Unclassified **NEA/RWM/FSC(2003)7/REV1**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development **30-Jun-2004**

English - Or. English

NUCLEAR ENERGY AGENCY
RADIOACTIVE WASTE MANAGEMENT COMMITTEE

NEA/RWM/FSC(2003)7/REV1
Unclassified

Forum on Stakeholder Confidence (FSC)

THE MENTAL MODELS APPROACH TO RISK RESEARCH - AN RWM PERSPECTIVE

Secretariat Paper

JT00166949

English - Or. English

FOREWORD

Despite an emerging new dynamic of dialogue, the technical specialists, the environmentalists, and the general public still render divergent verdicts and opinions on the impact of radioactive waste on people and on the ability to manage it properly. Technically, it can be observed that RWM has a very low radiological impact in non-accidental situations. The impact is, at present, less than one hundredth of the impacts from other sectors of the nuclear industry (mining, operation of nuclear power plants…). The long-term target impact of HLW repositories is projected not to exceed one tenth of the background, natural radioactivity. Public opinion is rather different, however, as shown, for instance, by the Eurobarometer 2001. Indeed, at the basis of the concepts of risk and safety there is more than just the concept of radiological impact. Familiarity and control, for instance, also play an important role on the perception of risk, and it is known that familiarity and control must be gained through public involvement and social learning processes.

On the other hand, the question can still be posed of what are effective ways to decrease the opinion gap that exists between lay people and experts. The Secretariat has started the investigation of this problem by looking at social research in mental models of risk. One of its branches considers the existing knowledge and beliefs of lay people and tries to eliminate gaps and misconceptions and to explain the real relationships. The Secretariat's paper is meant to help the FSC and other NEA groups reflect on the problem.

ACKNOWLEDGEMENTS

This paper was prepared by A. Vàri

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SUMMARY OF KEY POINTS

Over the last three decades, several empirical studies have reported insights into ways people interpret health and environmental risks and make inferences and decisions in situations including such risks. Efforts have been made to apply the results of these studies in policy making, conflict management, and communication. The primary motivation of researchers lies in the fact that democratic political systems have not devised mechanisms that would adequately support decision makers in handling divergent views on socially acceptable risks and identifying the role of experts and various stakeholders in controversial decisions.

One specific direction of the above research efforts is the so-called *mental models approach.* This approach assumes that, in situations of having to form a decision, people generate mental representations of the problems associated with the decision and use these representations to make inferences and decisions. The mental models approach aims at investigating the judgment and decision-making processes of both expert and lay groups. *Descriptive studies* endeavor to draw generalized conclusions on such processes on the basis of elicited mental models. *Prescriptive studies* are targeted to develop communication, education, and decision support tools that fit these models.

A specific methodology developed within prescriptive research, the so-called *mental models methodology,* is aimed at the elaboration of communication/education tools which make up for the gaps in lay knowledge by improving and "correcting" the mental models and thereby having an indirect impact on people's decisions. According to this methodology, risk communication is based on a comparative analysis of the mental models of expert groups and target lay groups. Considering the existing knowledge and beliefs of lay people, the mental models methodology tries to eliminate gaps and misconceptions and to explain the real relationships.

Descriptive studies

Empirical research focusing on risk perception has revealed various biases in risk estimates, as well as qualitative factors influencing perceived risks. Most studies, however, failed to investigate the deep knowledge underlying risk judgments. The mental models approach based on exploring such knowledge has been developed to complement the above directions of research. Eliciting mental models on a variety of risks has yielded rich insight into the sources of individual, social, and cultural biases and the divergence found among the views of various stakeholders.

Prescriptive studies

In order to reduce the biases and inconsistencies characterizing risk judgements and to better handle divergent views held by different stakeholders, a number of tools have been developed. These tools include, for example, complex information systems, advanced decision aiding methods, consultations with experts and the involvement of stakeholders in the process of decision making. The past decades have witnessed an integration of various tools in risk communication efforts, which aim at increasing the effectiveness of decisions by improving the communication between lay people and the technical-managerial elite. Research indicates that exploring the mental models of decision makers and other actors facilitates the development of adequate tools for decision support, conflict management, and risk communication.

The mental models methodology

Drawing on the mental models concept, a specific direction in risk communication research, the so-called *mental models methodology* has been established. The main feature of this methodology is that the elaboration of communication tools is based on the differences between the mental models of the expert community and those elicited from the target audience. This methodology has been applied for a variety of hazards, including for example, exposure to radon, and the use of nuclear energy sources on space vehicles. Experience gained from these applications indicates that the mental models methodology can best be applied in communication situations characterized by the following:

1. The primary goals of communication may be encouraging behavior change or facilitating participation in public discussions, but these goals are pursued indirectly, by conveying substantial information about a hazard, rather than directly trying to influence choices.
2. Communication is targeting relatively new risks, which have not linked to many pre-existing mental constructs yet.
3. Communication is targeting rather non-controversial issues, which are laden by few normative and emotional elements.
4. Communication is targeting decisions that are not to be made under time pressure.

RWM: Main findings of descriptive research

Descriptive studies exploring beliefs on RWM and RWM facilities have accumulated a significant amount of data. Research results indicate that such beliefs are frequently associated with the concept of nuclear power, and even with those of nuclear weapons and nuclear war. Cross-cultural studies also suggest that – although idiosyncratic economic, social, and political factors may lead to some differences, - there is a surprisingly large similarity among the mental models of the opponents of RWM facilities in different countries.

It has been revealed that an individual's support for or opposition to an RWM facility can largely be explained by his or her beliefs regarding the health and safety, environmental, and socio-economic consequences of the operation of such facility. However, anticipated impacts are not the only determinants, other factors like perceived fairness of the decision processes and general attitudes to nuclear power seem to have high explanatory power to public acceptance as well. It has also been demonstrated that beliefs related to the risks of RWM may become integrated into a broader socio-political context, intertwining for example, with the views on the operation of society, the prevailing power relations, concepts of social fairness, and the trustworthiness of experts.

RWM: Main lessons from prescriptive research

One of the most important conclusions to be derived from descriptive studies is that a better understanding of the connections between mental models related to the physical-technical aspects of RWM and those related to the social-political context would be crucial. In order to develop effective decision support, conflict management, or risk communication tools, it is imperative that such connections be explored and compared for various target groups, including proponents and opponents, directly and indirectly affected stakeholders, etc.

Research also suggests that for effective conflict management, parties have to take into account not only their partners' mental models, but also consider the potential changes in them. If not,

they could lose the opportunity of reaching an agreement through untimely suggestions. On the other hand, only effective communication from the beginning of a decision process can fill the vacuum and prevent the utilization and stabilization of irrelevant mental constructs, which interfere with the constructive resolution of the conflict.

RWM: A potential application area for mental models methodology

It has been revealed that in most contexts the knowledge of the expert community and the lay public on RWM may be significantly different. In spite of such differences, no application of the mental models methodology to risk communication has been reported in the field of RWM. The main reasons for this may lie in the highly controversial nature of the RWM issue. On the other hand, as described earlier, the mental models methodology is most effective if applied for relatively new risks which have not been connected to many pre-existing mental constructs yet, – a condition which is rarely met in decision/communication situations related to radioactive waste.

