Chapter 10

Managing Technogenic Risks with Stakeholder Cooperation

Riitta Molarius

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70903

Abstract

Risks involved in new technologies or arising from novel configurations of old technologies recurrently result in major accidents. For example, the new bioleaching technology to extract nickel from ore was taken into use in Finland in 2008. Later, one of the personnel died as a victim of hydrogen sulfide exposure and there were unplanned releases of process waters that contaminated lakes and rivers. Several risk analyses were performed but none of them considered the local climate and surrounding environmental circumstances. A comprehensive risk assessment process combining the knowledge of different stakeholders, authorities, and citizens would have helped to avoid the sad outcome. A single enterprise has a very clear picture of the risk figure on its own, but is reluctant to reveal commercially sensitive information to others, and even incapable of understanding all the expectations and constraints that the natural and built environments may impose. Only governmental authorities are in a position to form a comprehensive picture of all the risks. This paper presents a new approach for a proactive risk identification method based on collaborative integrated assessment. It states that by implementing this method society is able to utilize the science-based information in an efficient way for managing the emerging technogenic risks.

Keywords: risk identification, risk assessment, technogenic risk, stakeholder cooperation, hydrogen, fuel cell

1. Introduction

New technologies have been involved in several accidents. For example, in Germany, the novel magnetic levitation train collided with a maintenance vehicle and killed 23 people in 2006 [1]. Ten years later, in 2016, two trains collided again in Germany, killing 11 people and injuring 85 people despite the automatic braking system that ought to have been at work [2].

In 2016, the autonomous car claimed its first victim when the radar system of the autopilot failed to recognize a truck that was crossing the road in Florida [3]. In June 2017, at least 80 people died in a huge fire that took place in a London tower block that was covered with a new type of cladding, which included polyethylene foam [4]. In 2008, the new bioleaching technology used to extract nickel from ore was taken into commercial use in Finland, the first to adopt it in Europe [5]. Four years later, in 2012, one of the personnel died (as a victim of hydrogen sulfide exposure) due to a lack of safety equipment [6]; additionally, there were significant challenges associated with the management of the process waters, which consequently resulted in the company filing for bankruptcy [7]. Today drones hit people all over the world and collisions with helicopters and planes are just a matter of time [8].

Sociologist Ulrich Beck warned us over 20 years ago about the "risk society" where society is gradually exposed to the risks it creates and finally the negative effects of the progress become greater than the positive impacts [9]. The fast change and development of new kinds of technologies have increased likelihood and probability of technogenic risks even if there is a strong attempt to identify and anticipate risks. The term "technogenic risk" stands here for risks whose origin is in man-made technology, also including newer technologies, such as nanotechnology, biotechnology and information technology. In this article, technogenic risks not only mark accidental risks but also the creeping effects of risks to society, such as gradual land pollution or effects to human welfare.

Today's risk landscape consists of many interlinked elements, including interdependency, complexity, uncertainty, ambiguity, and cascading effects, which are all amplified by an increased dynamic of globalization [10, 11]. Advances in information and communication technology as well as in other kinds of technologies have increased these linkages and connections between states, institutions, corporations, civil society, and individuals. As a result of this process, the amount of interdependencies between persons, nations, markets, and societies is bigger than ever before [10]. Due to the complexity of the systems, it is difficult or even impossible to identify or quantify causal links between causes and the adverse effects of the unwanted phenomenon. One initial event may inflict different consequences in different parts of the state or world. Uncertainty is an inevitable part of different and distinct components of risks, such as statistical variation, measurement errors, ignorance, and indeterminacy [12]. Uncertainty reduces confidence in the estimated cause and effect chains. Ambiguity implies different interpretations based on human observations or data assessments. It strengthens the effect of cultural differences on risk assessment. Cascading effects describe the second, third, etc. step consequences of the initial risks to society as a whole, which, unfortunately, due to the previous elements are difficult to assess. It has been stated that in the near future different technologies, such as nanotechnology, biotechnology, information technology, and cognitive science (NBIC), will converge [13–15]. Due to this, the technogenic risks of new technologies grow even harder to understand and manage.

