SAFETY SCIENCE Monitor

Issue 1 2007

Article 1 VOL 11

THE PULLEY MODEL
A DESCRIPTIVE MODEL OF RISKY DECISION-MAKING

Accepted for publication - Safety Science Monitor, 22 December, 2006

BENJAMIN BROOKS
Inaugural Peter Vulcan Scholar, Monash University Accident Research Centre, Monash University. Currently: Injury Prevention Advisor, Department of Health and Human Services, Government of Tasmania, Australia. Postal address for correspondence: c/o Injury Prevention and Management, 'Allambi', Private Bag No.5, Launceston, Tasmania 7250 Tel: +61 3 9905 4357 Fax: +61 3 9905 1914 Email Ben.Brooks@dhhs.tas.gov.au

Abstract - The pulley model aims to describe how people make decisions about health and safety risks. As a descriptive model, it attempts to combine several factors that influence the decision process – cultural, historical, social and cognitive in the analysis. Decision-making in this perspective includes third party risk assessments and physical interactions with risks during work processes. At its broadest level, the pulley model should be considered like a 'gestalt', an overarching, non-linear picture of how we make decisions about risk. The model is considered with respect to decisions made by fishermen and wood products workers.

Keywords: Pulley, Risk, Decision-making, Accident models

1.0 INTRODUCTION

The pulley model aims to describe how people make decisions about health and safety risks. As a descriptive model, it attempts to combine several factors of decision-making – cultural, historical, social and cognitive in the analysis. At its broadest level, the pulley model aims to be considered like a 'gestalt', an overarching, consistent picture of decision-making about risk.

A pulley is a simple machine used to change the direction of the application of a force on a load. It is a combination of a grooved wheel on an axle, through which a rope passes. A load or weight is attached to one end and a force applied to the other end, moving the load. Individual pulleys can be linked together to create a mechanical advantage, reducing the force required to move the load. The combination of pulleys is known as a 'block and tackle'. Making decisions about risks is considered analogous to this combination of pulleys.

The term 'decision-making' as applied to this model, requires an initial clarification. Hale and Glendon (1987) have previously suggested three classes of OHS decisions – decisions about work practices, decisions during risk assessments and planning or design decisions. The pulley model is most appropriately applied to work practice and risk assessment decisions. These are decisions where a potential or actual 'deviation' (an event or condition in the production process that conflicts with the norm for the faultless or planned process) (Kjellen 1987) has been noticed, and individuals within an organization interact to establish a response to that risk.

For this model, decision-making includes the initial assessment on the magnitude of the problem and the process that leads to some type of action (or inaction) based on that assessment. Modelling does not extend to an analysis of the affective (emotional) factors and does not account for physiological factors affecting risk responses. The model mentions, but does not address in any detail the goals and intentions of individuals making decisions about risks. The model assumes that a hazard is able to be perceived or observed and that the associated

risk can, to some degree, be assessed for the likelihood of an injury outcome, local exposure, the credibility of the accident pathway and the severity of that injury.

2.0 MODELLING AND DECISION THEORY

A model of risky decision-making in occupational situations is closely associated with, while remaining slightly different to an 'accident model'. Accident models emphasise the path to a known outcome (injury) and the factors associated with that path. A risky-decision model allows for both injury/accident and non-injury outcomes. Laflamme (1990) however included decision models as a type of accident model, describing four types of models: decisional, sequential, energetic, and organisational. While sequential models focus on tasks and undesirable outputs (accidents) energetic models focus on undesirable exchanges of energy between the system and the individual. Organisational models tended to describe the background factors influencing accident outcomes. This section highlights several accident, decision and behavioural models that have influenced the design of the pulley model. It is not exhaustive. For detailed summaries of accident models see (Surry 1974; Heinrich, Petersen et al. 1980; Kjellen and Larsson 1981; Kjellen 2000).

2.1 ACCIDENT MODELS

In attempting to describe the causal factors and sequence of events that leads to an accident and injury in a workplace, most models have included extra-personal factors in their analysis. One of the earliest models of the accident process did not incorporate extra-personal factors, focusing instead on individual 'accident-proneness'. It suggested that a few people have many accidents while most have none. Logically, this led to a concentration on individual factors such as personality, however the theory has not been effectively supported by scientific evidence (Suutarinen 2003).

No discussion about accident causation would be complete without reference to the Heinrich's original domino theory of accident modelling. In the original domino theory causation was described in a linear way – one domino hits another and eventually causes an accident. Heinrich proposed that any injury (5^{th} domino) is necessarily caused by an accident (4^{th} domino), that the accident is caused by unsafe conditions or unsafe acts (3^{rd} domino) caused by a person (2^{nd} domino) influenced by the social environment (1^{st} domino) (Heinrich, 1931). It followed that removing any one domino would stop the accident occurring. Updated versions of this model sort to clarify the initial phases of the domino theory to include lack of control by management, and to include 'job related' factors in the personal domino (Heinrich, Petersen et al. 1980).

Theories that followed suggested a more complex, dynamic and non-linear approach to accident causation. Benner was one of the strongest advocates for a more sophisticated perspective on accident causation (Benner 1975) during the 1970s. In his Multi-linear Events Sequencing Method, Benner concluded that accidents could be understood as the combination of actors (including objects) acting over time. This model is partly based on a process theory called P-theory, which states that an initiating event causes an imbalance in the system and starts a chain of events that ultimately leads to the accident (Kjellen and Larsson 1981).

The OARU Model (Kjellen and Larsson 1981) might be thought of as a determining factor model, closely linked to Laflamme's (1990) description of both an energetic and organizational models. The accident sequence was divided into three phases and four transitions: (a transition from a normal set of conditions) an initial phase (a transition from lack of control to loss of control) the concluding phase (the target starts to absorb energy) and the injury phase (energy absorption ceases). In using energy as a key element of the model, OARU borrowed from earlier work by Gibson that suggested that transfer of energy that breached a body's energy threshold would result in an injury (Kjellen 2000). "The state of lack of control is characterized by the presence of *deviations* in the system" (Kjellen 2000 p.36). To avoid the problem of causation, the model considered 'determining factors' characterised as Physical/Technical (e.g. work intensity or equipment design), Organisational/Economic (e.g. quality control, systems of remuneration) and Social/Individual (e.g. individual knowledge, workplace norms) (Larsson, 1982).

TRIPOD-Delta' (Reason 1997) is a coherent safety philosophy, a safety management system and an accident model all rolled into one. It models "how erroneous decisions at different management levels lead to the circumstances in which the accident is a result" (Kjellen, 2000 p.35). The model begins with a set of processes called General Failure Types (GFTs) that disrupt normal safe operations. When combined with local triggers, GFTs cause unsafe acts and potentially lead to accidents. Accidents identify and confirm the GFTs. The model suggests that safety management is essentially an issue of organisational control and that the main focus should therefore be to decide what is controllable and what is not. TRIPOD concludes that control can be exercised in a

number of ways: through measuring and controlling GFTs, training and motivating employees, and learning from accidents (Reason 1997).

