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Frykmer, Tove

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Problems, problem-solving and problem-solving networks - a theoretical foundation for FIRE21

Author:
Tove Frykmer, Division of Risk Management and Societal Safety, Lund University

Contents

1 Introduction

This document is created within the research project Nordic Fire and Rescue Services in the Twenty First Century (FIRE21). In this project, the fire and rescue services are seen as both governed by, and dependent on, formal and informal networks. A fundamental assumption in the research project is that efficient emergency management is dependent on efficient problem-solving in these networks. As a consequence, the formal and informal networks are here seen as potential problem-solving networks (PSN) that can facilitate efficient problem-solving for the fire and rescue services, and thereby contribute to better handling of emergencies and disasters.

Solving problems is as obvious as it is challenging during an emergency or disaster. Some of the problems are easy to understand and solve, others are more difficult or cannot even be understood or solved. Some problems occur immediately, while others appear along the way. As a theoretical concept, problem-solving is part of many fields and studied in many different ways. It has played, and still plays, an important role in various fields like mathematics, psychology and computer science. Theories and ideas that develop in such diverse fields are not always in sync and quite often in conflict with each other. The purpose of this document is however not to present a comprehensive review on problem-solving research, but rather to describe literature and ideas concerning problems, problem-solving and problem-solving networks that can be relevant to FIRE21. It also serves to contribute to a common understanding of these concepts for FIRE21 project members, an understanding that can be used in common deliverables in the project.

DISCLAIMER:
It should be noted that much of the text in this document is taken from other research projects (mainly from Frykmer, 2021) and from a compendium used in the Lund University course *Introduction to Disaster Response Management* (Uhr & Frykmer, 2021). Thus, the terminology and ideas described in this document have not been specifically developed within FIRE21 and may not be in full accordance with the views and preferences of individual project members.

2 Problems and problem-solving

When it comes to what a *problem* is, there is reasonable agreement that this means: "*there is some form of undesirable current state, it is desired to be in another state and there is no direct, obvious way to move from the given to the goal state*" (Mayer, 1992). This resonates well with influential authors in the problem-solving domain, such as Duncker (1945) and Newell and Simon (1972), and represents the view on problems in this document. As problems represent a gap between perceived reality and something desirable, problems are intrinsically subjective and shaped by each individual's beliefs, preferences or goals (Dery, 1983; Smith, 1989). Nevertheless, problems can express beliefs about real things (Smith, 1993), such as people dying or being injured during emergencies and disasters.

Although problems are commonly described according to their level of complexity, their subjective nature means that these descriptions are not objective and, in fact, reflect a value judgment (Dery, 1983). Nevertheless, problems can be described as well-defined/well-structured (Reitman, 1964; Simon, 1973) or structured-bounded (Mitroff & Linstone, 1992), i.e., relatively easy to grasp and solve; or,on the other side of the scale, problems can be conceptualised as wicked (Rittel & Webber, 1973), ill-defined/ill-structured (Reitman, 1964; Simon, 1973) or unstructured-unbounded (Mitroff & Linstone, 1992). Denoting similar characteristics, the main message is that the latter types of problems are ambiguous, unconstrained and there are no objective solutions to be found. Current states and goal states are difficult to define, and, in fact, whether there is a problem or not may be highly subjective ('t Hart & Boin, 2001; Smith, 1992), and how to reach the goal might not be easily agreed upon (Klein, 1998). In addition, these types of problems cannot be separated from the environment, i.e., they are difficult to place boundaries around, and they appear to have an infinite number of solutions, where a "good enough" solution often has to make do. Evaluation of implemented solutions is also challenging with these problems, due to the complex surroundings consisting of a multitude of interrelated factors and the issue of not being able to find objective solutions (Rittel & Webber, 1973). Solving such problems can be called complex or dynamic problem-solving (Fischer et al., 2012, 2017; Greiff et al., 2012). Even though the perception of a problem can depend on the eye of the beholder, many problems in emergencies and disasters are nevertheless considered wicked, or ill-defined, in the literature (see e.g. Boin et al., 2020; Christensen et al., 2016; Roberts, 2001).

How humans actually *solve* problems has, on the other hand, been the subject of lively debate. In psychology, where much research on problem-solving has been performed, it is denoted as a cognitive process and is often connected to thinking and reasoning (Mayer, 1992, 2013; Sternberg, 1994), or as a chain of associations (se Thorndike, 1911 i Mayer, 2013). Thinking is considered to be at the heart of most cognitive processes, and sometimes thinking, problem-solving, and cognition are even used interchangeably (Mayer, 1992).

There are many ways to present the diverse area of problem-solving. In this document, problem-solving is linked to the theory of *human information processing*, based on humans as processors of information and computer programs being used as models for human thought. The theory was developed by Allen Newell and Herbert Simon in the 1970s (see e.g. Human Problem-solving from 1972) and is still influential within this field. Previous theories described separate parts of problem-solving but not how these were connected or should be handled by the problem solver, while Newell and Simon presented a coherent theory for how problem-solving could, or should, be performed (Hunt, 1994). The problem solver creates a mental representation of the relevant parts of reality, where the problem exists. A more familiar synonym for mental representations is *mental models*. Mental models and their function are discussed and applied in a number of different research fields. Problem-solving is subsequently about manipulating the inner, mental representation in order to find a solution, and then applying it to reality. Viewing problem-solving from this perspective means that there is no need to interfere with the external world until the problem is solved using the internal representation (Hunt, 1994).

Newell and Simon call the mental representation the *problem space*, consisting of nodes and links between them, see Figure 1. The nodes represent the current state, the desired state, or goal state, and possible solution steps along the way. The problem solver must, after recognising and understanding the problem, define the problem space and a strategy for getting from the current state to the goal state via relevant solution steps. Problem-solving is thus a method for finding activities that reduce or eliminate the difference between the current state and the goal state (Simon, 1996). In addition to the problem solver's capability to define the problem space and the solution steps, Newell and Simon (1972) describe the importance of analysing the environment in which the problem is located, which also affects the problem space.

