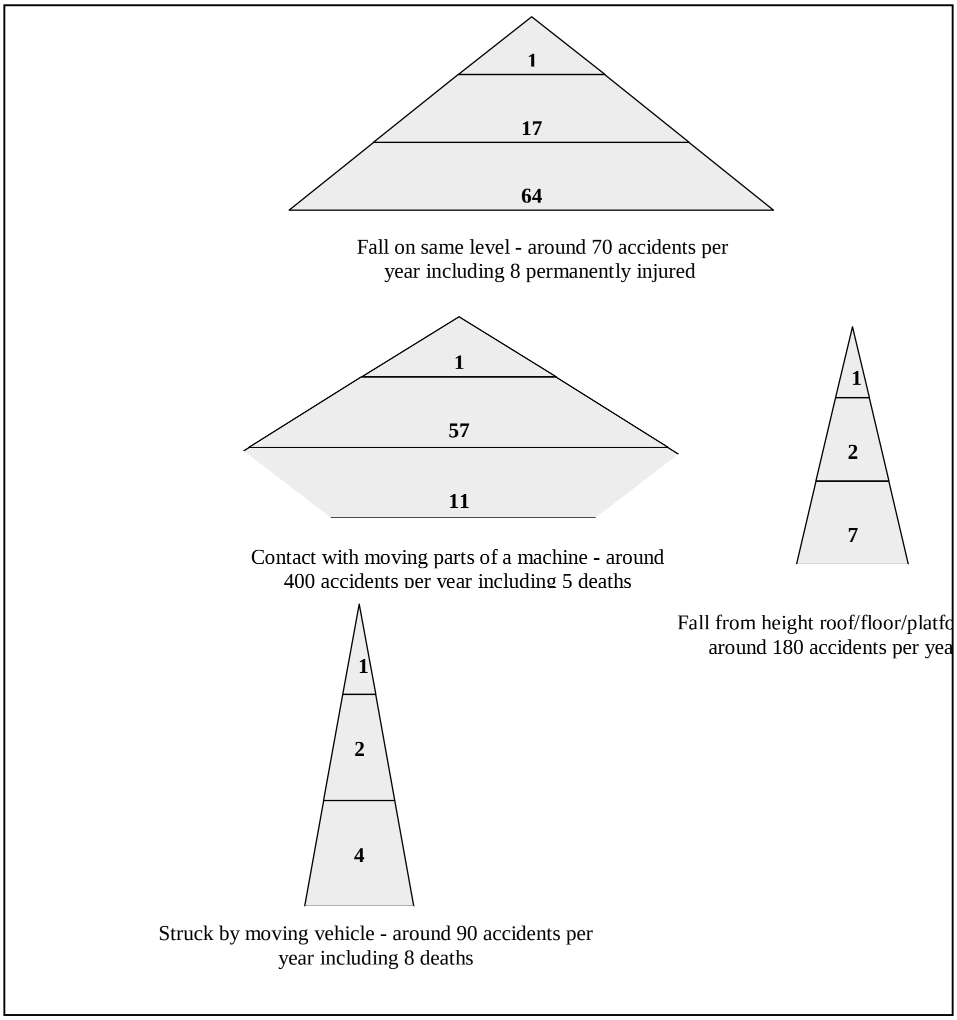

Figure 10 Selected accident triangles with ratios of death: permanent injury: recoverable injury with number of accidents per year below each triangle

Further analysis of the *Struck by Moving Vehicle* storybuild illustrates the structure found in all storybuilds as follows:
(1) Activity: Scenarios begin with the activity in this case of the driver and of the victim. Driving ahead and in reverse are more or less equal in the accident frequencies but there are even cases of an apparently still vehicle having an unexpected unintentional movement because, for example, the brake is not used when parked (7.5% of all bowtie 2 accidents). In most cases (31.4%) the victim is standing by passively.
(2) Equipment type: Usually the storybuild specifies the type of equipment involved. In this case 58% of accidents involved equipment category ESAW 11.04 Mobile handling devices, handling trucks (powered or not) - barrows, pallet trucks, etc. 46% of all struck by moving vehicle accidents were caused by forklifts.
(3) First barriers group: In this case substandard layout barriers such as insufficient space between the vehicle and pedestrian routes (17% of the accidents)
(4) Second barriers group: In this case driver/vehicle failures such as visual contact failure (47%) and lock out failure, such as leaving the vehicle prematurely, vehicle not on the brake, ignition key not removed or start-up due to other errors (18%)
(5) 3rd barriers group: In this case pedestrian related such as being in a hazardous location (43%) including passing by or standing by the rear of the vehicle (24% of the accidents).

All barrier failures have management delivery and task failures associated with them. Averaged across all barrier failure modes the management delivery results are shown in Figures 11 and 12. Motivation/commitment failure dominates. Motivation/ Commitment refers to incentives and motivation with which people have to carry out their tasks and activities, i.e. with suitable care and alertness and according to the appropriate safety criteria and procedures specified for the activities by the organisation. This delivery system also includes the aspect of alertness, care & attention, concern for safety of self and others, risk avoidance and willingness to learn & improve. More personal aspects, such as violation of procedures, are covered by Motivation and Commitment.

Figure 12 shows that failure to use the barriers constitutes 63% of *struck by moving vehicle* accidents.