Engineering 'event-and-fault-tree' (or bow-tie models) have improved the complexity of our understanding of accident causation as potentially multi-linear (many paths to the one accident). They depict the events prior and subsequent loss of control of a hazard. Like the OARU model described below, these events can be modelled as deviation processes. Deviation can be controlled by the insertion of barriers at various points as initially suggested by (Haddon Jr 1973). This might be considered similar to Heinrich's initial idea that the best way to prevent accidents is by removing the third domino (unsafe acts and conditions). By following barriers and controls through their individual 'life-cycles' integration with the safety management system occurs. Barriers can be physical systems or behavioural processes. The barrier concept has recently been refined and classified (eg. permanent or temporary, passive or active, manual or automated) (Goossens 2003; Hale and Guldenmund 2004; Hollnagel 2004).

2.2 DECISION THEORY AND MODELS

Decisional models emphasise the interactive dynamics of working situations. Previously these types of models have been inspired by psychological theories in information processing. These models are often built "in a deterministic and algorithmic way" (Suutarinen 2003 p.16-17). The progression of decision-making theory has guided modelling in this field, and is worthy of short examination. Classical Decision-Making (CDM) (Von Neumann and Morgenstern 1944; Savage 1954), was followed by Behavioural Decision Theory (BDT) (Edwards 1954) and Organizational Decision-Making (ODM) (Simon 1957). Naturalistic Decision-Making (NDM) appeared in the 1980s as a response to the 'unnatural' experimental settings that other decision-making research was typically applied in.

The characteristics of Classical Decision Making (CDM) include the requirement for choice among alternatives, an input-output orientation that focuses on prediction of the correct choice, an ideal that combined a deliberate analytic process with a thorough information search in formal, quantitative testing (Hogarth 1987). It suggested that the decision-maker could know all the alternatives, all the criteria for choosing between alternatives and make a thorough assessment of all those alternatives during the decision-making process. CDM is therefore primarily concerned with the logical consistency of the decision process (Bordley 2001) and the selection of a 'correct' outcome given that process. Bernoulli proposed the replacement of measures of preference (eg. goods, money) with a concept called 'utility' in the 1700's. He suggested that a 'rational' person will identify all the possible outcomes, determine their values (positive or negative) and their probability of occurring. Multiplication of these two measures gives an *expected value.* CDM therefore applies the theory of utility-maximization – that the goal of human action is to maximize pleasure (with a positive utility) and minimize pain (with a negative utility), suggesting that human behaviour can be predicted because people will seek the highest utility (Sternberg 1998).

Over time some authors have suggested the emergence of BDT, ODM and NDM have seen the classical perspective relegated to a position that is mostly irrelevant to the majority of decisions made in the 'real-world' (Meso, Troutt et al. 2002). However within the field of injury prevention ideals – such as a vision of zero injuries in workplaces – are used as integral concepts of complex safety management systems. Further, the classical decision-making combination of 'value' and 'probability' is closely associated with the definition of 'risk'. For these reasons, classical decision-making will continue to retain a prominence in this field.

Organizational Decision-Making began with the seminal work of Simon in the 1950s (Simon 1957). By applying the concept of 'bounded rationality' he demonstrated that decision-maker's deviations from the rational choice model make sense if the cognitive apparatus is considered as a limited (bounded) attentional system continually striving to minimize the information processing load caused by decision-making. Simon also suggested that effective adaptation by decision-makers does not require complete analysis of the decision problem (Simon 1978). This emphasis on the role of the cognitive apparatus in the decision process undermined the classical decision model.

Savage developed a formal system for integrating Bernouli's utility concept into a new normative rule: maximizing *Subjective Expected Utility (SEU)* (Savage 1954). SEU combines a personal utility function and a personal probability analysis based on Bayesian probability theory. This was an outcome, not a process oriented perspective. He suggested that SEU could be defined in reference to choices among gambles (Cohen 1993).

Behavioural Decision Theory retained a formality in modelling, yet also undermined the descriptive validity of the classical model by showing how people tend to deviate systematically from a rational choice model (Tversky and Kahneman 1981; Tversky, Sattath et al. 1988; Kahneman and Tversky 2000). This was

demonstrated to occur even when the 'bounded rationality of decision-makers was not placed under significant pressure (ie. with relatively simple problems). This work included empirical evidence of *heuristics* or (intuitive decision strategies) that described how people applied them to reduce their cognitive load.

Prospect Theory has been a foundation-stone of BDT (Lipshitz, Klein et al. 2001). Prospect theory has three stages. (A) Translation: People give the outcome of the available alternatives a subjective values, and they translate the probabilities associated with those outcomes into a decision weight. (B) Combination: After the translation, the values & weights are combined into prospect values. (C) Decision - The prospect values are then applied to make the appropriate decision (Kahneman and Tversky 2000). The models therefore retained the formalism found in CDM and still compared actual decisions to these formal 'standards'.

Naturalistic Decision-Making (NDM) is differentiated from these other perspectives of decision making research by a number of factors. These include studying dynamic environments, ill-structured problems, focusing on experts rather than novices, accounting for time stress, action feedback loops, competing goals and organizational goals/norms (Orasanu and Connolly 1993). Lipshitz *et.al.* suggest that NDM research is 'marked' by five essential characteristics: "proficient decision-makers, situation-action matching decision rules, context-bound informal modelling, process orientation and empirical based prescription" (Lipshitz, Klein et al. 2001 p.332). The same authors note that these characteristics became obvious to researchers when they began building descriptive models of expert decision-makers in natural environments without taking a rational model as the starting point (Lipshitz, Klein et al. 2001). As Cohen notes, "formal models fail not because people irrationally violate them (as the rationalists argue) but because models themselves do not capture the adaptive characteristics of real world behavior." (Cohen 1993 p.49)

The focus on 'context-bound informal modelling has been particularly important. NDM has recognised that expertise has a degree of context specificity (Ericsson and Leman 1996) and also that decision-makers monitor for both the structure and order of information as well as the information's meaning (Wagenaar, Keren et al. 1988). This perspective perhaps reflects the concept of the deep structure of grammar as defined by Chomsky (Chomsky 1977) in which a base structure is reflected by and transformed to a surface structure. The emphasis on 'context' and 'informality' has perhaps made decision-making research more complicated and uncertain, in direct contrast to the highly structured environment of classical decision experiments and their emphasis on utilities and bayesian statistics.

The factors that characterise NDM environments are readily found in risk assessment decision-making in occupational environments. Here a number of factors can influence the decision about the risk, there is a need to decide on actions to take, the environment is dynamic and often time stressed, and it all occurs within the context of the organization's goals and norms (and culture). Also, the person facing the risk could be viewed as a type of 'expert' – for rarely will they injure themselves in comparison to the number of work-operations performed.

