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Black swans
Improved risk assessment to better reflect the knowledge dimension and surprises

Report 2015
Status
Plans for 2016

Terje Aven
Innhold

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1 Introduction

This report reviews the activities for the Black swan project for 2015, and outlines plans for 2016.

2 Goals

The primary objective of the project is to develop a new practical framework for the proper understanding and assessment of risk, in particular major accident risk, for the Norwegian petroleum activities, that gives due attention to the knowledge dimension and surprises.

Secondary objectives:

- Establish a theoretical platform and conceptual clarity
- Provide an assessment and recommendations on how to use alternative quantitative approaches (including probability-bound analysis, imprecise probabilities, possibility theory, evidence theory) in the industry
- Provide an assessment and recommendations on how to use qualitative approaches in the industry in relation to quantitative risk assessments
- Establish suitable approaches and methods linked to different decision-making situations
- Publish minimum 15 papers in international peer-reviewed journals.

The goals for the period 2015 have been met:

1. More than 15 papers published or accepted for publication in international journals with review. See separate list in Section 4.
2. Many presentations at international scientific conferences. See list in Section 4.
3. Several PhD students are (have been) linked to the project but not funded from the project: Henning Veland (UiS) (defended his thesis June 2014), Christine L. Berner (UiS), Torbjørn Bjerga (UIS), Gelyani A (UiS) (defended his thesis in December 2014), Jahon Khorsandi (UiS), Øystein Amundrud (UiS), Anders Jensen (UiS), Ingrid Årstad (UiS) and Kjartan Bjørsen (UiS). Several relevant master theses have also been conducted. See list in Section 4.
4. For scientific results, see Section 3

3 Research

The research is divided into the following main research tasks (activities):
1 Study of the risk assessment context and various decision-making settings (S1)
2 Establishing a theoretical platform and conceptual clarity (S2)
3 Assessing and providing recommendations on how to use alternative quantitative approaches (S3)
4 Assessing and providing recommendations on how to use qualitative approaches (S4)
5 Development of the practical framework (S5)
6 Testing the framework on some cases (S6)

In the following we give a brief summary of the work performed for these tasks in 2015. The two first tasks are seen as one, so are the third and fourth, and the two last tasks. Focus areas for the coming research are also highlighted.

### 3.1 Foundational issues (S1 and S2)

For the successful realisation of the project, it is essential to develop a proper foundation for the framework. This includes in particular a unifying methodological basis. By this we mean some common pillars for the research, without restricting the use of different approaches and paradigms when appropriate.

The work for 2015 is summarised in the following selected book/paper abstracts:

**Ignoring scenarios in risk assessments: understanding the issue and improving current practice**

In risk assessment we are typically faced with a huge number of potential scenarios and events, and in practice some of these are ignored, either because they are not identified or because of judged low probability. However, a scenario or an event may occur despite being extremely unlikely. Considering a large population of such scenarios and events, the occurrence probability is not necessarily negligible. In this paper we take a closer look at this challenge, the main aims being to clarify the issue and provide some recommendation on how to best handle it in practice. A main conclusion is that the risk assessment should be placed in a sufficiently broad framework, ensuring that the outcome and main event spaces are complete, and sufficient focus is placed on the hypotheses and assumptions supporting the detailed scenarios that are identified.

**Quality of risk assessment: definition and verification**

The quality of a risk assessment stands on its meeting some “scientific criteria” and on its “being useful” in a decision making context. In this perspective paper, we reflect on this, analysing what these criteria should be and how “useful” should be interpreted. We bring new insights into the topic by considering two novel aspects: a) the modern view of risk assessment which shifts the focus from the accurate risk estimation to the characterization of knowledge and lack of knowledge, and b) the recognition that decision makers need to go beyond the conditional risk as described and assessed by the risk analysts and experts, to consider unconditional risk. We, then, consider the quality of risk assessment within the context of a) and b), addressing the questions of what it depends
on, how it can be guaranteed and how it can be checked. A main conclusion is that the current practice of risk assessment needs to be improved, in particular with respect to the way knowledge and lack of knowledge is understood and communicated.

