JOURNAL OF MARITIME RESEARCH
Vol. IX. No. 2 (2012), pp. 13 - 18
ISSN: 1697-4040, www.jmr.unican.es

Managing Multiple and Conflicting Goals in Dynamic and Complex Situations: Exploring the Practical Field of Maritime Pilots

M. Mikkers*, E. Henriqson[1] and S. Dekker[2]

ARTICLE INFO

Article history:
Received 21 October 2011;
in revised form 19 November 2011;
accepted 20 February 2012

Keywords:
trade-off decisions, decision making, meta-knowledge, system safety, complexity

ABSTRACT

Maritime pilots have to deal with multiple and conflicting goals during their work. They experience three critical points during their job: (1) entering the waters within the breakwaters; (2) entering and leaving the lock and (3) the mooring of the ship / leaving the quay. At these critical points the situation can be described as more dynamically complex (because for example more decisions are made under time pressure) and tightly coupled (for example because slack is limited) than at other points during the trip. The research results suggest that maritime pilots prepare and manage multiple and conflicting goals, including safety production trade-off decisions, during simpler and loosely coupled times in the operation. Such preparation for trade-off decisions, and meta-knowledge about them, is consistent with earlier findings in e.g. fighter pilots. It makes it possible for a maritime pilot to respond to unexpected and sudden changes, creating margin, or resilience in their operations.

1. Introduction

1.1. Trade-off decisions, production and safety

Trade-off decisions, particularly those that result from conflicting goals (e.g. safety and production, efficiency and thoroughness) are an important feature of safe working practices (Hollnagel, 2009a; Rasmussen, 1997b; Reason, 1997). Rasmussen (1997a) proposed that a system is constrained by three boundaries: the boundary of economic failure; the boundary of unacceptable workload; and the boundary of acceptable performance. Between these boundaries individuals or organizations make on-going trade-off decisions. At the management level (the so-called blunt end of an organization), trade-off decisions are made between production, safety, time, quality, budgets, and other considerations. Employees working close to production (the so-called sharp end) also make many larger and smaller trade-off decisions each day (D. D. Woods, Dekker, Cook, Johannesen, & Sarter, 2010). Blunt end trade-off decisions influence sharp end trade-off decisions and vice versa. In complex systems, countless (trade-off) decisions and adaptations are made (without central coordination), to balance all kinds of pressures and safety. This is done on a local level and based on experiences, without always being able to know if safety is sacrificed (Dekker, 2011).

Woods and Wreathall (2003) explicitly analysed trade-off decisions between safety and multiple pressures to achieve throughput and efficiency from a resilience perspective. They refer to these tradeoffs as 'sacrifice decisions', because "acute production or efficiency-related goals are temporarily sacrificed, or the pressure to achieve these goals relaxed, in order to reduce risks of approaching too near safety boundary conditions" (p. 3). According to Woods and Wreathall it is necessary to know when to relax acute production and efficiency goals, which implies a proactive approach. Management can anticipate on complex and tightly coupled situations. Most trade-off decisions are made implicitly and might go unrecognized, which, according to the authors, results in riskier behaviour than an organization actually wants. In hindsight it is often difficult to determine if the sacrifice decision was justified or not when nothing went wrong. This offers some insight in the process of decision-making, especially at the sharp end. If most of the trade-off decisions are made implicitly and go unrecognized, will explicit decision making result safer outcomes? If so, how can organizations and employees recognize these trade-offs? Woods and Wreathall (ibid.) assume that explicit sacrifice decisions lead to more safety (production is re-

* Corresponding author. Safety researcher, Dutch Railways, Laan van Puntenburg 100, 3511 ER Utrecht, The Netherlands. Email: m.mikkers@gmail.com, Tel. +31886712995, Fax.+31886712381.
[1] Associate Professor, Pontifical Catholic University, Av. Ipiranga, 6681, Building 10/106, 90619-000 Porto Alegre, Brazil. Email: ehenriqson@pucrs.br, Tel. +555133023542.
[2] Professor, Griffith University, 176 Messines Ridge Road, 4122 QLD Mt Gravatt, Australia. Email: s.dekker@griffith.edu.au, Tel. (07) 37355761.

laxed more often so there is more time for contemplating consequences of the decision in terms of safety).