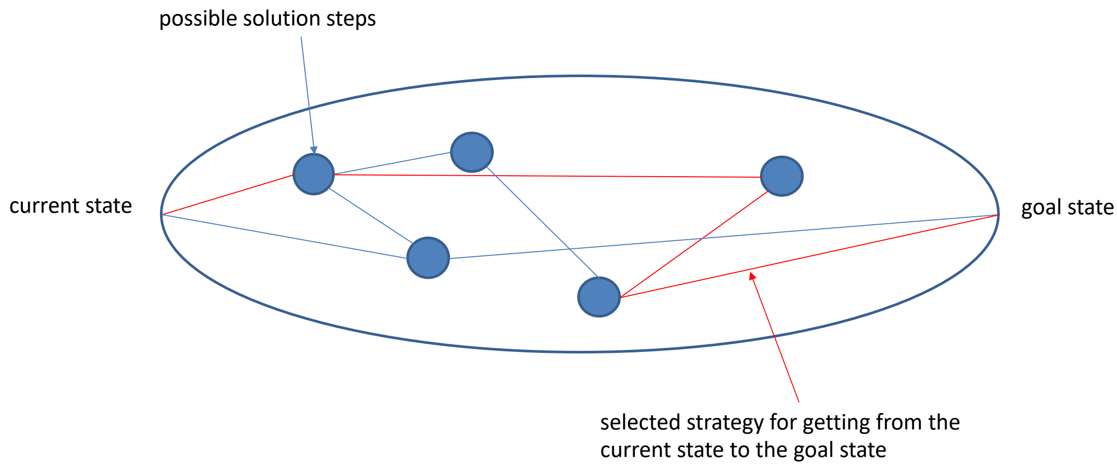

Figure 1. The problem space with the current state, goal state, possible solution steps and the chosen solution strategy. Based on Newell and Simon (1972).

Another way of illustrating problem-solving is through *phase models*, which show a logical sequence of steps to be taken in the problem-solving process and argue that the outcome will be more successful if the steps are followed. Shortcomings in phase models have been observed by several researchers (see e.g. Klein, 1998; Lipshitz & Bar-Ilan, 1996; Mintzberg et al., 1976; Witte et al., 1972). Notably, the descriptive validity of their linear logic has been questioned in real-world settings (Klein, 1998; Klein et al., 1993), and steps have been found to be blurred (Witte et al., 1972). Phase models for problem-solving can also be criticized for being based on traditional notions of how people operate (e.g. linked to rationality) and not taking into account the research that exists, which indicates that we sometimes decide on solutions before we formulate the problems (March & Shapira, 1987); or the extensive research conducted by Daniel Kahneman for example, which shows intuitive non-analytical mental processes in connection with decision making. Researchers in the field of naturalistic decision making, such as Gary Klein, have shown that experts successfully manage problems without consciously analysing the problem. To better suit the context of real-world problems, such as in emergencies and disasters, Klein (1998, p. 122) suggests a non-linear problem-solving model as a contrast to linear phase models. This model allows for redefinition of the problem and re-evaluation of the course of action, important activities that are perceived as lacking in phase models.

For both linear and non-linear problem-solving models, however, the steps can generically be summarised as: representing the problem, generating a course of action, evaluating the course of action and carrying out the course of action (Klein, 1998). Based on these general steps, and in line with Witte et al.'s (1972) argument that phase models can nevertheless be useful in structuring thoughts and ideas, Figure 2 illustrates a model that can be used to analyse problem-solving in emergency and disaster response management. It is emphasised that the model is used as a tool for reasoning and that it does not necessarily show how problems *should* be solved. The model is not a description of how problem-solving necessarily takes place, but shows potential steps and paths in a problem-solving process. In fact, there is still a need for empirical studies investigating the prescriptive validity of the problem-solving process as a whole, although it has been shown that effective problem-solving relies on proper execution of early steps in the process, such as problem representation (Lipshitz & Bar-Ilan, 1996).

The arrows with the dashed lines in Figure 2 point to the possible paths of problem-solving. This illustrates the *iterative* aspects of the problem-solving process, where all steps can be revisited during the process. Literature has shown, for instance, that many problems are initially defined incorrectly (Lyles, 1981), illustrating the importance of iterations. Further, when solving complex problems, the problem solver usually has to systematically interact with the problem (Fischer et al., 2012), thereby naturally causing iterations. In this model, the focus is not on the precise details in each step, or which steps are followed and which are not in a specific problem-solving situation, rather it aims to explain *how* problem-solving can be accomplished, in order to provide a link to emergency and disaster response management.

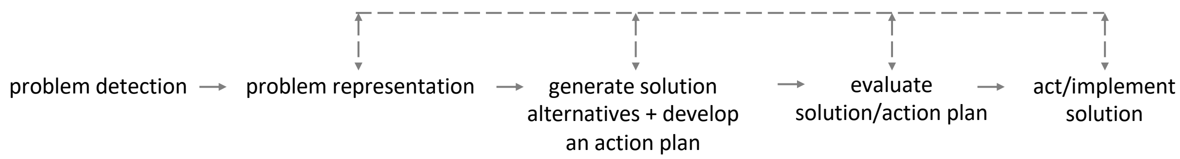

Figure 2. A model of the problem-solving process, with its steps and possible paths.

Problem-solving begins with a problem being *detected*, i.e. one experiences a discrepancy between reality and the desired state. This first step in problem-solving is associated with cognitive processes such as perception (Smith, 1989). Problem detection is thus about our capability to detect when something is about to go, or has gone, awry and must be dealt with. In the *representation* step, one tries to specify and represent (also called define) the problem for oneself and others. This step usually involves setting goals, i.e. the desired goal state and/or sub-goals for the solution steps, and, if necessary, analysing and determining the cause of the problem. The importance of representing the problem before solving it is commonly emphasised by researchers in the problem-solving domain (Baer et al., 2012; Büyükdamgaci, 2003; Klein, 1998; Lipshitz & Bar-Ilan, 1996; Lyles & Mitroff, 1980; Massey & Wallace, 1996; Newell & Simon, 1972; Smith, 1989). Considering that problems are subjective conceptualisations of a perceived gap in preferences and not, for example, physical entities that can be easily pointed to, it is argued that they must be described and expressed in order to have their existence communicated and to enable problem-solving (Ackoff, 1978; Baer et al., 2012; Smith, 1989). Problem representation becomes even more important when faced with *messes*, i.e., situations consisting of complex systems of problems that are changing and interacting with each other and are difficult to define (Ackoff, 1979), such as are commonly prevalent in emergencies and disasters. In these situations, it is especially important to represent the problem in order to avoid solving the wrong problem correctly (Büyükdamgaci, 2003; Mitroff &

Linstone, 1992; Niederman & DeSanctis, 1995; Smith, 1989). Nevertheless, whether real world problems, which are by definition ill-defined/ill-structured and carry no objective solutions, can be represented at all can be questioned (Dery, 1983; Klein, 1998; Smith, 1989). In the problem-solving process, the problem representation can be used to *generate solution alternatives* and *develop an action plan*, which is then *evaluated* against the goals. Mental models could be said to play a central role in these first steps, which are about internal representations of the problem, potential solution alternatives and the choice and evaluation of a solution. For example, Newell and Simon's problem space can be linked to the problem representation step as well as the step for generating solution alternatives and developing an action plan. The final step in problem-solving involves *implementing* the chosen and evaluated solution in reality. That is, this is the step when the internal representation is tested externally.