Klein proposed a model focused on rapid decision-making called the Recognition-Primed Decision Model (RPD), based on data collected from urban fire-ground commanders (FGC) about events they had recently responded to (Klein 1993). The FGC attempted to recognize and appropriately classify a situation. Once they had made a classification, they knew a typical way to react to it. If complex enough, they might follow a virtual causal sequence of events, to discover if anything might go wrong. If problems arose, the option might be modified or rejected outright.

Klein therefore anticipated three stages in his model. Simple situations would occur when the pattern is so obvious that the action to be taken is equally obvious. More complex situations require deliberation of a possible causal sequence. Finally, modification of the strategy occurred if, while considering the possible causal sequence, too many problems arose. The premise of this model is therefore that people in these situations do not choose one of a range of alternatives, but assess the nature of the situation and find an action appropriate for that situation. As Pomerol (2001) notes of Klein's model, the important step in the decision is a diagnosis of the current state of the world, with each state triggering a decision.

Image theory proposes a model containing three knowledge structures influencing individual decision-making: enduring beliefs and values, an agenda of goals, ongoing plans to reach goals (Beach, Chi et al. 1997). The triple-structure of knowledge occurs not only in the individual making a decision, but also in the organization (Meso, Troutt et al. 2002). Image theory does not describe a causative relationship between organizational and individual knowledge structures, but does suggest that the two are inextricably linked to each other.

A considerable amount of research on health-related action has relied on a social-psychological approach, known as the Health Belief Model. This is derived from theories of decision-making under uncertainty, and in particular from the value-expectancy approach (King 1983).

"The model postulates that the individual's decision to undertake health related actions in governed by specific health beliefs: namely the patient's perceived vulnerability to, and the perceived severity of, a particular illness, and his or her perception of efficacy, costs and benefits involved in the recommended health action. Additional influences may be demographic, social or cultural, and various 'triggers' such as a letter from the doctor or illness in the family" (King 1983 p.171).

The application of the Health Belief Model (Figure 1) to risky decision-making and risk perception is not so straightforward. "There is very little evidence from the HBM on how beliefs about risk, for example, are actually acquired or formulated. It is possible that the notion of risk may be determined, in part, by different types of causal explanations about the illness itself" (King 1983 p.173).

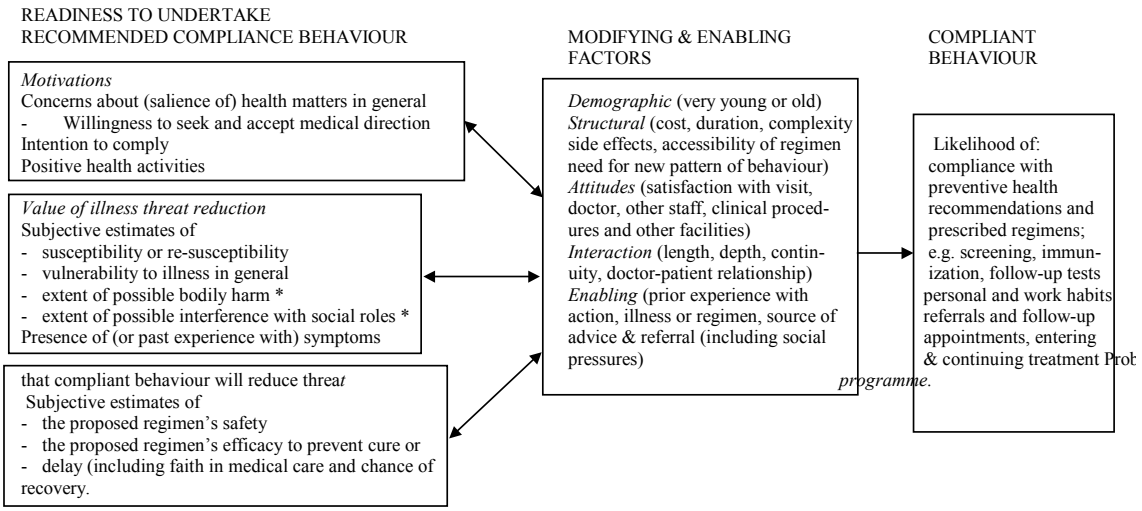

Figure 1: The Health Belief Model

2.3 BEHAVIOURAL AND COMPOSITE MODELS

One of the most regularly cited descriptions of human behaviour in safety science is Rasmussen's hierarchy of cognitive control. (Rasmussen and Lind 1982; Rasmussen 1987; Rasmussen 1993) The human is characterised by Rasmussen as an active information seeker. At the basic level they are guided by skilled sensori-motor performance controlled by automated patterns of movements. At the next level (rule-based) they look for cues to derive a choice of action and match those cues to stored routines. At the top level (knowledge-based) conceptual models are used and these 'trickle downwards' through planning to the generation of rules at the next level. Repeated exposure and success of the rules brings an increasing degree of semi-autonomous movement. Therefore while the model is hierarchical, it is also circular, the higher levels feeding back on each other. It is also one of the few models with such a strong emphasis on the physiological basis of human behaviour.

Barth proposed a generative decision-making model on the basis of ethnographic studies of 'native' cultures and studies of decision-making on Nordic fishing vessels. He suggested that the "most simple and general model available to us is one of the aggregate of people exercising *choice* while influenced by certain constraints and incentives" (Barth 1966 p.1). Barth was part of an anthropological movement called 'Social Action Theory'. This theory sought to paint a picture of man as a member of a group not passively obedient to the norms and pressures of society and its institutions, but as an entrepreneur manipulating norms for his own benefit (Boissevain 1974).

He argued that complex and comprehensive patterns of behaviour (roles) may be generated from simpler specifications of rights (statuses), according to a set of cultural rules or values. These values serve as general incentives and constraints on choice. The behaviour Barth focused on involved 'transactions':

In the transaction we can observe and study a basic process which creates consistency between the different standards of evaluation in a culture. This effect is implicit in the basic features of a transaction. It is constituted by a basic flow of prestations between two or more actors; in its most elementary form 'A' offers prestations '*x*' and 'B' reciprocates with prestations '*y*', thus $A \overset{x}{\rightleftharpoons}_{y} B$.

> Furthermore, according to the definition, each party consistently tries to assure that the value gained is greater than the value lost. This defines two thresholds: for A, $x \leq y$, *for B,* $x \geq y$ (Barth 1966 p.13).

Workplaces are good examples of transactional environments. An employer offers wages and various other incentives to employees in exchange for their labour. Various derivatives of this transaction now occur including the use of sub-contractors instead of employees. With respect to risky decisions, the employee will make choices about the risk with respect to the incentives to take the risk (which might include, for example, remuneration, challenges to professional competence and physiological triggers) and constraints (such as the ability to process information and limitation of power within the role).

