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AN EXPERT PANEL APPROACH TO SUPPORT RISK-INFORMED DECISION MAKING

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ABSTRACT

The report describes the expert panel methodology developed for supporting risk-informed decision making. The aim of an expert panel is to achieve a balanced utilisation of information and expertise from several disciplines in decision-making including probabilistic safety assessment as one decision criterion. We also summarise the application of the methodology in the STUK's RI-ISI (Risk-Informed In-Service Inspection) pilot study, where the expert panel approach was used to combine the deterministic information on degradation mechanisms and probabilistic information on pipe break consequences. The expert panel served both as a critical review of the preliminary results and as a decision support for the final definition of risk categories of piping.

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FOREWORD

This study has been performed in the connection to the research project “Methods of risk analysis” (METRI) belonging to the Finnish nuclear energy research programme FINNUS. The work has been carried out at VTT Automation. The work was ordered and financed by the Radiation and Nuclear Safety Authority (STUK). We express our gratitude to Mr. Jouko Mononen, who acted as the co-ordinator of the study. Our warmest thanks are also due to Mr. Reino Virolainen and to the STUK's experts who participated in the RI-ISI expert panels.

1 INTRODUCTION

Regulatory bodies and nuclear utilities are increasingly interested in using the probabilistic safety assessment (PSA) results in decision making related to the operation and maintenance of nuclear power plants. Experiences show that risk-informed applications may lead to a simultaneous increase of safety and decrease of costs. When moving towards risk-informed regulation and plant operation, decision-making situations often involve expert opinions from several disciplines.

This report describes an expert panel approach developed for decision-making situations where probabilistic and deterministic information from various sources should be combined in order to achieve an optimal decision. The role of the expert panel is to synthesise the views of various experts and identify and characterise the uncertainties in their analyses. A structured approach is needed in order to find a balance and consensus between the arguments of experts representing different disciplines. An expert panel is also important in forcing the expert to discuss the bases of their argumentation among each other and the decision maker. The expert panel report, summarising the discussions and decisions from the panel sessions, is a document containing the bases for the decision, and is thus essential for the tractability and transparency of the decision process.

The expert panel approach was applied to the pilot study on risk informed in-service inspection (RI-ISI), conducted at STUK during 1998–1999 [1,2]. The aim of the study was to test the suitability of EPRI RI-ISI methodology [3] for helping regulatory decision making in Finland. In this application, the expert panel approach was used to assess the preliminary categorisation of piping segments of selected systems from Olkiluoto and Loviisa power plants.

The panel consisted of experts representing several areas such as process, structural and material engineering, in-service inspections, and PSA. Further, two external normative experts conducted the discussions and acted as facilitators in the panel. The aim of the panel was to discuss the justification behind the categorisation of segments, and to identify related uncertainties. The preliminary categorisation was verified and changes in segmentation and categorisation were identified. The panel process can be considered both as quality assurance of the results and as a decision support for the final categorisation of segments.

2 DESCRIPTION OF THE EXPERT PANEL APPROACH

Planning of activities like in-service inspection program or selection of accident management measures can be seen as a complex decision problem. In making such decisions, various kinds of expertise together with subjective assessments are utilised in order to evaluate the decision alternative against many, possibly conflicting criteria. In nuclear safety decisions, the criteria may be related to risks, measured e.g. by quantitative PSA results, consequences of accidents, properties of the process and materials, and costs. In some cases, the decision criteria are conflicting, and there are no decisions, which are best with respect to each decision objective. An important aim of the decisions is to find cost-effective approaches for improving and maintaining the safe operation of nuclear power plants.

Decision analysis is an approach for resolving difficult decision situations. It aims at modelling the subjective assessments of the decision-maker. During the course of a decision analysis, it is essential to distinguish decision goals and attributes, and the uncertainties related to the state of the nature and the outcomes of decisions. In other words, facts, their uncertainties and values related to the situation are identified. In addition to this, establishing a clear structure for the decision problem in hand is important.