Complete risk management is challenged by a lack of knowledge. Although our knowledge of the world around us grows day by day, we are not aware of what pieces of information are still missing [16]. It has been pointed out that we do not have enough knowledge of, or we do not have enough understanding of climate change, technological innovations, wars, human behavior in different circumstances or changes in markets [12]. Moreover, even if the required information exists somewhere, we do not want to accept it due to our personal biases. Nicolas Taleb presented, in 2008, the concept of "Black Swans," which are highly consequential but unlikely events [16]. They are easily explainable but, unfortunately, only after the event. The existence of Black Swans highlights human nature: even if we have all the required information, we do not see—or we do not want to see—what is coming. Risk is a very adaptable and flexible unit, and for some, it appears to be a threat and at the same time for others an opportunity; risk is relative and individually defined. Renn has stated that the more ambiguous risk is, the more need there is for interpretation, and it also creates more cognitive, evaluative or normative conflicts [17]. These conflicts cannot be solved only by pure scientific knowledge, as even the scientific opinions of complex issues differ. There is a need for multidimensional discussion and collaborative multidisciplinary risk assessment.

In a standard risk management procedure, risk identification is the first step toward holistic risk management. It creates the basis for reasonable, effective, and comprehensive risk assessment. Risk identification ensures the quality of risk assessment and finally the effectiveness of the whole risk management process. Thus, the risk identification stage should be done with considerable care.

In spite of all the scientific knowledge about risk identification, assessment, and management, the main responsibility for managing technogenic risks in the European Union is put on operators, corporations, manufacturers, and suppliers. The latest SEVESO III directive (Directive 2012/18/EU) insists that operators and corporations should cooperate to identify the domino or cascading effects of initial risks. This is a challenging task to perform, as often in the same industrial area there are many competing companies that are not willing to share commercially sensitive information. In addition, at least in Finland, the latest technogenic risks ensued from the following initial faulty or poor solutions [18]:

- The new technology (train steering system) was not compatible with the existing one (old tracks and steering methods).
- The built environment gradually accumulated risks, while new technology was combined with the old one. Due to this, liquid ammonia was released inside the factory leading to evacuation.
- There was not enough communication between the authorities and the company and thus the identified risks were not known. This resulted in damages to natural gas pipelines.
- There were too many subcontractors, and no one understood the entirety of the new building construction. Due to this, several roofs of sports halls and commercial buildings collapsed during the winter.
- There was not enough knowledge of what happens in elderly peoples' homes during long electricity blackouts. When it happened during the winter, society was not prepared to evacuate people as soon as it should be done.
- The authorities did not have enough knowledge of new technologies, and therefore, they made faulty decisions with environmental licenses.

None of these technogenic risks could have been prevented by the cooperation of single companies but may have been by broader stakeholder collaboration.

Due to the rapid change in new technologies and a shrinking and convergent world, it is clear that no person or organization alone is capable of identifying all the emerging technogenic risks. There is a need for effective collaboration between all the different stakeholders, authorities, scientists, politicians, and civilians. The commonly admitted and approved solutions should be retrieved with cooperation and a common valuation of differing values. The future is not defined in advance, but we are all able to change and reconstruct it a little toward the plausible future. Using the methods of future studies, we can create new methods to manage future risks, and in this way, we can define what kind of future we want to have.

Despite all the requirements, it is not a very conventional task to collect all the requisite stakeholders together or combine their knowledge to focus on identifying the technogenic risks of future technologies. The next chapters present not only the method developed for this risk identification task but also the basis for the solution.

2. Research process and methods

To ensure that societies are prepared against technogenic risks due to new technologies, the aim of this research process was to develop a risk identification process that is able to combine information of new technologies from different disciplines as well as from different stakeholders to anticipate future risks.