On the use of conservatism in risk assessments

It is common to use conservatism in risk assessments, replacing uncertain quantities with values that lead to a higher level of risk. It is argued that the approach represents a practical method for dealing with uncertainties and lack of knowledge in risk assessment. If the computed probabilities meet the pre-defined criteria with the conservative quantities, there is strong support for the “real risk” to meet these criteria. In this paper we look more closely into this practice, the main aims being to clarify what it actually means and what the implications are, as well as providing some recommendations. The paper concludes that conservatism should be avoided in risk assessments – “best judgements” should be the ruling thinking, to allow for meaningful comparisons of options. By incorporating sensitivity analyses and strength of knowledge judgements for the background knowledge on which the assigned probabilities are based, the robustness of the conclusions can be more adequately assessed.

Risk assessment and risk management: review of recent advances on their foundation

Risk assessment and management was established as a scientific field some 30-40 years ago. Principles and methods were developed for how to conceptualise, assess and manage risk. These principles and methods represent to large extent also the foundation of this field today, but many advances have been made, linked to both theoretical platform and practical models and procedures. The purpose of the paper is to perform a review of these advances having a special focus on the fundamental ideas and thinking that these are based on. We have looked for trends in perspectives and approaches, and we also reflect on where further development of the risk field are needed and should be encouraged. The paper is written for readers with different types of background, not only experts on risk.

CRITICAL SLOWING DOWN FRAMEWORK FOR DEVELOPING EARLY WARNING SIGNS OF SURPRISING/UNFORESEEN EVENTS IN COMPLEX SYSTEMS

A description of risk is fundamentally linked to the background knowledge about the system behavior and associated modeling assumptions. However, the validity of these assumptions are difficult to express, but need to be addressed to adequately understand, assess and manage risk, in particular the risk related to potential surprises and unforeseen events. This paper presents a general framework for developing measures that can provide the information about the dynamic stability of the system behavior based on observations, the aim being to better read signals and warnings. The framework is based on the concept of the statistical signature of the critical slowing down and utilizes time series and signal processing methods. Several examples are included to illustrate the application of the framework.
An enhanced framework for integrating risk management and performance management

There is increasing interest for agencies and industries to develop risk management processes for a wide variety of applications. Traditional risk management processes are motivated by controlling risk and avoiding losses. In contrast, other organizational processes focus on managing performance and value generation. In this paper we argue that risk management also adds an important contribution to these processes. However, this requires “proper” risk management extending beyond narrow safety oriented perspectives built on quantitative risk analysis and tolerability/acceptance criteria. There is need for a broad risk-performance framework with uncertainty being a main component of risk, and where knowledge and surprises are adequately reflected. In the paper we present and discuss such a framework. The framework is developed on the basis of an analysis of combinations of different risk management and performance management practices/policies. We show how the risk and performance management processes can be improved by proper risk conceptualization and a holistic thinking on how to develop and use goals in the organization, how to balance different concerns, and consider the need for agility – “sensitivity to operations”, as well as how to give weight to vulnerabilities, resilience, and antifragility.

On the appropriateness of using the ALARP principle in safety management

In this paper we discuss the appropriateness of using the ALARP (As Low As Reasonably Practicable) principle in safety management. We show that ALARP can be an appropriate ruling principle in safety management but only if the grossly disproportionate criterion is interpreted differently for different decision-making contexts. The ALARP principle should be interpreted such that it ranges from one extreme, where decisions are made with reference to expected values in some decision contexts, to another, in which the cautionary principle is adopted with no reference to cost-benefit analyses for others. A static interpretation of the grossly disproportionate criterion is not appropriate.

3.1.1 Focus areas for 2016

The research will continue to study fundamental issues related to risk, surprises and black swans, with a special focus on the link between knowledge and risk.

Examples of planned work:

Aven T & Flage R. Assumptions in quantitative risk assessments: when explicit and when tacit?

In a quantitative risk assessment a number of assumptions have to be made in order to compute the risk metrics addressed. Such assumptions may for example be linked to the number of people exposed to specific hazards, the reliability of a safety system and the load a wall is able to withstand. In addition there are more or less tacit assumptions, for example when making a probability judgment about an event to occur. The probability
judgment is based on some knowledge - which essentially captures data, information and justified beliefs - and here tacit assumptions may exist even if explicit assumptions have not be formulated, for example a belief about how the system works. The risk metrics are conditional on this background knowledge and these assumptions, and the strength of this knowledge and the “risk” related to potential deviations in the assumptions then need attention. This paper discusses this topic, the main aims being to clarify the issues raised and to provide some guidance on how to formulate the background knowledge to distinguish between explicit and non-explicit (tacit) assumptions.

