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QUALITATIVE METHODS FOR OCCUPATIONAL RISK PREVENTION STRATEGIES IN SAFETY, OR CONTROL BANDING – SAFETY

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INTRODUCTION

Control banding is a rather powerful tool. Although nobody understands the term Control Banding, it can be describes as: an approach to exposure control using a tool designed by occupational hygienists and toxicologists to enable users of chemicals, using readily available information about the chemicals and the workplace, to rank hazard and assess risk'. 'Depending on level of risk users are directed to control solutions provided in a series of control sheets, or to seek specialist advice' (Zalk, 2005).

Control banding is a qualitative tool, using the same steps as more traditional occupational hygiene strategies; where you measure exposures, compare the outcomes with for instance exposure limits, and finally control the levels of exposures to acceptable levels. In Control Banding the same strategy is followed, only using so-called banding principles to assess hazards and exposure scenario's, and to decide appropriate control strategies. Although the Control Banding tool has received criticism (see for instance Kromhout, 2002; Swuste et al, 2004), the focus on controls, without a lot of expert input, is a strong point of the tool and makes it applicable in branches and countries, which are deprived of expert support.

The possibilities to apply control banding principles in occupational safety are explored. Occupational safety is not restricted to chemical safety, e.g. the use of flammable and/or exploding chemicals in production processes. But a more general topic of occupational safety is considered, focussing on causes of both major and minor occupational accidents. As a start a few models of accident causation will be discussed, listening to colourful names as 'Swiss cheese', and 'Bow-tie'. In the second part of the presentation the example of vertical lifting of loads will be discussed, an activity with substantial occupational hazards and risks.

MODELS OF ACCIDENT CAUSATION

Models of occupational risk prevention are essential to understand the causal pathway of accidents. These models will describe which data are relevant to collect. Together with insight in the context of the events occurring, these data can be transformed into information, and with the aid of models information can be turned into knowledge. Knowledge on causal pathways of accidents not only provides insight in reasons why accidents occur, but also directs efforts to prevent these accidents. The scientific field dealing with occupational risk prevention, however, is relatively young, and so are the models presented (Swuste, 2006).

Swiss cheese model

The Swiss cheese model of Reason (1993, 1997), which name is coming from its presentation (see figure 1), is a comprehensive model to understand the difficulties companies encounter to prevent hazards from becoming risks and create losses. The different slices of the model represent the many layers of defenses, like barriers, safeguards, a company has installed as part of their risk prevention program. The model refers to long latency periods of the so-called latent conditions in the company's decision making process, long before critical events actually take place. The holes in the cheese represent the active failures or the unsafe acts immediately prior to the consequences, or losses, but also these latent conditions. Reason compares latent conditions in technological organizations with resident pathogens in a human body. Examples of latent conditions are poor design, gaps in supervision, undetected manufacturing defects, defects or maintenance failures, unworkable procedures, clumsy automation, shortfalls in training, or less than adequate tools and equipment.

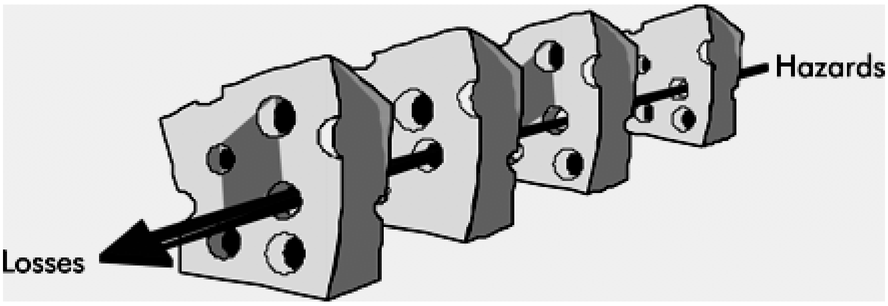

Figure 1 Swiss cheese model

Like pathogens, latent conditions may be present for many years before they combine with local circumstances and active failures to penetrate the many layers of defenses, as is shown in the simplified Swiss cheese model at figure 2.

