Modelling human and organizational behaviour in a high-risk operation

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Abstract: A core part of the risk modelling program for the Oil and Gas industry being carried out at Delft University of Technology is the influence of humans, within an organisation, as well as the technical factors. Specific attention is given to the incentive structure of operators, staff and managers, which in previous models had only been indicated more generally by motivation and conflict resolution. An incentive structure represents an empirical framework for an organisation which characterises the relationship between specific behaviours of employees and the probabilities of receiving various incentives. Most of the scientific literature on incentives is about the formal incentive structure that companies have in place. There are however, many more incentives so that a decision to choose one from several possible courses of action and decide to commit to safety above other personal and organizational goals is certainly influenced by personal safety attitudes, but there are also strong organizational aspects to these influences. Management influences and management actions are considered important in this respect because their actions influence personal safety attitudes to some degree. For instance, personal "need" and "incentives" are factors / motivations that can be coupled with a company's goals influenced by management influences. Employees who feel they have access to good career development opportunities, or who are praised by managers for doing a good job, are more motivated and more likely to committed to their work. Lin (2008, 2011) studied quantifying the influences of management actions on human performance, expressed through the quality and operation of the management actions. Interviews with personnel serve to uncover which signals are sent by managers and colleagues and how they are received. This paper discusses the different incentive structures identified and describes methods used to uncover and quantify them in a wider risk model.

Keywords: intention, human behaviour, incentives, self-efficacy, planning.

1. INTRODUCTION

Accidents like the recent blow-out and subsequent environmental disaster in the Gulf of Mexico show that local optimisation decisions made by a very limited number of people have the possibility to bankrupt an entire company. At this moment, a risk modelling program for the Oil and Gas industry is being carried out at Delft University of Technology (Ale, Hanea et al. 2011). The goal of this model is to show that it is possible to observe the vulnerability of a company in a meaningful way, even when the events of interest differ by orders in magnitude in probability as well as in consequence. Such observations can be used to steer management towards not only controlling the short term risks, for which the reward is immediately visible, but also the rare disasters that individual managers are unlikely to see in their term in office, but may ruin the company as a whole. The current development builds on the earlier developments in the IRISK, ORM and CATS projects (Bellamy, Oh et al. 1999; Ale 2006; Ale, Bellamy et al. 2006a; Papazoglou and Ale 2007) to connect the descriptions of management, human behaviour and technology into a single framework that allows a more in-depth analysis of the interdependencies. Probability distributions, rather than simple bifurcations, are used to take account of the wide range of context-dependent factors that can ultimately result in disaster or, alternatively, provide knowledge essential to both take risks and then run them successfully and profitably. This novel approach to probabilistic models, Bayesian Belief Networks, has already been successfully applied in civil aviation and developed into a rigorous framework capable of being applied to other high-hazard industries such as petrochemicals and shipping (Ale, Hanea et al. 2011). BBN's are a concise way of representation of joint probability distribution of a set of variables. By definition, a BBN is a directed acyclic graph in which nodes represent variables and arcs represent probabilistic or functional influences. Further explanation on the BBN for this research can be found in Ale et al. (2011).

In this paper, the on-going modelling of the human behaviour part of the model will be discussed and the different incentive structures are identified. This paper will first describe the structure of the overall model. This will be followed by an explanation of the models that are used to describe the human behaviour. Finally, the integration of the human behaviour into the overall model will be discussed, as well as further research that is needed to quantify these influences.

2. MODEL STRUCTURE

Ale et al (2007) describe how ESDs (event sequence diagrams) and the FTs (fault trees) for civil aviation were converted into BBNs, enabling the construction of the CATS model as one integrated BBN. This allows the use of distributions of values rather than point estimates wherever appropriate. It also allows a convenient and consistent handling of dependencies and interdependencies throughout the model. For this development the mathematics of BBN's were further developed, allowing continuous distributions (Kurowicka, 2004).