Perhaps one of the more interesting models of human behaviour in the face of OHS risk has come from Cooper's adaptation of Bandura's model of reciprocal determinism (Figure 2). Although this is not an accident model, it does demonstrate a move towards embracing a perspective that is more consistent with the way individuals' view their relationship with their cultural surrounds. "People are neither deterministically controlled by their environments nor entirely self determining. Instead they exist in a state of reciprocal determinism with their environments whereby they and their environments influence one another in a perpetual dynamic interplay" (Cooper 2000 p.118). The model links psychological determinants, behavioural determinants, and situational determinants together in a triangular model that allows for each determinant to influence the other. This is therefore a separation of the individual into two distinct elements (thoughts and actions) and then linked to extra-personal factors (situational determinants).

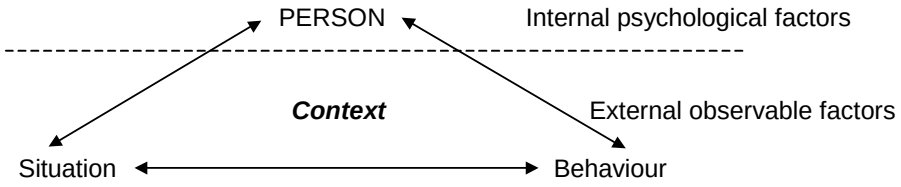

Figure 2: Cooper's Adaption of Bandura's model of reciprocal determinism

In part, this perspective sits well with the tenants of Social Action Theory because it proposes that the individual is much more active in their relationship with their culture. Cooper has also merged this model with the U.K. Health and Safety Executive's OHS management model and declared this "has given us all the potential to make a quantum leap in the improvement of industrial safety performance at the turn of the 21st Century" (Cooper 2002 p.14). His efforts can also be seen as an attempt to resolve the problem of embedding a model of safety culture within organisational culture. This is an issue highlighted by Hale as a significant one for safety science/culture to overcome (Hale 2000).

Recently it has been suggested that a model connecting behaviour, attitudes and beliefs, safety norms/safety culture and the physical and organizational environment are suitable risk factors to integrate into a model for accident prevention (Lund and Aarø 2004). The pulley model might be seen as one attempt to meet Lund and Aarø's model components.

3.0 DESCRIBING THE PULLEY ANALOGY

As noted above, the model functionally separates the individual and the group. Within the model there are three main factors (in bold, underlined) that link **an individual**, working within a **socio-cultural environment** to **a risk.** The link is created by the rope (an information flow) and the pulley apparatus as shown in Figure 3.

The contextual elements (social and cultural) can be separated by proximity to the individual. Close to the individual and the risk are the immediate social group or work mates. Social factors include roles and statuses of individuals as they relate to each other within an organisation. The model contends that while cultural factors are ever present, the reality of social life is that the individual tends to spend her time with a typically small group people. These people and interactions have the greatest direct influence over her behaviour.

The risk itself has characteristics that are not discussed in detail within the general description of the model because they are risk specific. Chemical inhalation risks are different from musculo-skeletal risks from lifting or carrying objects. Risk of capsize for a fisherman is different again.

The model is bounded by two elements. Beyond the organizational culture are broader cultural perspectives – occupational, regional and national cultural phenomena. The lower boundary includes OHS and

workers compensation laws and institutions and their officers. The model does not address factors that cross these boundaries in any significant way, although a perspective on occupational culture was perhaps derived in (Brooks 2005) and the introduction of Individual Fishing Quotas for fishermen was a regulatory action that had significant effect on the exposure to risk.

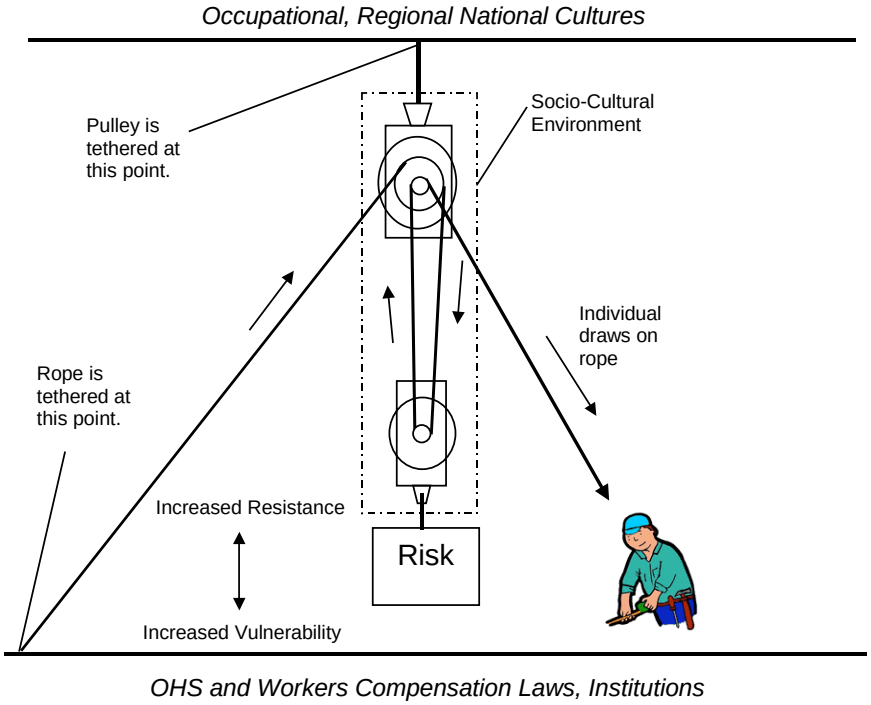

Figure 3: The Pulley decision making model

This model combines the idea that knowledge must be bounded with Douglas and Wildavsky's perspective on knowledge as a changing product of social activity. "It is not so much like a building, eventually to be finished, but more like an airport, always under construction. It has been compared to an open-ended communal enterprise, to a ship voyaging to an unknown destination but never arriving and never dropping anchor" (Douglas and Wildavsky 1983 p.193). The acceptable or accepted risk always has some weight (some residual risk), the pulleys are always changing the nature of their interaction with the individual via the rope which connects each element to each other.

3.1 THE RISK

The risk is likened to a suspended load. This analogy requires that an opposing force must be exerted even to keep a risk at the same point in the safety space, suggesting that risks are rarely 'static' phenomena.

The weight or load that the pulley attempts to move is the risk – such as a fall-from-height while working on a scaffold. In this regard it has a physical form that must be recognised. More complex decisions are likely to be associated with more significant risks (which equals a greater 'load'). Any change in the risk is made with reference to 'the safety space'. This is a concept developed by Reason which suggests that a company can be positioned in a two dimensional space "that reflects their intrinsic resistance or vulnerability to their operating hazards" (Reason 1997 p.111).

