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# Exploring the relationship between major hazard, fatal and non-fatal accidents through outcomes and causes

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ABSTRACT

Smaller severity more frequent accidents can provide information about the direct and underlying causes of bigger severity more catastrophic accidents but only if looking within the same hazard category. Use is made of a database of around 23,000 Dutch serious reportable accidents 1998–2009 that have been analysed in Storybuilder™ in 36 hazard specific bow-ties using a management-task-safety barrier model of failure causation. The data are first developed as hazard specific accident triangles to show differences in lethality. Then comparisons of fatal and non-fatal accident causes are carried out, showing commonality in causes. The same is done for two case studies of catastrophic accidents – the Amercentrale power station scaffold collapse in the Netherlands and the major chemical accident at the Buncefield oil storage depot in the UK. Results indicate that, provided accidents from different hazard bow-ties are not mixed together, small severity more frequent accidents can be used to consider the causation and hence prevention of the bigger severity rarer accidents. This leads to the conclusion that the analysis of occupational accidents can help in addressing major ones providing it is restricted to the same hazard type, contradicting the view that personal and process safety are totally unrelated.



## 1. Introduction

Occupational accidents are frequent, usually single victim, events. There are statistics on their numbers, such as published by the European Commission (2009). Amongst occupational accidents fatal accidents are rarer events than the non-fatal (Hämäläinen et al., 2009). Multiple fatality occupational accidents are even rarer and may be referred to as catastrophes e.g. in the US the Occupational Safety and Health Administration describes in-patient hospitalisation of three or more employees as a catastrophe (US Department of Labour, 2014). Major accidents, a term generally associated with process safety and involving fire, explosion or toxic emission (EU Council, 1996), are also rare events and usually result in publically available investigation reports. So, a catastrophe or a major accident is denoted by its significant consequences such as multiple fatalities or the potential for multiple fatalities or an accident which causes significant social unrest. Well known major accident examples are the Union Carbide chemical loss of containment disaster at Bhopal in India in 1984 with 2500 deaths being reported within 5 days or the radioactive release from the Chernobyl nuclear power plant explosion in the Ukraine in 1986 leaving large areas contaminated with radioactive fallout. Major accidents can cost billions in property damage, criminal charges and compensation claims, like the Deepwater Horizon drilling accident in the Gulf of Mexico in 2010. They can create a lot of social concern like the Buncefield tank farm fire in the UK in 2005 which, despite being one of the UK's most costly disasters, did not make the 100 largest losses (Marsh Ltd., 2012) despite having an explosion which was heard as far away as Denmark and a very large plume of smoke.

Large scale accidents provoke a detailed investigation and cultural re-evaluation of precautions. Whatever the chance combination of factors, these rare events may have been preventable in hindsight, as many accident investigation conclusions aspire to show. Organisations are found with blind spots, communication problems and conflicts, incubating accidents and ignoring their warning signs (Turner, 1978). Increasingly complex high hazard technologies are seen as generating the inevitable "normal" accident (Perrow, 1984) where a seemingly minor malfunction can trigger an unexpected serious of interactions leading to catastrophe. By contrast to the large scale investigations of big accidents, occupational accidents rarely make large-scale investigation or the news. In the Netherlands some exceptions include the Amercentrale scaffold accident in 2003 where 5 people died when the scaffold they were working on collapsed (Ministry of Social Affairs and Employment, 2007), the collapse of a tower crane in 2008 in

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which the crane operator died (Swuste, 2013) or the roof collapse during extension work at the football stadium of FC Twente when 2 workers were killed and 9 injured (Dutch Safety Board, 2012).

This paper explores the relationship between big and the small consequence accidents, fatal versus non-fatal occupational accidents being one subset and major and occupational accidents being another. In some cases bigger and smaller severity consequence accidents are thought to be related because of models like Bird and Germain (1986) where unsafe acts and unsafe conditions are considered to be symptoms of bigger problems. In others they are thought to be unrelated as concluded by the Baker (2007) report of the Texas City refinery explosion which criticised the use of occupational injury statistics to measure process safety performance. Hale (2002) had earlier concluded that thinking that the prevention of minor accidents leads to the prevention of major accidents is based on careless and unsupported reasoning and highlights the need to take a scenario specific approach to understanding accident causation. In the current paper the author does just that by exploring the direct and underlying causes of occupational accidents to consider the potential for using that information for preventing the catastrophic and major accidents.