The question remains whether the mental models methodology know-how could nevertheless be transferred to the field of RWM. Provided that certain conditions are met, it could be. There is a better chance for an effective use of the methodology if:

1. The primary goal of communication is to educate people and to help them participate in public discourses, rather than change their views;
2. The target group consists of younger people or of individuals for whom the problem is new and who have not subscribed to any positions yet;
3. The communication occurs in communities where the communicating parties are on good terms and no political controversy related to the issue has been developed so far;
4. There is no urgent need for a decision.

In summary, application of the mental models approach may facilitate the mutual understanding between lay people and experts, or between different social groups. However, understanding is only a necessary but insufficient condition of resolving conflicts and will not guarantee a consensus by itself. This is of particular relevance in areas where conflicts are complex and obstinate, complicated by conflicting values and strong emotions, such as in the field of radioactive waste management.

I. INTRODUCTION

Lengthening of life and improving its quality is a widely accepted value in advanced democratic societies. However, there is no consensus on the ways of implementing this value. Societies based mostly on large-scale technologies have increasingly taken over from the individual the decisions on their own safety and have made them part of political processes. Yet, many people question the effectiveness and fairness of political decisions concerning health and environmental risks.

Over the past decades, society has changed its attitude towards technical development. The latter is not regarded as a key element of social development any longer, and the fact that a narrow political "elite" may make decisions on health and environmental risks affecting the entire society is considered insufficient. A wide perception exists that the “cost” of industrial development is too high. The above changes in societal values have incited political, legal and ethical disputes which have elicited a boom in research on the social aspects of risks since the 1970's.

Over the last three decades, several empirical studies have reported insights into ways people interpret risks and make inferences and decisions in situations including risks, and efforts have been made to apply the results of such studies in policy making. The primary motivation of researchers lies in the fact that democratic political systems have not devised mechanisms that would adequately support decision makers in handling divergent views on socially acceptable risks and identifying the role of experts and various stakeholders in controversial decisions.

One specific direction of the above research efforts is based on the study of so-called *mental models*[1]. This approach assumes that, in situations of having to form a decision, people generate mental representations of the problems associated with the decision and use these representations to make inferences and decisions.

The study of mental models has been motivated by two different aspirations. One group of studies aims at a better understanding of mental models in order to describe the key features of human decision making (descriptive studies). Another group of studies seeks to apply the results of descriptive research to develop decision-aiding tools. The role of such tools is to eliminate typical mistakes and inconsistencies during decision making and to resolve the conflicts that derive from the differences of the mental models of different individuals and groups (prescriptive studies). A specific methodology developed within prescriptive research, the so-called *mental models methodology* is aimed at the elaboration of communication/education tools which make up for the gaps in lay knowledge by improving and "correcting" the mental models and thereby having an indirect impact on people's decisions.

The following chapters provide an overview of the most important results of both descriptive and prescriptive studies focusing on mental models. Due to its importance, the “mental models methodology” is discussed in a separate chapter. Finally, examples for using the mental models approach in investigating public views on radioactive waste management are introduced and recommendations for further applications are made.

[1] The mental models approach is not restricted to problems associated with health and environmental risks, but this is its most emphasized field of application.

II. DESCRIPTIVE STUDIES

Empirical studies focusing on risk perception have revealed various biases in risk estimates and identified heuristics that are frequently applied by people when making judgements about risks (Kahneman *et al.*, 1982; Kunreuther and Linnerooth, 1984). Psychometric research, on the other hand, explored qualitative factors that could explain differences between risks perceived by lay and expert groups (Slovic *et al.*, 1984). Most empirical studies, however, failed to investigate the deep knowledge underlying risk judgments. By exploring such knowledge, the mental models approach complements the above directions of research (Tonn *et al.*, 1990).

The concept of mental model has been originated in the early work of Craik (1943, quoted by Thüring and Jungermann, 1986, p.) who defined the function of mental models as follows:

> „If the organism carries a small-scale model of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and future, and every way to react in a much fuller, safer, and more competent manner to the emergencies which face it."

Researchers proposing the mental models approach assume that, for any problem solving such models are used to simulate the consequences of various actions; namely the models are mentally run and thus generate inferences about potential events and states (Thüring and Jungermann, 1986). Mental models are conceptualized as consisting of two kinds of elements: *variables* which may refer to various components of a problem (e.g., options/actions, events, states, goals) and *relations* between the variables which describe the interdependencies among components.

Mental models are explored by social scientists from *individuals' or groups' responses to certain problem situations, tasks or questions.* There are two basic ways to explore such models: (i) individuals or groups are interviewed directly, or (ii) individuals' or groups' spontaneous responses to certain problem situations are reviewed. In the former case, typical research instruments include interviews, focus groups, surveys, while in the latter case, text analysis of written documents or audio-visual records are the most frequently used methods[2]. In both cases, methods can be *open-ended* where no (or very little) structure for the analysis is a priori defined by the researcher, or (*semi-)structured*, where (semi-)structured questions are applied to elicit views about a priori defined dimensions, or texts are analyzed in terms of pre-defined structures.

Since there is an infinite number of structures that can be used, mental models can be represented in many forms (Tonn *et al.*, 1990). The most frequently used structures include influence diagrams and scenarios. An *influence diagram* consists of nodes representing variables (e.g., actions, events, and states) and arrows interconnecting the nodes that represent the causal relationships between variables (Fischhoff *et al.*, 1993). Examples for influence diagrams are presented in Figures 1 and 2. On the other hand, a *scenario* is a chain of causally related events and states that may follow from certain actions (Jungermann, 1985). Again, actions, events and states are represented by nodes, while causal relations are represented by arrows. However, unlike influence diagrams, scenarios do not contain loops. Examples for scenarios are presented in Figures 3 and 4.

Researchers emphasize the dynamic nature of mental models: namely, mental models are not ready-made networks in the brain, but rather they are compiled when humans are confronted with a specific problem. Therefore, *mental models elicited by interviews may vary significantly if questions*

[2] A number of text analysis methods have been developed and applied, e.g., Axelrod (1976), Gallhofer *et al.* (1986), Vari (1991), etc.