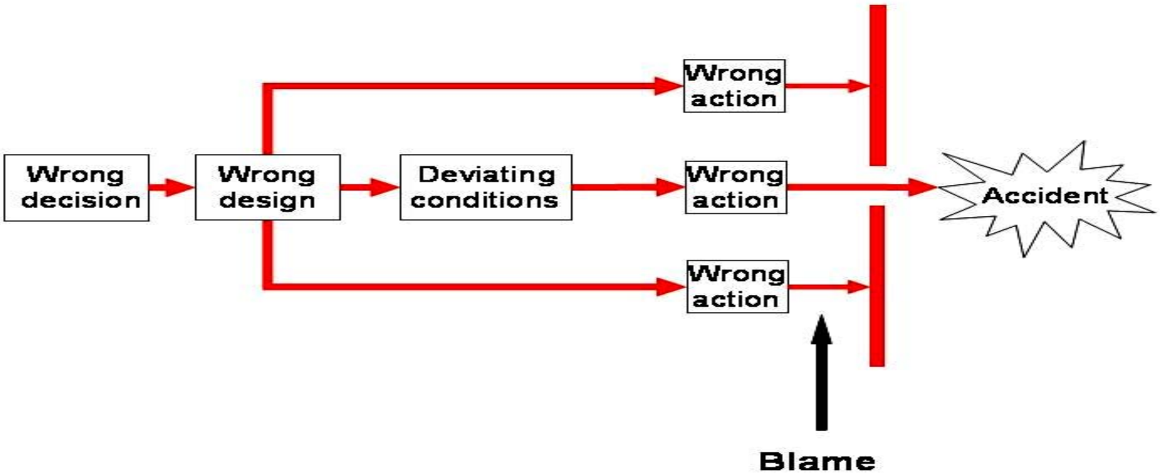

Figure 2 Simplified Swiss cheese model

Unsafe acts are mostly situated in the last slices, while latent conditions are the holes throughout the cheese. Accidents and major accidents are not only caused by direct physical events. The biggest threat is not the isolated human errors of workers at the sharp end of an accident or disaster sequence, but the accumulation of latent failures. Human errors and failures are not seen as causes, but as consequences.

Bow-tie model

A bow-tie is a combination of a fault tree and an event tree, linked together by a 'central event'. As with the Swiss cheese the name of this model reflects its presentation (figure 3). The left side of the bow-tie represents a fault tree consisting of a set of scenario's starting from exposure to a hazard, or energy, and following a path of critical events through AND and OR gates to the central event. This central event can depict a loss of containment in, for instance the process industry, or a 'loss of control'. Falling from heights, or a falling object from a crane, for instance, are examples of loss of control. From the central event onwards the event tree on the right side of the bow-tie describes the scenario pathways leading to different kinds of damage.

This way of presenting (major) accidents has a major advantage. The model focuses risk prevention activities to central events. Companies can focus their attention on central events they would like to avoid most, either guided by past experience, or guided by the notion that some central events will jeopardize their production. It is astonishing to see that most companies only have vague ideas on central events they need to avoid.

