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Lecture 7

Assessment of Organisational Factors

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L7 – The effect of organisational factors on risk

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Summary

This paper discusses organisational factors and their effects on risk. Organisational influences are often considered to be important contributors to plant economy and safety. However, most analysts admit that their proper consideration in studies such as probabilistic safety assessment (PSA) is difficult. The idea of this paper is to show that this is not necessarily true. The paper first presents an introduction to cultural and organisational factors (COFs) and how they affect safety. Then, selected approaches used to include organisational influences and processes In PSA are presented. Finally, the state-of-art is discussed and conclusions are made.

1 Introduction

Many severe accidents have been attributed by phenomena often called organisational factors. Examples of such events are, e.g., Estonia shipwreck in the field of maritime transportation, Bhopal in the chemical industry and Chernobyl and Tokai Mura in the nuclear industry. Consequently, there has been an increasing demand during the past few years to study organisational influences to safety. This has led to a number of national and international projects, reference to which may be found in the references and an extended list of other suggested readings.

At the same time that people have got used to speak about human errors, the interest to organisational factors has grown. However, the researchers have found themselves in a confusion about defining the object of their study. There is no commonly accepted

definition for what the organisational factors really are despite several international efforts in that direction, e.g. the OECD/NEA/CSNI/PWG1 task force 7 work /OECD 98/ and the ORFA project belonging to the EU NFS-2 programme /WAH 99/. The somewhat fuzzy term "organisational factors" has many dimensions in safety context. There are, at least, six different points of view that may be taken. Luckily, these views lead, at the end, to a rather similar synthesis as seen in section 2.

This paper first presents an introduction to organisational factors and the different ways they affect safety. Then, approaches to analyse organisational processes and their safety influence are presented. Finally, the state-of-art is discussed and conclusions are made. The discussion looks at the issue from PSA point of view, but extensions are made outside probabilistic safety assessment (PSA) to a limited extent. Especially, tangible approaches that may be used to approach organisational factors are presented.

2 Organisational factors and safety culture

There are many possible views on the organisational factors. The first one is presented by /OECD 98/, which indicates that one may mean by organisational factors either organisational processes or their outcome, called here the process-outcome approach. This is an important distinction that forces us to think about what we want to study. Let us take an example. Communication is often mentioned as an important organisational factor. It is a process, and it definitely also has input (e.g. an instrument reading), output ("it is growing!") and often also feedback ("What? Really?"). The output affects the performance of the recipient in NPP operations or in maintenance. Furthermore, the communication amount and style are in way outcomes of, e.g. the culture and managerial examples of acceptable performance. This shows clearly how there are different levels in the organisational factors (discussed more in the second and third point of view in this section).

It is often easy to find problems in the outcome of organisational processes. For example, an inadequate training or communication may be an important contributor to disturbances. However, finding a remedy requires an investigation of the organisational processes. We may either study the processes or their outcome depending on the current need. Approaches in the PSA context for that are presented in section 4.

The process-outcome approach is well depicted in the famous Figure 1 by J. Reason /REA 95/. Especially, one has to observe that the organisational factors affect both the human performance and technical components, systems and processes through human actions (normal or deviating), as also /DAWA 94/ and /PAAN 98/ discuss. Further, Reason /REA 90/ also discusses the feedback loops by which an undesirable performance may be corrected.

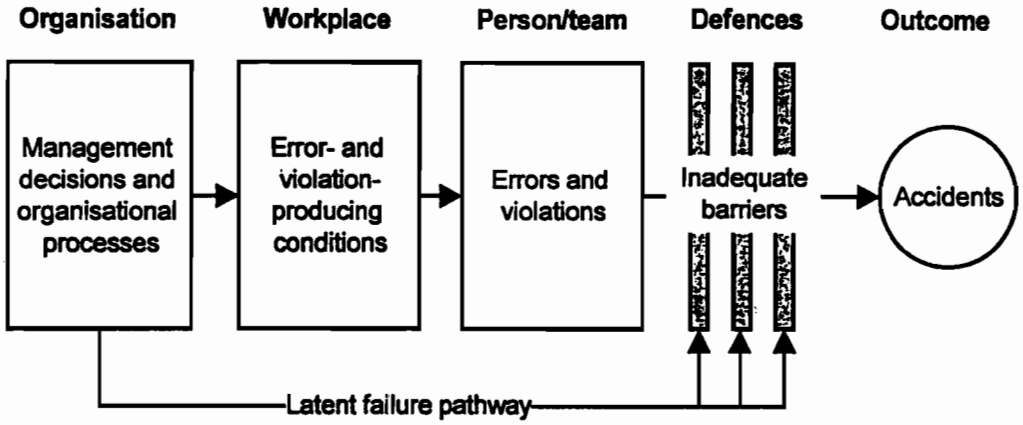

Figure 1. A model of organisational accident causation by Reason /REA95/.