2.1 A dynamic system of problems, organised in a hierarchy

Problems and problem-solving in emergencies and disasters are further conceptualised through describing ideas on a *dynamic system of problems, organised in a hierarchy*. Newell and Simon's problem space is not necessarily static throughout the problem-solving process but may be changed and modified during the course of the process, such as when a particular problem-solving method does not work satisfactory. During the problem-solving, new problems may appear or be produced as a result from the problem-solving behaviour. Also, it is important to note that the problem solver may not have the entire problem space represented internally when solving a problem, but rather a small set of it at a given point in time. Sometimes, the problem is too large to represent completely, or too complex to know all possible solution steps at the outset.

This description fits well with the context of emergencies and disasters, which, due to their dynamic and uncertain nature, can be described as a dynamic system of problems, where problems are connected in a hierarchy. These ideas are based on experiences from a study on problem representations expressed in common operational pictures during the wildfires in Sweden in 2018 (Frykmer & Svenbro, n.d.). During an adverse event, at a given moment in time, some problems are known and some are deemed as possible future problems. New problems, foreseen or unforeseen, appear over time. The situation resembles a dynamic system of problems, similar to Ackoff's (1979, p. 99) *messes*, or "*complex systems of changing problems that interact with each other*". In this dynamic system of problems, a hierarchy of problems can be distinguished, as illustrated in Figure 3.

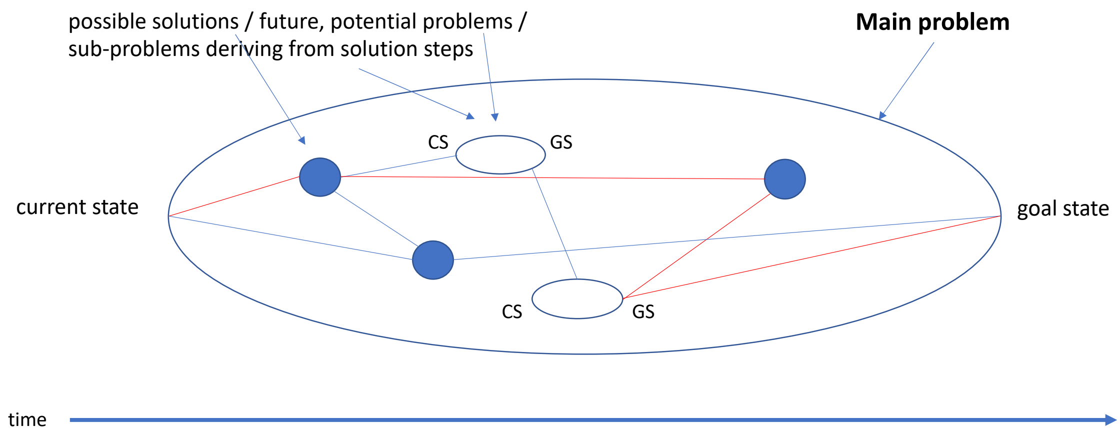

Figure 3. The dynamic system of problems in emergencies and disasters.

The adverse event represents the main problem, which is the reason for the response system to be active in the first place. This is connected to a current and a goal state, which may change throughout the course of the problem-solving process. Connected to the main problem are other problems, which are seen as problems on lower hierarchical levels. Some are sub-problems resulting from the main problem's solution steps, and some are future, potential problems that may appear from the problem-solving itself or from some other factor, such as the evolving situation. Sub-problems and future, potential problems must often be solved before progress can be made toward the main problem's goal state. Both the problem-solving progress and future, potential problems may change throughout the course of the problem-solving and thus alter the path towards the goal state.

The hierarchy of problems is further illustrated in Figure 4. Here, the problems are exemplified using the wildfires in Sweden in 2018. The first order problem described is part of the main problem (there is a wildfire), namely the wildfire is threatening lives. Other first order problems associated with the main problem could be that the wildfire threatens property, which would call for other measures than illustrated in Figure 4.

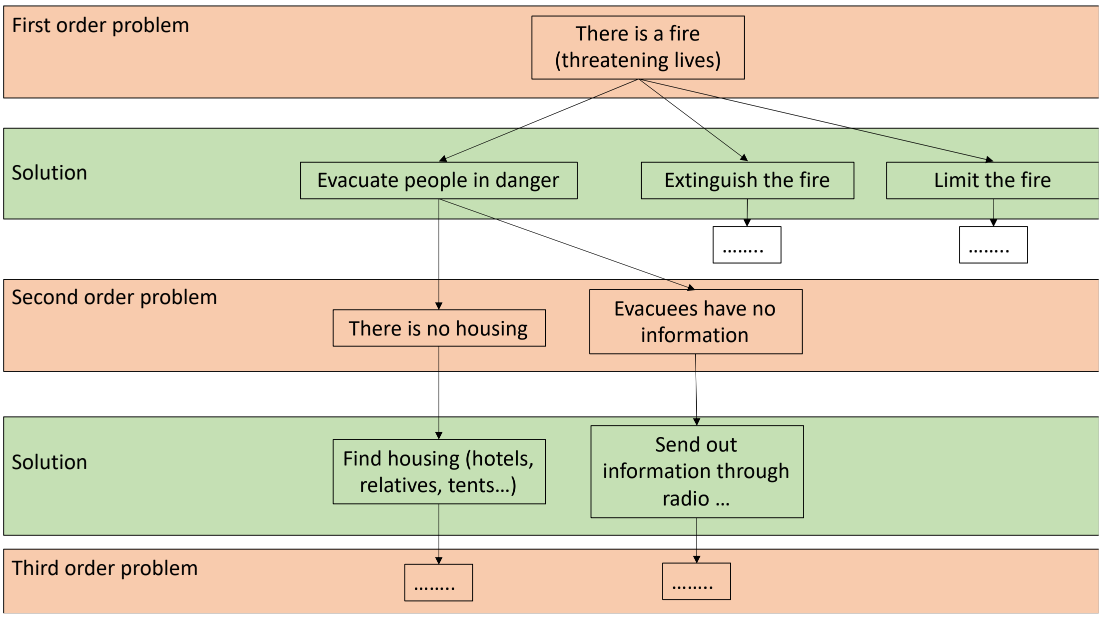

Figure 4. Exemplifying the hierarchy of problems.