Hollnagel (2009b) investigated trade-off decisions in more depth – especially with regards to decision making -, in his book 'The ETTO Principle: Efficiency – Thoroughness Trade-off'. Hollnagel defined the ETTO principle as:

> In their daily activities, at work or at leisure, people routinely make a choice between being effective and thorough, since it rarely is possible to be both at the same time. If demands for productivity or performance are high, thoroughness is reduced until the productivity goals are met. If demands for safety are high, efficiency is reduced until the safety goals are met (p. 15).

The ETTO-principle suggests a binary approach of efficiency (productivity) and thoroughness (safety). It proposes that efficiency and thoroughness rarely can be reached at the same time. In a complex world all kinds of opposing goals exist, driven by all kinds of pressures and reducing this to efficiency and thoroughness has its limitations. Besides that, relaxing productivity (which means being less efficient) in order to be thorough, can introduce new (probably unknown) risks.

1.2. Trade-off decisions, complexity and coupling

Many trade-off decisions, and often the more critical operational (sharp end) ones, must be made in complex and tightly coupled settings (Perrow, 1984), under conditions of uncertainty (Orasanu, 2001). Complexity, as understood here, means a lack of transparency and predictability in how parts in a system interact and can produce novel system behaviors. Sequences of events, in complex situations, are unfamiliar, unplanned or unexpected, and either not visible or not immediately comprehensible. Tight coupling exacerbates operational difficulties. It means that, because system parts and events are closely interconnected, sequences of interactions can spread and escalate rapidly and that possibilities for meaningful intervention degrade, and margins for recovery shrink (Perrow, 1984). In tightly coupled situations, delays in taking action may not be possible, things have to be done in an invariant order, there is only one method to achieve a goal, and there is no opportunity to recruit additional expertise other than that which is already in the operation at that moment (Hoven, 2001).

Operational settings are not complex or tightly coupled in a fixed sense, of course (Snook, 2000). Complexity can increase, and couplings between different parts of the operation can tighten with changes in context (weather, equipment functioning, available expertise, procedural learning and adaptation, etc.). Coupling and complexity thus wax and wane during an operational workday (Rosness, Guttormsen, Steiro, Tinmannsvik, & Herrera, 2004), changing not only the sheer number of trade-off decisions, but exerting different pressures, criticalities and uncertainties on the trade-off decisions that operators need to make. The dynamics of different operational states (simple to complex, loosely to tightly coupled) in which a system can function at different times, demands operational adaption but also preparation (Hollnagel, Nemeth, & Dekker, 2008, 2009), as uncertainty can increase and cognitive resources for decision making diminish (Orasanu & Connolly, 1993).

1.3. Meta-knowledge

The implications of complexity and coupling are that operators in dynamic worlds "must make decisions in a limited time; his decision being often irreversible; in a partially uncertain environment; where the diversity factor is important" (Valot & Amalberti, 1992). Valot and Amalberti found that operators actively manage their own cognitive resources depending on the demands of the situation, applying a "meta-knowledge" of the tasks and their dynamic context. As one important aspect of expertise (Chi, Glaser, & Farr, 1988; Farrington-Darby & Wilson, 2006), Gruber (1988) describes meta-knowledge as strategic knowledge derived from knowledge of an expert about the capacity and reliability of the system. This knowledge is used for weighing factors like cost, time, reliability, danger, etc. (Hayes-Roth, Waterman, & Lenat, 1983). Meta-knowledge is accumulated as a result of positive and negative experiences, and it widens the range of responses in dynamic and complex situations. Valot and Amalberti (1992) suggest that meta-knowledge is not only formed by objective and accurate notions, but also by 'rough notions' and beliefs, and that it gets drawn on to find compromises between available time, control accuracy and the management of mental sources, sparing mental capacity. There is a cost to this, of course—sacrificing accuracy to achieve rough adjustments in dynamic situations is itself a risk (Dorner, 1983; Feltovich, Ford, & Hoffman, 1997; Feltovich, Spiro, & Coulson, 1997).

1.4. Maritime pilots, trade-off decisions and meta-knowledge

Maritime pilots form a well-trained and highly skilled professional group, who have the task of manoeuvring all kind of ships safely into or out of harbors. Ship masters often need someone who has knowledge of local conditions and skills for manoeuvring all kind of ships, especially for the critical parts of the trip into or out of a harbor. A maritime pilot comes into play at a complex and more tightly coupled part of the journey from the ship and their crew. As a 'newcomer' on the bridge of a ship he or she also has to understand how the bridge team works together and how the team communicates with each other. This is the part of the journey where the phenomena of negotiating multiple and conflicting goals, especially safety and production, is interesting. What influence has the bridge team on the trade-off decisions of the maritime pilot and the other way around? It is interesting to understand how people act in practical situations and how do they experience the phenomenon of trade-off decisions. All kinds of factors can influence the decisions about goal conflicts, for example capacity of the locks, weather and current forecasts and even personal factors.