The research process included two main steps:

1. Development of the risk identification tool. This stage of the process started from interviews with authorities and literature research to find out the most suitable methods and to select the best one for stakeholder cooperation. The tool was then tested in a real-life situation to find out the risks to society initiating from hydrogen and fuel cell technology.
2. Development of the risk identification procedure for risk identification workshops. To arrange effective collaboration in workshops, a broad literature study was done to tackle the worst mistakes preventing fruitful cooperation and to create the guidelines for authorities for workshops.

As a result of the research, a new risk identification method called anticipation of future technogenic risks identification (FuTecRI) was developed. This risk identification method was developed in close cooperation with Finnish authorities, such as the Finnish Chemical and Safety agency (TUKES), the Pirkanmaa and Uusimaa Centres for Economic Development, Transport and the Environment, the Rescue Services of Helsinki, the City of Virrat and the Council of Tampere Region, for example. These authorities were interviewed, they took part in workshops and they evaluated the method after the workshop. They also did self-assessment of their accrued knowledge of hydrogen and fuel cell technology before and after the workshop.

3. FuTecRI: a method for risk identification

The developed future technogenic risks identification (FuTecRI) tool is based on the future studies method called the Futures Wheel that was developed in 1971 by Jerome Glenn. It was developed to organize future events in a reasonable order. The method is a visual one, and it helps one to receive a comprehensive picture of the issue discussed. The Futures Wheel is mainly used to present thoughts about future development or trends [19].

In this study, the FuTecRI method was developed mainly for the authorities' needs. Their opinion was taken into account when selecting a suitable method for risk identification. The Futures Wheel was selected as a base ground for the tool development among 22 different risk assessment and future studies methods for six main reasons:

1. It can be used for studying technical systems and their connections with the natural and built environment.
2. It is suitable for studying future aspects of risks.
3. It is suitable for collaborative brainstorming.
4. It is easy to learn and take into use.
5. It does not require much time resources from professionals, authorities, or scientists.
6. It does not necessarily require any facilitator services.

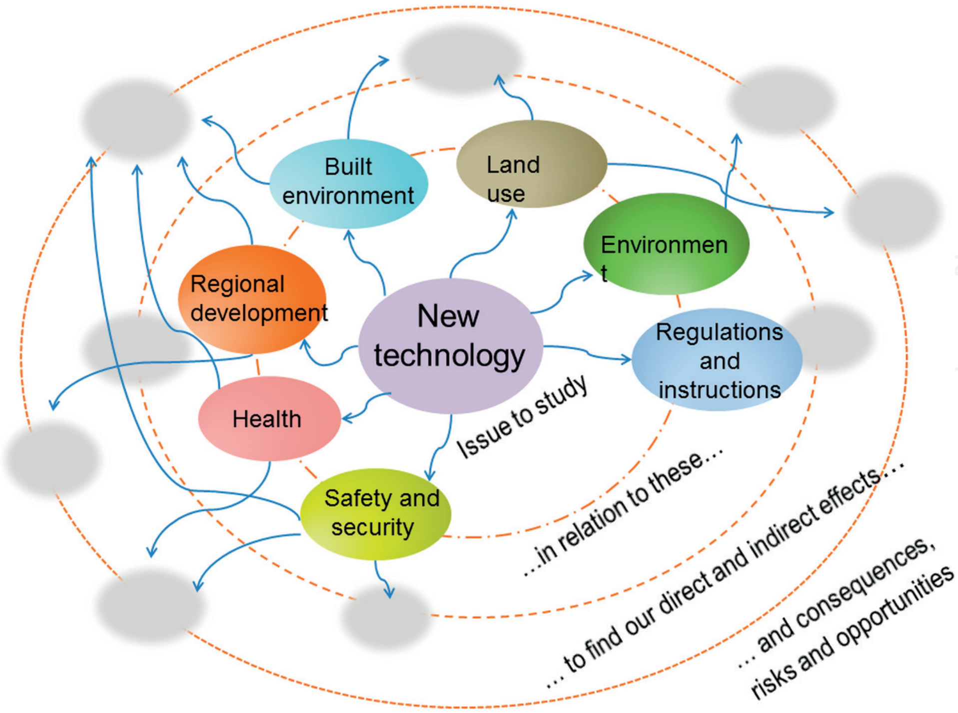

Figure 1. FuTecRI tool for identification of the future risks introduced by new technologies [18].