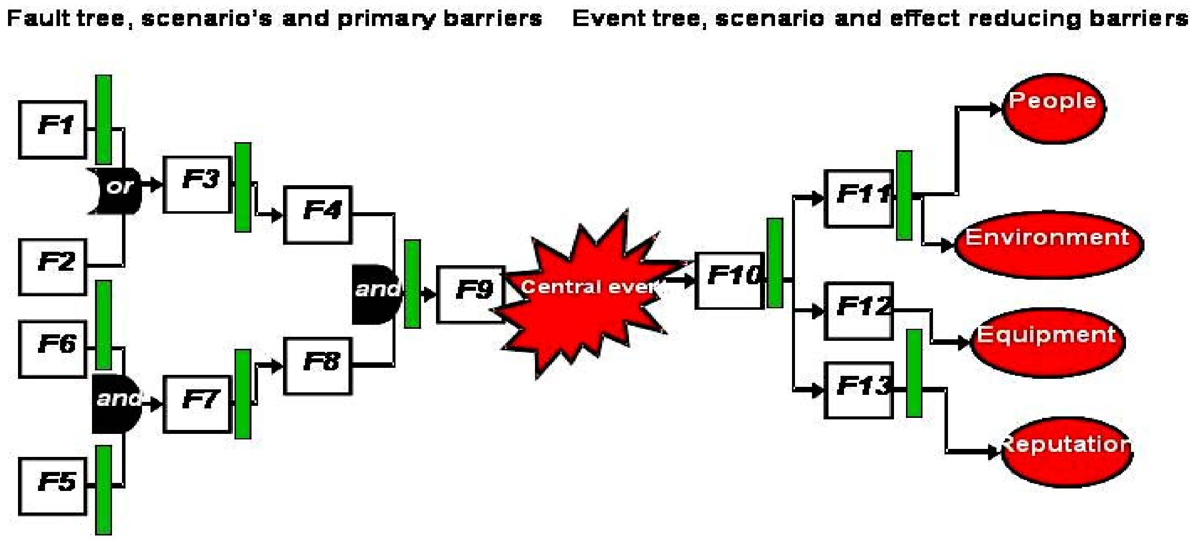

Figure 3 Bow-tie model

The bow-tie model directs the attention towards various barriers to prevent scenarios from propagating. This is a second advantage of this model. These barriers block the stream of energy, and usually are hard ware devices. But the quality of these barriers is determined by management factors. These management factors provide a clear link with safety management systems, because management decides which type of barrier is relevant for which hazard, or risk, and for which scenario. At the bottom line management of safety is nothing more than managing barriers, to provide, install, and maintain them, to develop procedures and training when necessary as well as inspection.

Finally the bow-tie model has scenario's as a main component of the model, either for major or for minor accidents. This difference between different types of accidents is important. It is a common belief that minor and major accidents share the same causes, or accident scenarios and their consequences are largely governed by chance. The well known accident triangles on the relation between major and minor accidents are based upon this assumption. But quite some references in the field of safety science argue an opposite view. Lost-time and non-lost-time industrial accidents show a different pattern (Shannon and Manning, 1980). And also between fatal and non-fatal occupational accidents different mechanisms of causation have been demonstrated (see for instance Salminen et al. 1992; Salonemi and Oksanen, 1998). This means that differences in severity of scenarios is basically a difference in accident scenarios. The amount of energy locked up in a process and released by the accident process will significantly determine the amount of damage done (Hale, 2002). The observation of differences in accident scenarios is very relevant for risk prevention activities. If central events from minor accidents do not contribute to major accidents, because of differences in pathways, then it does not make sense to try to prevent major accidents by conquering minor ones.

In The Netherlands the bow-tie is being used for the analysis of accidents reports of the Factory Inspectorate (Mud, 2005), but also audit applications have been developed, and tested. Recent publications on scenario based auditing look very promising (Guldenmund et al. 2006; Zemering and Swuste, 2005).

Central events

Falling from heights is an important central event, already a long period of time And also nowadays this central event still ranks number one on the list of central events from accidents occurring in The Netherlands, as can be seen from table 1. Apparently we are not able to reduce scenario's leading to this central event.

Table 1 derives from a large project on accident causation in The Netherlands, using all accident reports (n = 12.655) from the Dutch Factory Inspectorate (Mud, 2005). This registration contains all serious and fatal occupational accidents in the period 1998 – 2003, and provides an overview across all branches of industry.