In the figure, possible solutions to the first order problems are shown. The solution of "evacuate people in danger" is then further illustrated with new problems deriving from that solution, which in turn is exemplified with new solutions, and so on. Viewing problems in an adverse event as a dynamic system of problems organised in a hierarchy enables a holistic overview by visualising connections between problems, thus revealing potential "showstopper problems" and establishing an order of priority and solution. This way of viewing problems can also facilitate a forward-looking, proactive, approach as it visualises future, potential problems.

2.2 The relationship between problem-solving and decision making

In the literature, some see problem-solving as an umbrella term including decision making, and some see decision making as an umbrella term including problem-solving (Klein, 1998). Often, problem-solving and decision making are used interchangeably (Dery, 1983; Smith, 2009). Here, decision making is seen as part of problem-solving. The reason for not assuming the opposite, or focusing solely on decision making, which is relatively common in both response management research and practice, is foremost that problem-solving can be used as a wider framework. Some decision-making theories, that focus on selecting between known solution alternatives, also do not fit a realistic setting where it may be difficult to understand the situation, let alone suggest possible solutions, which means that the focus on decision making loses significance (Gralla et al., 2016; Mendonça et al., 2001). Second, the belief is that a decision should not be made for the sake of making a decision, but rather as a part of solving a problem. As Brehmer (1992) found, decision making was always directed towards some goal and never the primary focus of activity. Nevertheless, decision making is central to several parts of the problem-solving process, and there are therefore relevant decision-making approaches that are useful in a problem-solving framework (Landry, 1995). Some of these are presented here.

Classical decision theory assumes that people make rational choices and that the decision problem is largely about identifying decision alternatives and choosing the most optimal one based on expected benefits. A typical way to simply describe the steps in decision making as a process is to (1) first identify the problem, (2) then identify the courses of action and finally (3) choose the best course of action (Cole, 2004). These steps are similar to the problem-solving model above. Classical decision theory often assumes that there are well-defined goals, that the problems are clear, that all alternatives can be identified, that the preferences are clear and constant, and that the best choice is what gives the best "return on investments" (Robbins, 1932). This form of decision making tends to focus on a specific decisions rather than seeing the decision as part of a larger context, or as part of a longer process (Campbell & Knox Clarke, 2018).

During the 1950s, however, an alternative view of decision making emerged that was based on research that showed that people are not always able to identify all the courses of action and that rationality is relative (referred to as *bounded rationality*). One example of this school of thought is the theory of *satisficing* (Simon, 1956). Simon argues that an often-realistic way to make decisions is to identify criteria for what you want to achieve, and when a situation that meets these criteria arises, you “strike”. This school does not place much focus on choosing the right alternative between a number of known alternatives, rather, it is about setting realistic criteria for when a solution is good enough.

Thereafter, however, descriptive research on how humans actually make decisions, often called *naturalistic decision making*, has made significant progress. Examples of researchers who have made significant contributions here are Daniel Kahneman and Gary Klein. Both researchers show how people largely make decisions without the conscious analytical processes on which the classical theories were based, but rely on e.g. intuition and rules of thumb (see e.g. Kahneman, 2011; Kahneman & Tversky, 1979; Klein, 1998, 2008; Klein et al., 1993). One difference between the researchers' results is that while Kahneman proved through experiments that we are rather bad intuitive decision makers, Klein demonstrated the opposite. An important difference, however, is that Klein predominantly based his studies on how experts make decisions in critical situations, while Kahneman, to a greater extent, based his theory on experiments where the subjects did not always have domain knowledge. Klein is best known for his research and development of the *Recognition Primed Decision model*, or RPD (Klein, 1993, 2008). The model describes how professionals in critical situations make decisions under conditions of uncertainty and time constraints by matching the situation to previous experiences, and then simulating possible solutions in order to finally follow the first possible solution that materialises (like satisficing above). According to Klein (2008), RPD consists of some intuition (the matching) and some analysis (the simulation). The model has been developed through studies of response situations and of the stakeholders who are normally involved in such situations, such as the fire and rescue services or the military.

Finally, Campbell and Knox Clarke (2018) describe a form of decision making that is defined in advance for the individual. This concerns established plans, processes or checklists (plans, procedures, protocols) that are intended to be used in specific situations, often typical incidents, activities or geographical areas. However, the authors discuss literature that warns that these plans should only be used as a guide to, rather than to completely replace, decision making. This is especially true in situations of, for example, an atypical nature where the plans do not fit the emergent situation.

Figure 4 shows how the aforementioned decision-making theories are linked to the problem-solving process. Naturalistic decision making, of which RPD is a part, focuses not only on the specific decision but also on the context, and the whole process can thus be likened to the whole problem-solving process, while the narrower approach in classical, rational, decision making connects to specific parts of the process. The "substitute" for decision making in the form of plans, processes or checklists can be linked to the action plan, as this is determined in advance. The image shows an advantage in using a problem-solving perspective as opposed to the sometimes-narrow decision-making perspective. Indeed, in some decision-making models, no emphasis is placed on understanding what the problem really is, i.e. problem representation.

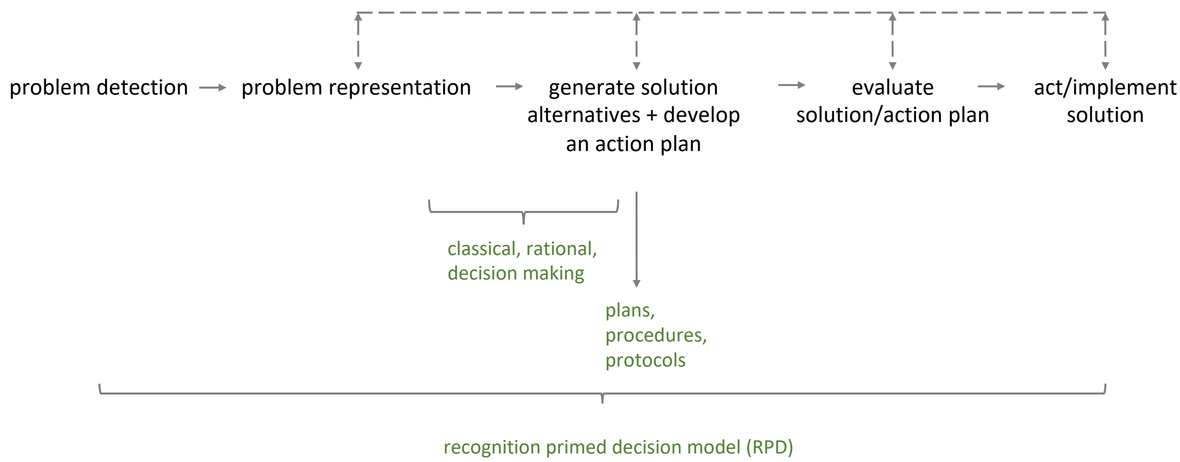

Figure 5. The problem-solving process and how it relates to certain decision-making theories.