The Futures Wheel approach was further developed to identify the future negative effects of new technologies In the first stage, four different prior new technologies (chimney, matchstick, steamboat and train, electricity, and mobile phone) were analyzed to find out what tor tens of years ago. These changes were categorized to select key words for the FuTecRI tool against which the risk of new technologies should be identified and evaluated. The breakthrough times of these old technologies were different (chimney 400 years, mobile phone 34 years), which also indicates the amount of changes needed in the regional culture to accept new technologies. The selected key words were health, safety and security, environment, built environment, regulations and instructions, land use, and regional development of the area.

The developed FuTecRI tool is a fill-in-the-blanks diagram presented in **Figure 1**. The central term in the figure describes the discussed new technology that should be evaluated in relation to the key aspects (surrounding it) to find out the potential risks.

4. Challenges of collaborative brainstorming

The risk identification tool alone does not ensure effective risk identification, but great attention must be paid to the participants of the workshops. To find out the rules for selection of these participants and for facilitation of the workshops, another broad literature research was done.

Cognitive sciences highlight that multiprofessional and multidisciplinary cooperation is a key for collaborative grading through which a group can achieve better results in problem solving than by working individually [20] and in group work people are able to solve problems that are unsolved by working alone [21]. This is because in difficult decision-making situations people use other actors and people's knowledge to widen their own knowledge and understanding, and thus, they can effectively solve challenging problems [22, 23]. When people are working in groups, they are also forced to recognize the shortcomings of their own knowledge and they can even change their opinions accordingly [24]. It has been pointed out that when all the knowledge dealing with a common target from different disciplines is combined, it is possible to find solutions that cannot be found by any single discipline alone [25].

However, group work does not automatically ensure better results than working alone. To work effectively, the group must be multidisciplinary or at least multiprofessional. The participants need to understand the idea of the workshop, they have to engage with the work and they should deliver their knowledge to other participants. Bohm and Beat have presented a method for creative dialogue insisting that all the participants should be flexible and they should have the ability to negotiate about their opinions with others [26]. The result of this negotiation is not a compromise but rather a creative solution that will be acceptable to all the participants. The creative dialogue can be received if the participants present broadly different disciplines.

One of the main challenges for the multiprofessional group work comes from the competition between professions. Profession is defined here as an authorized status or post in relation to other professionals with specialized knowledge, and the ability to use one's own discretion at work [27]. It seems that professional competition is very common and it becomes apparent when discussing who has the power to make decisions in a certain context [28]. Very often,

http://dx.doi.org/10.5772/intechopen.70903

the professions feel cooperation with other professions is a threat to their own knowledge and authority. People are also unwilling to receive new knowledge if it contradicts their existing knowledge [29]. One of the best situations in which to exceed professional competition and to share and receive new knowledge is in multidisciplinary workshops that are targeted at sharing knowledge with other professionals [30].

Even when the participants are ready to take part in the workshops and share their knowledge, there are still barriers to overcome. Different work cultures may prevent or hinder cooperation; for example, in hierarchically arranged organizations, such as the police and in hospitals, the valuable knowledge of subordinates might stay invisible. Also, the different paradigms, beliefs, terminologies, and methods will prevent common understanding [26, 31].

Finally, there are some other difficulties that may prevent cooperation. Especially dominant persons may hinder discussion and prevent the group from sharing all information and knowledge they have [32]. It is important that all the participants are interested in the subject they are discussing and they have booked enough time for the work. To get through all these impediments, it is important to create a safe and trustful environment for the work groups. The participants must feel that they can trust not only the expertise of other participants but also their behavior, which should be appreciative, friendly, and predictable [33].