In the current model the same approach is used to integrate the existing Bow-Ties (integrating ESDs and FTs and already available within the oil and gas organization) with the management model from IRISK and CATS and the newly developed incentive structures reported here into a single BBN. The incentive structure combines influences from within the company and influences from personality and social context into a personal tendency to take a risk or to avoid it in a particular circumstance for a particular person, be they an operator, a supervisor, a manager or an executive decision maker.

3. HUMAN BEHAVIOUR

A core part of this research program is modelling and quantifying the influence of humans, within an organisation. Specific attention is given to the detailed incentive structure, or rather the motivational factors of operators, staff and managers, which in previous models had only been indicated more generally by two factors - motivation and conflict resolution. An incentive structure represents an empirical framework for an organisation which characterises the relationship between specific behaviours of employees and the probabilities of receiving a range of incentives. An incentive can be a broad variety of economic (raises, bonuses or promotions) or non-economic (satisfaction at getting the job done, compliance with peer pressure, improving self-image or feelings of self-efficacy) 'rewards' (Fenker 1977). The incentive or motivation to act safely is not only determined by the explicit actions of management, but also by such things as peer pressure, private circumstances, personality, and the choices made by layers in the organization between the formal statements by top management ("We do it safely or we don't do it at all"), middle managers who are rewarded for production performance rather than stoppages, and the actual operator, who may expect a bonus if corners are cut to improve productivity or simply believes that this is what the organization really wants. What is looked for here is the equivalent of the incentive structure that emerged for the sale of sub-prime mortgages, where a bonus was paid on the basis of mortgages sold without the requirement of the buyer to be able to pay the loan back, where the risk was taken by the bank but run by the client, while the benefits accrued to the seller (Dekker, 2006).
Most of the scientific literature on incentives (Ross 2004; Lam and Rosch 2006; Zhang 2008) is about the formal incentive structure that companies have in place. There are, however, many more incentives in operation, so that a decision to choose one from several possible courses of action and decide to commit to safety above other personal and organizational goals may certainly be influenced by personal safety attitudes, but there are also strong organizational aspects to these influences. Management and supervisory influences and management actions are considered important in this respect because their actions influence personal safety attitudes to some degree. For instance, personal "need" and "incentives" are factors that can be coupled with a company's goals influenced by management influences. Employees who feel they have access to good career development opportunities, or who are praised by managers for doing a good job, are more motivated and more likely to be committed to their work (Fenker 1977).

4. MODELLING HUMAN BEHAVIOUR

Lin (2011) studied quantifying the influences of management actions on human performance, expressed through the quality and operation of the management actions. These management actions are: Procedures, Equipment, Ergonomics, Availability, Competence, Communication and Commitment to safety. The human behaviour is captured in the deliveries commitment to safety, as can be seen in Figure 2 of Ale et al. (2012).

4.1 Contractor human factors

An initial set of human factors has been selected after a review of literature (Gordon, Flin et al. 1996; Gordon 1998; HSEUK 2012) and after having talked to the experts in this oil company. Table 1 presents the list of selected human factors for contractors.

Table 1.Initial selection of performance shaping factors

Performance shaping factors
Procedures, guidelines, instructions
Competence (technical knowledge and skills)
Job specific communication
Commitment and motivation
Human factors in design
Fatigue and shift work

Each of these factors is briefly discussed in the following sections.

Procedure: Procedures and permits-to-work provide important controls for ensuring high standards of performance and safety. The role of procedures is to provide sufficient information to allow the user to carry out tasks correctly, while permits and isolation certificates ensure that the appropriate safeguards are in place to allow the task to be carried out safely. The quality of procedure is important factor which specify what the result of the activity should be. However, according to the experts in Shell, quality of procedure is currently not a major problem in Shell. Rather, the problem is more the amount of procedures that the contractors have to follow, and whether they comply with these procedures.

Competence: Competence refers to the training and competence that are necessary for the operating personnel to carry out their jobs without causing any incident/accident. Evidence shows that a lot of incidents were related to the competence in non-typical situations. Thus, we will cover the capability of the individual to work in a competent manner for normal operations and also on rarely-performed tasks.