3 Problem-solving networks (PSN) in emergency and disaster response management

In order to place problem-solving in the context of emergency and disaster response management and to discuss problem-solving networks in the fire and rescue services, it may be appropriate to use Brehmer's (2000) simple cybernetic model of emergency and disaster response as a control problem, as illustrated in Figure 6. This means that one system (the response system) tries to control another system (the adverse event) in order to meet needs and minimise consequences. Relating back to the common definition of a problem stated above, emergency and disaster response management can in fact be viewed as a problem-solving activity where relevant actors during an adverse event (current state) solve problems in order to meet needs and minimise consequences (goal state). The arrows in the figure illustrate that the two systems are dynamic and change over time.

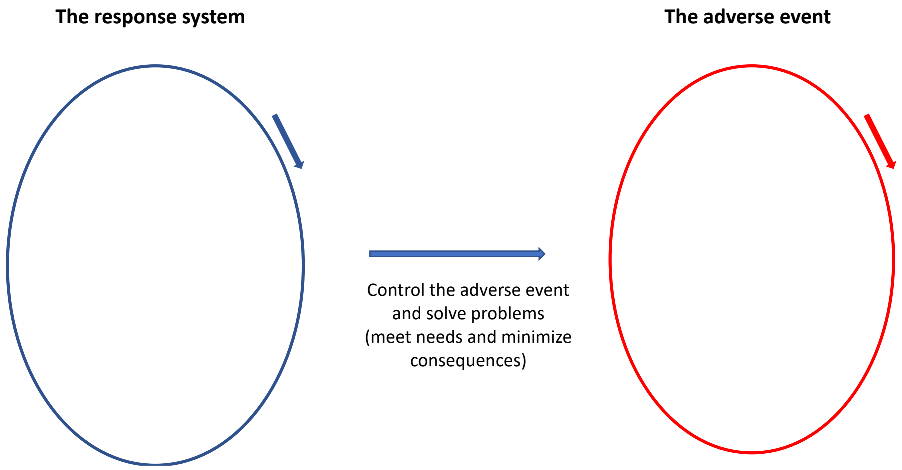

Figure 6. Emergency and disaster response management as a control problem (adapted from Brehmer, 2000).

In Figure 6, the response system represents the various resources involved in responding to the adverse event, such as individuals, organisations and artefacts (tools). The response system includes official authorities such as the fire and rescue services, the police and the emergency medical services, as well as actors from the private sector, volunteers and non-profit organisations (Uhr et al. 2008). Central for the response system is to solve problems related to both the event and to the response system itself (as also noted by McEntire, 2015; Quarantelli, 1997 in light of agent and response generated needs). These two types of problems can also be called external and internal problems. The external problems relate to, e.g., a fire or pandemic that needs to be dealt with, whereas the internal problems relate to the responding actors' need to remain capable of handling the event. Important to note is that internal problems should always be dealt with keeping the external problems in mind. In other words, the purpose of the activities of the responding actors should always be aimed at meeting needs and minimising consequences related to the adverse event. This means that common internal problems such as those associated with coordination should be solved in order to improve the solving of external problems, not for the sake of coordination itself.

In relation to FIRE21, the PSN for the fire and rescue services are associated with solving these two types of problems. Various PSN can be identified in the response system, based on what perspective is taken. For example, some problems are solved through formal PSN whereas others are solved through informal PSN. In fact, the entire response system could be seen as a

PSN. A helpful tool when analysing different system perspectives is described in Bergström et al. (2016), where system properties of dimension, scope and resolution are applied. For the purpose of this document, however, it is sufficient to assume that there are various PSN in the response system. Figure 7 is an attempt to illustrate PSN in the response system. Note that also individuals are included in this figure, so as to highlight the fact that individual properties also affect how problems are solved in the networks, not only organisational capabilities.

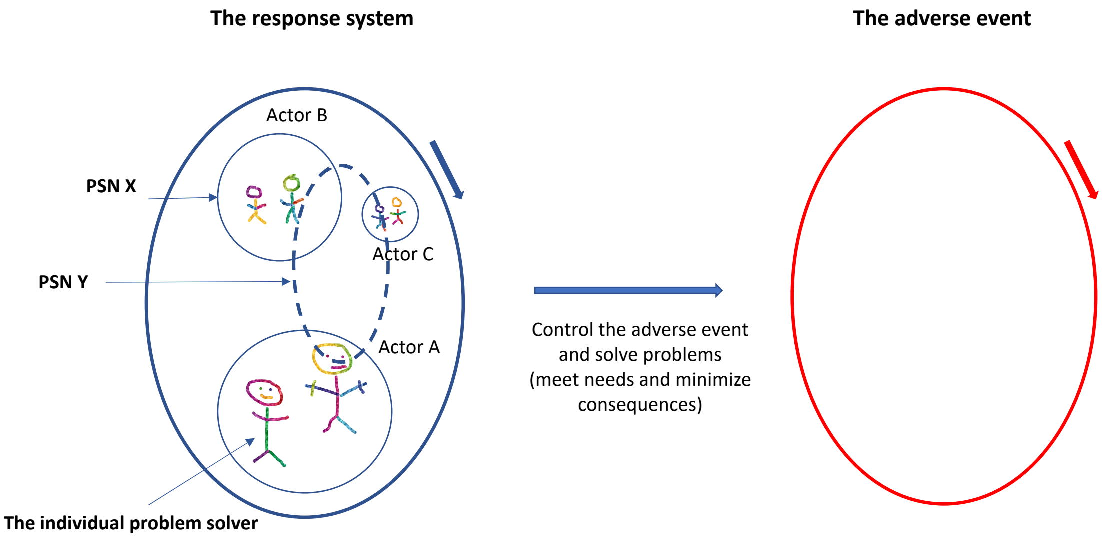

Figure 7. Examples of PSN in response management.