The field research reported here has studied the way maritime pilots deal with trade-off decisions and goal conflicts vis-à-vis contractions in the complexity and coupling of their operations. We were particularly interested in how maritime pilots manage continuous multiple and conflicting goals, such as safety and production, and what resources and strategies do they rely on to do so effectively when entering situations that may already be well on the way to becoming both complex and tightly coupled?

2. Method

Over a number of weeks, we studied the situated work of a group of (in total) 65 maritime pilots, active in the IJmond region in the Netherlands. The proximity of the port of Amsterdam meant a considerable diversity in their work (and in our sample): all kinds of different ships visit it, with ships having to pass through a relatively small lock and deal with strong currents. We studied piloting work both on inbound and outbound trips. Although not as busy as the port of Rotterdam, IJmond is a challenging region for maritime pilots. A combination of interviews and observations was used to gather field data, which was used in particular to map and investigate those situations which maritime pilots considered as tightly coupled and complex, and how they were prepared for them. The data gathered was also used for a thematic analysis across the cases and experiences related to safety production trade-off decisions, inspired by the method of Yin as described by Creswell (2007). The common themes and patterns found in the analysis were consequently linked to the articulated assumptions as derived from the literature review to establish if the grouped data were consistent with the assumptions.

3. Research results

3.1. Critical points: Tightly coupled and intractable situations

All interviewed maritime pilots agree on the critical points regarding the part of the trip when they are aboard of the ship concerned. One of the interviewed pilots said:

> When I get on the bridge, I 'read' the master and his crew. This is necessary for anticipating their reaction to commands when I enter the area within the breakwaters, the lock and for the mooring of the ship. These are the parts of the trip where piloting is most difficult and communication with the bridge crew is essential.

When a pilot steps aboard on open sea he or she has enough time to get a feel for the situation at hand and also enough time to get a good impression of the bridge crew aboard. The research data suggests that the pilots can confirm that a system can be in a tractable and loosely coupled state and an intractable and tightly coupled state.

The first critical point identified by all pilots is the point where incoming ships pass the breakwaters at IJmuiden.

One of the interviewed pilots explains:

> The current just outside the breakwaters can be very strong. In combination with windy conditions and ships with a large surface catching the wind, it requires a seasoned and experienced pilot to guide the ship inside the waters within the breakwaters. In order to achieve this successfully the ship needs some speed to stay on course. Within the breakwaters the current is negligible, causing some difficulty controlling the ship, since at that precise moment of entering the breakwaters the ship is also still partly under the influence of the strong current outside the breakwaters.

It is interesting to note that the pilot refers to ships with 'a large surface catching the wind', which means that the difficulty of entering the area within the breakwaters depends on the ship type. According to several pilots passenger vessels and car carriers are real 'wind catchers'. Also, within the breakwaters the speed needs to be reduced, especially in situations when tugs are necessary to help the ship along further. "Speed reduction, especially if abrupt, always leads to reduced or lost controllability because the reduced water flow over the rudder", a pilot stated. The situation is even more complex and intractable when there are other ships close by, for example outgoing ships. Passing the breakwaters and entering the area within the breakwaters, requires a great deal of the maritime pilot with regard to navigation, assessing the correct speed and communication with the bridge crew. One maritime pilot added "when something unexpected happens, this is an area where safety margins are small". The maritime pilots do not judge the situation of ships leaving the harbor through the breakwaters as equally complex and intractable. Therefore this is not considered a critical point.

The second critical point, which is encountered in most trips, both for incoming and outgoing ships, is the maneuvering in and out of the lock. The space available to maneuver the ships in the locks can be extremely limited, ships up to 45 meter wide are allowed in the "North lock" (the biggest lock), which has a width of 47 meter free water space. Some ships use a tug or two tugs when maneuvering in and out of this lock. An additional challenge identified by the pilots is the water level in the lock; ships with a large draft need enough water in the lock to pass through, limiting the time frame for ships. Therefore, maneuvering ships in and out of the lock is considered as complex and tightly coupled by the maritime pilots.

