SAFETY PERFORMANCE INDICATORS FOR NUCLEAR POWER PLANTS[1]

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Abstract: This paper contains a discussion of the use of safety performance indicators at nuclear power plants. The aim is to provide a view on how management, organisation and safety culture can be included into safety performance indicators. The paper starts with a discussion of how safety is constructed in activities and practices. The task of managing nuclear power plants is considered using the loop of strategy formulation, communication, planning and feedback. After that the use of various organisational support systems is discussed briefly. The concept of safety culture is introduced and reference to some recent studies is given. The use of performance indicators as a management tool is discussed in more detail. The main argument is that performance indicators to be an efficient tool should be integrated into the management system, which is used in the organisation. The last main part of the paper gives brief answers to a set of questions discussed at the workshop. The conclusion of the paper is that a consideration of performance indicators is a worthy exercise, but that due consideration should be given to the complexity of the task of managing people and organisations.

1 INTRODUCTION

Safety Performance Indicators (SPI) have been proposed as a tool to support the evaluation of safety at nuclear power plants. A set of well-chosen safety performance indicators can be of large help both in monitoring safety and in reacting on possible degradations of safety performance. Both utilities and regulators have initiated activities to find suitable safety performance indicators, but no conclusion has so far been reached on which indicators to use.

Within the Nordic Safety Research (NKS) safety indicators were discussed already many years ago (cf. [1], [2]). This discussion was continued at a seminar arranged in 1999 [3]. At that seminar a research project funded by SKI was also described [4]. IAEA has in a recent report described the pilot implementation of safety performance indicators at four nuclear power plants [5]. Nuclear regulators have also found it useful to create safety performance indicators to support their regulatory oversight programmes [6].

The need to address the influence of organisational factors on safety has been recognised and discussed [7], [8]. This need was addressed in another project LearnSafe[2] also funded by the European Union [9]. The present paper has been built on results from these projects and on various tasks commissioned by the nuclear utilities and regulators in Finland and Sweden.

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[2] Learning Organisations for Nuclear Safety, contract number FIKS-CT-2001-00162. The project has established an open web-site at http://www.vtt.fi/virtual/learnsafe/ for providing information on progress.

The intent with the paper is to discuss how the influence of management, organisation and safety culture can be included in safety performance indicatorsto be used by nuclear utilities and regulators. This is done through a brief discussion of how safety is achieved at the nuclear power plants. Then some aspects of the management of nuclear power plant are brought up. Organisational support systems are introduced with a few examples. The concept of safety culture is discussed together with references to some recent reports. The use of performance indicators in the management of organisations is discussed in more detail. In the final main section of the paper ten questions given to the participants before the seminar are commented briefly. The conclusion of the paper is that a discussion of safety performance indicators is important, but due care should be exercised not to use too simplistic models in the use of safety performance indicators.

2 THE CONSTRUCTION OF SAFETY

A discussion of safety performance indicators has to rely on an understanding of how safety is achieved at the nuclear power plants. Safety can be characterised by an absence of risks, which means that threats are known and have been acted upon in a proper way. In practice this implies that the basic safety principles of prevention, control, protection and mitigation of possible threats have been applied to erect defences and barriers for unwanted courses of events. These defences and barriers could be both physical and administrative. A typical characteristic is that they for their function rely on several preconditions that have to be maintained.

From a safety management point of view safety relies not only on the technical preconditions, but also on the personnel and the organisation. A necessary precondition for safety is that the plant and its technical systems are in a good condition, but to achieve that the personnel has to be well trained and committed and the organisation has to be well structured with a clear division of authority and responsibility. Safety management can thus be defined to include all work processes, activities and tasks that are needed to maintain these preconditions.

According to common practices there are two main actors, the operator of the nuclear power plant and the regulator, which have their own roles in the continuous quest to maintain safety. The operator has the full responsibility for safe operation and is in addition obliged to provide necessary evidence that this precondition is fulfilled. The regulator acts on behalf of the society in a task of both issuing safety requirements and inspecting that they are followed. If safety regulations are not followed or if necessary evidence cannot be produced that the plants are safe, the regulator can require the plant to be shut down.

Another way to look at the construction of safety is to consider accidents and their causes. According to common understanding it is very seldom that an accident can be attributed to a single cause, but instead they are caused by multiple interacting errors and failures of which some have been hidden in the technical systems and/or organisational practices for a considerable amount of time. This recognition puts an emphasis on the necessity to ensure that also small seemingly unimportant details that can have an influence on safety are managed prudently.

The two final questions in a discussion of safety are:
- Have we covered all important threats?
- Have we done enough to act on the threats we know?