## 2. Database

### 2.1. Background

The database used for the current paper contains 23,030 occupational accidents which occurred in the Netherlands between 1998 and 2009 and which are the investigated more serious accidents which are reportable under Dutch labour law according to Article 9 of the Working Conditions Act (*Arbeidsomstandighedenwet*) by virtue of being a death, permanent injury or leading to hospital admission. Over the past decade certain databases developed in the Netherlands have focused on collecting accident scenario data by analysing the investigations carried out by the inspectorate of the Ministry of Social Affairs and Employment. Accident analysis needs a vision or model of the framework an accident is going to fit into. Accidents can be re-used over and over again in many different frameworks for identifying patterns in the data and categorising them. The selection of data categories filters the information and much may be lost from the details of an accident story if preconceived filters are applied. This can be troublesome if the future use of the database and the questions to be asked are not yet known. For this reason a tool was developed called Storybuilder™ (Bellamy et al., 2006, 2007, 2008; RIVM, 2008) which would facilitate the building of accident scenarios without having a preconceived classification system. Evolving models of safety barriers were constructed within Storybuilder™ covering all the workplace hazards encountered in the data set. This model is further described in Section 3.2. Analysts capture the sequence of events in an accident within the bounds of a set of modelling rules and according to witness accounts and in-depth investigations by the regulator. Such information is always hindsight and so subject to filters and biases of observers and investigators. The regulator for example performs enforcement tasks and so is looking to see if the law has been broken. The regulator is not generally looking for other things outside the model for investigation. This means that the data for accident analysis will primarily be about the failures which could constitute a breach of the law plus a certain amount of data about causal mechanisms and contingent factors.

### 2.2. Dutch occupational accident database

Dutch serious investigated reported accidents occurring between 1998 and 2009 (12 years) were examined by a team of analysts using the model described in Section 3.2 and from the data of 23,030 accidents with 23,799 victims. These accidents constitute about 1% of all Dutch occupational accidents and are the more serious which are reportable under Dutch labour law. Note that a proportion of the occupational accidents which were reported are non-reportable (such as non-hospitalised victims with recoverable injuries or accidents involving the self-employed or natural deaths) but some of these have nonetheless been investigated (estimated to be less than 10% of the accidents analysed). There is also estimated to be a certain amount of underreporting which may be as much as 50% (Schouten et al., 2008).

The accidents have been analysed in the program Storybuilder™ mentioned earlier. The accidents are distributed over 36 hazards in the form of scenarios running through 36 bow-tie diagrams, these being models of causes and effects on the left and right side respectively of a centre event representing the release of the agent of harm. Data are kept separately on characteristics of the victims and companies making it possible to analyse the data for specific sub selections of scenarios, such as for the construction industry (Ale et al., 2008). The database and software are available from RIVM (2014).

## 3. Models

### 3.1. Accident ratios: triangles and hills

The accident triangle has long been a model representing the relationship between the number of occurrences of more and less serious consequence accidents. Two pioneers of the accident triangle are Heinrich (1931) and Bird (Bird and Germain, 1986). The basic concept of this model is that the more severe the accident the less there are and that taking care of the smaller accidents or accident components, like unsafe acts, will reduce the chance of bigger less frequent accident. The idea is that to prevent the severest accidents, use can be made of the knowledge that could be gained from the more numerous smaller accidents and near misses which occur at the base of a triangle of accidents as shown in Fig. 1, the famous Heinrich triangle.

At a statistical outcome level it was a belief of some that a low frequency of serious occupational accident outcomes was a good general safety indicator for process safety as well. However, the Baker Panel Report (Baker, 2007) emphasised that occupational safety indicators were not good predictors of process safety and could even hinder the perception of process risks. Another negative

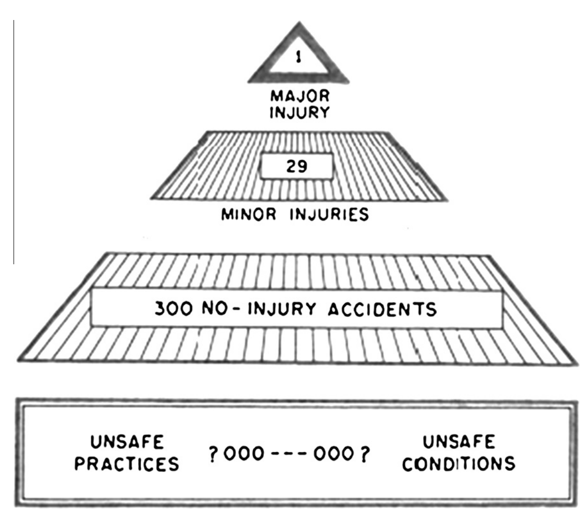


**Fig. 1.** Heinrich triangle (Heinrich, 1931).