A third critical point concerned mooring and anchoring of the ship and the abandoning the quay. This includes maneuvering in the direct space of the quay, which can be very tight. Not only the communication between the maritime pilot and the master is crucial, but also the subsequent communication of the master and the crew involved in, for example, mooring the ship. Finally, the communication with the tugs is important (this is done directly by the pilot). Besides the skills and knowledge needed to succeed in the action(s) described above, a great deal of patience is required since mooring and anchoring (including the necessary maneuvering) a ship is a time consuming process. This is not surprising given the fact that sometimes the available margin to maneuver can be as small as one meter for ships with a length up to 250 meters.

3.2. Dealing with multiple and conflicting goals at critical points

One of the interviewed pilots stated "I pursue sharp passing of other ships near the lock, because this increases the capacity of the lock [… and] this shows my craftsmanship and certainly is not unsafe, but of course this means smaller safety margins". Like this pilot, all pilots view trade-off decisions not as 'black and white decisions', not as decisions of 'entirely safe' versus 'reckless production'. They regard trade-off decisions as decisions to be made about taking some extra (to them acceptable) risks and settling perhaps for a smaller safety margin in order to perform their job of piloting ships to their destination in or out of the harbor. Besides that, the pilots acknowledge that trade-off decisions can enhance safety, but also can introduce new risks. For example, the pilots can wait on open sea for the wind to weaken and enter the area between the breakwaters, but this can mean a stronger current at the time they enter.

Consistent with research results on e.g. fighter pilots (Sarter & Amalberti, 2000), Maritime pilots make a number of important decisions before getting into tightly coupled and complex situations, in this case reaching the area between the breakwaters. In most cases these decisions are clear and do not differ from pilot to pilot. However, sometimes the decision is less clear and the decision can differ depending on the pilot. For example, maritime pilots make different decisions about the use of tugs. One pilot illustrates this by saying: "sometimes I see a pilot using tugs, when this is absolutely not necessary… this is wasted money". Another important decision a pilot has to make concerns the timing of entering the area between the breakwaters. One pilot states he has to consider if it is "sensible to wait for that other ship to come out first or to enter and pass that ship after I come in". This decision is especially important when weather conditions are bad (for example due to strong winds or low visibility), when the water level is low or when the current is strong. The timing is also crucial when approaching the next critical point, the locks. What the pilot generally wants to avoid is to float around within the breakwaters, waiting for permission to enter the lock. 'Floating' with big ships is complicated, especially with strong winds. This was witnessed this during an in loco observation; during the floating of the ship the pilot had to give a lot of instructions to the bridge crew in order to control the ship. All these examples are illustrations of the trade-off decisions pilots make. The decisions have a safety element; extra safety margin often can be created by using tugs, although using tugs introduces new risks; extra communication is necessary, the tugs need to be fastened to the ship, etc. These risks become bigger when there is a lot of wind and then tugs are needed most.

As expected, trade-off decisions are a constant presence in piloting work. One pilot stated that because he wanted to avoid the waiting time for the 'northern lock' (the lock normally used for the type of ship he was piloting), he took the tighter 'middle lock' (thereby compromising some margin). Other examples of trade-off decisions include:

- The use of tugs costing the shipping company money, versus not using tugs resulting in missed turnover for the tug company or a delay with respect to the estimated time of arrival means a loss of income or extra costs for the shipping company;
- Tides that allow for a limited time frame to maneuver. If the time frame is missed it will cost a lot of money as well as cause frustration to the pilot, the crew and other stakeholders;
- The demonstration of professional prowess and acquired skills. This may lead, according to some of the pilots interviewed, to situations with uncalled for smaller safety margins.
- The responsibility to serve the harbor by piloting its ships swiftly and safely. When performing well, especially in terms of swiftness, it helps the harbor to stay attractive for shipping companies to keep visiting.

It is normal for pilots to experience tighter coupling and greater complexity at the critical points described earlier. The interview data confirms that much time is spent preparing the trip, and this preparation continues whilst the system is in a tractable and loosely coupled state. Before going aboard, pilots study weather conditions; especially wind force and wind peaks, currents, tides / depths, traffic movements[1] and characteristics of the ship. By studying this, pilots prepare how and when to approach the critical points, especially passing the breakwaters and entering the lock.