The problem-solving capability of a PSN, or the entire responding system, can be said to rely on the composition of individuals, organisations (or similar) and artefacts, and the relationships between, which can be used as an analytical lens when analysing the effectiveness of problem-solving in emergency and disaster response management.

4 Conditions for problem-solving in emergencies and disasters

The difficulty in solving problems (or making decisions) in emergency and disaster response management varies based on a number of factors associated with the adverse event or the response system. Here, some of these *conditions* for problem-solving are described.

Emergency and disaster response management is often described in terms of complexity, which can be linked to both the adverse event and the response system. Brown, Karthaus, Rehak and Adams (2010) summarise challenges to decision making in complex environment in terms of the following five components:
1) There is a considerable degree of *dependency*, which means that a decision can create opportunities or limit the next decision.
2) There is a high degree of *uncertainty*.
3) It is important to make decisions that are good enough within a sufficient time frame. Therefore, *time* is a critical factor.
4) The decision situations involve the *risk of losses*. The cost of making the "wrong" decision can be significant.
5) The problems to be solved are *difficult to structure*; there may be different goals, and the prioritisation of these goals may change as the situation develops. This aspect is closely related to the aforementioned description of wicked, or ill-defined, problems.

As described in these challenges, *uncertainty* plays a major role in response management. A similar concept, *ambiguity*, is also seen as an important condition. In this document, a distinction is made between the two. Uncertainty and ambiguity are both linked to the situation, but the problem solver's experience, knowledge and capability play a major role in how the two are perceived. The two are also closely connected to the problem representation step in the problem-solving process. The following categorisation of uncertainty and ambiguity is mostly taken from Schrader, Riggs and Smith (1993), who believe that the difference between mental models can be used to distinguish between ambiguity and uncertainty. Let us use two different situations to further clarify the distinction:

<u>Situation 1</u>
An individual faces a problem, s/he may feel that s/he knows what to do, what information to look for, and what results to strive for. In this case, there is a mental model available that is adequate for the problem situation, as well as a clear understanding of the problem. Understanding the problem sets the boundaries of the problem and identifies the necessary tasks in order for the problem to be solved.

<u>Situation 2</u>
An individual faces a problem, s/he does not have a particularly good "grasp" of the situation. This creates difficulties when determining the scope of the problem, defining which tasks are needed, sorting out irrelevant input and identifying relevant input, and identifying the desired outcomes. The problem solver has no adequate mental model as a basis for his/her understanding of the problem, and hence a vague understanding of the problem. The person must find or create a better mental model as part of the problem-solving process to move forward and make the problem comprehensible.

The first situation is characterised by problem-solving under uncertainty. The uncertainty is created by the problem solver not knowing the exact outcome of the problem-solving process. If the outcome were known, it would no longer be about problem-solving. The problem solver has a sufficiently clear problem representation and problem structure, based on a satisfactory mental model, as a basis for the problem-solving process. The information needs are well defined and there is a low level of ambiguity. The second situation is characterised by problem-solving under ambiguity. The ambiguity exists because the problem solver does not yet have a clear problem representation, probably because the underlying mental model is not a sufficient basis for creating precision in the problem representation. The first thing s/he must do is find a mental model that is perceived to be sufficiently useful to be able to form the basis for problem-solving. It is important to mention that the experience of ambiguity is highly individual and subjective (Uhr et al., 2018).

Additional conditions for problem-solving and decision making are represented by Brehmer's (2013) *possibility space* (eds. translation). The possibility space represents the “space” of possibilities for action that a decision maker has at a certain time for a certain activity. An important task in emergency and disaster response management is to determine the current possibility space, in order to, *inter alia*, understand the constraints under which one acts and to choose a course of action. According to Brehmer, the possibility space, and thus the courses of action, for operations in response to emergencies and disasters is limited by six factors:

1) the more or less clearly formulated *task*, i.e. the needs that must be met,
2) the available *resources*, in terms of quantity and type, as well as their condition, or capability,
3) the *time* available,
4) the *accident* and how it might develop,
5) the *legal framework* within which the work takes place, and
6) the *environment* in which the accident has occurred

Two other conditions were later identified in a study by Andersson and Uhr (2019), namely *collaboration conditions* and *command conditions*. Command mandate, leadership philosophy (e.g. assignment tactics), command capacity (e.g. level of knowledge), as well as leadership and trust would be aspects of the command conditions. Collaboration conditions are specifically relevant in situations where two or more organisations that do not have control over each other in any way collaborate, for example in civilian operations.

Individuals' capabilities and limitations naturally affect problem-solving and decision making in emergency and disaster response management. For example, cognitive limitations to working memory or analytical capability, level of knowledge and expertise affect the problem solver's capability to solve problems or make decisions (Hunt, 1994; Newell & Simon, 1972).

The research in naturalistic decision making by, among others, Kahneman and Tversky have shown that people are not always “good”, rational, decision-makers, but often act on the basis of cognitive “biases” and rules of thumb (se t.ex. Kahneman, 2011; Kahneman & Tversky, 1979). These biases and rules of thumb can be likened to quick fixes to our cognitive limitations described by Simon (1996), but they put us in problematic situations just as often as they facilitate decision making situations. Kahneman (2011) , for example, shows that we often rely on our cognitive *system 1*, which is fast, works effortlessly and tends to be driven by bias, rather than our analytical and rational *system 2*, something that can lead to erroneous assumptions and decisions. In crisis situations, where there are often time constraints and uncertainty, it is natural, and sometimes necessary, for the problem solver to resort to system 1. It is important to understand that we cannot switch off system 1, but it is possible to create conditions that enable us to “switch on” system 2 to supplement problem-solving and decision making with analytical and rational capabilities, which can lead to better outcomes in crisis management.

In addition to the factors linked to the possibility space above and that relate to the crisis management system in general, a study by Frykmer (2020) addresses some factors that may affect the *collective* problem-solving process in the system. The study showed that the existence of formal hierarchical structures, relationships and laws/regulations can hinder or enable the creation of a collective problem-solving representation, something that is considered fundamental for effective crisis management.