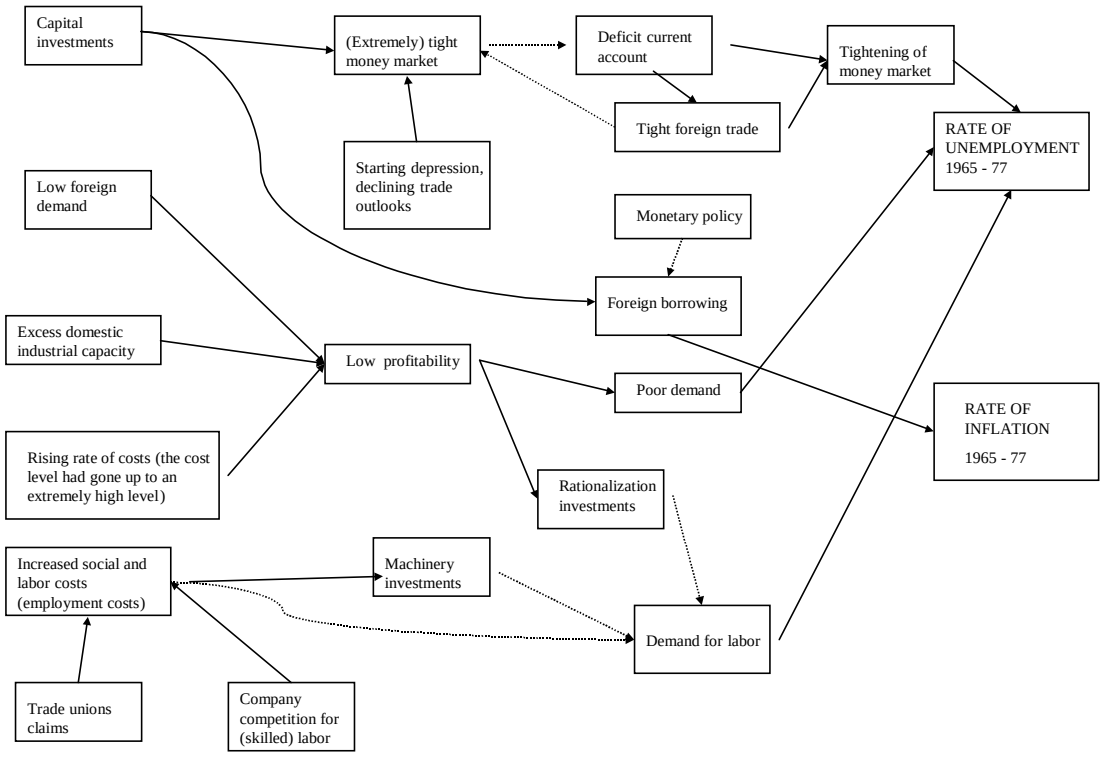
are framed differently. For example, Thüring and Jungermann (1986) found that groups who were asked questions about the causes and consequences of California earthquakes in slightly different ways, generated different mental models about the same problem. Sevón (1984) found that even the temporal characteristics of a task may influence the construction of mental models. By comparing mental models generated in relation to past and future processes, she found that subjects' conceptions on the past causes (explanations) of recent events are more complex than those of future ones (see Box 1 and Figures 1 and 2).

Box 1

Mental models of past and future economic events[3]

In order to find out about mental models of managers on recent and future (forecast) inflation and unemployment in Finland, interviews eliciting the causal relations concerning the above issues were conducted. Figure 1 and 2 present typical mental models[4] generated by the interviewees. The figures illustrate that managers gave a much more comprehensive explanatory framework for recent inflation and unemployment than for future ones.

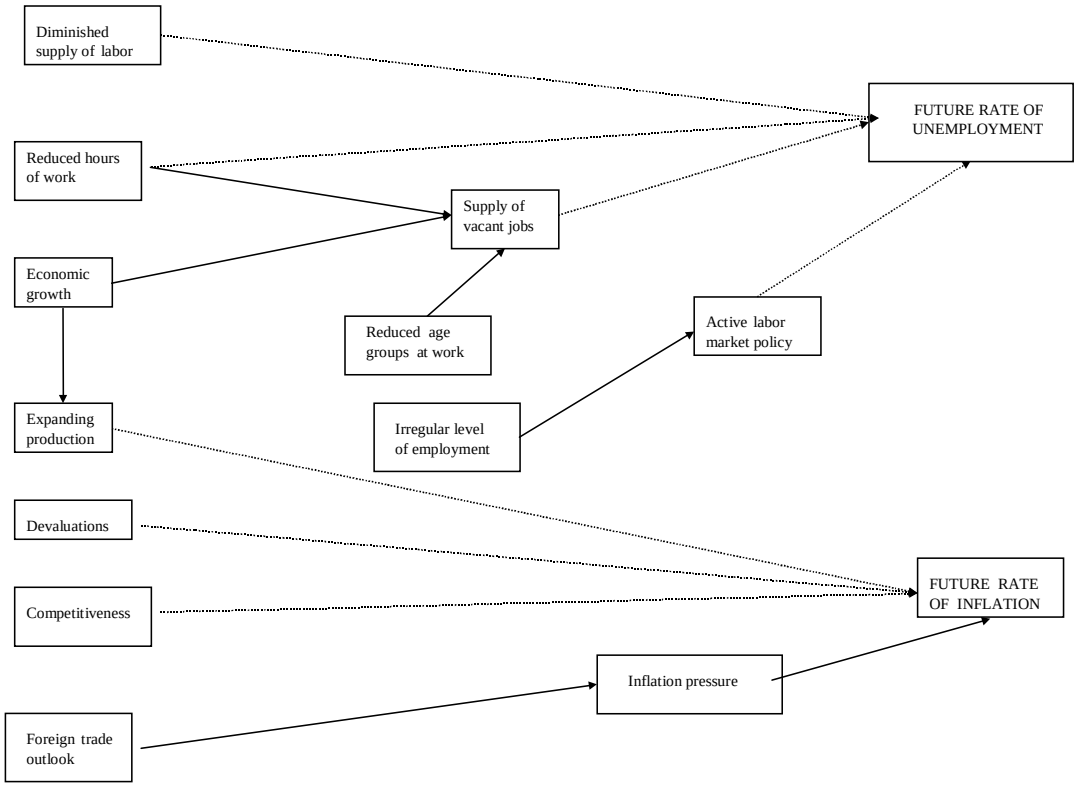
Figure 1



3 See Sevón (1984)

4 Influence diagrams in which not only the dependencies, but also the positive or negative correlations between variables are shown (see Figures 1 and 2), are also called cognitive maps (Sevón, 1984)

Figure 2



Differences between the mental models generated by different stakeholder groups have been investigated by a number of studies (Mason and Mitroff, 1984; Biel and Montgomery, 1986; Checkland and Scholes, 1990; Humphreys, 1998). It has been revealed that there can be significant differences among the views of various stakeholders concerning the objectives and the hierarchy of goals, the past and future states of the problem environment, as well as the alternative actions and their consequences. Stakeholders may disagree even on the problem to be resolved. This may lead, especially in the cases of decisions including short-term attractions and long-term risks, to conflicts where different stakeholders „are acting in good faith and on the basis of good information – but solving different problems" (Fischhoff and Svenson, 1982). Differences between mental models of various stakeholders are illustrated by a study on heating systems (see Box 2 and Figures 3 and 4).

Box 2

Mental models on energy planning[5]

Politicians and officials at the municipal energy works in ten Swedish towns were interviewed about current alternatives for supplying heat in their own town. The key issue was whether a district heating system should be built or expanded at the expense of other systems such as electrical heating or local plants. Interviewees were chosen so that different opinions in each town should be represented.