Aven, T. and Ylönen, M. The enigma of knowledge in the risk field

In recent years we have seen a growing interest for the knowledge dimension in risk settings. The interest has been motivated by developments within the fields of risk assessment and risk management, which have highlighted the important role that knowledge plays in probabilistic risk analysis. Schemes for characterizations of strong and weak knowledge for the probabilities have been suggested. In this paper we reflect on how the knowledge concept used in this context matches the wealth of studies on knowledge that we find in philosophy and sociology. We question if the risk field can learn from these studies and further develop the knowledge dimension in risk assessment and management. The aim of the paper is to provide new insights on these issues and in this way strengthen the foundation of risk analysis and improve its practice. The paper will address both epistemological and ontological issues related to knowledge, and provide reflections of the suitability/unsuitability of various conceptualisations of the knowledge concept in a risk context.

3.1.2 Scientific collaboration

The project is carried out in collaboration with the professors Ortwin Renn (Germany), Enrico Zio (France and Italy), Seth Guikema (USA), Ivan Damnjanovic (USA), Marja Ylonen (Finland), among others.
3.2 Approaches and Methods (S3 and S4)

These subtasks are concerned about developing new methodology for conceptualisation, assessment and management of risk and the unforeseen. The work for 2015 is summarised in the following selected paper abstracts:

Replacing quantitative risk assessments with a two-stage approach where the second stage addresses unconditional risk

A quantitative probabilistic risk assessment produces a conditional risk description given the knowledge of the analysts (formulated to a large extent through assumptions). However, the management and decision makers need to relate to the unconditional risk. Important aspects of the risk may be concealed in the background knowledge of the analyst and the assumptions. In this paper we discuss this issue, the main aim being to present a two-stage risk assessment approach where the second stage addresses unconditional risk and relates to the decision alternatives of the decision maker. This second-stage approach is to a large extent qualitative with the use of checklists and is based on interactions between the analysts and the decision makers. Examples are used to illustrate the method.

Risk assessment with broad uncertainty and knowledge characterisations: A case study of a university master study program in risk management

This paper presents a risk assessment, including the planning and use stages, of a university master program in risk management, highlighting challenges related to issues like student recruitment, quality of study program, quality of graduates, job opportunities for graduates, and teaching and supervision capabilities. The assessment is to support decision making on how to best develop the program in the coming years. The aim of the paper is to apply this case to show how a risk assessment can be conducted and used when risk perspectives are adopted which highlight knowledge and uncertainty characterisations that go beyond the standard approach based on probability modelling and estimations. Such perspectives have been given considerable attention recently, and real life examples have been sought showing the practical implications of these perspectives. The example is simple and allows for clarifying discussions of critical aspects of the analysis process, including goal setting; risk conceptualisation and measurements; the need for quantification (using for example probability); treatment of uncertainties; characterisations of the knowledge available; potential for surprises; vulnerability, robustness and resilience considerations, and continuous improvement. It is concluded that with integration of the new ideas from the early planning stages, the risk assessment is not more difficult to run than for the traditional approach; the decision process is however in our view substantially improved as the decision makers are better informed on many of the aspects important for the decisions to be made.
A decision support method for prioritizing investments subject to uncertainties using strength of knowledge and target sensitivity analysis: An application for emergency management investments

Decision making for risk problems needs to consider uncertainties in future consequences of alternative arrangements, investments, and mitigation policies. Current thinking for assessing these uncertainties and their importance in the decision making process is based on a probabilistic perspective and decision analysis, including evidence combined with multi-criteria scenario analysis. This thinking needs to be further developed to reflect the strength of knowledge (SoK) for fundamental assumptions. The paper presents a new method for prioritizing investments with consideration of the most influential uncertainties from the decision point of view, thereby allowing for systematic SoK considerations. The illustrated multi-criteria priority setting approach concurrently evaluates future uncertainties with utilization of target sensitivity decision support. The method is demonstrated on an emergency management system that is vulnerable to future economic, environmental, and political factors.