Associated with the risk are certain physical characteristics of the hazard – it may be a fall from heights, a chemical exposure, a physical hazard like noise or dust or an ergonomic hazard. It might be the wave height as perceived from a certain vantage point on land, associated with the risk of capsize for a fishing boat. The nature of the hazard therefore has a significant bearing on the risk assessment process. Also, the process of dealing with the risk provides the person with feedback that may modify their behaviour. A fisherman learns more about weather conditions as the day emerges, a cabinet-maker gathers feedback from the machine as they saw timber

3.2 THE ROPE EQUALS FLOWS OF INFORMATION,

'The rope' is the mechanism that connects the person to their work-mates, the organizational culture in dynamic interplay to the risk. 'The rope' may be variously represented as flows of information, dialogue, values or physical objects (in fact anything that transfers or confers meaning to the situation) associated with the risk and also as a partial representation of the time sequence over which the decision is made and action is taken. From a cultural perspective the rope is what is transferred between individuals, small groups and across entire organizations. This concept is perhaps similar to (Dawkins 1989), notion of a 'meme'. A meme is a cultural unit of replication.

3.2.1 THE ROPE HAS ELASTIC PROPERTIES

The analogy suggests an instantaneous movement of the weight (change in the risk) and the pulleys as the rope is drawn upon (as action is taken to respond to the risk). However the rope should be considered to have a degree of elasticity, creating a time-lag between any decision and change in risk, between any force brought to bear on the risk and change in resistance to the risk. Elasticity represents both the degree of uncertainty and the need for the rope to translate information without changing the position of the suspended mass (the risk) to account for this time-lag.

By holding and drawing upon the rope, a person exerts control over the risk. In grasping the rope, the individual must first draw the conclusion that there is or could reasonably be a deviation that requires investigation.

To be consistent with the pulley analogy, the 'rope' must be pulled for a greater distance, but with a much lower force required. In real terms the greater distance does not necessarily equate to increased time. This would be inconsistent with the concept of cognitive 'short-cuts' or heuristics. The 'distance' might be simply understood as any decision having to account for the context in which information and dialogue flow over time between multiple persons in individual and socio-cultural contexts.

3.3 TETHERING THE PULLEY – REGULATION AND CULTURE

The individual and extra-personal aspects of the model are tethered by the development and enforcement of relevant legislation, and by the institutions that control them. Relevant legislation includes generic OHS Acts, and other associated act on dangerous goods, industrial relations and so on. In Australia many of these are informed by non-regulatory mechanisms such as Australian Standards. Institutions include the government workplace inspectorate and the workers compensation authority. Failure within this element of the system can cause massive collapse as seen in accidents like Piper Alpha oil platform or Challenger Space Shuttle explosion (Reason 1997 figure 10.1 p.234). The pulley model accounts for this by suggesting that failure of decision making at regulatory and statutory institution levels can collapse the entire risky decision making system. While it is unlikely to occur, the results can be catastrophic. This aspect of the model represents the very outer limit, the focus has very much been on the relationship between the individual and the organization.

"Each culture is founded on a distinctive institutional base, which gives it interests to protect, and its own conventional way of doing things. Consequently each culture allocates blame to different sectors, and they vary according to the amount of blaming that they tolerate. In this perspective the risk signals for which the social amplification researchers are looking would be features of the systems of accountability in each cultural type" (Douglas 1999 p.226). The organizational culture and historical pulley is itself tethered in a wider occupational, regional and national culture. Again, this aspect of the model represents a boundary of inquiry, and the thesis has not explored the relationship between organizational and nationally occurring cultural phenomena.

3.4 FORCE DISTANCE TRADE-OFF

Pulleys have some characteristic elements. The most important of these is that pulleys magnify the force that can be directed towards the movement of a load. There is, however, a cost associated with the magnification, and that is that the pulley proportionally diminishes the distance through which the magnified force can act. (This is known as the force-distance trade-off). Pulleys make the reduction in pulling force needed by the person through a change the direction of the force through the pulleys.

The introduction of cultural, historical social and transactional pulleys can ease the decision load because there are conventions or norms of how to act, and often groups can act more effectively than individuals. 'Heuristics' in this respect are still cognitive but perhaps influenced by social, cultural, or historical factors. The combined experience within the organization has the potential for greater injury experience, greater knowledge of OHS and work processes and therefore the possibility to reduce the decision load on the individual. People move

between their own goals, between the impressions they need to manage in a social group (Goffman 1959) and between cultural assumptions to derive a course of action.

However there is a trade-off. It takes time to build social organization and cultural norms – so decisions early on in an organization's life and before small groups come to agree on social conventions may be slow, or at least place greater weight on the cognitive processes of the individual. The greater force can only be applied by diminishing the distance over which the force can act. In our pulley analogy, it is possible to imagine a person making decisions about risks – like a fisherman deciding whether to fish in questionable weather conditions. Their social and cultural interactions, and reflections on historical considerations can only affect a person who exists within that particular social and cultural framework.

3.5 PULLEYS

The decision making process includes multiple changes of direction – between the social situation and the culture, between the individual and the social situation. However these are all linked back to the individual. The relationship between the individual and the culture is considered to be a dynamic one, the goal-directed individual will not always make choices consistent with norms, and norms 'shift' through the aggregation of similar individual decisions over long periods of time. For example, we might see a transition from a non-reporting of near-misses to a reporting culture. This transition will probably relate to modifications of the social and cultural environment, but is dependent upon individuals reporting personal near-misses, and the consequences of making that report being favourable (action taken to reduce the risk).

3.6 FRICTION AND IMBALANCE OF PULLEY-WHEELS

Pulleys are machines designed to help us do work. For the majority of the time, pulleys assist people with their natural desire to reduce the cognitive strain work imposes on them. But sometimes they don't help. Even with good intentions, sometimes action isn't taken to improve resistance to risks or the action that is taken doesn't help. How does this change occur? The model uses the concepts 'Friction' and 'Imbalance'.

Friction is the resistive force acting between bodies that tends to oppose and damp out motion (Hanks 1979). Friction is usually distinguished as being either static (the frictional force opposing placing a body at rest into motion) and kinetic friction (the frictional force tending to slow a body in motion) (Weisstein 2004). Static friction involves elements of the model stopping the decision making process from even beginning. Some issues may be too large, too difficult or too confrontational to even consider solving. For example, the decision about how to refurbish an outdated spray-booth might be too expensive, so instead employees are given supplied air respirators and the job never begins. This might be related back to the organization's cultural assumptions about money and the value of improvements in health and safety. It might be considered too difficult to solve problems with winches on lobster boats – this is partially attributable to fishermen's perspective on learning (Brooks 2005). The 'communication as a weapon' cultural assumption used by the participants in another study to punish and reward each other acts as static friction for risky decisions (Brooks 2006). The decision process never begins because the risk is hidden to punish the other party.