Man takes care of the operation, maintenance, modifications and testing in various parts of an NPP. These are primary activities, where man is in direct touch with the process and equipment, whereas there also are planning, design, supervision and other secondary support activities. This primary-secondary action in e.g. /PYY 00/ point of view is our second approach. The so-called organisational processes, in reality, consist of human actions. Their outcome is not change in process, system or component status but rather support to primary (shop floor) actions.

There always is an organisational structure in enterprises, too. Our third approach to organisational factors leads us to describe this structure and different channels of communication (information flow) as /HAWS 98/ discusses. Representations of the structure may be static (organisation box chart) or more dynamic (flow diagrams, Petri nets etc.). Information flows inside the "organisational boxes" and between them. There also may be a formal organisational structure and an informal one. This means that, in practice, people use different communication channels in their work than the ones prescribed in the company organisational chart. Different factors affect this performance, which is an outcome of higher level organisational processes, and these lower level processes affect the operations and maintenance. A SADT-graph example of modification process flow in Finnish NPPs is shown in
Figure 2.

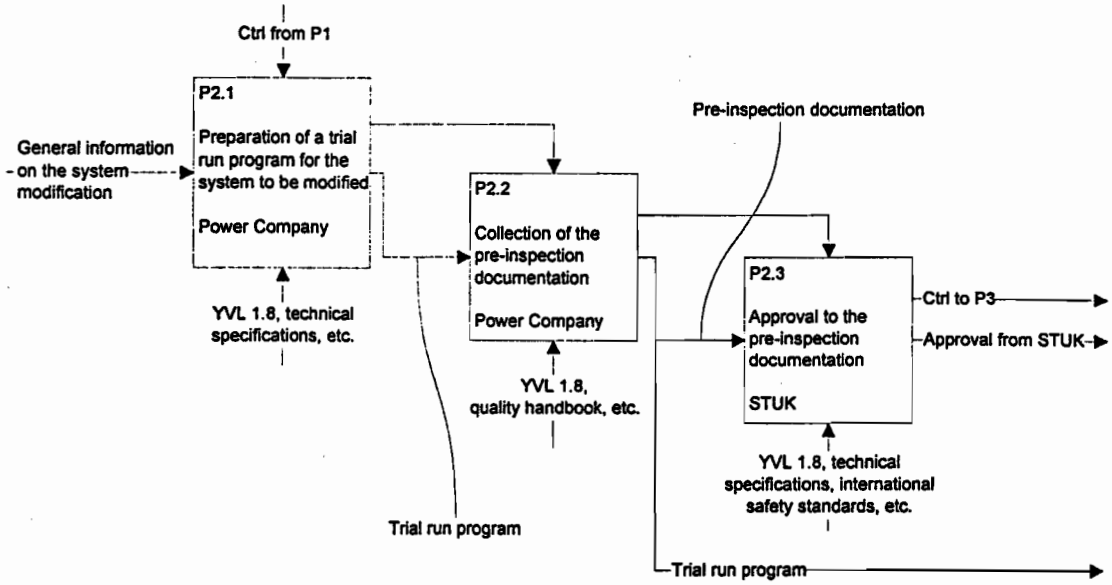

Figure 2. A SADT-flow diagram of one phase (P2 = Pre-inspection of the system) in modification process flow in Finnish NPPs (STUK=regulatory body, YVL=NPP regulatory guide).

The idea of organisation as a hierarchical structure leads us taking a look at the fourth way to approach the organisational factors. This may be called the top-down and bottom-up approach /RASV 00/. The bottom-up approaches look at organisational factors from the shop-floor human action perspective. The goal is to assess their effect on the human performance (and its reliability). A bottom-up strategy tries to find out relationships between the shop-floor activities and other (secondary) activities, often even in a quantitative manner as in PSA. A typical weakness is that many elements that affect safety, such as "company culture" and "external pressures" seldom appear PSA parameters, and even if this were the case a significant effort is required to generate models and data for the influences (see section 4). The top-down perspective attempts to study and explain organisational factors starting from the upper level, i.e. safety culture, organisational learning, organisational "types" etc. The top-down perspective is important but sometimes difficult to use as a basis for assessment, partly because the concepts are difficult to transform into unambiguous measurement dimen-

sions, the difficulty of abstraction and, related to that, the problem of data collection. However, this dimension highlights the need to also include cultural influences in the analysis of organisational factors (COFs = cultural and organisational factors).