The next important phase of preparation starts as soon as the pilot enters the bridge. All pilots start by immediately checking the position[2] (electronically and visually), speed and rudder indicator, etc. Another aspect of the preparation that is related to the management aspect, is getting an idea of how the bridge crew functions. Two pilots stressed the importance of building trust between the pilot and the bridge crew, especially with the master. Such built-up trust is in itself a source of preparedness for more tightly coupled, complex situations. One pilot stated that the first decision ideally should be a decision the pilot does not need to correct. If this is not the case, it will be more difficult to reinstall trust. Later during the trip, if the first decisions do not need correction, the master generally will accept corrections without this resulting in loss of trust. This pilot developed the strategy that, because of this reason, his first orders[3] are 'certainties' where the pilot cannot go wrong. The aim of this trust building is to ensure that when something unexpected happens, the master and the crew react adequately to an order from the pilot. Most other pilots recognize the importance of building trust, except for one pilot. He said "I trust my own skills and do not want to be dependent on how the crew reacts". This is remarkable, since a pilot generally works together with a bridge crew. This pilot added, "when I think the bridge crew does not react adequately, I will build in some extra margin for myself". The other pilots did not have a specific outspoken strategy for building trust, but they did state they invest in building trust just by acting calm and self-assured as well as in communication with the master. This building of trust can be seen as a form of 'management', namely the management of the bridge crew, aimed at getting a better idea of how the bridge crew reacts in an unexpected situation. This trust building, one pilot adds, forms an important part of 'bridge resource management training' pilots attend during their career.

4. Discussion

Most pilots confirm that preparation and management helps to create extra margins when entering critical points. This is consistent with findings on the value of mental simulation before engaging in a complex, time-critical tasks (Klein & Crandall, 1995). Preparation regarding weather conditions, tides, currents, and so on, especially helps to get the timing for entering the area within the breakwaters and the locks right. For this timing the movement of other ships is also important. This information only becomes apparent when entering the critical points, by visual observation, radar images and information from traffic control. The more accurate and complete the information is, the bigger the chance of getting the timing of entering the critical points is right creating extra safety margin at the critical point. The management of the bridge crew, especially investing in building trust and communication, seems to create extra resilience. The research data suggests that this investment increases the ability of an organization to retain or recover rapidly from a mishap or great ongoing pressure (Wreathall, 2006), as well as the ability to manage great pressure, as well as conflicts between safety and production objections.

Other interview data also points at the importance of this preparation and management. This data can be derived from situation when ships are guided passing the breakwaters with shore based pilotage. On the site of the Dutch Maritime Pilot Association (Loodswezen), shore based pilotage is described as follows (Loodswezen, n.d.):

> When transferring pilots to and from ships using yawls and tenders is made impossible due to adverse weather conditions... Smaller ships can be piloted through shore based pilotage. This means that a shore-based pilot, with the help of RADAR information and radio communications, directs the vessel. However, RADAR information is, by definition, not representative of manoeuvres in real-time. For example, information concerning the ship's course, its speed and turning speed, is not up to the minute information. The safety margins, in this case, have to be increased, which means amongst other things, that overtaking of other ships has to be avoided. The pilot will board an incoming ship as soon as it is possible within the breakwaters.

Pilots acknowledge the need to increase safety margins when using shore-based pilotage. The relation between preparation and management and resilience was mentioned explicitly in nearly every interview; pilots stated that when they board a ship within the breakwaters, they have to orientate themselves quickly and immediately start with action. Time pressure is high and there is for example no time to build trust with the bridge crew. All interviewed pilots mentioned that getting aboard of ships that had been guided to area between the breakwaters with shore based pilotage is much more difficult and safety margins are smaller. That is why the pilot organization only allows shore based pilotage if complexity is reduced, for example by reducing traffic intensity within the breakwaters. Even in this case, considerable preparation and management is done when the system is in a tractable and loosely coupled state (outside the breakwaters). This can be viewed as an 'investment' in resilience for the critical points.