Job specific communication: Spoken and written communication can be critical in maintaining safety. Communication occurs either verbally about safety information (face-to-face, or through communication channels such as radio or mobile telephone) or non-verbally (by passive written messages emanating from data link, e-mail, memo) between team members or between different teams during operations or maintenance work, and emergency communications. The key topics contains in this research including:

- Shift communication including shift handover.
- A Permit-to-Work, or PTW between site management, plant supervisors and operators, and those who carry out the work.

The communication covered under this title is formal communication which is “job specific”. Whether the shift handover is well understand and the main risks is communicated to the workers by the permit holder will immediately influence contractors’ performances at work. There are also general communication e.g. warning signs, posters, and the manager visiting the workplace- all communicate a message about the company’s safety culture. This part of the communication will determine employees' work attitudes and their perception of company's safety attitude. This part of long-term-effect of communicator will be cover under commitment and motivation.

Commitment and motivation: Commitment and motivation is concerned with being attentive when actions are needed, to carry these out in the correct way, and to resolve any conflicting pressures, which might make incorrect behaviour attractive or even necessary. It deals with incentives of individuals carrying out the primary business activities not to choose other criteria above safety (such as ease of working, time saving, social approval etc.) as well as the resolution of conflicts between safety and other criteria. In this research, specific attention is given to the incentive structure of operators which in previous models had only been indicated more generally by motivation and conflict resolution, and not quantified in the human performance models. An incentive structure represents an empirical framework for an organization which characterizes the relationship between specific behaviour of employees and the probabilities of receiving various incentives.

Fatigue

Fatigue results from poorly-planned shift systems including excessive hours of work. Poorly designed shift work and long working hours that do not balance the demands of work with time for rest and recovery can result in fatigue, accidents, injuries and ill health. There are a number of key factors in shift schedule design, which may be considered when assessing the risks of shift work. These include on duty time, off duty time, rest length, and break length.

Specific attention is given in the development to the incentive structure of operators, staff and managers. The current general incentive structure model starts from the figure that is depicted in Figure 1.

The numbers in this model are examples, and are not yet based on actual observations. The commitment to safety node and the reward (incentive) node are further specified in Figure 2. Operator model for the BBN – which is based on existing literature (Sniehotta, Scholz et al. 2005; Ale, Bellamy et al. 2009). All the factors are formulated in the negative in this BBN model, i.e. towards increasing the probability of an accident. Having a clear incentive structure can provide a framework for evaluating an organisation and defining the extent to which it is likely to be effective in achieving its goals (Fenker 1977). It represents a dynamic but measurable statement of its goals and policies.

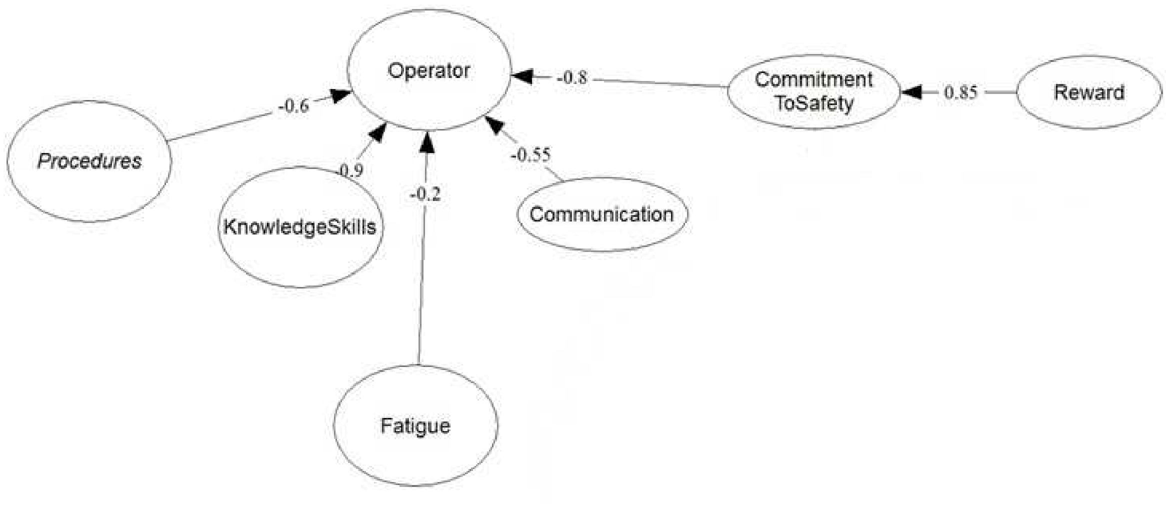

Figure 1. Operator model for the BBN (Sillem and Ale 2011)