A complete decision analysis requires also the construction of quantitative decision model for identifying the solution, which fulfils the goals and values of the decision-maker. From a practical point of view, a straightforward application of formal decision analysis is often too resource consuming, as the earlier experiments have shown (see e.g. [4]). However, in risk-informed decision making, a suitable format for group decision making is needed in order to structure the problem and find a balance between the risk-based and other criteria. It can also be expected that the discussion between experts reveal contradicting criteria, which can not be treated without a systematic approach.

When a safety critical decision situation is encountered, the first task is to identify the expertise needed in the analysis of the technical or other relevant issues and to decide what kind of analyses are made in order to solve the situation. Depending on the extent and nature of the decision problem, the expertise may come from many disciplines. Further, in the context of nuclear safety, the analyses needed include often studies of structural integrity, severe accident analyses, thermohydraulic considerations as well as extensive use of PSA results. In addition to analysts, the decision situation always involves a decision maker and referendary. The task of the decision maker is not only to make the final decision, but also to inform the experts about the significance of the decision and make clear the decision situation. The referendary is a kind of project leader, who organises the analysis work, proposes the decision possibilities and summarises the case under consideration to the decision maker. The collection of existing analyses and other relevant information is also the task of the referendary.

In general, the expert panel process may be started immediately, when a decision situation has been encountered. Then, as the first step, the experts participating to the process are selected and their analysis tasks are defined according to the requirements of the situation. However, it is more natural to start the expert panel process when the initial analyses have been made, and at least their preliminary results can be discussed.

In the following description of the approach, we assume that the technical experts have already been selected, and they have performed their analyses and formed their initial opinions on the subject. The role of the expert panel is to

Table I. *Role of participants in an expert panel process.*

	Decision Maker	Referendary	Technical Experts	Normative Expert
Problem Structuring	presents the strategic view and role of the decision	describes the case, selects the experts	(give detailed information if needed)*	familiarises with the case, structures the problem, proposes ranking criteria
Development of Formats		(comments the formats)	(comment the formats)	develops formats based on problem structuring
Preparation for Panel Session		prepares for presenting the case	fill the formats, summarise their own analyses	prepares for leading discussions
Panel Session	(observer, may take part in discussions)	presents the case, takes part in discussions	present their analyses, participate in discussions	leads discussions, facilitates communication between experts, takes notes
Reporting		comments and accepts the summary report	(comments the summary report)	summarises the discussions and results of the panel

* optional participation in parentheses

synthesise the views of various experts and identify and characterise the uncertainties in their analyses in order to find a balance and consensus between the possibly contradicting arguments of experts representing different disciplines. In addition to this, panel is important in forcing the expert to discuss the bases of their argumentation between other experts and decision maker. Further, the panel sessions serve as a tool for revealing new aspects that experts would not have considered without communicating together in a structured discussion.

To achieve a good basis for decisions, a decision-maker, a referendary (e.g. project leader), technical experts, and normative expert(s) should participate in the experts panels. The roles of these participants depend both on the case at hand and the resources available for discussions and additional work.

The expert panel process has the following basic steps: 1) structuring of the problem, 2) development of suitable formats for identifying the background for experts' judgements, related uncertainties and rationale of argumentation, 3) preparation for the panel session, 4) panel session(s), and 5) reporting of the results. If in the course of the panel session, needs for additional analyses or checks are identified, tasks are assigned for responsible experts and a new panel session is arranged after obtaining the complementary information. The roles of various participants in the steps of a typical expert panel process are described in Table I.

The first step of the expert panel process concentrates on the case description. The analyses made for solving the problem are discussed shortly, and the relevant information is distributed to the participants. The decision maker describes the safety significance of the case, and clarifies the decision criteria and objectives. The nature of the case is discussed and the normative expert structures the case following the principles of decision analysis. If necessary, the decision criteria and decision alternatives together with their ranking principles are defined.

The second step of the expert panel process is prepared mainly by the normative experts. The aim of this task is to create a format for the panel discussions and for documenting the views and results obtained by the technical experts. In order to obtain an appropriate and functional format, it is beneficial to let the technical experts comment the format. The format includes both the forms for the panel meetings and the documentation of the results. The documentation formats may be developed separately for different technical expertise areas, and their task is to present the results of technical analyses, to identify the most important assumptions and uncertainties of the analyses, to present explicitly the experts reasoning and its bases. The documentation and discussion format is case-dependent.