Hazard/threat identification – using different creative methods to support the Anticipatory Failure Determination approach

An essential part of risk analysis is to identify possible harmful events. One approach for this purpose is the Anticipatory Failure Determination (AFD) method, which is based on I-TRIZ – a theory of inventive problem solving. In this paper, we look into possible ways of extending the AFD method by basing it on a broader set of alternative creative methods. We develop an integrated approach which we illustrate with an example using the Osborn-Parnes problem-solving model as creativity method.

On the need for rethinking current practice which highlights goal achievement risk in an enterprise context

This paper addresses the issue of how performance and risk management can complement each other in order to enhance the management of an enterprise. Often we see that risk management focuses on goal achievements and not the enterprise risk related to its activities in the value chain. The statement “no goal, no risk” is a common misconception. The main aim of the paper is to present a normative model for describing the links between performance and risk, and to use this model to give recommendations on how to best structure and plan the management of an enterprise in situations involving risk and uncertainties. The model which has several novel features is based on the interaction between different types of risk management (enterprise risk management, task risk management and personal risk management) and a structure where the enterprise risk management overrules both the task and personal risk management. To illustrate the model we use the metaphor of a ship, where the ship is loaded with cash-generating activities and has a direction over time determined by the overall strategic objectives. Compared to the current enterprise risk management practice, the model and related
analysis are founded on a new perspective on risk, highlighting knowledge and uncertainties beyond probabilities.

**The capability concept – On how to define and describe capability in relation to risk, vulnerability and resilience**

Capabilities-based planning and capability assessment are high on the agendas of several countries and organisations as part of their risk management and emergency preparedness. Despite this, few definitions of capability exist, and they are not easily related to concepts such as risk, vulnerability and resilience. The aim of the present study was thus to broaden the scientific basis of the risk field to also include the concept of capability. The proposed definition is based on a recently developed risk framework, and we define capability as the uncertainty about and the severity of the consequences of an activity given the occurrence of the initiating event and the performed task. We provide examples of how the response capability for a fictive scenario can be described using this definition, and illustrate how our definition can be used to analyse capability assessments prepared according to the Swedish crisis management system. We have analysed the content of 25 capability assessments produced in 2011 by stakeholders on local, regional and national level. It was concluded that none addressed uncertainty to any appreciable extent, and only a third described capability in terms of consequences and task, making it difficult to relate these capability assessments to risk assessments.

**Combined analysis of unique and repetitive events in quantitative risk assessment**

For risk assessment to be a relevant tool in the study of any type of system or activity, it needs to be based on a framework that allows for jointly analysing both unique and repetitive events. Separately, unique events may be handled by predictive probability assignments on the events, and repetitive events with unknown/uncertain frequencies are typically handled by the probability of frequency (or Bayesian) approach. Regardless of the nature of the events involved, there may be a problem with imprecision in the probability assignments. Several uncertainty representations with the interpretation of lower and upper probability have been developed for reflecting such imprecision. In particular, several methods exist for jointly propagating precise and imprecise probabilistic input in the probability of frequency setting. In the present position paper we outline a framework for the combined analysis of unique and repetitive events in quantitative risk assessment using both precise and imprecise probability. In particular, we extend an existing method for jointly propagating probabilistic and possibilistic input by relaxing the assumption that all events involved have frequentist probabilities; instead we assume that frequentist probabilities may be introduced for some but not all events involved, i.e. some events are assumed to be unique and require predictive – possibly imprecise – probabilistic assignments, i.e. subjective probability assignments on the unique events without introducing underlying frequentist probabilities for these. A numerical example related to environmental risk assessment of the drilling of an oil well is included to illustrate the application of the resulting method.
A note on the layered approach for implementing ALARP and the grossly disproportionate criterion

In this note we discuss what the implications are for safety management of using a recently suggested layered approach for implementing the ALARP principle. We show that the weight given to risk reduction and uncertainties largely depends on the interpretation of this approach. One way of interpreting the approach is that the ALARP principle gives strong weight to the uncertainties for all decision-making contexts. Another way to interpret the approach is that the ALARP principle may range from one extreme, where decisions are made with reference to an expected value with limited or no weight on the cautionary principle for some decision contexts, to another, in which the cautionary principle is adopted without any reference to cost-benefit (cost-effectiveness) analyses for others.