To summarise the conditions mentioned in this chapter, the idea of the possibility space can be combined beneficially with the problem space. It is conceivable that the possibility space's limiting factors also limit the problem space that can describe problems and problem-solving during emergencies and disasters. Figure 8 shows how the conditions mentioned can shrink or expand the possible problem space in a given situation. For example, the legal framework sets limits for a stakeholder in the form of what means can be used to solve a problem, and time will determine what solution steps a problem solver has the time to develop. It is also natural to imagine that the task largely determines the desired goal state.

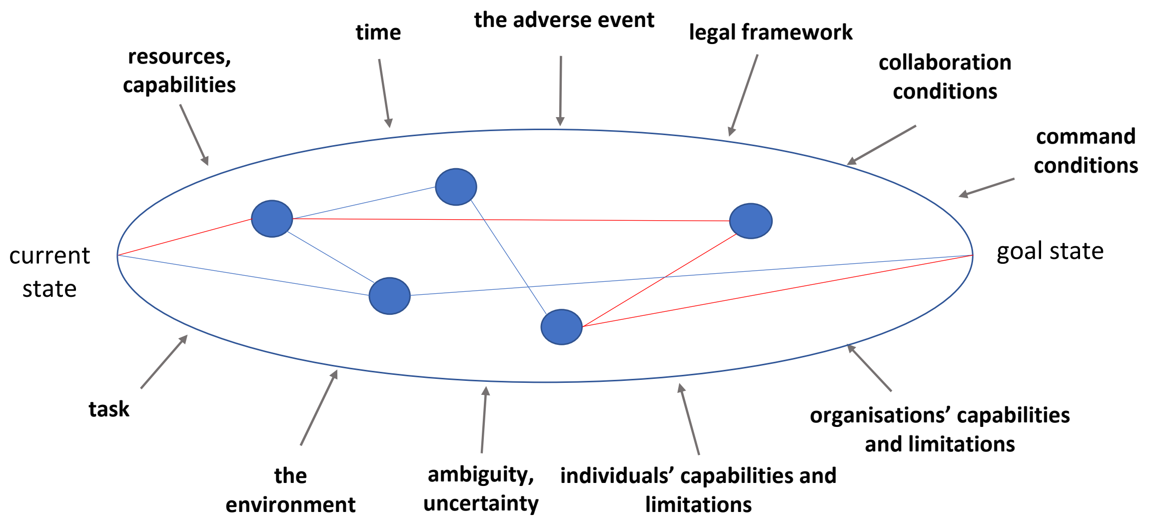

Figure 8. Summary of conditions for problem-solving in emergencies and disasters.

5 References

’t Hart, P., & Boin, A. (2001). Between crisis and normalcy: The long shadow of post-crisis politics. In U. Rosenthal, A. Boin, & L. K. Comfort (Eds.), *Managing crises - Threats, dilemmas, opportunities* (pp. 28–46). Charles C. Thomas, Ltd.

Ackoff, R. (1978). *The art of problem-solving*. John Wiley & Sons, Inc.

Ackoff, R. (1979). The future of operational research is past. *The Journal of the Operational Research Society*, *30*(2), 93–104. https://doi.org/10.2307/3009290

Andersson, I., & Uhr, C. (2019). Vad kan vi göra nu? Möjlighetsrummets avgränsningar och dess potential vid civil-militär samverkan. In *Ledning och samverkan i kris och krig: slutrapport 2016-2018*. Försvarshögskolan.

Baer, M., Dirks, K. T., & Nickerson, J. A. (2012). Microfoundations of strategic problem formulation. *Strategic Management Journal*, *34*(2), 197–214. https://doi.org/10.1002/smj.2004

Bergström, J., Uhr, C., & Frykmer, T. (2016). A Complexity Framework for Studying Disaster Response Management. *Journal of Contingencies and Crisis Management*, *24*(3), 124–135. https://doi.org/10.1111/1468-5973.12113

Boin, A., Ekengren, M., & Rhinard, M. (2020). Hiding in Plain Sight: Conceptualizing the Creeping Crisis. *Risk, Hazards and Crisis in Public Policy*, *11*(2), 116–138. https://doi.org/10.1002/rhc3.12193

Brehmer, B. (1992). Dynamic decision making: Human control of complex systems. *Acta Psychologica*, *81*, 211–241. https://doi.org/10.1016/0001-6918(92)90019-A

Brehmer, B. (2013). *Insatsledning*. Elanders.

Brehmer, Berndt. (2000). Dynamic decision making in command and control. In McGann;Pigeau (Ed.), *The Human in Command: Exploring the Modern Military Experience* (pp. 233–248). Kluwer Academic/Plenum Publishers, New York.

Brown, A., Karthaus, C., Rehak, L., & Adams, B. (2010). *The Role of Mental Models in Dynamic Decision-making*.

Büyükdamgaci, G. (2003). Process of organizational problem definition: How to evaluate and how to improve. *Omega*, *31*(4), 327–338. https://doi.org/10.1016/S0305-0483(03)00029-X

Campbell, L., & Knox Clarke, P. (2018). Making Operational Decisions in Humanitarian Response: A Literature Review. In *ALNAP Study*.

Christensen, T., Lægreid, P., & Rykkja, L. H. (2016). Organizing for Crisis Management: Building Governance Capacity and Legitimacy. *Public Administration Review*, *76*(6), 887–897. https://doi.org/10.1111/puar.12558

Cole, G. A. (2004). *Management: Theory and practice* (6th ed.). Thomson Learning Bedford Row.

Dery, D. (1983). Decision-making, Problem-solving and Organizational Learning. *Omega*, *11*(4), 321–328.

Fischer, A., Greiff, S., & Funke, J. (2012). The Process of Solving Complex Problems. *The Journal of Problem-solving*, *4*(1). https://doi.org/10.7771/1932-6246.1118

Fischer, A., Greiff, S., & Funke, J. (2017). The history of complex problem-solving. In *The nature of problem-solving: Using research to inspire 21st century learning* (pp. 107–121). https://doi.org/10.1787/9789264273955-9-en

Frykmer, T. (2020). “What’s the problem?”-Toward a framework for collective problem representation in emergency response management. *Journal of Emergency Management*, *18*(6), 511–524. https://doi.org/10.5055/jem.2020.0504

Frykmer, T. (2021). *Improving emergency and disaster response management performance: A problem-solving perspective*. Lund University.

Frykmer, T., & Svenbro, M. (n.d.). *Common operational pictures as collective problem representations: The case of the 2018 wildfires in Sweden*.