The panel meetings should be planned carefully. The technical experts document their analyses according to the agreed format, and summarise their analyses. It is important that the documentation is available in good time before the panel meeting, so that the normative expert and the referendary can plan the expert discussions, and ask for possible additional information.

The panel sessions are the core of the process. The technical experts present their analyses and views about the issue, and the normative experts facilitate and lead the communication between experts. The approach aims at some kind of rational consensus among experts, and thus it is essential to make the argumentation as clear as possible. In some cases, the assumptions behind certain analyses may be partially conflicting, and it is important that these points are discussed openly. Also, the limitations and restrictions of the analyses are discussed. In some cases, the analyses of one expert may be based on the results of other experts' analyses. In those cases it is important to check, whether the results and their limitations are understood properly.

The panel sessions aim at ranking of decision alternatives according to the criteria based on the different technical expertise. This ranking is made during the panel discussions, and the views from all experts are taken into account. Further, needs for additional analyses or information are identified, and persons responsible for making these additional studies are nominated.

The panel process ends with the final report of the discussions and findings. The reporting is based on the documentation formats created for the panel.

2.1 Application to RI-ISI

In the STUK-RI-ISI case study, two systems from both the Olkiluoto and Loviisa nuclear power plants were selected for evaluation. The systems were the high pressure injection system at Loviisa and the shutdown cooling system at Olkiluoto plant that are included in the present ASME programme, and the Loviisa emergency feed water system and the Olkiluoto service water system that are not covered by the ASME programme. In the evaluation, the piping of these systems were preliminary divided into segments and categorised. Although expertise from structural and material engineering, in-service inspections and PSA was the basis for this preliminary evaluation, there was initially no systematic interaction between the experts from various disciplines.

2.1.1. Structuring of the problem

In the RI-ISI pilot study performed at STUK, the EPRI RI-ISI approach was the basis for the analysis [1, 3]. In that approach, the decision problem, i.e. the classification of piping with respect to their safety significance and vulnerability to the degradation mechanisms, is structured by using a simple decision table (see Table II). In more specific way, the segments of piping are assigned into risk categories based on the probability of a pipe break occurring in the piping and the consequences of a break in that segment. Probability of a break is evaluated qualitatively on the bases of an assessment of the susceptibility of the piping to the degradation mechanisms known to effect such piping. The consequence of a pipe break is assessed by using the PSA model. The principal idea is to redefine the in-service inspection programme according to the risk importance of piping segments. The risk categories are presented in Table II. In the STUK RI-ISI case study, the pipe segments were identified prior to the expert panel process. The preliminary segmentation, together with the categorisation rules formed the structuring of the decision situation.

2.1.2 Development of formats for decision panel

The expert panel methodology was used to facilitate a structured re-evaluation of the preliminary segmentation and categorisation, and to achieve a balanced utilisation of deterministic information on degradation mechanisms and probabilistic information on pipe break consequences.

In this pilot study, the only decision made was the categorisation of piping segments of certain nuclear power plan systems. However, the expertise from several fields and the uncertainties involved in both evaluation of degradation potential and consequences of pipe failures make the problem complicated enough for application of simplified decision analytic methods.

Table II. *Risk matrix for pipe segments [4].*

Risk categories		LOW	MEDIUM	HIGH
	Consequence category			
Degradation category	**None**	**Low**	**Medium**	**High**
Large	LOW	MEDIUM	HIGH	HIGH
Small	LOW	LOW	MEDIUM	HIGH
None	LOW	LOW	LOW	MEDIUM

Specific forms were developed to collect in a condensed form the background information related to the categorisation of segments, and to the identify criteria and uncertainties related to the categorisation (see Appendix). The forms were discussed by the normative and technical experts and the referendary, and the issues to be addressed were clarified. In order to capture the most important characteristic of the problem, the following information needs for the review of the degradation potential classification were defined:

- *Description of possible degradation mechanism(s):* sensitivity for conditions, and possible knowledge on degradation rate
- *Influencing factors and their impact in the segment:* material properties, environmental stresses, transient history, geometry
- *Current inspection program and method:* accessibility, inspection method, earlier inspection results, limiting/ restricting factors, worker safety
- *resulted degradation category*

For the review of consequence categorisation, following questions were addressed:

- *Consequences of pipe failure and their models in PSA:* initiating event, CCI standby failure, demand failure, isolation of the leakage, degree of detail of PSA models
- *Uncertainties related to the conditional core damage probability (CCDP) quantification, CCDP estimate*
- *resulted consequence category*

The experts were provided with the forms in good time prior to the panel, so that they could collect the necessary information. In this case study, the filled forms were discussed at the panel sessions. In more complex decision cases, it would be beneficial to distribute the filled forms to the normative experts prior to the panels. The task of the normative experts would then be to check that the technical experts have addressed the issues in a proper way, and to identify issues for deeper discussion between the technical experts.

2.1.3 Panel sessions and reporting

The panel consisted of STUK's experts having knowledge of structural and material engineering, in-service inspections, plant processes and PSA. Further, two external normative experts conducted the discussions and acted as facilitators in the panel. The aim of the panel was to discuss the justification behind the categorisation of segments, and to identify possible needs for changes in the original segmentation and categorisation.

During the panel discussion, each segment was evaluated separately, and the experts were requested to identify the related degradation mechanisms and uncertainties related to the environmental conditions for each segment, according to the given format. In this connection, the existing in service inspections were reviewed and the factors influencing the effectiveness of inspection were discussed. The consequence evaluation was made by using the plant specific PSAs, and the assumptions and simplifications of the quantitative evaluation were considered in the panel. The normative experts tried to clarify the basis of the technical experts' argumentation. In this connection, it was ensured that the assumptions and results of different experts analyses were understood, and their impact on the final categorisation related was made as explicit as possible.

During the sessions, needs for additional analyses were identified, and the persons responsible for carrying out the analyses were nominated. When the additional analyses by technical experts were available, a summary panel was organised. The updated forms were checked and accepted by the referendary. The final reporting of the expert panel application consisted of a report summarising the panel discussions and the final versions of the filled forms.

3 EXPERIENCES FROM EXPERT PANELS

3.1 RI-ISI specific experiences

One of the major benefits of the expert panels was the identification of needs for complementary information for justifying the categorisation of segments. Some of these needs were quite generic and should be taken into account in possible new applications of the RI-ISI methodology. Other more specific needs were related to the analysis of systems in the pilot study.

As the experts were prepared to present their analyses to each other, the insights of various disciplines could be combined in a most useful way. For instance, within such a limited pilot study, the consequence evaluation did not consider the possible secondary effects of pipe breaks in detail. During the panel discussions, insights from process and material engineers helped in identifying and evaluating the most important secondary effects, e.g. impact of flooding or loose piping on nearby equipment. As another example, isolation valve failure probabilities used in the PSA were subjected to criticisms in case of abnormal conditions due to a break in the pipeline.

The panel discussions resulted also in practical recommendations for the plants. For instance, related to one segment, the correspondence of the pressure between testing and demand situations in the testing line were discussed in the panel. It was noticed that the pressure in demand situations of the system is probably significantly higher than during the test, and thus the risk for pipe failure is larger in demands. This has also an impact on PSA calculations where the CCDP is calculated basically with the real test interval. A leakage test was recommended in order to decrease the pipe break risk on demand.

The generic needs of background material that should be collected and analysed during the preparation of data for the segment categorisation were discussed. The panel process indicated that attention should have been given to the results of previous in-service inspections, which were not analysed in this pilot study. Also, the initial information should contain results of pre-operational system and component tests.

The segmentation according to the degradation potential was discussed in the panels. There were first some proposals to distinguish some individual welds as own segments. However, later on it was decided that no separation is needed because the original segmentation was considered sufficient according to the ASME code case N-578 [5]. Instead, within some segments, certain locations were identified as most important to be inspected. The segments were categorised conservatively if the information available was considered insufficient to reliably justify a lower category. In several cases, however, it was agreed that the degradation classification of segments could later be lowered depending on further investigations or e.g. results of additional vibration or temperature measurements.