The fifth point of view on organisational factors is related to time. To take an example, let us fix the time point zero to the beginning of a process disturbance and place ourselves in a control room. On one hand, we are dealing with the results (outcome) of organisational processes such as control room design, organisational structure, policy, training, procedures etc. They appear as (static) preconditions to our activities in this disturbance. On the other hand, there are dynamic events that take place during the disturbance having an impact on our behaviour, such as changing situation with system faults (maintenance) and information about them, arriving communications, resources available etc. Again, we are back in the fact that there are processes and their outcomes, and one has to choose a practical level in their assessment.

The sixth point of view is related to the outcome of organisational processes and individual response to them. As discussed earlier, the effect of organisational factors is not straightforward and linear – sometimes an organisation having many vices can go on without a major catastrophe for a period of time despite the fact that there may be opportunities for them. Lacking organisation support does not always have to show on individual performance - especially this is true in short term. As an example, an employee once told me "well, the Lords may do what they want, I just do my job as well as I can". There are counterexamples, too, where no organisational support may make up lacking personal skills and motivation. Even in case of a perfect organisational support and good workers accidents happen – you just may have a bad luck. A simplified contingency table for organisational support and human performance is shown in Table 1. Several indicators have been developed to describe the functioning of the plant and organisation on different levels as discussed in section 3.3.

Table 1. A simplified presentation of relationships between organisational support and human performance

Organisation (secondary activities):	Human performance (indicators)	
	positive	**negative**
supportive	- indicators tell that the shop floor actions are going well - organisation supports performance - acceptable long term situation	- indicators tell that the shop floor functions are not satisfactory - staff incapable of using the organisational support or - bad luck
disruptive	- no direct indicators pointing at less qualified organisational support (good luck ?) - good staff, improvises and compensates for lack of support (short term)	- indicators tell that the shop floor functions are not satisfactory - the organisation does not support shop floor activity - unacceptable long term situation

All organisations are subject to cultural dimensions. Safety culture is definitely one of the most important of them and, therefore, deserves some discussion. The term has been defined by the International Nuclear Safety Advisory Group as "... an assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear power plant safety issues receive the attention warranted by their significance" /INS 91/. The definition further states that safety culture is made up of individual attitudes and competencies, organisational culture, and all of the organisational structures required to safely operate a plant. On individual level this means a prudent questioning attitude towards safety related matters.

Safety culture is a cornerstone of (at least) western safety thinking. If there are severe flaws in it, no technical barrier may guarantee safety, as e.g. the Chernobyl and Tokai-Mura events have shown. It is affected by **artefacts, norms & values and underlying assumption**s */SCH 92/*. Artefacts are the visible entities in organisational structures and processes. The espoused or implicit norms and values (ethics and moral) are reflected in strategies, goals and philosophies. These two levels can be observed and measured by various methods, but the underlying assumptions, which are unconscious taken-for-granted beliefs, perceptions and feelings, are far more difficult to assess.

3 Organisational influences on safety

3.1 COFs, PSFs and HRA

The headline may seem to be mysterious for those not familiar with human reliability analysis but an explanation will follow. In section 2, different points of views were presented to be considered in the analysis of organisational factors. There is not one and only valid approach to include them in safety assessments. Partly related to that, there is a very common misunderstanding that organisational factors are not taken into account in PSA. They are actually very often included in one specific part of PSA closely related to COFs - human reliability assessment (HRA).

In HRA, the influence of COFs is represented by PSFs (performance shaping factors). These are factors that affect human primary action performance so that the probability of failure either increases or decreases. So that the jungle of acronyms would be even more extensive, in some HRA methods the PSFs are called PICs (probability influencing contexts), CPCs (common performance conditions), PIFs (performance influencing factors) etc. What is common is that they affect the probabilities of failed human actions. This is the case in almost all HRA models. Table 2 shows some most generic performance shaping factors used in HRA. In the table, CREAM /HOL 98/ is a recent development whereas the others are from the 1980s.