5. Risk identification procedure

As a result of the analyses of the advantages and disadvantages of the collaborative group work, a range of conclusions were made and the working procedure for the authorities was produced. One remarkable note was that all the participants taking part in the workshops should have a personal interest in the discussed topic. However, the authorities are overworked in these days, and therefore, an interest is not enough; they also need to have enough time to take part in the workshops. This led to the conclusion that all the workshops arranged to identify technogenic risks should be strongly justified. This means that for one new technology there should be only 1–2 workshops in the whole country, and they should be planned to combine broadly all scientific knowledge, professional data, and stakeholder opinions in an efficient way. **Figure 2** presents the decision frame to start a new risk identification workshop as well as the main steps of the risk identification workshop. All stakeholders have the possibility to start a new risk identification workshop if they feel that it is needed for ensuring safety and security of society in the future. In the beginning, they have to answer three questions, and if the answer is always "yes," they should start the process. If this condition is not met, the FuTecRI method should not be used, but other methods may be more useful. For example, if the impacts of the new technology are only local, traditional risk assessment methods are more suitable.

The participants of the workshops should be selected in a reasonable way taking into account the following viewpoints [18]:

- Multiprofessionality—the participants should represent all the different authorities in charge of preventing the risks of new or novel technologies, or of preserving or maintaining a safe and secure society.
- Multidisciplinary—the participants should represent the latest academic and scientific knowledge of the technology in question.
- Personal features—the participants need to be personally interested in the technology discussed, they should be open-minded and responsible persons, and they should want to find good solutions for everyone.