The quantification of pipe break consequences with PSA analyses was problematic in some cases. One difficulty arose from the pipe break modelling of the Loviisa PSA, where all LOCA initiating events were assumed to occur in one redundancy of the plant piping. Further, the consequences could not be straightforwardly evaluated with the conditional core damage probability in the case of a system where a pipe break does not generally cause an initiating event. Although leakages in the system do not cause initiating events, they may have an impact on consequences if an initiating event requires the operation of this system. Thus, the CCDP was conditioned both on the occurrence of another initiating event and a pipe failure in this system. The approximate (and conservative) plant specific PSA-models prevented the exact calculation of these CCDPs, and some of the quantitative estimates could be seen only as relative indications of consequences of pipe breaks. Expert judgement was needed in determining the consequence categories, and this was discussed in the panel.

The panel discussed the categorisation adopted from the EPRI approach. The resolution with the consequence categories was felt too low in many cases. Further, in some cases the simple conditioning by the LOCA-initiating event was difficult and made the absolute evaluation impossible. To find a better categorisation rule, some sensitivity studies or even additional research may be needed. Another possibility is to determine the categorisation principles on case by case basis. This requires, however, calibration with other cases. Concerning the degradation categories, it was suggested that the division into four categories instead of three should be considered.

In the course of the panel sessions and after obtaining the complementary information requested by the panel, some changes in segmentation and categorisation were made. The panel proved to be an essential part of the RI-ISI pilot study, as it clarified the justifications behind the final risk categories and helped in reviewing and reporting the results of analyses.

3.2 Experiences relevant to risk-informed decision making

The RI-ISI case study discussed in this report was rather simple, and thus it is difficult to draw strong general conclusions on the basis of it. However, since the problem involved two different types of expertise (i.e. PSA and degradation mechanisms), some of the observations made during the expert panel process are relevant to more general risk-informed decision making process.

In this case the structuring of the problem and the rules for segment categorisation were given. The consequences were measured basically by quantitative PSA results, which were in some cases only comparative. The categorisation to low, medium etc. classes was made according given quantitative limits for the CCDP frequency. Another possibility would have been the use of PSA results directly, without any division to classes. A step towards this would have been the use of finer categorisation, i.e. use of more categories instead of the four applied here.

If the risk-informed decision making is looked from a larger perspective, it is important to compare the decisions and their safety consequences using similar or comparable probabilistic criteria for all kinds of decisions. In order to obtain a balanced view over different safety issues, the use of absolute PSA results is beneficial, provided that the uncertainties and assumptions behind the results are identified and documented. Thus, a consistent set of comparable probabilistic and deterministic decision criteria, or even consistent decision hierarchy, is needed. To reach this kind of decision machinery, the criteria should be developed further and their properties should be evaluated by using decision theoretic tools. Furthermore, much more experience from practical use of such criteria in different contexts would be beneficial.

Although a holistic view on all safety related decisions would, in principle, lead to a well balanced solutions, it may not be possible in practice due to the complexity of the plant and different analyses. Further, other regulatory requirements may necessitate a separate treatment of various issues. Often, exactly similar PSA-based criteria do not fit to the different cases. For example, it was necessary to apply the conditional core damage probability instead of the usual core damage frequency in the case study. Thus the straightforward use of PSA results may be misleading. As observed in the case study, the existing PSA model is sometimes insufficient to describe the safety significance of decisions under consideration. The issue may not be described in the PSA model at all (e.g. the lack of flood PSA to describe the impact of leaking water on reliability of safety systems, or the time dependent stand-by failure modes not taken into account explicitly in PSA). Another possibility is that the PSA model uses approximations or simplifications, which prevent the proper analysis (e.g. the location of pipe breaks is not included in PSA model).

One can say that the use of PSA in risk-informed decision making must be compatible with the PSA model. The PSA model must have sufficient degree of detail, and it must say something about the phenomena related to the decision issue. In order to see whether PSA model is compatible with the decisions, one must be able to analyse the assumptions behind the PSA model and their dependence on the decision issue. At the same time, one must be able to critically evaluate the uncertainty in PSA. This sets strong requirements on the documentation of PSA. At the same time, the PSA tool (i.e. the computer code) must be flexible and the model enough simple to make for example, sensitivity analyses possible.