Swain's PSFs /SWGU83/ represent larger PSF classes than in the other three methods and organisational influences are a part of the situational characteristics. The organisational influences generally appear in HRA, e.g. through the existence of procedural guidance, man-machine interface and training. However, in some cases, they affect directly the task success by influencing time windows and availability of tools. This is easily forgotten, if analysts only look at entities like errors and stress.

The history of HRA is full of different formulas and approaches to take the PSF influences into account. Influence diagrams and decision trees to represent them are generally used. Very often, a linear combination with a log-linear or logistic mathematical linking function is used. The log-linear case used in SLIM /EMET 84/ is shown in Formula (1).

$$\log(p) = \Sigma_i W_i^* R_i + b \qquad (1)$$

,where

R_i = rating associated with ith PSF
W_i = weighting factor (indicating degree of influence of ith PSF); $0 \leq W_i \leq 1$ and $\Sigma_i W_i = 1$
p = *probability of human failure.*

Table 2. PSFs for selected HRA methods found in literature.

THERP[1] /SWGU 83/	HCR[2] /HAET 84/	SLIM[3] /EMET 84/	CREAM[3] /HOL 98/
Situational characteristics	(1)Operator experience	Procedures available / Requires diagnosis	Adequacy of organisation
Task and equipment characteristics	(2)Stress level	Stress level	Working conditions
Psychological stressors	(3)Quality of operator / plant interface	Time pressure	Adequacy of MMI and operational support
Physiological stressors	Time [(4) median / available]	Severity of consequences	Availability of procedures / plans
		Complexity	Number of simultaneous goals
		Requirement for teamwork	Available time
			Time of day
			Adequacy of training and experience

[1] these are main classes of several subcategories and, thus, different from the other method PSFs (other methods concentrate upon the most important PSFs, only).
[2] The (1-3), having 3-5 classes each, influence the median time (4) - used in a Weibull model together with total available time - in the form of a multiplicative model
[3] The PSFs have 9 classes influencing probability through a success likelihood index (SLI)
[4] No explicit realization in the form of probability estimates available, yet

Consequently, many HRA methods take into account the COFs. It is completely another thing if the models are too straightforward or not. At this point, it is reasonable to notice that unlike in physics, the idea of PSA is not to generate as accurate models of reality as possible. The principle is to knowingly have an as simple model as possible that still can be used to support decision making.

Most HRA methods nowadays consider a wide variety of COFs. As an example, Jacobs and Haber /JAHA 94/ identify the following categories of COFs: administrative knowledge, communications, decision making, human resource allocation, and culture. These categories include 20 classes of factors shown in Table 3.

Table 3. Organisational factors defined by Jacobs & Haber, 1994 /JAHA94/.

Categories	Definitions of Organisational Factors
Culture	1. Organisational Culture: refers to plant personnel's shared perceptions of the organisation. It includes the traditions, values, customs, practices, goals and socialization processes that endure over time and that distinguish an organisation from others. It defines the 'personality' of the organisation. 2. Ownership: refers to the degree to which plant personnel take personal responsibility for their actions and the consequences of the actions. It also includes commitment to and pride in the organisation. 3. Safety Culture: refers to the characteristics of the work environment, such as the norms, rules, and common understandings, that influence plant personnel's perceptions of the importance that the organisation places on safety. It includes the degree to which a critical, questioning attitude exists that is directed toward plant improvement. 4. Time Urgency: refers to the degree to which plant personnel perceive schedule pressures while completing various tasks.
Communications	5. Communication-External: refers to the exchange of information, both formal and informal, between the plant, its parent organisation, and external organisations (e.g., NRC, state and public). 6. Communication-Interdepartmental: refers to the exchange of information, both formal and informal, between the different departments or units within the plant. It includes both the top-down and bottom-up communication networks. 7. Communication-Intradepartmental: refers to the exchange of information, both formal and informal, within a given department or unit in the plant. It includes both the top-down and bottom-up communication networks.
Decision Making	8. Centralization: refers to the extent to which decision-making and/or authority is localized in one area or among certain people or groups. 9. Goal Prioritization: refers to the extent to which plant personnel understand, accept and agree with the purpose and relevance of goals. 10. Organisational Learning: refers to the degree to which plant personnel and the organisation use knowledge gained from past experiences to improve future performance. 11. Resource Allocation: refers to the manner in which the plant distributes its financial resource. It includes both the actual distribution of resources as well as individual perceptions of this distribution. 12. Problem Identification: refers to the extent to which the organisation encourages plant personnel to draw upon knowledge, experience, and current information to identify problems.
Administrative Knowledge	13. Coordination of Work: refers to the planning, integration, and implementation of the work activities of individuals and groups. 14. Formalization: refers to the extent to which there are well-identified rules, procedures, and/or standardized methods for routine activities as well as unusual occurrences. 15. Organisational Knowledge: refers to the understanding plant personnel have regarding the interactions of organisational subsystems and the way in which work is actually accomplished within the plant. 16. Roles/Responsibilities: refers to the degree to which plant personnel and departmental work activities are clearly defined and carried out.
Human Resource Administration	17. Performance Evaluation: refers to the degree to which plant personnel are provided with fair assessments of their work-related behaviors. It includes regular feedback with an emphasis on improvement of future performance. 18. Personnel Selection: refers to the degree to which plant personnel are identified with the requisite knowledges, experiences, skills and abilities to perform a given job. 19. Technical Knowledge: refers to the depth and breadth of requisite understanding plant personnel have regarding plant design and systems, and of phenomena and events that bear on plant safety. 20. Training: refers to the degree to which plant personnel are provided with the requisite knowledges and skills to perform tasks safely and effectively. It also refers to plant personnel perceptions regarding the general usefulness of the training programs.