An improved method to express risk level and detect trends in risks in the Norwegian petroleum industry

In this paper we review and discuss aspects of the current method used by the Norwegian Petroleum Safety Authority to express risk level and detect trends in risks in the Norwegian petroleum industry. We show that this method to trend analysis could be improved. The main analytical problem is that issues such as strength-of-knowledge and robustness in the conclusions are not systematically described and dealt with. To contribute to the ability to achieve more informed decisions upon risk levels and trends, we suggest incorporating assessments of strength-of-knowledge and robustness. A more consistent and transparent decision-making process is then achieved. An example is included to illustrate our main points.

Prioritizing of safety measures in land use planning. On how to merge a risk-based approach with a cost-benefit analysis approach

The Norwegian Water Resources and Energy Directorate (NVE) is a governmental body, which i.a. seeks to improve society's ability to deal with floods and landslides. The NVE is required by the national government and the Norwegian parliament to prioritize flood defences and avalanche damage in those situations considered of highest risk. At the same time, the NVE should also prioritize safety measures with reference to cost-effectiveness. Within the NVE, prioritizing safety measures with reference to risk and to cost-effectiveness is stated as challenging, and in some situations contradictory. To improve this situation, and to contribute to the ability to achieve more informed decisions upon prioritizing of safety measures against floods and landslides, we have in this paper developed a semi-quantitative approach which incorporates assessments of both risk and cost-effectiveness. A more consistent and transparent decision-making process is then achieved. An example is included to illustrate our ideas.

3.2.1 Further plans

The activities will continue the work from 2015, highlighting approaches and methods that can improve the way the knowledge and surprise dimensions are reflected in risk assessment and management. The activity is closely linked to the applications studied in Section 3.3.
Examples of planned work:

Berner CL & Flage R. Potential uses and limitations in the use of the NUSAP uncertainty and quality assessment scheme in semi-quantitative risk assessment.

Berner CL, Aven T, Ferson S & Flage R. A comparison between a probability bound analysis and a traditional subjective probability approach to express epistemic uncertainties in a risk assessment context – a simple illustrative example.

Aven T & Flage R. A qualitative dynamic risk assessment approach for emerging risk management.

3.2.2 Scientific cooperation

As for the activities in Section 3.1.
3.3 Applications (S5 and S6)

This work has an applied testing perspective, and is based on case studies, in collaboration with ConocoPhillips and Safetec Nordic.

Arbeid i 2014 og første del av 2015 er oppsummert i dette abstraktet:

Uncertainty and strength of knowledge in QRAs

Quantitative risk analyses (QRAs) often form part of the basis for decision making for oil and gas installations, e.g. during platform design, during modifications and in identifying cost-effective, risk reducing measures. In order to provide an informed basis for decision making, many authors have highlighted the importance of seeing the results of risk assessments in view of the assumptions made, i.e. understanding how the assumptions affect the risk assessment. As a QRA normally comprises a long list of assumptions and other premises, it is a challenge to provide an easy-to-understand overview of these premises. This paper propose to use a schematic denoted a “map of premises”. The map highlights and summarizes in a new way the risk linked to the premises of the analysis, by reflecting the strength of knowledge aspect of risk. The method is demonstrated by an example for establishing dimensioning fire duration on an offshore oil platform

Arbeid i andre halvdel av 2015:

Risikoanalysen i designfasen er en stor og omfattende analyse, som dekker alle hendelser som kan medføre omkomne på en offshore olje- og gassinnretning. Formålet med risikoanalysen er å gi innspill til design av barrierer og å dokumentere et forsvarlig risikonivå. Men ofte er man godt innenfor akseptabelt risikonivå. Dessuten er det flere minimumskrav i regelverk og standarder som bestemmer designet av barrierene. Hensikten med dette prosjektet er å kartlegge og diskutere:

- Hvordan påvirker risikoanalysen design av innretningen?
- Kan vi fokusere på de delene av risikoanalysen som påvirker design, og ha en grovere vurdering av de delene som ikke har påvirkning på design?
- Hvordan påvirker dagens «1E-4-regime» design av en innretning og hvilke alternative mål er hensiktmessig å bruke for akseptabel risiko?