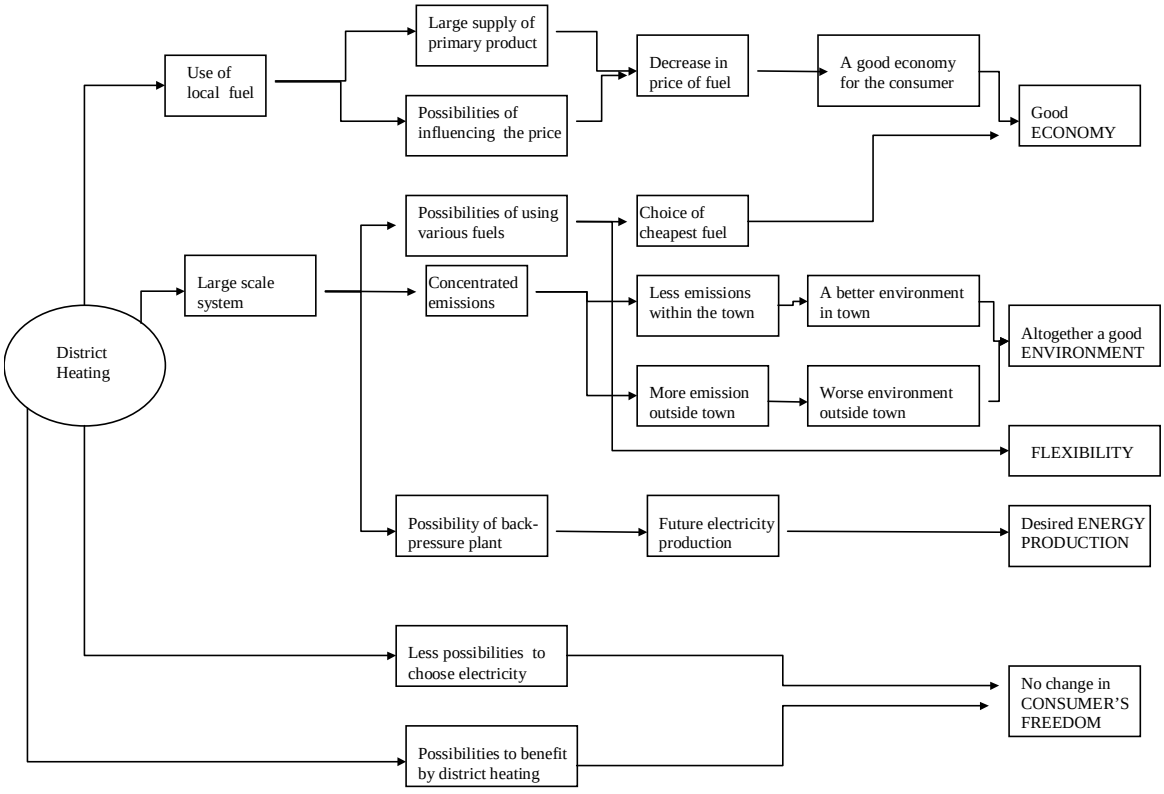
…/...

5 Biel and Montgomery, 1986

Figures 3 and 4 present typical mental models (scenarios) of a supporter and an opponent of the building of the district heating system.

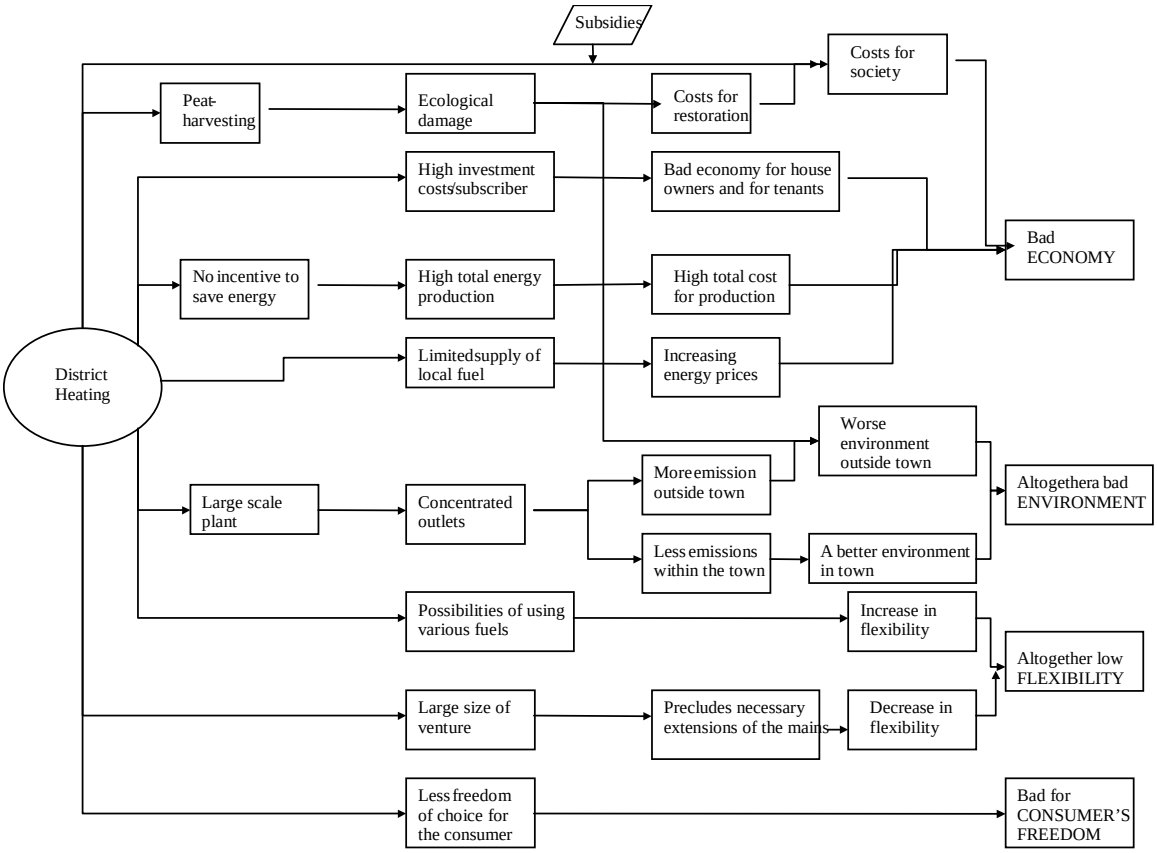
It appears that that there is a significant overlapping between the two persons in terms of variables reflecting goals (economy, environment, flexibility, and consumer's freedom), and consequences of the two options (e.g., emissions, price of fuel, etc.). Although the parties refer to the same variables they disagree almost completely about the relations between these variables. The most striking differences are found in how large scale systems are viewed. The advocates assert, for example, that large scale systems give possibilities to use different kinds of fuels, which implies that cheap fuels could be used, which in turn leads to good economy. The opponents, however, imagine high investment costs, energy losses in culverts, and monopoly on heating that contribute to bad economy. The advocates also emphasize that a large scale leads to a decrease in the number of plants what results in less emission. According to opponents, however, the choice of particular fuels in large scale systems leads to more pollution, etc. In general, to the advocates of district heating, big is beautiful, while in the opponent's scenario big is evil. Here, two distinct value systems, or even two worldviews seem to clash[6].

Figure 3



6 This aspect was not further investigated in the above mentioned study (Biel and Montgomery, 1986)

Figure 4



Research on mental models is strongly related to theories associated with the organization of human memory. According to recent theories, human memory is organized around *schemas*, which are abstract and general rules developed on the basis of the individual's prior experiences as well as information from other persons and other sources (Shank and Abelson, 1977; Minsky, 1977; Kleindorfer *et al.*, 1993). Such theories suggest that as soon as certain schemas are initiated, they direct behavior and also serve as a framework for influencing the acceptance and assimilation of further information. In a novel situation, the individual recalls from his or her memory the necessary schemas in order to make sense of the new information. In the case of new phenomena (e.g., modern technologies), relevant prior schemas may be lacking, and have first to be constructed. In Box 3, theories on the development and application of schemas and other mental constructs are outlined.