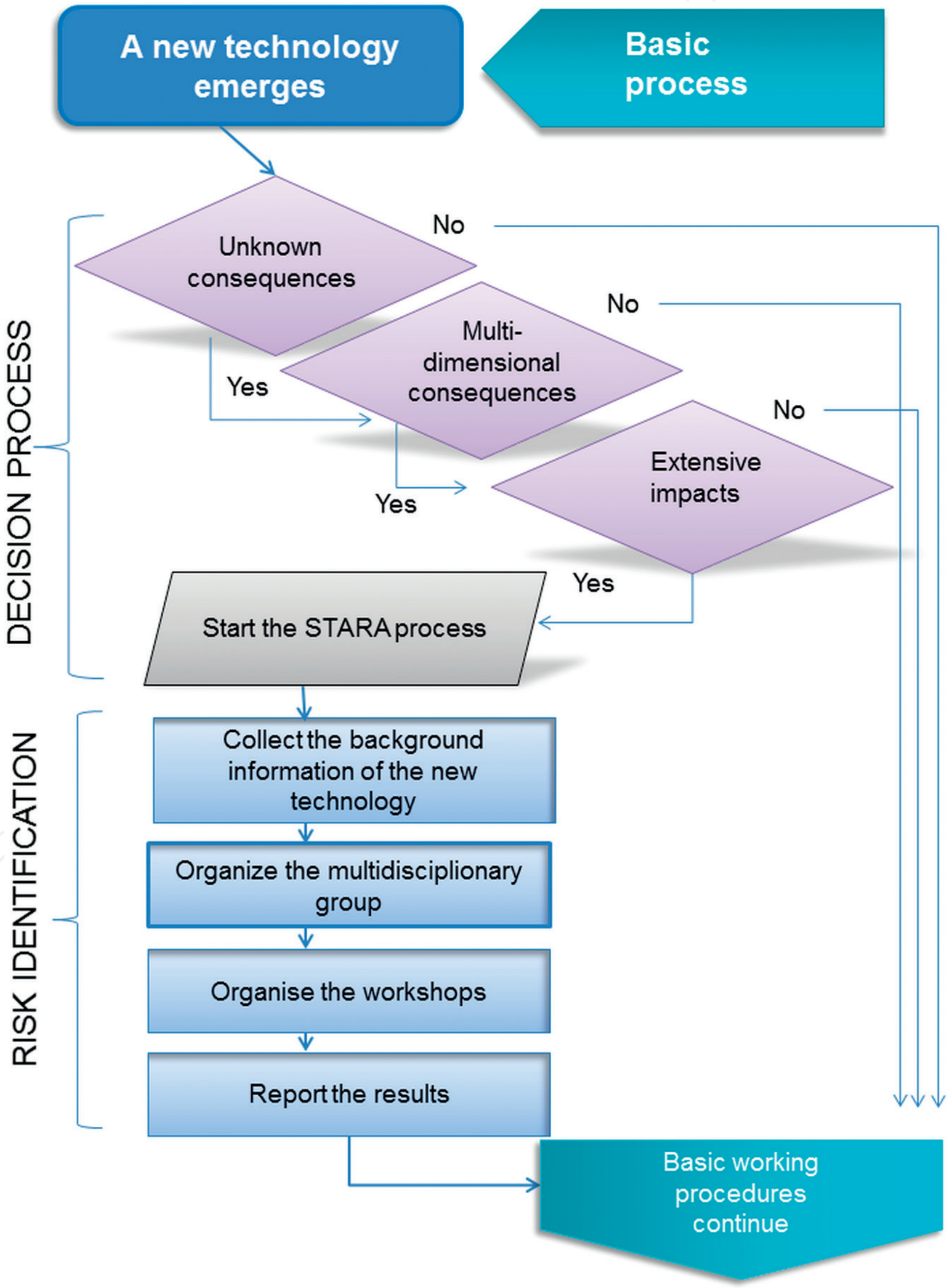

Figure 2. Decision process to start the FuTecRI workshop and the main steps for arranging it [18].

The main question for a successful FuTecRI workshop is how to ensure that the authorities especially, but also other stakeholders, put aside their professional and official position during the workshop because it may prevent them from sharing their personal knowledge and receiving new information. This is an issue that should be clearly discussed at the beginning of the workshop. The participants must understand that they are not in the workshop because of their official status but because of the knowledge they have, and their role is to deliver this knowledge to other participants.

To focus the group on the same target, the flow of the FuTecRI workshop must be well organized and the frame and content should be clear (**Figure 3**). At the beginning of the workshop, it is essential to highlight the importance of risk identification as well as to justify the working method. The importance of the identification of the risks of technogenic risks can be stated by Geel's theory of sociotechnical change [34, 35]. According to this theory, new technologies may break through and spread all over if external circumstances are favorable to them. In these cases, they may affect huge changes in culture, infrastructure, regulation, and markets, for example. A good example of this kind of change took place when mobile phones came into the market. It is clear that some technologies have the potential to change the whole society, and society should be able to handle and remove risks before they are actualized.

To ensure that the topic of the workshop is clear, there should be a state-of-the-art presentation of the discussed technology before the collaborative work. In this presentation, all the known aspects of the technology in question, pros and cons, should be given to the participants, and therefore, this presentation should be given by academic or research institutes. The challenge is to present the technology with terminology and concepts that are understandable to all stakeholders and authorities, professionals, and nonprofessionals.