Kinetic friction involves the decision process being slowed after initial movement forward. The necessary barrier to a risk might be found to reduce the magnitude of that risk, but it is never implemented. Some amount of kinetic friction will always be present when making decisions about health and safety risks. The reason for this is the combination of people, weighted risk, rope and pulley as a system is efficient, but not totally efficient.

Making a decision to take action about an OHS issue may be slowed and eventually paralysed by the need to negotiate across various levels of the organization. Friction between health and safety requirements and short term production goals may lead to unnecessary risk taking. This is another example of kinetic friction, slowing (and potentially disabling) the decision-makers intended action to increase resistance to OHS risks. Industrial relations friction between management and employees may lead to OHS being used strategically as a weapon of negotiation. The need to move decisions through the cultural and social structure may cause friction – a new hearing protection policy could be seen as a challenge to carpenter's traditional communication strategies increasing the potential for industrial relations conflicts. Some decisions, and some organizations, might therefore have a high 'coefficient of friction' – requiring significant force to be applied to move decisions towards outcomes.

Balance can be defined as to be or come into harmony or equilibrium (Hanks 1979). Imbalance, as the opposite of balance, is considered as a lack of harmony or equilibrium as applied to the social and cultural variables. Social imbalance might occur between individuals uncomfortable with the roles and statuses that they hold within work-groups or the organization as a whole. – a supervisor may not be considered by a less senior

person to deserve their status. Cultural imbalance might occur between competing or inconsistent cultural assumptions held by people or groups in the organization – people's perspectives on the significance of their job versus their family may cause imbalance. People will bring with them different historical perspectives on safety and different accident histories. Some degree of friction is unavoidable, however balance is considered to be more of a function of structural problems, problems with the structure of the safety system, or socio-cultural structures or the fundamental organization of the enterprise itself.

Theses are essentially problems that occur within the classes of variables, independent of the broader system. Imbalance reduces the efficiency of the pulleys. We can look at the cultural assumptions and the social organization and ask if the various elements are in balance, and, as importantly, when and where they might be out of balance. As imbalance occurs, the action of the rope moving through the pulley creates further friction.

3.7 SUMMARY

The Pulley model is laden with concepts. A summary of each is provided in Table One. An individual with certain demographic characteristics comes to interact with a risky decision. That decision might be to actually perform a work practice or a 3rd party assessment of the risk associated with a work practice. The rope can be basically represented as a flow of information, and connects the individual to the immediate social interactions in their small work team, to wider cultural factors, to the boundaries of the model and ultimately to the risk itself. The rope has a degree of elasticity, with actions not necessary leading to immediate results. The risk is considered to have a 'load' and that load can be moved from its present position to one that is either more vulnerable to the risk being realised as an accident or more resistant.

The pulleys provide an advantage by assisting to reduce the cognitive load and allowing people to make easier decisions. The trade-off for this mechanical advantage is that it can only work within the boundaries of the organization. There will always be some friction either stopping decisions from being initiated or slowing decisions in progress. The result is a descriptive, yet dynamic analogy of the process of making decisions about risks.

Table One: Summary of Pulley Model concepts

Concept	Explanation
Pulleys	Pulleys relate to 2 classes of variables at different proximities to the individual and the risk. When linked together into a block and tackle, pulleys have the potential to provide the user with a mechanical advantage and deal with significant risks.
Load/Risk	The risk is likened to a suspended load. More complex decisions are likely to be associated with more significant risks (which equals a greater 'load').
Safety Space	The safety space is a concept developed by Reason (1997) which suggests that a risk can be positioned in a two dimensional space that reflects the intrinsic resistance or vulnerability to that risk.
The rope	The rope' is the mechanism that connects the person to their work-mates, the organizational culture in dynamic interplay to the risk. 'The rope' may be variously represented as flows of information, dialogue, values or physical objects (in fact anything that transfers or confers meaning to the situation).
Rope elasticity	Elasticity in the rope creates a time-lag between any decision and change in resistance to the risk.
Tethering	The model is tethered at one boundary (cultural) and the rope at another boundary (legislation & institutions that control them). These boundaries represent the limit of inquiry for the thesis and the decision-making model.
Force-distance tradeoff	The trade-off proportionally diminishes the distance through which the magnified force can act. Only people working within the cultural boundaries can apply this particular pulley.
Friction	Friction is the resistive force acting between bodies that tends to oppose and damp out motion. (Hanks 1979) Friction is either static (opposing decision analyses beginning) or kinetic (slowing a decision once begun).

4.0 DISCUSSION

The model is proposed to be used for detailed examination of risky decisions. One decision considered in (Brooks 2007) is as follows: At 4.30am the rock lobster fishermen must make a decision whether to fish or not on that day. "Most of the time there is no hesitation, however sometimes the weather and sea conditions are such that the decision requires considerable analysis. The safety implications are obvious – a decision not to fish results in zero exposure to workplace risks" (Brooks 2007 p.252).

4.1 THE RISK

The risk is a combination of loss of property and loss of life, the load is a significant one. The risk retains a credibility, has a low frequency but high severity, exposure at sea is continuous. The risk of capsize is a credible one, and more credible for the older, smaller boats. The passage out through the heads to open water (and back again) is particularly risky in rough weather, waves can turn boats sideways and then tip them over. Although there have been no capsizes since the introduction of the IFQs, all fishermen were aware of the five that occurred between 1986-1993. They know that the conditions can worsen quickly, and typically all weather factors (swell, wind strength and direction) tend to degrade together. The consequences are a potential loss of their boat (and therefore income) as well as los of life.

Once a decision to fish is made, it takes 15 minutes to transit to the main boat and prepare to leave port. Even in this time weather can change. Once out in open water and in the fishing grounds they are approximately one hour from port. The decision needs to be made by 5.30am to allow them enough time to haul all fishing traps (pots) and return home by the end of the day.

4.2 THE INDIVIDUAL

The fishermen that participated in the study described in (Brooks 2004; Brooks 2005) could be referred to as experts with an average experience in the industry of 24 years. A typical injury history includes many low severity injuries (cuts, stings) and some musculo-skeletal ailments (knee and back strains). Capsize is considered by the group a foreseeable possibility linked closely to weather conditions.

Since the introduction of Individual Fishing Quotas fishermen have greater choice whether to fish or not (enter the danger). Because catch volumes are good, they can easily catch their quota in a season and if they choose not to fish, no-one else can catch their (individual) quota. There are benefits to working difficult conditions, particularly early in the season when the fishermen need to build up cash reserves. Difficult conditions test the expertise of the skipper and the crew and this test of their professionalism can be as enjoyable as the financial benefit derived from the catch.