Gralla, E., Goentzel, J., & Fine, C. (2016). Problem Formulation and Solution Mechanisms: A Behavioral Study of Humanitarian Transportation Planning. *Production and Operations Management*, *25*(1), 22–35. https://doi.org/10.1111/poms.12496

Greiff, S., Wüstenberg, S., Funke, J., & Funke, J. (2012). Dynamic Problem-solving: A New Assessment Perspective. *Applied Psychological Measurement*, *36*(3), 189–213. https://doi.org/10.1177/0146621612439620

Hunt, E. (1994). Problem-solving. In R. J. Sternberg (Ed.), *Thinking and Problem-solving* (pp. 215–232). Academic Press, Inc.

Kahneman, D. (2011). *Thinking fast and slow*. Farrar, Strauss and Giroux.

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, *47*(2), 263–292.

Klein, G. (1993). A Recognition-Primed Decision (RPD) Model of Rapid Decision Making. In G. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 138–147). Ablex Publishing Corporation.

Klein, G. (1998). *Sources of power. How people make decisions*. The MIT Press.

Klein, G. (2008). Naturalistic Decision Making. *Human Factors*, *50*(3), 456–460. https://doi.org/10.1518/001872008X288385.

Klein, G., Orasanu, J., Calderwood, R., & Zsambok, C. (1993). *Decision Making in Action: Models and Methods*.

Lipshitz, R., & Bar-Ilan, O. (1996). How Problems are Solved: Reconsidering the Phase Theorem. *Organizational Behavior and Human Decision Processes*, *65*(1), 48–60. https://doi.org/10.1006/obhd.1996.0004

Lyles, M. A. (1981). Formulating Strategic Problems : Empirical Analysis and Model Development. *Strategic Management Journal*, *2*(1), 61–75.

Lyles, M. A., & Mitroff, I. (1980). Organizational Problem Formulation : An Empirical Study. *Administrative Science Quarterly*, *25*(1), 102–119.

March, J. G., & Shapira, Z. (1987). Managerial Perspectives on Risk and Risk Taking. *Management Science*, *33*(11), 1404–1418.

Massey, A., & Wallace, W. A. (1996). Understanding and facilitating group problem structuring and formulation: Mental representations, interaction, and representation aids. *Decision Support Systems*, *17*(4), 253–274.

Mayer, R. E. (1992). *Thinking, Problem-solving, Cognition* (2nd ed.). W. H. Freeman and Company.

Mayer, R. E. (2013). Problem-solving. In D. Reisberg (Ed.), *The Oxford Handbook of Cognitive Psychology* (pp. 769–778). Oxford University Press.

McEntire, D. A. (2015). *Disaster Response and Recovery: Strategies and Tactics for Resilience*. John Wiley & Sons, Inc.

Mendonça, D., Beroggi, G. E. G., & Wallace, W. A. (2001). Decision support for improvisation during emergency response operations. *International Journal of Emergency Management*, *1*(1), 30–39. https://doi.org/10.1504/IJEM.2001.000507

Mintzberg, H., Raisinghani, D., & Théorêt, A. (1976). The Structure of "Unstructured" Decision Processes. *Administrative Science Quarterly*, *21*(2), 246–275.

Mitroff, I., & Linstone, H. A. (1992). *The Unbounded Mind*. Oxford University Press.

Newell, A., & Simon, H. (1972). *Human Problem-solving*. Prentice-Hall Inc.

Niederman, F., & DeSanctis, G. (1995). The impact of a structured-argument approach on group problem formulation. *Decision Sciences*, *26*(4), 451–474. https://doi.org/10.1111/j.1540-5915.1995.tb01436.x

Quarantelli, E. L. (1997). Ten Criteria for Evaluating the Management of Community Disasters. *Disasters*, *21*(1), 39–56. https://doi.org/10.1111/1467-7717.00043

Reitman, W. R. (1964). Heuristic decision procedures, open constraints, and the structure of ill-defined problems. In M. Shelly & G. Bryan (Eds.), *Human Judgments and Optimality* (pp. 282–315). John Wiley & Sons, Inc.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169. https://doi.org/10.1007/BF01405730

Robbins, L. (1932). *An Essay on the Nature and Signifiance of Economic Science*. Macmillan.

Roberts, N. (2001). Coping with wicked problems: The case of Afghanistan. In L. Jones, J. Guthrie, & P. Steane (Eds.), *Learning from International Public Management Reform: Part B* (pp. 353–375). Emerald Group Publishing Limited.

Schrader, S., Riggs, W. M., & Smith, R. P. (1993). Choice over uncertainty and ambiguity in technical problem-solving. *Journal of Engineering and Technology Management*, *10*(1–2), 73–99. https://doi.org/10.1016/0923-4748(93)90059-R

Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review*, *63*(2), 129–138. https://doi.org/10.1037/h0042769

Simon, H. A. (1973). The structure of ill structured problems. *Artificial Intelligence*, *4*(3–4), 181–201. https://doi.org/10.1016/0004-3702(73)90011-8

Simon, H. A. (1996). *The sciences of the artificial* (3rd ed.). The MIT Press. https://doi.org/10.1016/S0898-1221(97)82941-0

Smith, G. F. (1989). Defining Managerial Problems: A Framework for Prescriptive Theorizing. *Management Science*, *35*(8), 963–981. https://doi.org/10.1287/mnsc.35.8.963

Smith, G. F. (1992). Towards a theory of managerial problem-solving. *Decision Support Systems*, *8*(1), 29–40. https://doi.org/10.1016/0167-9236(92)90035-N

Smith, G. F. (1993). Defining Real World Problems: A Conceptual Language. *IEEE Transactions on Systems, Man and Cybernetics*, *23*(5), 1220–1234. https://doi.org/10.1109/21.260656

Smith, G. F. (2009). Teaching Decision Making. In *The Oxford Handbook of Organizational Decision Making* (Issue December 2019, pp. 1–21). https://doi.org/10.1093/oxfordhb/9780199290468.003.0024

Sternberg, R. J. (1994). *Thinking and Problem-solving*. Academic Press, Inc.

Uhr, C., & Frykmer, T. (2021). *Ledning och samverkan över hela hotskalan*.

Uhr, C., Tehler, H., & Wester, M. (2018). An empirical study on approaches to ambiguity in emergency and disaster response decision-making. *Journal of Emergency Management*, *16*(6), 355–363. https://doi.org/10.5055/jem.2018.0384

Witte, E., Joost, N., & Thimm, A. (1972). Field research on complex decision-making processes - the phase theorem. *International Studies of Management & Organization*, *2*(2), 156–182.