The incentive structure consists of personal (the blue cells, with a ‘W’ for work floor) and organizational factors (the light green cells, with an ‘M’ for management). For now, only one layer of management has been added to the model, to be able to clearly explain the purpose of this part of the model. Later all management layers, such as front-line supervision and executive management, will be added.

The commitment to safety node is considered to be influenced by three separate processes within the human, which in this model are called ‘self’, ‘group’ and ‘organisation’ (Lin 2011). The ‘self’ part of the model is determined by the intentions of the individual, which are in turn formed by motivations of the individual to commit to safety. This motivation is again determined by the individual’s attitudes (towards safety, towards the company, etc.) and its self-image (feeling of control) (Fishbein and Ajzen 1975; Ajzen 1991). The attitudes are further strongly influenced by the individual’s perception of both the commitment to safety of peers and management as well as possible rewards for safe behaviours. Each manager again has the same influences as the individuals on the work floor; they also have an incentive structure, but the actual values within that structure may differ significantly. The intentions of people are not enough, on their own, to explain their eventual behaviour. Good intentions do not guarantee corresponding behaviour (Sniehotta, Schwarzer et al. 2005). This so-called intention behaviour gap indicates that formulation of intentions and implementation of these intentions are separate processes. A theoretical distinction is made between the motivation phase, in which numerous factors influence the formation of intentions, and the volition phase (planning and maintenance self-efficacy in Figure 2), the phase in which the aim is to implement the intentions, but during which a number of other factors may prohibit this from actually happening (Schwarzer 1992). Self-regulation seems to play a role in goal pursuit. This self-regulation can also be called action control (Kuhl and Fuhrmann 1998). In the motivational phase, an individual forms an intention, based on perception of the risks, attitudes, outcome expectancies, and perceived self-efficacy. Without these explicit intentions, changes or habitual behaviour patterns are unlikely to occur (Schwarzer, Sniehotta et al. 2003). In the volitional phase, these intentions must be transformed to planned, initiated and maintained behaviour (Prochaska and DiClemente 1984). Problems such as learned, habitual or innate responses must be overcome, even where personal resources are limited, social influences are pressing and where strong routines are involved. According to Sniehotta et al. (2005) there are three main problems in going from intentions to actions, Problems with action initiation, problems that have to do with overcoming obstacles to action implementation and problems that have to do with persisting in the new behaviour over time. In the model these problems are captured under planning and maintenance self-efficacy. In action planning, the process of linking goal-directed behaviours to environmental cues by specifying when, where and how to perform the behaviour takes place. In maintenance self-efficacy (or coping planning), a more barrier-focused self-regulation process takes place. Here, the individual makes a link between anticipated risk situations and suitable coping responses, to deal with these problems that may make them decide not to perform the intended behaviour. The reward node consists of immediate monetary factors, such as pay, bonus, profit, as well as longer term factors such as (the prospect of) promotions. The other, non-monetary incentives are found in factors such as acclaim and esteem. These factors are found in the group, feeling of control, attitude and external factors nodes. The immediate monetary factors are treated separately because they also figure in the balance sheets of a company, which translates into shareholder value and general societal reputation or image, which may often be the driving force for company actions.