4.3 THE SOCIO-CULTURAL PULLEYS

At a social level, the roles are fixed {skipper and deckhand(s)} but status varies, mostly depending on kinship. A father is more likely to afford his son an opportunity to learn the role of skipper because his status is such that he will one day inherit the business and licence. Wider cultural boundaries (the points at which the pulley and rope are tethered) were not considered in this study although legislative and institutional factors (translated through the introduction of IFQs) continue to have a significant effect on the fishery.

There are a range of cultural assumptions that influence the decision such as 'the sea can be mean' – an ideological assumption about the changeability and unforgiving nature of the sea. 'The skipper's word is law' describes the ultimate power for decision-making wielded by the skipper. 'Keep it in the family' describes the nature of boundaries within the fishery, with membership a birthright for many. Those outside the 'family' are destined to always play a minor role.

The decision-making process is played out in a ritual at certain 'look-outs' around the port, between the boat crew and skipper. The ritual has a familiar location, and also follows a familiar process. Crews watch the weather and attempt to integrate other information they have access to. The act of making the decision with each other is cherished as much as the outcome of the decision, in part, because it cements the relationship between skipper and deckhand(s).

4.4 THE ROPE

'The rope' represents information about the environmental conditions and the other benefit-related factors. Information derived from television, radio, web-based weather forecasts is supplemented by the fishermen's own perception of environmental conditions and how those conditions are changing over time.

For this decision they tended to go through an iterative procedure, gathering information to see if the risk was reducing or increasing, all the time reducing uncertainty about their likely exposure to the risk. During and before this time they are taking into account the benefits of taking the risk. Do the crew need some experience in heavy weather? Is the wholesale price good today? What is the likelihood of a good catch? They are also aware of the proximity of the cultural assumptions – 'the sea can be mean', 'the skippers word is law', these guide the care used in the assessment and the ultimate responsibility for the skipper to make the final call.

4.5 FORCE-DISTANCE TRADEOFF AND FRICTION

The force-distance trade-off proportionally diminishes the distance through which the magnified force can act. Only people working within the fishery are subject to the social organization and the cultural assumptions that are brought to bear. The corollary of this statement is of course that the defined social organization and cultural assumptions act like heuristics, creating cognitive 'short-cuts' for the fishermen during the decision process.

Friction is limited for a number of reasons. For the majority of the season, there is limited pressure to fish on poor weather days. Since the introduction of IFQs and the stabilization of fishing stocks, the skipper has a true choice to enter of leave the danger. The attractiveness of the decision-ritual to conduct the analyses and reach a conclusion suggests limited friction to stop the analysis or slow the decision once begun.

At a financial level, because all parties take a share of a predefined catch, their only way to maximize profit is to maximize the price they sell the lobsters for. This assists the decision process because all parties access the financial benefits of fishing or not fishing along the same dimensions. For those working within a kinship dynamic, there is limited social friction because they realise that ultimately the operation of the vessel will pass to them, and that working as a deckhand within this context is part of the 'right of passage' to the skippering role. The lack of individual, social or cultural friction, supported by well defined cultural assumptions, eases the decision process to one that is fluid and dynamic and process, rather than outcome oriented.

5.0 CONCLUSION

The accident models described earlier all make a distinction between the physical, individual and the group environment. Surry notes "on reflection none of the models are incompatible with any of the others, each simply stresses different aspects" (Surry, 1974 p.34). Using concepts like dominos falling on one another, or energy transferring from one point to another, or multiple actors taking actions that diverge or converge, these models have suggested that the nature of the accident process is either linear or multi-linear in process. The pulley model is non-linear, and although focused on an individual interacting with a risk, doesn't have a starting or ending point. It is a Gestaltist interpretation of risky decision-making that seeks to explain the complex interaction between individuals, small groups, cultural factors and risks as something that occurs dynamically and instantaneously throughout an accident or decision making process.

Decision theory began with a rational choice model that supposedly describes how 'ideal' decision-making should proceed. The thorough analysis of alternatives, using all appropriate criteria, leads to the best alternative being selected. Progressively we have come to understand the limitations of the cognitive apparatus to meet the requirements of 'rational choice' and the influence that contextual factors have on the decision process. Context has sometimes been considered an 'extra' factor to be considered in the decision-making process. For the pulley model, the context is an inseparable part of the process. Indeed, one of the significant aims of the pulley model has been to explain risky decision-making in a way that is socio-culturally consistent. In this regard it has been important to accept the role of cultural 'assumptions' and group dynamics while also understanding the individual is a self-interested manipulator of the environment, continually modifying social and cultural norms through decision processes and outcomes.

Interaction between smaller work groups, organization wide cultural values and information/interaction (via the rope analogy) is considered qualitatively by the amount and type of friction that occurs. The concept of a continual flow (the rope) of information/interaction between individual, social environment, cultural assumptions and machine/risk interface is used to represent the dynamic and continuous interaction between these factors. Perhaps the model falls down in that a block and tackle is a passive system, however socio-cultural factors in this model are anything but passive. Ultimately, for any decision about risk, there is some sort of 'calculation' or weighing up of the risk and benefit of any action, based on this, moves to reduce the risk may or may not occur.

The analogy of a pulley is considered useful because it introduces a practical and easily demonstrated system (block and tackle) to explain decision making in the face of OHS risks. The model explains why decision

processes might be made easier (through the creation of a socio-cultural 'advantage') or more difficult (due to friction). The key conclusion to take from the Pulley Model is that the individual, on their own decision path, is intimately and simultaneously connected to the other factors via information and interaction. The model at its coarsest level should be considered as a decision 'gestalt' – an overall picture of the decision-process.

Acknowledgements:

The Monash University Accident Research Foundation (MUARF) is the sole funding body for this research.. Professors Tore Larsson (KTH, Stockholm) Tom Triggs and Ian Johnston (Monash University Accident Research Centre) have provided valuable advice and comment.

6.0 REFERENCES

Barth, F. 1966. Models of Social Organization. Royal Anthropological Institute of Great Britain and Ireland. Glasgow.

Beach, L., Chi, M., Klein, G., Smith, P. and Vincente, K. 1997. Naturalistic decision making and related research lines. In Zsambok, C., and Klein, G. (Eds) Naturalistic Decision Making. Lawrence Erlbaum & Associates. Mahwah, NJ.

Benner, L. 1975. Accident Investigations: Multi-linear Events Sequencing Methods. Journal of Safety Research. Vol.7 No.2, 1-10.

Boissevain, J. 1974. Friends of friends - networks, manipulators and coalitions. Blackwell, Oxford.

Bordley, R. 2001. Naturalistic decision making and prescriptive theory. Journal of Behavioral Decision Making. Vol.14(5), 353-384.

Brooks, B. P. 2005. Not drowning, waving! Safety management and occupational culture in an Australian commercial fishing port. Safety Science. Vol.43, 795-814.

Brooks, B. P. 2006. The natural selection of organizational and safety culture within a Small to Medium Sized Enterprise (SME). Submitted to Journal of Safety Research.