The first question has to do with the completeness of analysis and the second question with the level of spending on actions counteracting the threats. This means the safety is acceptable

if and only if the safety management activities can be considered reasonable complete and efficient.

3 MANAGEMENT IN NUCLEAR POWER PLANTS

Management of nuclear power plants is, as in any other process industries, to a large extent concerned with the management of people and resources, but it also has certain specific flavours. Management can on a generic level be seen as implementing a loop of visions and strategy, communication and linking, planning and target setting, and feedback and learning. The tasks of management can roughly be divided to be concerned with the four main areas of economics, personnel, technology and organisational practices. Within these areas daily routines of managers engage in the following types of activities:

– communication and information collection,
– task formulation and delegation,
– problem solving and decision making.

Management has also to do with the implementation of an organisational structure with a division of authority and responsibility. At the nuclear power plants this is often done by separating between the functional areas of operations, maintenance, technology and support, which are further subdivided in sections and groups. Another way to look at the organisation is to consider major work processes such as management, operation including outage planning, experience feedback, and plant modifications to ensure a smooth flow of errands over organisational borders. The organisational structure is described in a set of documents, which typically includes company mission and values, job descriptions, a quality handbook, administrative instructions, etc.

Management has also to do with power and prestige. Authority over people and power to allocate resources are sources of prestige within organisations. This also means that managers are targets for various motions and proposals from people within the organisation. There may be competition between managers at the same level, which means that senior managers have to take stand on various conflicts and make decisions, which the organisation by large can accept and consider fair. In addition senior managers represent their own organisations externally. All these tasks have to be carried out in a balanced way, not to leave small things unattended that may grow and became problems at a later instant.

Management can also be seen as the task of finding structure in a stream of unstructured demands coming both from the inside of the organisation and from its environment. A typical characteristic is that these demands have to be responded to in real time, which means that delays in responding may be fatal in one way or another. It is evident that senior managers cannot respond to all these demands themselves, but have to delegate a large part of them to specialised functions within their organisation. This delegation process takes time and effort, because the most suitable group of people should be selected and instructed. This can only be done if the managers have a good understanding of abilities and workload of the people they are responsible for.

4 ORGANISATIONAL SUPPORT

The difficulty of management is well known and therefore various organisational support systems have been built to ease the task. These systems can be based on a tradition of practices, they could be defined in instructions and manuals or they could be based on special tools designed for a specific purpose. The actual implementation of organisational support is not im-

portant, but the implied management model on which they are built is determining their usefulness.

Organisational support can be used at each level in the organisation and in support of the whole variability of activities and tasks. Plant status control for example is supported by various means such as indications in the control room, event logs, alarms and the configuration management system. On a generic level the information system, by which the collection, archiving and access to various documents is controlled, is one of the most important support systems. Other support systems include methods and tools for risk and event analysis, equipment failure data collection, monitoring of ageing, inspection and review, etc.

More generally organisational support is obtained through the collected experience from all nuclear power plants in the world that is available in documents and databases maintained by international organisations such as WANO, IAEA and OECD/NEA. These gives an access to collected management experience in good practices and in information that can be used to benchmark performance of the own plant with other plants in the world (cf. [10], [11]).

A special class of organisational support systems could be termed decision support systems. Decision support systems are usually built around formalised decision making situations, which are considered complex and important enough to warrant the effort. Experience has shown that decision support systems never can substitute human decision-makers, but at their best they can support important parts of the decision making process. This is possible only if they give access to correct and useful information and they are reliable, transparent and easy to use.

In nuclear power plants the Probabilistic Safety Analysis (PSA) has gained an established position as a methodology for a comprehensive assessment of risks. Efforts have therefore been spent on investigating possibilities to use the methodology also for assessing the influence of organisational factors on risks (cf. [12]). Given the theoretical basis for the methodology and its variation through different applications (cf. [13]), it seems however to be very difficult to establish believable models for characterising such influences.

5 SAFETY CULTURE

Safety culture was a concept that was introduced in the aftermath of the Chernobyl accident. The concept got immediately a large attention in the nuclear community worldwide and IAEA took the task to define it more closely. Since the first attempt to provide a definition of the concept (cf. [14]) and guidelines for how safety culture could be assessed (cf. [15]) quite a lot of activities have been initiated and completed with an attempt to make the concept operational. Unfortunately there still seems to be a rather large discrepancy how the concept safety culture should be defined and how it can be measured.

Safety culture has to do with organisational culture (cf. [16]) and therefore with organisational norms, beliefs and practices. More accurately one is often using a three-layered model of artefact, espoused values and underlying assumptions [17]. Safety culture is often associated with concepts such as openness, attitudes, commitment, competency, professional skills, ethics and common views [18]. A recent report discusses more generally how organisational culture can be assessed [19]. Another study has taken a look at the safety culture concept as seen from a regulatory point of view [20].