Ideas that could be associated with meta-knowledge were frequently referred to during the interviews and the observations, although not exactly called that way. All maritime pilots mentioned the extensive training program of eight years all pilots go through. The training program is very much aimed at gaining experience in the practical field of piloting. At the start of the program theory about currents, tides, etc. is studied thoroughly. But soon in the program the pilots start simulator training and piloting smaller sized ships. One pilot adds "piloting small ships can be as difficult as piloting big ships, but mistakes are not punished severely". So, a pilot on a small ship has a larger safety margin, and this larger margin is used to gain experience. This means that a pilot gets the opportunity to learn from negative experiences as well without (generally) causing too much damage to ships and / or the self-confidence of the pilot. During the program the pilot is step-by-step allowed to pilot bigger ships. The last step allows the him to pilot ships that are constrained by draft. During this eight-year training program, but also after the program, a maritime pilot develops meta-knowledge. The knowledge consists of strategic knowledge of how to handle certain situations. During their career (including the training program) they learn about the system, different situations in the system, the reliability of the system and especially about their own skills. One pilot illustrates this nicely: "When I get more experienced I gradually gain more tools for my toolbox allowing me to deal with difficult situations". This pilot also specifically related this to trade-off decisions: "the experience I gained during the years makes it more apparent when I really must choose for safety and abort an action, or when I know that I trust my ability to cope with the unexpected".

Another point related to meta-knowledge, which seven of the nine interviewed pilots referred to, is the cultural aspect of the crew. "People from different parts of the world have their 'own user guide'", states one pilot. One example, which several pilots refer to, is shipmasters from Asia. For these masters it is important that they are always treated with the utmost respect in front of their crew; "if they feel they are being bossed in front of their crew, you have a problem as a pilot". Thus, based on the origin of the bridge crew and the master, the pilot forms a strategy for dealing with the bridge crew and the master. This is in line with the statement of Valot and Amalberti (1992) that meta-knowledge is not only formed by objective and accurate notions, but is also based on 'rough notions' and beliefs.

Thus, meta-knowledge appears to be important in the job of maritime pilots. It helps them to efficiently prepare and manage safety production decisions creating extra safety margin. Meta-knowledge deals with the resilience of the system, but it also adds extra resilience to the system. Questions of course surround the acquisition of meta-knowledge—is this merely a result of long experience and exposure to operational situations, or can meaningful training short-cuts be found (Klein, 1998)?

5. Conclusion

This research aimed to shed light on how maritime pilots manage continuous multiple and conflicting goals (safety vs. production), and what resources and strategies they rely on to do so effectively when entering situations that may already be well on the way to becoming both complex and tightly coupled. An important aspect of this management is preparing these multiple trade-off decisions, when time is available and pressures are low; in other words, when the system is less dynamic and complex. Maritime pilots take time to invest in the relationship and communication with the bridge crew. Also, they invest in gathering information and keeping information up-to-date, for example about wind, currents, traffic movement of other ships, and so forth. This can be viewed as an investment in resilience in anticipation of situations in which the system becomes more dynamic and tighter coupled. When pilots eventually have to deal with unexpected situations, they have to consider fewer options to consider when having to decide, since they have already ruled out several options in their preparation and mental simulation.

Meta-knowledge is another important aspect of pilot expertise, which adds resilience to the system. The preparation of trade-off decisions and meta-knowledge about trade-off decisions make it possible for a maritime pilot to respond to unexpected and sudden changes in the system and creates more safety margin. These adaptations made by the pilots are based on continuous trade-off decisions and on continuous weighing of time constraints, costs, reliability, etc. Maritime pilots try to minimize insufficient and inappropriate adaptations or dealing with these adjustments, by using and increasing meta-knowledge instead of by constraining the pilots with prescriptive work methods and / or procedures. They invest in their ability to cope with unexpected situations.

Notes

[1] Two of the interviewed pilots mentioned this point

[2] When piloting the ship to the harbor

[3] We will use the word 'order' because it generally is carried out as an order, but it must be remembered that the master is responsible in the end with pilots functioning as an advisor; this means that an 'order' by an pilot in the strict sense is an advice.

References

Chi, M.T.H.; Glaser, R. & Farr, M.J. (1988): *The Nature of expertise*. Hillsdale, N.J.: L. Erlbaum Associates.

Creswell, J.W. (2007): *Qualitative inquiry & research design: Choosing among five approaches* (Second ed.). Thousand Oaks, California: Sage Publications Inc.

Dekker, S.W.A. (2011): *Drift into failure: From hunting broken components to understanding complex systems*. Farnham, UK: Ashgate Publishing Co.

Dorner, D. (1983): Heuristics and cognition in complex systems. In R. Groner, M. Groner & W. F. Bischof (Eds.), *Methods of heuristics*. Hillsdale NJ: Lawrence Erlbaum Associates.

Farrington-Darby, T. & Wilson, J.R. (2006): The nature of expertise: A review. *Applied Ergonomics, 37*, 17-32.