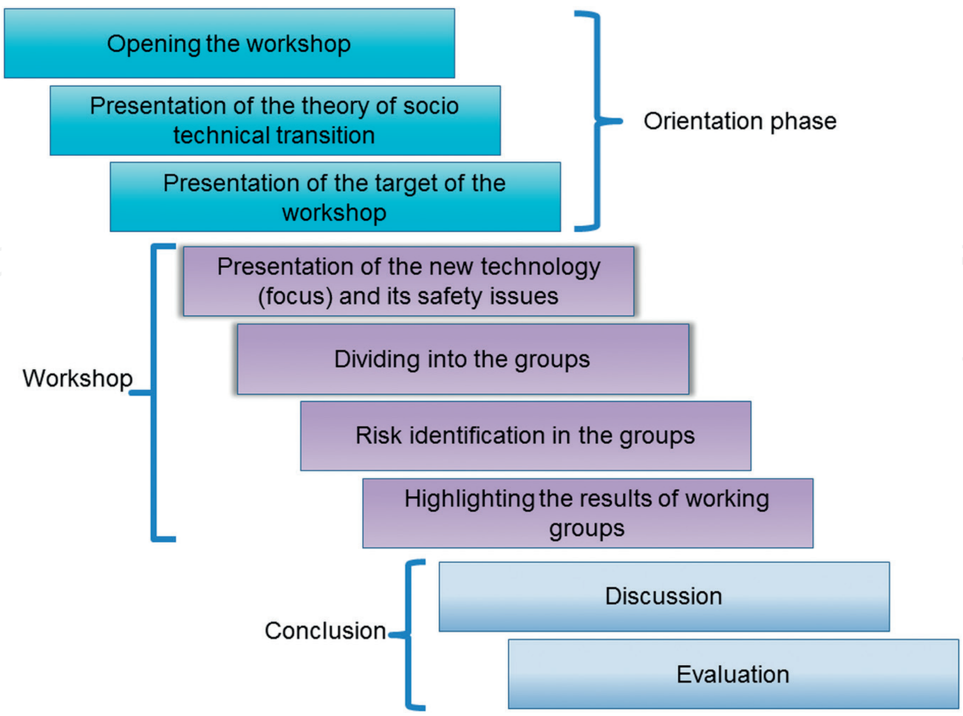

Figure 3. The flow of the FuTecRI workshop [18].

Finally, when risk identification starts, the participants should be arranged into smaller working groups. The group should include only five to seven participants, as this has been proved to be the most effective group size for cooperation [32]. In larger groups, nonparticipation increases because people easily forget their role in the workshop as a knowledge deliverer. It is also important that no notes of who-said-what are taken but all the notes are done as a group. This kind of working removes official roles and gives room for expertise. Each group may have a recorder of their own, but it is also possible for all the participants to make notes on the working tool.

6. Piloting the method: risks of hydrogen and fuel cell technology

The developed FuTecRI tool and working procedure were tested in a workshop arranged by hydrogen and fuel cell researchers from the VTT Technical Research Centre of Finland. Hydrogen and fuel cell technology is undergoing strong development work, and the researchers wanted to know if there is an understanding of what kind of requirements the new technology imposes on society. The participants of the workshop consist of representatives from the Finnish Chemical and Safety Agency (TUKES), the Pirkanmaa and Uusimaa Centres for Economic Development, Transport and the Environment, the Rescue Services of Helsinki and VTT; all together 11 participants were arranged into two working groups. The workshop followed the procedure presented in **Figure 3**. The new technology was presented by VTT researchers to the participants.

The workshop took 5 h, the first 2 h of which were discussions of dealing with the theory of sociotechnical change and the hydrogen and fuel cell technology and its current state. After the lunch break, people worked in groups for 2 h to explore what kind of risk hydrogen and fuel cell technology might create. Finally, both groups presented their results to each other. The results of the workshop were combined into the one mind map and delivered to the participants for their later use.

The workshop results brought out several issues regarding hydrogen and fuel cell technology that need to be discussed and managed at a governmental level, such as [18]:

- Environmental issues. The production of hydrogen and fuel cells requires platinum as a raw material. This will improve material recycling but also increase mining actions. The positive effects include emission-free fuel and quiet traffic.
- Built environment. The fuel distribution stations are not covered by any legislation. Thus, the hydrogen fuel can be delivered even from delivery trucks, which can cause dangerous situations. There is a need for new legislation. In addition, underground parking places need to be equipped with hydrogen sensors to avoid explosions.
- Safety issues. Road accidents involving hydrogen and fuel cell cars may cause danger to rescue services because the fuel cell vehicles do not visibly differ from other vehicles but the rescue operations vary depending on the fuel type of the vehicle. In addition, fuel cell vehicles move quietly, which may increase road accidents, as people may not hear the arriving cars especially in the winter.

- Land use. For safe land use, there is a need to plan regional hydrogen pipelines that are later suitable for different kinds of hydrogen use.

The workshop participants also took part into two different surveys. The first one was done in two parts, at the beginning of the workshop and immediately after it. This survey focused on evaluating the change in participants' knowledge of hydrogen and fuel cell technology. The idea was that people made a self-assessment at the beginning of the workshop evaluating their own knowledge on a scale of 5–10 (5: weak knowledge; 10: excellent knowledge). This scale was selected as it was used for a long period in Finnish schools, and therefore, it was easy for the participants to understand. After the workshop, they were asked to evaluate themselves a second time. They then had to answer two questions: What did they now think their knowledge was at the beginning of the workshop? and What did they think their knowledge level is after the workshop?