In the case study, the PSA results and the degradation mechanisms were rather independent on each other, which made the analysis relatively easy. This is not the case when e.g. accident management decisions are considered. In these more difficult cases, the assumptions made by one analysis may be contradictory with those made in another. Similarly, the uncertainties within different analyses may be strongly inter-related. Well structured expert panel approach would identify this kind of problems, and thus they may be recommended.

4 CONCLUSIONS

The application of risk informed principles aims at using PSA together with deterministic analyses in making safety related decisions. This requires not only the straightforward comparison of quantitative risk estimates and results of deterministic calculations, but also a structured decision analytic view on the problem at hand, and balanced combination of expertise from several technical areas. In addition to this, also the impact of related uncertainties must be evaluated. In this report, a simplified decision analytic procedure for resolving the above issues, based on expert panel approach, was discussed.

The developed expert panel approach was applied to the pilot study on risk informed in-service inspection (RI-ISI), conducted at STUK. The approach enabled a structured discussion between experts from several disciplines, which was felt very useful. In the course of the panel sessions, the expert judgements were carefully evaluated with an emphasis on identifying uncertainties in different kind of analyses. Thus, the expert panel approach was also seen as an inter-disciplinary quality audit of the different analyses, which is a very important feature.

The expert panel application generated observations relevant to risk-informed decision making. Although the decision criteria in the case study were partially qualitative, the need for more quantitative criteria was identified. Extensive application of risk-informed principles calls for a consistent and comparable set of PSA-based probabilistic criteria. The consistency and comparability of criteria should, however, be demonstrated by decision theoretic analysis and by experiences from practical cases.

Often, PSA results cannot be used directly, since the decision maker and other experts may not know the limitations, uncertainties and assumptions of the PSA model. The expert panel approach aims at identification and documentation of these critical issues. In addition to this, it forces the expert to communicate their argumentation to each other, which is an essential step towards risk informed decision making and enhanced safety culture.

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APPENDIX

FORMS USED IN THE RI-ISI EXPERT PANEL APPLICATION FOR COLLECTING BACKGROUND INFORMATION

Example of degradation severity evaluation.

	Background information for judgement			
SEGMENT	**Possible degradation mechanism(s)** (sensitivity for conditions, degr. rate?)	**Influencing factors and their impact in the segment:** -material properties, environmental stressors transient history, geometry	**Current inspection programme and method** uncertainties (accessibility, inspection method, etc.) earlier inspection results, limiting/ restricting factors, worker safety	**resulted degradation category**
321-AI 321-HI	thermal stresses	Penetrations are difficult areas due to stresses, old steel in the penetrations (AI: cc 0,042-0,043; HI: cc 0,046), otherwise the piping is of better material. Thermal stresses in the penetrations are not a problem unless there occurs sudden changes in temperature.	Inspection intervals 3 y. (outer) and 5 y. (inner). Penetrations can not be inspected	**L -> M** (division into two segments due to consequences)

Example of consequence evaluation

	Background information for judgement			
SEGMENT	**Consequences of pipe failure and their models in PSA** (initiating event, CCI standby failure, demand failure, isolation of the leakage, degree of detail of PSA models)	**Uncertainties related to CCDP quantification**	CCDP	resulted consequence category
321-AI 321-HI	Consequences are different depending on whether the pipe break occurs inside or outside the containment	If the pipe breaks near the valve, the valve operation may be highly uncertain (in PSA calculations the failure probability on demand of an isolation valve is $1,5x10^{-3}$). There are deficiencies in the design of supports near penetrations which increase the risk for missiles. If the inner isolation valve does not close and the leakage is locates outside containment, water is lost outside containment and the consequences are more serious **-> segment should be divided into two segments** In the current PSA, the possibility to retain the water inventory in the case of leakage outside containment is not modelled.	$4,6x10^{-5}$ (>$4,6x10^{-5}$?), releases, PSA level 2 problem	outside containment: **M -> H** inside containment M