Feltovich, P.J.; Ford, K. M. & Hoffman, R.R. (1997): *Expertise in context: Human and machine*. Menlo Park, Calif.: AAAI Press.

Feltovich, P.J.; Spiro, R. J. & Coulson, R. (1997): Issues of expert flexibility in contexts characterized by complexity and change. In P. J. Feltovich, K. M. Ford & R.R. Hoffman (Eds.), *Expertise in Context*. Cambridge, MA: MIT Press.

Gruber, T. (1988): Acquiring expert knowledge from experts. *Int. J. Man-Machine Studies, 29*, 579–597.

Hayes-Roth, F.; Waterman, D. & Lenat, D. (1983): *Building expert systems*. Reading, MA: Addison Wesley.

Hollnagel, E. (2009a): *The ETTO Principle: Efficiency-Thoroughness Trade-Off. Why things that go right sometimes go wrong*. Aldershot, UK: Ashgate Publishing Co.

Hollnagel, E. (2009b): *The ETTO-Principle: Efficiency - Thoroughness Trade-Off*. Farnham, Surrey: Ashgate Publishing Limited.

Hollnagel, E.; Nemeth, C.P. & Dekker, S.W.A. (2008): *Resilience Engineering: Remaining sensitive to the possibility of failure*. Aldershot, UK: Ashgate Publishing Co.

Hollnagel, E.; Nemeth, C.P. & Dekker, S.W.A. (2009): *Resilience Engineering: Preparation and restoration*. Aldershot, UK: Ashgate Publishing Co.

Hoven, M.J.V. (2001): *Moral responsibility and information and communication technology*. Rotterdam, NL: Erasmus University Center for Philosopy of ICT.

Klein, G. A. (1998): *Sources of power: how people make decisions*. Cambridge, Mass.: MIT Press.

Klein, G.A. & Crandall, B. (1995): The role of mental simulation in problem solving and decision making. In J. Flach, P. Hancock, J. Caird & K. Vicente (Eds.), *An ecological approach to human-machine systems I: A global perspective*. Hillsdale NJ: Lawrence Erlbaum Associates.

Loodswezen, D.R.R. (n.d.). 2011, from http://rijnmond.loodswezen.nl/en/services/shore-based-pilotage/1965/

Orasanu, J. M. (2001): *The role of risk assessment in flight safety: Strategies for enhancing pilot decision making*. Paper presented at the 4th International Workshop on Human Error, Safety and Systems Development Linköping, Sweden.

Orasanu, J. M., & Connolly, T. (1993). The reinvention of decision making. In G. A. Klein, J. M. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision making in action: Models and methods (pp. 3-20)*. Norwood, NJ: Ablex.

Perrow, C. (1984): *Normal accidents: Living with high-risk technologies*. New York: Basic Books.

Rasmussen, J. (1997a): Risk Managegement in a Dynamic Society: a modelling problem. *Safety Science, 27*, 183-213.

Rasmussen, J. (1997b): Risk management in a dynamic society: A modelling problem. *Safety Science, 27*(2-3), 183-213.

Reason, J.T. (1997): *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate Publishing Co.

Rosness, R.; Guttormsen, G.; Steiro, T.; Tinmannsvik, R.K. & Herrera, I.A. (2004): *Organisational accidents and resilient organizations: Five perspectives (Revision 1)* (No. STF38 A 04403). Trondheim, Norway: SINTEF Industrial Management.

Sarter, N. B., & Amalberti, R. (Eds.). (2000). *Cognitive Engineering in the aviation domain*. Mahwah, NJ: Lawrence Erlbaum Associates.

Snook, S.A. (2000): *Friendly fire: The accidental shootdown of US Black Hawks over Northern Iraq*. Princeton, NJ: Princeton University Press.

Valot, C. & Amalberti, R. (1992): Metaknowledge for time and reliability. *Reliability Engineering and System Safety, 36*, 199-206.

Woods, D. & Wreathall, J. (2003): Managing Risk Proactively: The Emergence of Resilience Engineering. Institute for Ergonomics, The Ohio State University.

Woods, D.D.; Dekker, S. W.A.; Cook, R.I.; Johannesen, L.J. & Sarter, N. B. (2010): *Behind human error*. Aldershot, UK: Ashgate Publishing Co.

Wreathall, J. (2006): Properties of resilient organizations: An intial view. In E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience engineering: Concepts and Precepts* (pp. 268-286). Aldershot, UK: Ashgate.