Prosjektet vil ta utgangspunkt i et utbyggingsprosjekt for en innretning som er designet de siste årene. Input vil være QRA for ulike designfaser for innretningen, samt mulighet for intervju av sentrale deltakere i prosjektet. Målet med prosjektet er å finne alternative måter å gjennomføre og utforme risikoanalyser som beslutningsstøtte i designfasen av en innretning. Prosjektet vil i tillegg diskutere relevante aspekter i driftsfasen.

Strengthening quantitative risk assessments by systematic treatment of uncertain assumptions

The results of quantitative risk assessments (QRA) are conditional on the background knowledge on which the assessments are based, including phenomenological understanding, models, data and expert statements used, as well as assumptions made. Risk indices established in the risk assessment, such as individual risk numbers and f-N curves, may have a more or less solid foundation, depending for example on the validity of assumptions made. Poor models, lack of data or simplistic assumptions are examples
of potential sources of uncertainty “hidden in the background knowledge” of a risk assessment. These uncertainties need to be reflected in the risk assessment. Recently, a method for treating uncertain assumptions in a QRA was suggested. The method is based on the different settings faced when making assumptions in risk assessments, considering beliefs about assumption deviation, sensitivity of the risk index to changes in the assumption, and the overall strength of knowledge involved. In the present paper we apply, test and adjust the method using a risk assessment of a lifting operation related to the oil and gas industry as a case. We find that an adjusted version of the method provides systematic guidance on how to treat uncertainties in a QRA.

**Further plans**

The work is planned to continue in 2016, on the basis of the work carried out in 2014-2015. This work will be carried out in close collaboration with the Norwegian Oil and Gas project Enhanced Risk Understanding. Workshop will be organised by this project, and these will provide input to this petromaks 2 project. A large conference is also planned in 2016.

**4 Publications. Papers**

**Books**


**PhD Theses**

Henning Veland (UiS) and Gelyani A (UiS) have defended their theses, both working on topics relevant for the project.

**International scientific journal papers with review. Published**


Submitted (or under revision) papers:


Abrahamsen EB, Abrahamsen HB, Selvik JT. 2015. On the appropriateness of using the ALARP principle in safety management.


Khorsandi, J. and Aven, T. (2014) From Surprises to Black Swans: Three levels of treatment drawing on lessons from High Reliability Theory 


Flage R & Askeland T. On uncertainty and imprecision in relation to quantitative risk assessment.
Flage R, Aven T & Dubois D. Combined analysis of repetitive and unique events in a lower and upper probability framework.

Berner CL, Staid A, Guikema SD & Flage R. Can model simulations be used to reduce the domain of black swans?


**Book chapters**


**Papers presented at international conferences, with full paper proceedings (with review)**


Presentation at international scientific conferences, workshops, etc.

Aven, T.: 
- Plenary talk ESREL 2015, Zurich, 8th September. Uncertainties in risk assessments.
- Keynote speaker and panel participant Risk field. SRA-Nordic 16-17 Lund Sweden.
- Invited Speaker Risk Series, Sandia National Laboratories, USA, 25th June 2015
- Invited talk at University Lausanne, Switzerland. How to define and interpret a probability in a risk and safety setting? 22/4-15.
- Invited speaker Metropol, København, Denmark, Black swans, 28 May, 2015.

Society of Risk Analysis annual meeting Denver, US, 8-10 December 2014
- Some reflections on uncertainty treatment in risk analysis Aven T University of Stavanger, Norway
- Risk analysis under deep uncertainty: a methodological comparison Shortridge JE, Aven T, Guikema SD Johns Hopkins University
- The complexity of critical infrastructures and the risk of black swans: some foundational reflections Bjerga T, Zio E, Aven T University of Stavanger, Ecole Central Paris- Supelec and Politecnico di Milano
• Can model simulations be used to reduce the domain of black swans? Berner CL, Flage R, Guikema S University of Stavanger and Johns Hopkins University
• A new SRA glossary for risk terminology Aven T University of Stavanger, Norway
• Defining emerging risk Flage R, Aven T University of Stavanger

Several talks are planned at the SRA annual meeting in December 2015. Also a roundtable on the topic is planned.

Other contributions

Master theses


Solbakk, M (2014) Selvorganisering i komplekse systemer og sammenhengen til sorte svaner. UiS.


E. Sunday, (2014) Extension and modification of Anticipatory Failure Determination approaches based on I-TRIZ. UiS