FAILED MANAGEMENT DELIVERY TO THE TASK	% OF TOTAL
Motivation/commitment	45.82%
Plans and procedures	22.11%
Equipment (tools, spares, parts)	10.32%
Ergonomics/ MMI	5.77%
Communication /collaboration	5.65%
Competence	5.65%
Conflict resolution	4.30%
Availability	0.37%

Figure 11 Management delivery failures for storybuild 2. Struck by moving vehicle

FAILED TASK FOR THE BARRIER	% OF TOTAL
Use	63%
Provide	32%
Maintain	3%
Monitor	2%

Figure 12 Barrier task failures for storybuild: Struck by moving vehicle

(6) The Centre Event *Struck by moving vehicle*, comes after the final lines of defence fail. It has 550 analysed reported accidents.
(7) Dose determining factors: For example, in 78% of cases where the velocity of the vehicle was known it was travelling at less than 5 km/hr. Another example is the wearing of safety shoes (Figure 13). In the known YES or NO safety shoes accidents the percentage with toe and foot amputations is higher in the NO group. Although the numbers are very small it seems reasonable to suppose that safety shoes reduce the chance of amputations.

(a) Victim wearing safety shoes?	(b) Number of accidents	(c) Accident with Toe and foot amputations	(c) ÷ (b) %
YES	46	3	6..5%
NO	22	7	31.8%

Figure 13 Toe and foot amputations in relation to wearing or not wearing safety shoes for storybuild Struck by moving vehicle

(8) Emergency response. For example there were 35 known cases of effective emergency response/first aid, meaning the first aider was on time there was no wrong diagnosis and there was an ambulance when needed (on time). This contrasts with 8 known cases of ineffective response such as not in time, wrong diagnosis and/or unqualified as first aider.
(9) Common casualties per accident path or subpath indicates the number of victims common to the subsequent path eg, C=2 means the paths through this box bear 2 casualties with common outcomes. C=1 was 550 with 551 casualties in *Struck by moving vehicle*.
(10) Part of body injured: 34% had leg injuries, and
(11) Type of injury: 58% had bone fractures.
(12) Hospitalisation: 84% were hospitalised
(13) Consequences: death, permanent or recoverable injury as shown in Figure 9. **(14) Absence from work**. For example 52% of permanent injures with known absence duration resulted in more than 6 months off work (25 cases) and 47% resulted in more than 1 month absence.

Depending on the type of storybuild there may be additional factors such as a block of barriers on the right hand side dedicated to protection measures and mitigation measures (as with *15 Loss of containment from normally closed containments*) or there may be less lines of defence in the left hand side as with storybuild *11 In or on vehicle with loss of control*. However, apart from small structural differences and detail, in principle all storybuilds follow the same left to right pattern.

4. Conclusion

A tool to analyse accident data in a consistent and coherent way has been developed. With this tool, called Storybuilder, all aspects of accidents can be captured which are relevant and necessary for the analysis and for the building of a causal model. The results obtained from the database of the Dutch Labour Inspectorate give valuable insights into the mechanisms of accident causation across all but the rarest types of occupational accidents. The tool is useful for identifying prevention and protection mechanisms and giving statistical information on failures at a level of detail never seen before. It is therefore important to enable this tool and the databases to be made widely available to safety professionals.

5. References

(1) Ale, B.J.M, Baksteen, H., Bellamy, L.J., Bloemhof, A., Goossens, L., Hale, A.R., Mud, M.L., Oh, J.I.H., Papazoglou, I.A., Post, J., Whiston, J.Y., 2006. Quantifying occupational risk: The development of an occupational risk model. Conference: Working on Safety 2006, The Eemhof, The Netherlands, 12-15 September.
(2) Arbeidesinspectie, 2002. Proposed structure of a risk analysis model for working conditions. In Dutch. (*Voorstel opzet risico analyse model arbeidsomstandigheden*). Unpublished Internal Labour Inspectorate Document,, Ministry SZW, The Netherlands .July 2002.
(3) Arbeidsinspectie, 2005. Internal instruction. The handling of reported occupational accidents Interne Instructie. Afhandeling meldingen van arbeidsongevallen http://www.arbo.nl/systems/organisations/

(4) Arbowet Artikel 9, 1999. Article 9 in the 1999 Revision to Dutch Working Conditons Law of 1998 & the Explanatory Memorandum. In Dutch *(Wet van 18 maart 1999 Arbeidsomstandighedenwet 1998)* Staatsblad van het Koninkrijk der Nederlanden 184.
(5) Bellamy L.J., Papazoglou I.A., Hale A.R., Aneziris O.N., Ale B.J.M., Morris M.I. & Oh J.I.H. 1999. I-Risk: Development of an integrated technical and management risk control and monitoring methodology for managing and quantifying on-site and off-site risks. Contract ENVA-CT96-0243. Report to European Union. Ministry of Social Affairs and Employment. Den Haag.
(6) European Commission, 2001. European statistics on accidents at work (ESAW) Methodology 2001 E Doc. ESTAT/E3/HSW/2001/1130.
(7) Haddon Jr., W., (1973) “Energy Damage and the Ten Countermeasure Strategies,” Human Factors Journal, Volume 15.
(8) Heinrich, H. W. (1931). Industrial Accident Prevention. New York: McGraw Hill.
(9) Leidelmeijer, K., Grieken, P. v., Pouw, N., Heemskerk, H. (2003) Towards a risk model of occupational accidents. In Dutch (*Naar een risicomodel arbeidsongevallen*). Report 83530, RIGO Research en Advies BV, Amsterdam, The Netherlands

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