Box 3

The process of development and application of mental constructs[7]

Mandler (1988) emphasizes the constructive and dynamic nature of the individual's cognitive processes. He starts from the premise that in human memory many competitive schemas exist. Making judgments and decisions is based on the activation of certain schemas, depending on external circumstances (e.g., pressures, constraints), and internal demands (e.g., endeavoring to achieve certainty and consistency). According to this theory, in routine life situations individuals apply their ready-made constructions. However, in more complex, externally or internally changing situations, new schemas are constructed which, when repeated, become stored in long-term memory. In order to be able to accommodate the world, a constant feedback mechanism comes into operation informing individuals of the effectiveness of their schemas.

Some studies are focussing on the complexity of the organization of human knowledge. Weir (1975) argues that the individual groups his knowledge base into cognitive „chunks" which operate as holistic panels. A panel contains a network of schemas constituting implicit theories. When meeting a new phenomenon, the individual has a tendency to draw upon the existing panels[8]. This kind of organization may make the retrieval of knowledge and the selection of an action quicker and easier, however, this speed can be to the detriment of effectiveness and flexibility. At the same time, this kind of organization may increase the tendency to ignore new data that do not fit into the implicit theories[9].

By integrating elements from the above theories, a process of the development and application of mental constructs has been suggested as follows:

1. The process starts from a situation where the individual meets a phenomenon about which (s)he does not have any specific knowledge. In this situation the individual is most receptive to any new information. In order to store recent information, the person can amend available (usually loosely related) schemas or construct new ones.
2. In the second step, the schemas are elaborated and consolidated. In this stage, individuals try to elect from the environment those pieces of information that do not contradict the schemas, but rather promote their consolidation.
3. In order to establish an easier way of information retrieval, individuals endeavor to organize schemas into panels. They may link schemas into existing panels or create new panels by interconnecting several schemas. In this stage persons are highly selective in their perception and tend to ignore information that does not fit into the implicit theories.
4. If the individual is pressured by external circumstances or internal demands into inferring judgments, taking decisions and actions, a search for appropriate mental constructs takes place. On the basis of the activated schemas and panels, judgments are inferred, and decisions and actions are taken.
5. The information received from the environment about the effectiveness of judgments, decisions, and actions may trigger the confirming or rejecting of the schemas, as well as the strengthening or dismantling of panels. In case of an unsuccessful intervention, a repeated search for more effective schemas may take place. However, dismantling of a panel usually results from a longer series of failures and is followed by trials to build new panels.

7 Based on Vari and Farago (1991)

8 Panels can be conceptualised not only as individual elaborations of cognitions, but also as cultural panels. Social cognitions become consolidated and robust in the form of generally accepted beliefs, ideologies, myths, or worldviews (Douglas and Wildavsky, 1983; Douglas, 1992)

The structure of memory, as described above, may result in biases in both the reception and processing of information, and has serious impact on the quality of human judgment and decision making. The organization of memory also provides (at least a partial) explanation for differences in opinion of social groups with varying beliefs, ideologies and worldviews. By eliciting mental models, a better insight can be gained into the sources of biases and divergent views, and more generally, into the characteristics of human cognition[10].

III. PRESCRIPTIVE RESEARCH

In order to reduce the biases and inconsistencies inherent in human judgments, as well as to better handle divergent views of the different stakeholders, a number of tools have been developed. These tools include, for example, complex information systems, advanced decision aiding methods, consultations with experts and the involvement of stakeholders in the process of decision making. The exploration of the mental models of decision makers and other actors facilitates the development of adequate tools for decision support and conflict management.

One of the main fields of prescriptive research related to problems including health and environmental risks involves *supporting the decisions of organizational management*, primarily in the case of complex strategic decisions. Another important field of prescriptive research involves *supporting the decisions of the lay public*. The past decades have witnessed an integration of these two fields resulting in *risk communication* efforts, which aim at increasing the effectiveness of judgment and decision making processes by improving communication, in the broad sense, between lay people and the technical-managerial elite.

Risk communication

The concept of risk communication can be – and has been – interpreted in many ways. At one extreme lies the image of „an inactive public docilely waiting for the transmission of vital information from those who know better." At the other extreme lie „highly interactive images of the communication process, in which the public shares responsibility for the social management of risks" (Fischhoff, 1989, p. 282).

We adopt the second perspective, according to which the term risk communication is not seen as consisting of one-way messages from experts to non-experts, but as „an interactive process of exchange of information and opinion among individuals, groups, and institutions" (NRC, 1989, p.2).

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[9] Panels may contain not only logical/empirical, but also normative/emotional components. In his socioeconomic theory, Etzioni (1988) argues that in many cases, the role of normative/emotional components may dominate the processes of information selection, screening, and processing.[10] It should be emphasized that mental models are not looked upon as models of the organization of human brain. However, structures used for representing mental models are usually consistent with theories of long-term memory (Tonn *et al.*, 1990).

Accordingly, the criterion of risk communication being seen as successful is not the acceptance of the views or arguments of experts by non-experts. Rather it is seen to be successful „to the extent that it raises the level of understanding of relevant issues or actions for those involved and satisfies them that they are adequately informed within the limits of available knowledge" (NRC, 1989, p.2). Therefore, we consider risk communication as *a social learning process.*

From the perspective of the communicators, Covello *et al.* (1986) identified four communication objectives as follows:

1. Information and education: Informing and educating people about risks and risk assessment in general (e.g., statistical comparison of the risks of different energy production technologies)

2. Behavior change and protective action: Encouraging personal risk-reduction behavior (e.g. brochures encouraging people to wear seat belts)

3. Disaster warnings and emergency information: Providing guidance in disasters and emergencies (e.g., sirens indicating the accidental release of toxic gas from a chemical plant)

4. Joint problem solving and conflict resolution: Involving the public in risk management decision-making and in resolving health, safety, and environmental controversies (e.g., public meetings about a possible hazardous waste site)

As Covello *et al.* (1986, p. 172-173) point out:

> "In the real world, these four types of risk communication tasks overlap substantially, but they still can be conceptually differentiated. The task of informing and educating the public can be considered primarily a non-directive, although purposeful, activity aimed at providing the lay public with useful and enlightening information. In contrast, both the task of encouraging behavior change and personal protective action and that of providing disaster warnings and emergency information can be considered primarily directive activities aimed at motivating people to take specific types of action. These three tasks, in turn, differ from the task of involving individuals and groups in joint problem solving and conflict resolution, in which officials and citizens exchange information and work together to solve health and environmental problems."