Central events (n = 12.655)
1. Falling from heights
2. Contact with moving parts of fixed machinery
3. Contact with falling objects
4. Stuck by vehicle
5. Loss of control in or on moving vehicles
6. Contact with hoisted, hanging, swinging objects
7. Contact with object a person in holding, using, carrying
8. Contact with handheld tools
9. Contact of moving person against object
10. Contact with charged objects
11. Loss of control of hazardous chemicals

Table 1 Central events from the Dutch accident registration, 1998-2003

VERTICAL LIFTING OF LOADS

Big Blue

Vertical lifting of loads is a rather hazardous operation. Although the number of registered accidents is relatively low, only 174 in the 6 years period, the consequences are mostly severe, due to the mass of the loads lifted and of the installations involved in lifting. Accidents with cranes are shown in media every once in a while, and always result is spectacular pictures. A famous accident is one occurring in the US, in Milwaukee in 1999. Regular viewers of Discovery Channel Frequently are probably familiar with the 'Big Blue' accident, as the crane involved was known (JS Online, 2006). The crane itself was a modern giant, with a counterweight of 1150 tons and a boom of 172 meter. The left picture of figure 5 shows the V shaped crane with an extended jib, while hoisting a roof element of 400 tons. At one moment the crane collapsed, leaving nothing more than a heap of scrap, as is shown in the right picture of figure 5.

A detailed analysis of this accident revealed that external conditions, a sudden gust of wind, created load instability and a consequential extreme torsion in the boom, leading to jib instability and finally to the crash of the crane. Apart from this direct cause of the accident the analysis also showed managerial factors, being the time pressure under which the project has to be performed, as well as the decision to start hoisting at the limits of acceptable weather conditions. In safety science this phenomenon is called 'conflict resolution', pointing at possible conflicts that can occur between safety and other company goals, like for instance production pressure.

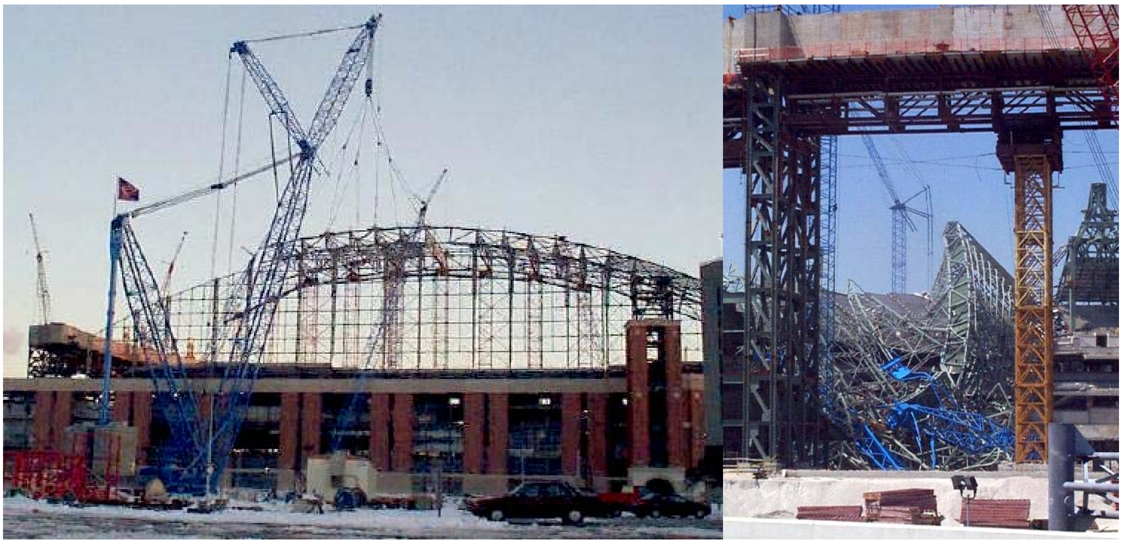

Figure 5 Big Blue, Milwaukee 1999, before and after

One can only conclude afterwards that apparently major accident scenario's were not taken seriously in managing this hoisting activity, or in more general terms that these accident scenario's and central event only played a minor role in decision making, and accident causation models were not an active part of the operational safety management system.