The attitude and feeling of control nodes are influenced by many factors, such as trust, emotion, worldview (Slovic 1999), safety culture (Guldenmund 2007), locus of control, and risk perception. For example, worldview is a general, social, cultural and political attitude that appears to have an influence on people’s judgments about complex issues: fatalism (I feel I have very little control over risks to my health, what happens in life is preordained) / hierarchy (decisions about health risks should be left to experts) / individualism (in a fair system, people with more ability should earn more, do their own thing, unhindered by government or other constraints) / egalitarianism (if people were more treated more equal, we would have fewer problems, power and wealth evenly distributed)/ technological enthusiasm(a high-tech society is important for improving our health and social well-being). Worldview is strongly linked to the perception of risk (Slovic 1999). This can be used to determine an individual's likeliness to take more or less risks.

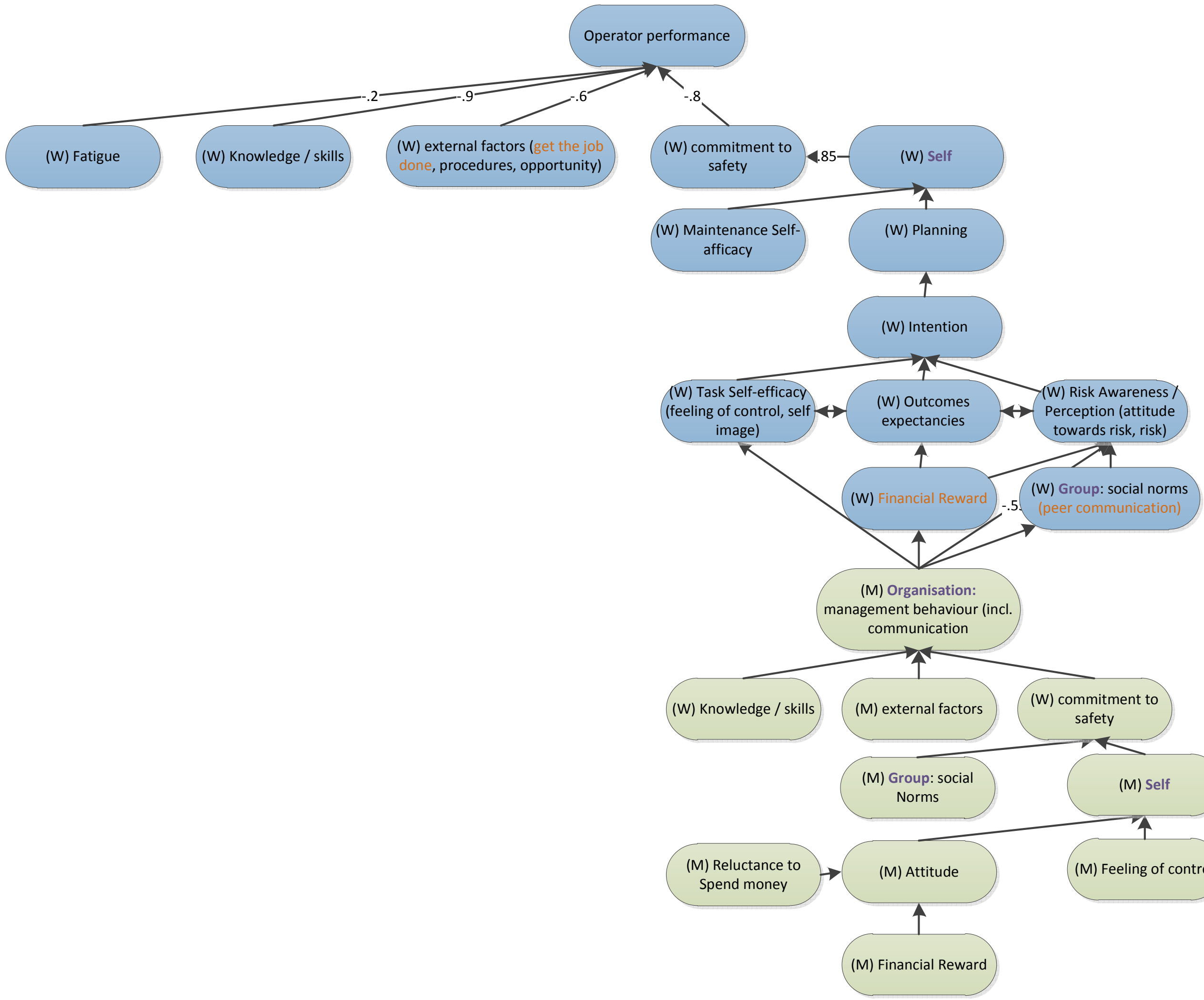

Figure 2. Operator model for the BBN

Another example is the possible limited effect of risk communication. One contributing factor may be lack of trust of the sender of the messages. Trust is created very slowly and destroyed very easily, negative events are more visible, negative events carry more weight than positive messages, distrust reinforces distrust and sources of bad news tend to be seen as more credible than sources of good news (Slovic 1999).

The final examples of influences on attitudes are a number of the cognitive biases (Kahneman, Slovic et al. 1982) that people have when dealing with information about risk. 1. Overconfidence bias: in general, people are overconfident in their state of knowledge or beliefs (Wickens and Hollands 1999). When a person is more confident than warranted about the correctness of their beliefs, they are unlikely to seek for additional information in order to verify or falsify their hypothesis. The evidence for this effect of overconfidence is strong. For example, the average driver typically believes he or she is part of 25% of the best drivers (Wickens and Hollands 1999).

However, 50% of people should think that they are below average drivers, as by definition they are. Confidence exceeds accuracy of peoples' own memory, for facts of general knowledge, recall or recognition of specific events. This makes people likely to stop searching for more evidence, feeling more confident than they should be that they know the truth. 2. Anchoring heuristic: even when additional evidence is sought, or simply presented, research suggests that not all hypotheses are treated equally. People sometimes have the tendency to bias their belief revisions in favour of the hypotheses that has initially been formed, as if we have put a 'mental anchor' to that particular hypothesis. People do not easily shift away to an alternative hypothesis. Such a tendency is consistent with the general idea that first impressions are lasting (Wickens and Hollands 1999). 3. Confirmation bias: the tendency of people to seek information and cues that confirm their held hypothesis or belief, and not to seek information that supports an opposite conclusion or belief. Ambiguous cues will be interpreted as if they support the initial hypothesis.