The mental models methodology

Drawing on the mental models concept, a specific direction in risk communication, the so-called *mental models methodology* has been established (Morgan *et al.* 1992). The main feature of this methodology is that the elaboration of communication tools is based on the differences between the mental models of the expert community and those elicited from the target audience. Atman *et al.*, (1994, p. 779-780) summarize this methodology as follows:

> "Whatever the goal of a communication, its designers need to address the mental models that recipients bring to it, that is, the pattern of knowledge gaps, overly general understandings, and outright misconceptions that can frustrate learning. Furthermore, these information needs should be determined through a combination of formal analysis and empirical study. One cannot rely on the intuitions of technical experts regarding either what lay people currently believe or what they need to know. … The three main tenets of this approach are that (1) the recipient of a communication needs a basic understanding of the exposure, effects, and

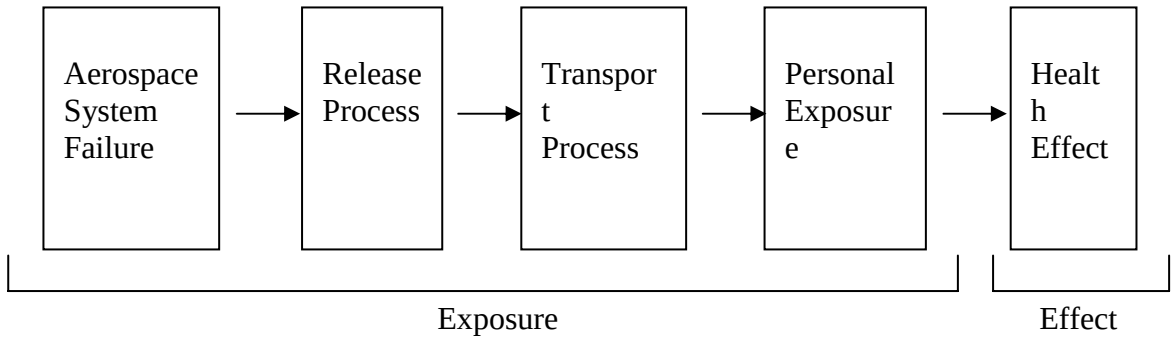
mitigation process relevant to making decisions about the hazardous process, (2) recipients' existing beliefs affect how they interpret and use any new information, and (3) the information should be presented with appropriate text structure and reinforced with textual aids (e.g., section headings), as established in the general research on text comprehension. In effect, a risk communication should complete a recipient's mental model of the relevant risk processes, which means both adding critical missing information and dispelling misconceptions that might affect decisions. Moreover, its contents should be specific enough to aid decision making: not so general that it cannot address the concrete decisions that recipients face, and not so detailed that it obfuscates the message with needless technical information."

The main steps of the methodology include the following (Bostrom *et al.*, 1992):

1. Creating an expert model
2. Identifying information needs (critical concepts) for the target group (laypersons)
3. Developing an interview questionnaire for laypersons
4. Conducting interviews with laypersons
5. Mapping lay beliefs into the expert model
6. Identifying correct beliefs, gaps, and misconceptions
7. Creating and evaluating a communication

The *expert model* is a hypothetical description of the processes creating and controlling the risk. To create such models, experts are consulted for their collective knowledge about a particular risk by direct interviews or through a literature review. By reflecting the comprehensive knowledge of the expert community, these models can be rather complex. For example, Figure 5 illustrates the general layout of an expert model for the risks of nuclear energy sources in space (Maharik and Fischhoff, 1992). It shows the relationships between the possible system failures, the release, transport, and personal exposure processes, and the health impacts of exposure. The full expert model contained a total of 113 nodes (concepts).

Figure 5



In an expert model there are nodes of varying relevance from the perspective of the potential decisions of the target audience. Therefore, the next step is to select the *most relevant elements* of the expert model, i.e., the knowledge which is most important for the target group in order to make informed decisions (the so-called critical concepts).

The following step is to prepare an *interview questionnaire* for the members of the target group. Such a questionnaire includes questions that aim at investigating whether the critical concepts of the expert model are included in the problem perceptions of lay people. The questions are deliberately open-ended, in order to minimize the imposition of any pre-defined structures on respondents.

Interviews are tape-recorded, transcribed, and analyzed. This will allow for the identification of the *critical concepts of the expert model* that are *included in the perceptions* of the majority *of lay people*. On the other hand, the most common *gaps and misconceptions* should also be identified.

In the *design of communication*, the basic idea to start with is that when people receive new information, they try to integrate it into their existing mental constructs. Therefore, the new texts should be preferably adjusted to the mental models identified during the interviews. On the other hand, focus should be on the communication goal. If the goal is to influence decisions then the communication instrument to be devised (e.g., brochure, booklet, web page, lecture, etc.) should *provide orientation* starting with purposes of lay people and proceeding towards the actions required for their implementation. At the same time, concepts and links missing from the mental models of lay people should be emphasized, and special focus should be put on the correction of mistakes.

The mental models methodology has been applied for a variety of hazards, including exposure to radon and lead, Lyme disease, skin cancer from sun, and nuclear energy sources on space vehicles (Bostrom *et al.*, 1992; Maharik and Fischhoff, 1992; Atman *et al.*, 1994). Experience gained from these applications indicates that the mental models methodology can best be applied in communication situations characterized by the following:

1. The primary goals of communication may be encouraging behavior change or facilitating participation in public discussions[11], but these goals are pursued indirectly, by conveying substantial information about a hazard, rather than directly trying to influence choices.
2. Communication is targeting relatively new risks, which have not linked to many pre-existing mental constructs yet.
3. Communication is targeting rather non-controversial issues, which are laden by few normative and emotional elements.
4. Communication is targeting decisions that are not to be made under time pressure.

Applications of the mental models approach in the field of RWM

Due to increasing public concerns about the use of nuclear energy and the management of radioactive waste, special attention has been paid to analyzing the social acceptance of policy decisions made in the above fields. A number of studies were carried out which investigated the factors of public acceptance by applying a variety of methods (van der Pligt, 1989, Dunlap *et al.*, 1993). In the following sections, examples for descriptive studies investigating mental models that underlie the attitudes toward RWM are presented.

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[11] Although not closely related to risks, the first applications of the mental models approach were aimed at educating people about complex technical issues. They focussed on how people understand technical devices like pocket calculators or physical phenomena like electricity (Gentner and Stevens, 1984).

Open-ended investigations

Slovic *et al.* (1991) conducted a comprehensive study aimed at exploring the public's mental images about an „underground nuclear waste repository" in various U.S. populations[12]. People were asked to free associate[13] to the concept of the repository. About 10,000 images were generated which were classified into 11 categories, the frequencies of which are shown in Table 1.

Table 1 illustrates that the most frequently reported images (40%) were classified into Category I, entitled „danger or harm to the environment and human health". Examples for such images included scenarios on water, soil, food contamination, cancer, mutations, birth defects, death, long-term effects on future generations, etc. At the same time, only 1.2% of the images were classified into Category II, entitled "safe to human health". *Remarkably, a number of scenarios related to "radiation and nuclear technology" and "nuclear weapons and nuclear war", most with negative connotation (e.g., TMI, Chernobyl, Hiroshima, World War III) were also identified* and classified into Categories IX and X (in total 7.5% of the images). In addition, about 9.3 % of the images were related to Category IV, entitled „other negative attributes", e.g., horror, terror, evil, dirty, ugly, smelly, corruption, and mismanagement, while the frequency of images related to "other positive attributes", e.g., clean, less pollution, safeguarded, controlled, effective etc., classified into Category VI, was around 3.2%.