Brooks, B. P. 2007. Mapping the risky decision space of commercial rock lobster fishermen. International Journal of Risk Assessment and Management. Vol 7(2), 248-262.

Chomsky, N. 1977. Language and Responsibility. The New Press, New York.

Cohen, M. 1993. Three Paradigms for viewing decision biases. In: Klein, G., Orasanu, J., Calderwood, R., and Zsambok, C. (Eds) Decision making in action: models and methods. Ablex Publishing Co, Norwoood, New Jersey, 36-50.

Cooper, M. D. 2000. Towards a model of safety culture. Safety Science. Vol. 36, 111-136.

Cooper, M. D. 2002. Surfacing your safety culture. Human Factors Conference 4-6th March at Ev. Akadamie, Loccum, Germany, Major Hazard Commission, Federal Ministry of Environment**:** 1-16.

Dawkins, R. 1989. The Selfish Gene. Oxford University Press, Oxford.

Douglas, M. 1999. Implicit meanings. Routledge, London.

Douglas, M. and Wildavsky, A., 1983. Risk and culture. University of California Press, Berkeley, California.

Edwards, E. 1954. The theory of decision making. Psychological Bulletin. Vol.51, 380-417.

Ericsson, K. A. and Leman, A. 1996. Expert and exceptional performance: evidence of maximal adaptation to task constraints. Annual Review of Psychology. Vol.47, 273-305.

Goffman, E. 1959. The presentation of self in everyday life. Doubleday Anchor Books, New York.

Goossens, L., 2003. What is a barrier? WORM Paper Safety Science Group. Delft University of Technology, Delft, Netherlands.

Haddon Jr, W. 1973. Energy damage and the ten counter-measure strategies. Journal of TraumaVol.13(4), 321-331.

Hale, A. 2000. Cultures confusion. Safety Science. Vol.34, 1-14.

Hale, A., and Glendon, A.I. 1987. Individual behaviour in the control of danger. Elsevier Science, Amsterdam.

Hale, A., and Guldenmund, F. 2004. Barriers and delivery systems WORM Paper 21. Safety Science Group, Delft University of Technology, Delft, The Netherlands.

Hanks, P. (Ed). 1979. Collins Dictionary of the English Language. Collins, Sydney.

Heinrich, H., Petersen, D., and Roos, N. 1980. Industrial Accident Prevention: A Safety Management Approach. McGraw-Hill Book Company, New York.

Hogarth, R. 1987. Judgement and choice. Wiley and Sons, London.

Hollnagel, E. 2004. Barriers and Accident Prevention. Ashgate, Aldershot, UK.

Kahneman, D., and Tversky, A. (Eds). 2000. Choices, Values and Frames. Cambridge University Press, Cambridge UK.

King, J. 1983. Attribution theory and the health belief model. In: Hewstone, M. (Ed). Attribution theory: social and functional extensions. Basil Blackwell, Oxford, UK.

Kjellen, U. 1987. Deviations and the feedback control of accidents. In: Rasmussen, J. (Ed). New Technology and Human Error. John Wiley and Sons, New York.

Kjellen, U. 2000. Prevention of accidents through experience feedback. Taylor & Francis, London UK.

Kjellen, U., and Larsson, T. 1981. Investigating accidents and reducing risks - a dynamic approach. Journal of Occupational Accidents. Vol.3, 129-140.

Klein, G. 1993. A Recognition-Primed Decision (RPD) model of rapid decision making. In: Klein, G., Orasanu, J., Calderwood, R., and Zsambok, C. (Eds). Decison making in action: models and methods. Ablex Publishing, Norwood, New Jersey.

Laflamme, L. 1990. A better understanding of occupational accidents genesis to improve safety in the workplace. Journal of Occupational Accidents. Vol.12, 155-165.

Lipshitz, R., Klein, G., Orasanu, J., and Salas, E. 2001. Taking stock of Naturalistic Decision Making. Journal of Behavioral Decision Making. Vol. 14, 331-352.

Lund, J. and Aarø, L. 2004. Accident Prevention. Presentation of a model placing emphasis on human, structural and cultural factors. Safety Science. In press: 1-54. (get correct reference)

Meso, P., Troutt, M., Rudnicka, J. 2002. A review of naturalistic decision making research with some implications for knowledge management. Journal of Knowledge Management. Vol.6(1), 63-73.

Orasanu, J. and Connolly, T. 1993. The reinvention of decision-making. In: Klein, G., Orasanu, J., Calderwood, R., and Zsambok, C. (Eds). Decision making in action: models and methods. Ablex Publishing, Norwood, New Jersey, 3-20.

Pomerol, J. 2001. Scenario development and practical decision making under uncertainty. Decision Support Systems. Vol.31, 197-204.

Rasmussen, J. 1987. Risk and information processing. In: Singleton, W. and Hovden, J. (Eds) Risk and Decisions. John Wiley and Sons, New York, 109-122.

Rasmussen, J. 1993. Deciding and doing: decision making in natural contexts. In: Klein, G., Orasanu, J., Calderwood, R., and Zsambok, C. (Eds). Decision making in action: models and methods. Ablex Publishing, Norwood, New Jersey, 158-171.

Rasmussen, J. and Lind, H. 1982. A model of human decision making in complex systems and its use for design of system control strategies. Proceedings of American Control Conference Vol.1, 270-276.

Reason, J. 1997. Managing the Risks of Organizational Accidents. Ashgate, Aldershot, England.

Savage, L. 1954. The foundations of statistics. Wiley, New York.

Simon, H. 1957. Administrative Behavior. Free Press, New York.

Simon, H. 1978. Rationality as a process and product of thought. Journal of the American Economic Association. Vol.68, 1-16.

Sternberg, R. 1998. In search of the human mind., Harcourt Brace College Publishers, Fort Worth TX.

Surry, J. 1974. Industrial Accident Research: A human engineering approach. Ontario Ministry of Labour, Toronto Canada.

Suutarinen, J. 2003. Occupational accidents in finnish agriculture - causality and managerial aspects of prevention. Ph.D. Thesis. Faculty of Agriculture and Forestry. University of Helsinki, Helsinki. 75pp.

Tversky, A. and Kahneman, D. 1981. The framing of decisions and the psychology of choice. Science. Vol.211, 453-458.

Tversky, A., Sattath, S., and Slovic, P. 1988. Contingent weighting in judgement and choice. Psychological Review. Vol.95(3), 371-384.

Von Neumann, J., and Morgenstern, O. 1944. Theory of games and economic behavior. Wiley, New York.

Wagenaar, W., Keren, G., and Lichtenstein, S. 1988. Islanders and hostages: deep and surface structures of decision problems. Acta Psychologica. Vol.67, 175-188.

Weisstein, E. (2004). Eric Weisstein's World of Physics. Online resource accessed on 7th January 2004 at: http://scienceworld.wolfram.com/physics/Friction.html.