As can be seen, the list of factors that can help determine an individual's attitudes to and performance of safe behaviours is considerably more complex than is implied in the literature that stresses purely monetary rewards. The ways in which all these factors are inter-related and how they may change over time (Hanea et al, 2012) can be used to develop a much more sophisticated understanding of how risks are approached in high-hazard industries such as oil and gas.

5. FURTHER RESEARCH

The next step in this research, next to continuing to improve the model, is to start to quantify the model. Sniehotta et al. (Sniehotta, Scholz et al. 2005) have quantified the part of the model from the 'self' downwards, to the last task self-efficacy, outcome expectancies and risk awareness. They have done this in another field of research (motivation for people to start exercising more after treatment for cardiac patients). However, the processes of forming intentions and trying to actually change behaviour seem to be very similar to those in our field, in which we look at motivations to change behaviour related to personal and process safety rather than health. Therefore, we will try to translate the research done by Sniehotta et al. (2005) so that we can use similar question sets in our research. In their study, a set of questions is made for each of the constructs. We will do the same, related to a certain type of safe behaviour, which has yet to be chosen. Examples of questions for each of the constructs are: risk awareness ("How do you estimate the likelihood that…"), outcome expectancies ("If I start doing this safely, I need to invest a lot of effort to organize it"), task self-efficacy ("I am confident that I am able to do this safely even if it turns out to be time consuming"), behavioural intentions ("I intend to engage in safe behaviour in at least 90% of cases"), maintenance self-efficacy ("I am able to maintain safe behaviour even if…") and action planning ("I have already planned when / where / how I will perform a certain safe behaviour"), which have to be rated on a 4 point scale. In our research, a similar approach could be used and this will reveal and quantify the relationships and between these constructs for our field of research.

6. CONCLUSION

Based on the scientific literature, the model keeps improving in representativeness and completeness of showing of the influences on motivations of the human. The next step is to start quantifying the human influence, so that it can be used in the larger BBN-model that is described in (Ale, Hanea et al. 2012).

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