Central events during hoisting activities

The central registration system allowed us to take a closer look at the central events occurring during hoisting activities. An overview is given in table 2. This table shows the dominant position of load instabilities, either occurring during hooking loads, or during load transport. The contacts with counter weights and jibs describe accidents which happen during crane movements, when people are hit by moving counter weights or jibs.

Central events of hoisting activities (n=174)	
Instability load	72 %
Contact counter weight, or jib	11 %
Instability crane	7 %
Instability hoisting gear	5 %
Instability jib	3 %

Table 2 Central events of hoisting activities

The other central events, like crane instability due for instance to ground instability, breaking hoisting cables (instability hoisting gear), or mechanical failures on jibs occur much less frequently. This reflects the high technological level of most cranes, which are equipped with all sorts of sensors to detect these events. (Swuste, 2005)

A closer look at the first central event, instability of load, will give an impression on the type of barrier failures occurring. This overview is given in table 3. This table is divided between failures of hardware barriers and management factors. Improper connection is a failure during hooking up the load, and hardware failures refer to braking hoisting chains or ropes. The killer hook in the table is a hook with a lacking or deficient security device allowing hoisting ropes to slip out of the hook.

At the management factors the earlier mentioned conflict resolution appears, meaning the hooking up of the load was carried out too hastily, and inadequately, due to time pressures. Competence failure refers to the competence of the man hooking up the load, he had no proper knowledge to execute the job adequately. And the ground location failure is the presence of workers inside the hoisting path. The communication failure refers to the lack of communication between the crane driver and these workers (Paas and Swuste, 2006).

Barrier failures, instability load	
Safety barriers (hardware)	Improper connection load, equipment failure
	Failing load securing mechanism, killer hook
Management factors	Improper connection, conflict resolution
	Improper connection, competence failure
	Ground location failure, communication failure
	Substandard external conditions, conflict resolution (big blue)

Table 3 Barrier failures, hardware and management factors, during load instability

CONCLUSIONS

Control Banding and Safety

At the bottom line, managing safety is nothing more than managing barriers. Going back to the three steps mentioned at the introduction the following remarks can be made regarding the Control Banding and Safety options.

'Measuring' in safety means an overview of dominant scenario's, their barriers, and finally the resulting central events. An overview of a hierarchy in central events of (major) accidents occurring in all branches of industry, as shown in table 1 can be a starting point. As the example of lifting vertical loads shows, in specific branches the hierarchy of central events and barrier failures can differ substantially from a general list, meaning that branch specific overviews are advisable.

'Comparing' in safety is a bit complicated, but can be tackled by comparing frequency rates of central events. We do have a so-called risk matrix, where actual or expected frequencies of central events are compared to actual or expected consequences. This matrix has a colour code as a result, which is an indication for the type of action required.

'Controlling', or better managing barriers can be divided into hardware barriers, or distance, and are similar to most of the control strategies of Control Banding. Management factors control the quality of these barriers, including the design process of barriers, the availability of competent and committed workers (training), procedures for barriers, inspection and maintenance etc., etc. These management factors have a direct relation to management systems and to scenarios a company likes to prevent. Using banding principles for management factors is not easy at first sight.

Small sized enterprises

The latent failures in the Swiss cheese model are similar to the management factors in the bow-tie model. These management factors have some similarity with the long latency periods, or with effects of chronic exposure to hazardous chemicals. But there is also a main difference between the field of occupational safety and occupational hygiene. Using the bow-tie model the long latency periods of occupational diseases, or the effects of chronic exposure to chemicals refer to the right hand site of the bow-tie, to the scenario's starting from the central events onwards. In occupational safety the time frame between the central events and their final consequences generally will take seconds, or even shorter periods of time. The time frame starting from hazards and leading to a central event, the left hand site of the bow-tie will generally take much longer, and may count for weeks or even years. If only a hazard are known, than the listing and prioritizing of central events will be a major effort and does need some further research. Possibly in various branches of small sized enterprises the central events are clear cut.

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