There seems to be diverging views on the possibility to assess the strength of safety culture at nuclear power plants. Some people think it is necessary to build methods and tools to measure

safety culture and others think that the concept is more valuable if everyone can give it their own meaning.

Safety culture has at the Finnish and Swedish nuclear power plants been used as a concept to trigger discussions during seminars and training courses, where managers have provided their own personal view on the concept and its interpretation. On the courses discussion groups have been formed both within and across functions with the task of defining for themselves what is meant with the concept. In this way safety culture has been used operationally to lift up various preconditions for safety to an internal discussion that provides opportunity for reflection.

6 THE USE OF PERFORMANCE INDICATORS

Performance indicators should not be seen in isolation, but be seen as a part of the entire management system. Performance indicators provide feedback to the management on performance achieved, but they also give important inputs for the formulation and communication of strategies and goals. Many nuclear power plants in Finland and Sweden apply the so-called balanced score card concept in their management processes [21]. According to the concept goals and targets are formulated and broken down according to organisational structure. In the feedback part of the management loop performance from lower hierarchical levels in the organisation are collected and combined to provide an indication of the performance of the entire organisation.

Performance indicators have been proposed to be used when it is difficult to obtain accurate measurements of performance. There is basically two ways to define the indicators, either top down searching for indicators that are connected to defined goals and targets or bottom up picking measurements or indications that are related to good or bad performance. In the first case the indicators are closely related to planning activities and in the second case to outcomes that are perceived as good or bad. These views can be considered complementary and both should be used in the management oversight.

Any formal system of performance indicators can be seen as an organisational support system that is designed for certain ends. This means that a set of performance indicators have their own intended users, whom are supposed to respond if the indicators degrade from a defined norm of acceptability. This implies that the indicators used by the management of a nuclear power plant will differ from those used by the regulator for their regulatory oversight. When indicators are used in the management processes they usually will trigger only additional information collection to identify and rectify underlying problems.

In a search for suitable performance indicators one could differentiate between objective and subjective measurements. Objective measurement are based on indisputable physical conditions and subjective measurements on opinions collected from people. Whenever objective measurements are available they are certainly to be preferred, but many factors connected to management, organisation and safety culture can only be assessed asking people for their opinion. Measurements as exercised within the behavioural sciences have their own methods and tools to ensure reliability and validity of such subjective indicators.

In using performance indicators it is important to have some norm on what should be considered a good and what a bad value of the indicator. Such norms can be based on earlier performance with some improvements set as a target. Another way is to benchmark suitable parts of the organisation with other organisations in an attempt to measure what best available practices can achieve. For subjective indicators the norms can be set using rating scales that are

anchored to observable behaviour. Finally it is beneficial to have some ideas of which control variables the management can use to improve the values of the performance indicators.

Establishing a formal set of performance indicators has the benefit of being systematic and to allow trending over time. On the other hand it may sometimes be more valuable to collect in-depth data on organisational performance in a single larger effort, than to use a more superfluous data collection that is applied for a continued use. When specific indicators are used it is important to note that they may divert the attention of managers and the organisation to the selected indicators from other equally important performance characteristics.

7 A SET OF QUESTIONS[3]

(1) Should impact of management, organisation, and safety culture issues be considered as part of any future risk-based safety indicator system?

Yes, provided that relevant information is collected and that this information is used with insight and understanding.

(2) Can the influences of management, organisation and safety culture be tracked using some specific indicators?

Good management and a well-structured organisation can a priori be assumed to have an influence on safety culture and thus also on the risk for accidents. To track these influences with specific indicators in a reliable and valid way seems however to be almost impossible. On the other hand specific indicators may give an indication of areas to prioritise in further organisational development programmes.

(3) Is it possible to assess the risk implication of such factors?

It seems to be very hard to build quantitative correlation between risk and factors that any of the suggested indicators can measure. Presently a lot of information is collected and the problem seems more to be how to use that information in an intelligent way than to collect more information.

(4) What data collection or reporting systems are available that could help in identifying such influences?

It is important to recognise that the sole act of agreeing on an indicator to be measured has an influence on the way people in the organisation tend to act.

(5) Are there ways that plant component reliability data could be utilised to extract potential influences due to management, organisation, and safety culture?

Performance data that is collected at the plants have a large, to some extent unused, potential to give important information on many issues including management, organisation and safety culture. The problem however, is to analyse the data without excessive manpower input. Unfortunately also the quality of the data tend to be rather low, which perhaps is indicating the present status of the databases.