The results were very interesting (**Table 1**). At the beginning of the day, participants thought that their knowledge was at a considerably low level, and only one participant (perhaps a researcher) thought that he had excellent knowledge. During the workshop, they understood that their knowledge level was not even at that level, and a comparison between the morning and afternoon estimations indicates that all of the participants lowered their estimations. The very interesting thing is that the workshop brought a lot of new knowledge to all participants. Even the hydrogen and cell fuel researchers received a lot of information regarding the impacts of new technology on society and the built environment. It seems that the FuTecRI workshop worked as it was planned to, it stimulated the participants to share their knowledge and accumulated new information on top of the old information, and in that way, it made it possible to also identify the risks of new technology.

Evaluation criteria: 5 = poor knowledge, 10 = excellent knowledge [18].

The other survey handled the content of the workshop. The survey was sent to the participants about 1 month after the workshop. The participants were asked how they later thought of the position of the workshop in their minds. The first questions dealt with the reliability and validity of the distributed information dealing with hydrogen and fuel cell technology. The participants were convinced that it was the latest and most up-to-date information they received. However, one researcher pointed out that private companies very often have the newest knowledge, but they are not willing to share it even with research organizations.

Self-evaluation of the level of knowledge, hydrogen and fuel cell technology	5	6	7	8	9	10	Av.
Estimated knowledge level before the FuTecRI workshop evaluated before the workshop	2	2	3	1		1	6.8
Estimated knowledge level before the FuTecRI workshop evaluated after the workshop	3	3	2	1			6.1
Estimated knowledge level after the FuTecRI workshop evaluated after the workshop			3	5	1		7.8

Table 1. The results of the survey dealing with the increase of knowledge in FuTecRI workshop.

The next questions concerned the functioning of the workshop. All participants were satisfied with the workshop proceedings. They felt that because of the small groups they were consulted and it was easy for them to bring their own knowledge into the process. The results of the brainstorming work were written directly on to a wide paper sheet where the main words were ready-written in the middle of the paper. This helped people to immediately start the brainstorming process, and the fear of the empty paper was tackled. The participants were very active in discussing the hydrogen and fuel cell technology, which was surprising to all.

7. Discussion

The FuTecRI method was developed to help authorities to be prepared for future technogenic risks introduced by new technologies. The use of the method requires effective stakeholder cooperation at least from authorities and scientists. The results may be even better if the companies developing new technology could also take part in the process. According to the results of the FuTecRI workshops, it is possible to steer the development of society toward a safe and secure future through the use of, for example, new regulations or improved land use planning.

To work well, the method should involve not only the authorities and other stakeholders but also researchers from academia and research institutes. It is especially important that the focus of the workshop, the new technology, is presented by special researchers who are specialist in the technology in question. Otherwise, the result of the workshop might be just guesswork and no future solutions can be built on it.

Because the FuTecRI method involves a large group of professionals and scientists, it is important that no workshops are performed in vain, because it will reduce the motivation to take part into the FuTecRI method. Therefore, the results of each workshop should be delivered to all essential authorities through their own information networks.

However, this kind of workshop works only as a starting point to manage the risks of new technologies. The method should be further developed to also produce guidelines on how to analyze the highlighted risks or take them into account in different kinds of processes, such as environmental or chemical licenses, or land use planning.

Acknowledgements

This research and article presents the main findings of the thesis of the author [18]. I am greatly thankful to the representatives of the Finnish authorities who helped me through this work and gave me valuable information. The work was carried out during the years 2012–2015, and it was not the main duty either for these authorities or for me. Because both parties also had other duties to perform, the collaboration was important to the success of this work.

http://dx.doi.org/10.5772/intechopen.70903

Author details

Riitta Molarius

Address all correspondence to: riitta.molarius@vtt.fi

Technical Research Centre of Finland, Ltd., Finland

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