The study concluded that for the vast majority of the targeted U.S. public, perceptions of a repository was extremely negative. Data indicate that *the concepts of nuclear power plant accidents, and even those of nuclear weapons and nuclear war are indeed connected to the mental models of the facility planned for the safe management of radioactive waste* (Easterling and Kunreuther, 1995).

[12] A total of 3,334 individuals were interviewed. These included samples in Phoenix, South-Carolina, Nevada, and a national sample was also used.

[13] Research suggests that the method of continued associations is an efficient way to explore mental constructs (e.g., Szalai and Deese, 1978)

Table 1. **Free-Association Responses to „Underground Nuclear Waste Repository**

	Category of Image	Frequency (%)
I.	Danger or Harm to Environment and Health	40
II.	Safe to Human Health	1.2
III.	Issue of Risk and Safety Raised (ambiguously)	5
IV.	Other Negative Attributes	9.3
V.	Personal Opposition or Distaste	5.9
VI.	Other Positive Attributes	3.2
VII.	Locations	9
VIII.	Physical Features of Repository System	8
IX.	Radiation and Nuclear Technology	4.6
X.	Nuclear Weapons and Nuclear War	2.9
XI.	Miscellaneous	5.2

Source: Slovic *et al.* (1990) quoted by Easterling and Kunreuther (1995)

Semi-structured investigations

Kraft and Clary (1993) analyzed the transcripts of public hearings organized by the U.S. Department of Energy (DOE) related to the selection process for a high-level waste repository in the states of Wisconsin, Maine, North Carolina and Georgia during 1984-86[14]. Texts were classified into several categories, including e.g., anticipated repository impacts, political/social concerns, technical criticisms, DOE competence and credibility, and the degree of opposition to the facility. It was found that the most frequently mentioned issues included political/social concerns (80% of the respondents addressed at least one such issue), technical criticisms (76% addressed at least one technical issue), repository impacts (71% raised issues of this kind), and DOE competence and credibility (58% raised questions about these issues).

Table 2 illustrates the results of a more detailed analysis of the concerns associated with the perceived repository impacts. Remarkably, *environmental impacts and economic issues were mentioned more frequently than public health issues. Also, scenarios related to environmental and economic impacts appeared to be more specific (e.g., water resources, forests, endangered species, tourism, agriculture) than those related to public health.*

[14] At the hearings a total of 1,045 individuals testified, and the full text of their responses was analyzed in terms of a number of dimensions.

Table 2. **Perceived Impacts of a Nuclear Waste Repository**

Impact on	Percentage of Public Statements Where Issue Was Raised
Water resources	36
Economy	26
Public health	23
Tourism	22
Quality of life	18
Agriculture	13
Forests	10
Recreational opportunities	10
Sense of psychological well-being	8
Endangered species	6

Source: Kraft and Clary, 1993

Vari *et al.* (1991) conducted a comparative analysis of public concerns about siting low-level radioactive waste disposal facilities in the U.S., the U.K., and Hungary. The study was based on analyzing publicly expressed responses to facility siting processes in order to identify the nature and range of public concerns[15].

Based on the analysis of the data from all the three countries[16], a taxonomy of public responses was defined (Table 3). Responses structured in the form of scenarios were classified into twenty concerns and six categories: including health-safety, economic, environmental, social-political impacts, technical-procedural deficiencies, and proposed alternative solutions.

Comparison of data revealed that there was a substantial similarity in the concerns expressed in all three countries. Fifteen of the twenty concerns were observed in all three, and another two were shared by two. However, there were significant differences among the relative importance of the concerns and the nature of specific arguments. Most notably, environmental concerns were relatively more important in the U.S. than in the other two countries (scenarios about environmental damages appeared in 30% of the New York responses, but in less than 10% of the responses in the other countries). On the other hand, health and safety concerns were more **emphasized in Hungary than**

15 In New York State, 100 letters were randomly sampled from residents in „candidate areas" protesting against a possible disposal facility in 1988-89. For the U.K., a complete data set composed of 1,714 letters written by individuals in „geologically feasible areas" during 1987-88, commenting on proposals to establish a disposal facility was analyzed. In Hungary, 294 responses were analyzed from a representative sample of „short-listed site" residents opposing a proposed disposal facility in 1989.

16 The method used in the study was developed on the basis of Toulmin's (1958) argumentation theory.

elsewhere (in Hungary such scenarios were found in 62% of the responses, while their occurrence in the U.K. and U.S. responses was below 40%). Nevertheless, health and safety, and environmental concerns seemed to dominate everywhere. *The results suggest that – although idiosyncratic economic, social, and political factors may lead to some differences, - there is a surprisingly large similarity among the mental models of local opponents of radioactive waste disposal facilities in the three countries*[17]. Such similarities allow of using only a limited number of concerns in large, cross-cultural surveys (e.g., Eurobarometer 1999; 2002)[18].

Table 3. **Taxonomy of Public Concerns Associated with a LLRW Facility**

I. Health and Safety Impacts
- Operational risk
- Transportation risk
- Accumulated risk (existing risks from other activities)
- Health risks to future generations

II. Economic Impacts
- Damage to private property (real estate values)
- Damage to tourism and recreation
- Damage to agriculture
- Interference with other activities (e.g., mining)
- Stigma effect

III. Environmental Impacts
- Damage to natural environment
- Damage to historic sites
- Detrimental effects on the quality of life

IV. Social Impacts
- Equity-related impacts (e.g., exploitation of rural communities, regions and ethnic groups)
- Depopulation of the area
- Damage to national or ethnic cultures
- International conflicts (e.g., with Canada)

V. Technical-procedural Deficiencies
- Natural characteristics (geology, hydrology) of the site unsuitable
- High population density near the site
- Disposal technology is not safe
- Distrust in the siting and operation procedures

VI. Alternatives to the Recent Siting
- Site on another place
- Store waste close to generators on-site
- Develop new, safer technology
- Moratorium or close-down nuclear power plants

Source: Vari *et al.* (1991)

17 Mental models of local proponents of RWM facilities will be discussed in the next section.

18 The Eurobarometer surveys are conducted in the 15 EU countries and occasionally in some accession countries as well. In a recent survey investigating attitudes toward radioactive waste, a total of four negative impacts seemed to cover 99% of respondents' major concerns (Eurobarometer, 2002).

Structured investigations

A number of structured studies started from the general assumption that the more a person believes that an object (e.g., a technology or a facility) will have good or bad impacts, the more favorable his or her attitude tends to be toward it[19]. For example, studies investigating attitudes of the general public toward nuclear energy found that most variations in respondents' attitudes could be explained by a limited number of perceived impacts. *Individuals with pro-nuclear attitudes attributed a higher importance to economic and technical benefits, while people with anti-nuclear attitudes were more concerned about health and environmental risks of nuclear energy* (Otway *et al.*, 1978; Woo and Castore, 1980).

In the Netherlands, Van der Pligt *et al.* (1986) analyzed attitudes of local residents to a potential nuclear facility to be built in their neighborhood. Data indicated only modest differences between the forecasts on various impacts generated by the pro- and anti-nuclear groups, while the weights attributed to the individual impacts by the two groups were significantly different. *Interestingly, the perception of psychological risks, specifically the "personal peace of mind" proved to be the primary determinant of attitude* (van der Pligt, 1989).