(6) An expert-elicitation based study sponsored by SKI has resulted in following SPIs that are believed to "correlate" with changes the failure rates in nuclear power plants (cf. Table 1).

[3] The questions were created by the SPI-project and sent to the participants before the workshop.

Do you think a list such as this should be developed, and data collection methods be established to better assess the specific relationship to risk/safety?

Table 1: Identified list of event "forerunners" with potential impact on plant hardware & performance.	
1	Annual rate of safety-significant errors (i.e., reportable violations of technical specifications) by plant personnel, contractors, and others.
2	Annual rate of maintenance problems (defined as maintenance rework or overdue maintenance).
3	Ratio of corrective versus preventative maintenance work requests (MWRs) on safety equipment.
4	Annual rate of problems (deviations/failures) with repeated root cause (i.e., a cause previously identified by a vendor, the plant, another plant, the regulator, etc., for a similar plant or group of plants, or for similar components).
5	Annual rate of plant changes that are not incorporated into design-basis documents by the time of the next outage following the change.

The list is basically OK, but a good or a bad value of the indicators can be a reflection of many different things. The indicators proposed in the list may also have an impact on the reporting rate and the willingness to search for root causes for bad performance.

(7) Several methods are available that allow the incorporation of management, organisation, and safety culture on plant risk. Do you believe these methods should be further developed to enable a more quantitative means of tracking such influences? Please support your recommendations.

None of the methods seems to provide reliable and valid measurements of management, organisation and safety culture. The implication is then that the methods cannot provide estimates of the risk level of the plant. Still it is possible that the methods can provide valuable indications for the management that something has to be done. When such signals are obtained more efforts could be spent identify areas for development within management and organisation.

(8) What recommendations can you make about selection of specific approaches for inclusion of impact of management, organisation, and safety culture on safety/risk?

An explicit identification and documentation of preconditions for good performance can provide a kind of norm for what is accepted and what is not. If such a norm is available it is easier to make an assessment of how these preconditions are met.

(9) In your opinion, what is the best approach for identification of SPIs that can be used to assess potential deterioration in safety performance?

Already the notion of the existence of one best approach is flawed. When indicators are used, they should be used to provide indications. Only evidence collected from many independent sources can provide the necessary insight to select the most appropriate route of actions when a serious deterioration of safety is suspected.

(10) Please list any other recommendations for future research that could help advance the state-of-the art in safety performance monitoring of nuclear power plants.

The monitoring of safety performance relies on an implicit model of safety in terms of preconditions and precursors to conditions and events. If that model could be made more explicit

to be communicated to managers as well as to specialists, it could be helpful also in a discussion of safety performance indicators. Such a model might be based on the Bayesian Belief Network (BBN) methodology. Another question that may be worthwhile to address, is the task of managing a nuclear power plant with its components of decision making under uncertainty in an unpredictable terrain with a flood of unstructured real time demands for decisions.

8 CONCLUSIONS

A consideration of safety performance indicators is important, because it opens up a discussion of various precursors to safety. Such a discussion can help in creating understanding and awareness of how different issues interact and therefore contribute to a continuing safety of the nuclear power plants. However, the belief that safety performance indicators would allow a major break through either in safety management or in regulatory oversight is naive. People and organisations are more complex than any simplistic model of cause and effect can cope with. In practice this means that the gut feeling of insightful senior managers often can provide better indications of true performance than any formal system of performance indicators.

In a discussion of safety performance indicators it is necessary to have an appreciation also for economic performance. Without a sound economy it is not possible to maintain the safety of the plant and vice versa it is not possible to maintain a sound economy if the plant is not safe. If problems emerge at a plant, it is a very tricky decision process for selecting a proper intervention from the management board or the regulator, because it may easily take a wrong turn and be counterproductive for safety.

The pressure to implement safety performance indicators can perhaps be seen in a larger framework in the society, where a market orientation of organisations have forced them to provide more accurate account of both present and future performance. This orientation has had the benefit of making organisations more efficient, but with the price paid of an increased pressure on people. Unfortunately this pressure has in the business world sometimes lead to fraud and criminal acts, where managers have been caught in attempts to cover up bad performance. It can only be hoped that the nuclear industry never will be forced into such viscous spirals of greed and dishonesty.

Perhaps the best strategy for a continued safety is to institute a quest for continuous improvements in the organisations, because safety has to be continuously be reconstructed in the minds of people. This implies the simultaneous creation of many mental models of safety to be applied in the day-to-day work routines. If this kind of attitude and commitment can be maintained at the nuclear power plants world-wide there should not be any problems for nuclear power to stay as a viable option for energy production also in the future.

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