In Finland, Litmanen (1999) investigated the relations between concerns on various future scenarios associated with the siting of a high-level radioactive waste repository and the acceptance of the facility. In a survey conducted in three candidate towns, Eurajoki, Kuhmo, and Aanekoski, it was found that respondents in the two latter towns were significantly more concerned about all impacts than those of Eurajoki. For example, approximately 50% of the respondents in Kuhmo and Aanekoski were very concerned about health and safety impacts, while in Eurajoki only 35% of the respondents fell in this category. *Concerns about the various scenarios proved to be a good predictor of overall attitudes toward a facility*: in Kuhmo and Aanekoski 63-63% of the respondents opposed the facility and 24-21% accepted it, while in Eurajoki the ratio of supporters and opponents was about the same[20].

Several surveys (Kunreuther *et al.*, 1987; 1990; Desvousges *et al.*, 1993; Easterling and Kunreuther, 1995) investigated the potential factors of acceptance of the planned U.S. high-level waste repository in Yucca Mountains, Nevada. Estimated likelihood of various scenarios associated with the facility (e.g., transport accidents, earthquakes, terrorist attacks, decrease in tourism, increase in jobs) were elicited from Nevada residents and national samples. These studies confirmed that an individual's support for or opposition to a facility can largely be explained by the health and safety, environmental, and socio-economic scenarios he or she perceives to be most likely to occur as a consequence of the facility. However, *anticipated impacts are not the only determinants: perceived fairness of the decision processes and general attitudes to nuclear power seem to have high explanatory power to public acceptance as well*.

Dynamic investigations

To understand the dynamics of the construction and application of mental models, Vari and Farago (1991) studied the process of an (unsuccessful) siting of a low- and intermediate level radioactive waste disposal facility in Hungary[21]. By analyzing a series of semi-structured interviews

19 The underlying model is the so-called model of attitude formation proposed by Fishbein (1963).

20 These differences proved to be relevant in the long-term as well. It is Eurajoki, which stands out as the only community that has been willing to host the high-level waste repository.

21 The siting process took place between 1976 and 1989.

and surveys carried out in subsequent phases of the siting process, changes in the views of investors and local residents were followed. Residents of the affected communities were found to adopt the views of the local elite relatively quickly, although initially only a minority had any information or opinion with regard to the facility. For example, the scenarios of potential accidents, water leakage or earthquakes were initially present in the mental models of the local elite only, but later similar scenarios appeared in the mental models of the majority of the residents as well. In addition, the study demonstrated *that the beliefs related to the risks* ***became integrated into a broader context, intertwining with the views on the operation of society, the prevailing power relations, the fairness of the siting process, and the*** *trustworthiness of experts.* The investors and the local elite had divergent views on such social-political issues, therefore, the evolving conflict soon acquired a political dimension. As soon as the residents' scenarios on the siting became linked to these broader issues, the conflict could not be controlled any more.

The study concluded that *for effective conflict management, parties have to take into account not only their partners' mental models, but also consider the potential changes in them*. If not, they could lose the opportunity of reaching an agreement through untimely suggestions. On the other hand, *only effective communication from the beginning can fill the vacuum and prevent the utilization and stabilization of irrelevant mental constructs, which interfere with the constructive resolution of the conflict* (Vari and Farago, 1991).

Mental models methodology in RWM

It has been revealed by several studies that beliefs of the expert community and the lay public concerning the risks of RWM may be significantly different. For example, by comparing the perceptions of the lay public and those of members of the American Nuclear Society, Flynn *et al.* (1993) found that while only 33% of the general public agreed with the statement that during the operation of a disposal facility „contamination of underground water supplies will not occur", 77% of the expert sample agreed with it. Similar differences were found in other studies (e.g., Jenkins-Smith *et al.* 1991) as well.

In spite of the marked differences in opinion between the experts and the lay people, no application of the mental models methodology to risk communication has been reported in the field of RWM. The main reasons for this may lie in the highly controversial nature of the RWM issue. On the other hand, as described earlier, the mental models methodology is most effective if applied for relatively new risks which have not been connected to many pre-existing mental constructs yet, – a condition which is rarely met in decision/communication situations related to radioactive waste.

The skepticism toward the usefulness of risk communication in the RWM area has been expressed by Kraft and Clary (1993, p. 98) as follows:

> "… improved risk-communication processes will not necessarily alter opposition to repository siting. Opposition is not explained by a low level of understanding of the technical issues, and hence concentrating on building the public's knowledge of these issues offers no guarantee of reduced opposition".

The question remains whether the mental models methodology know-how could nevertheless be transferred to the field of RWM. Provided that certain conditions are met, we believe it could be. There is a better chance for an effective use of the methodology if:

1. The primary goal of communication is to educate people and help them participate in public discourses, rather than change their views;

2. The target group consists of younger people or of individuals for whom the problem is new and who have not subscribed to any positions yet;
3. The communication occurs in communities where the communicating parties are on good terms and no political controversy related to the issue has been developed so far;
4. There is no urgent need for a decision.

For example, application of the mental models methodology could be contemplated in communities where radioactive waste has been stored or disposed of. Preparing the local public for community oversight activities would be a task typically implementable with the help of mental models methodology.

Application of certain elements of the methodology would be reasonable for other purposes as well. For example, it could be useful to identify the details of the expert models on the risks of various RWM technologies (storage, disposal, reprocessing) and to compare them with the beliefs of different lay groups. Also, it would be important to investigate whether scenarios concerning some new threats (e.g., global climate change, terrorism) are present in the expert and lay mental models related to radioactive waste. Finally, in order to facilitate communication, a better understanding of the connections between mental models on radioactive waste and mental constructs of social-political nature in various target groups should be attained. As Litmanen (1999, p. 218) points out:

> "Instead of spending resources to the education of strong opponents, it would be more important to study the cultural basis of the resistance. By understanding the logic and meanings of resistance, support and neutrality, it would be easier to establish a dialogue between the parties".

CONCLUSIONS

The mental models approach aims at investigating the judgment and decision processes of both expert and lay groups, by using a number of different tools. Descriptive studies endeavor to draw generalized conclusions on such processes on the basis of elicited mental models. On the other hand, prescriptive studies are targeted to develop communication, education, and decision support tools that fit these models.

According to the mental models methodology, risk communication is designed on the basis of comparative analysis of the mental models of expert groups and target lay groups. Considering the existing knowledge and beliefs of lay people, the mental models methodology tries to eliminate gaps and misconceptions and to explain the real relationships.

In summary, application of the mental models approach may facilitate the mutual understanding between lay people and experts, or between different social groups. However, understanding is only a necessary but insufficient condition of resolving conflicts and will not guarantee a consensus by itself. This is of particular relevance in areas where conflicts are complex and obstinate, complicated by conflicting values and strong emotions, such as in the field of radioactive waste management. As Maharik and Fischhoff (1992, p. 391) point out, in such areas the outcomes of risk communication processes remain highly uncertain:

> "… Knowing more about what experts believe should help laypeople identify courses of action in their own – and their society's - best interests. In some cases this will reduce conflicts. In others it will sharpen them, by clarifying the grounds for disagreement. Both outcomes could be the result of a successful risk communication process. Achieving a social consensus regarding the fate of technologies requires not only agreement over the facts, but also agreement about values and political processes".

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