The classes presented for COFs in Table 2 and Table 3 are no way the only ones. For example, the ORFA literature survey /WAH 99/, reviewed several methods to assess organisational performance (see Appendix). That review produced some 160 organisational factors, which are highly overlapping. The factors could be finally structured into seven general categories (the output is the eight one). These factors form hierarchical structures. The ORFA model for nuclear safety and the organisational influences on it is shown in Figure 3.

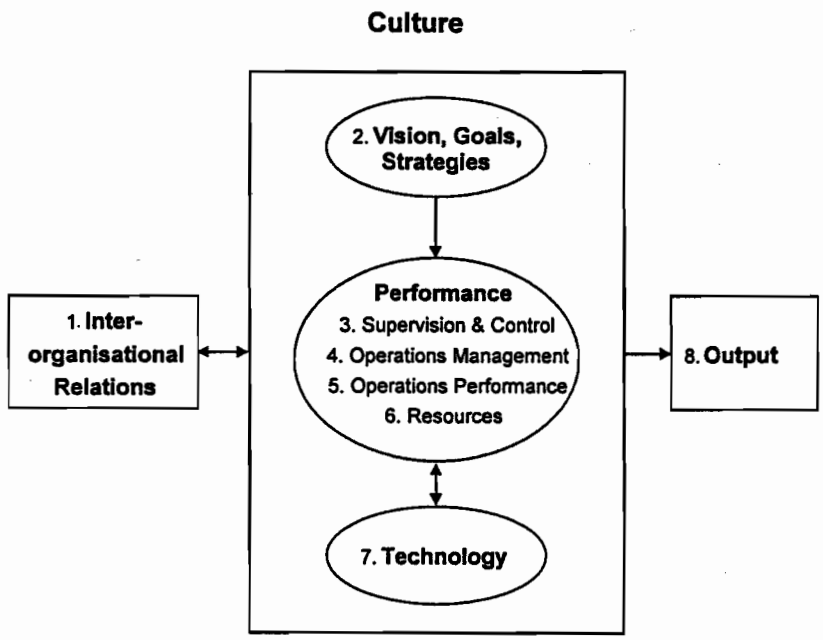

Figure 3. Organisational factors and nuclear safety: A categorisation of relevant variables (modified from /WAH99/).

3.2 COF influences on safety and economy outside HRA

A systems perspective that recognises human, technical and organisational elements and their interactions is a necessary foundation for acquiring high safety and efficiency in production systems. This, in turn, demands co-operation among many disciplines. A system interacts with its environment and can be subdivided into parts. Considering

organisational aspects of nuclear safety, five different subsystems have been identified in ORFA /WAH99/ completing the view presented in section 3.1. They are: 1) the environment in which the NPPs are operating, 2) the technology used in their construction, 3) the individuals working at the plants, 4) the groups and their norms of behaviour and 5) finally the organisation with its structure and work processes. These five subsystems interact and there are organisational factors important for nuclear safety within each of the subsystems and at their interfaces (Figure 4). As seen, safety culture permeates all interactions between the five subsystems.

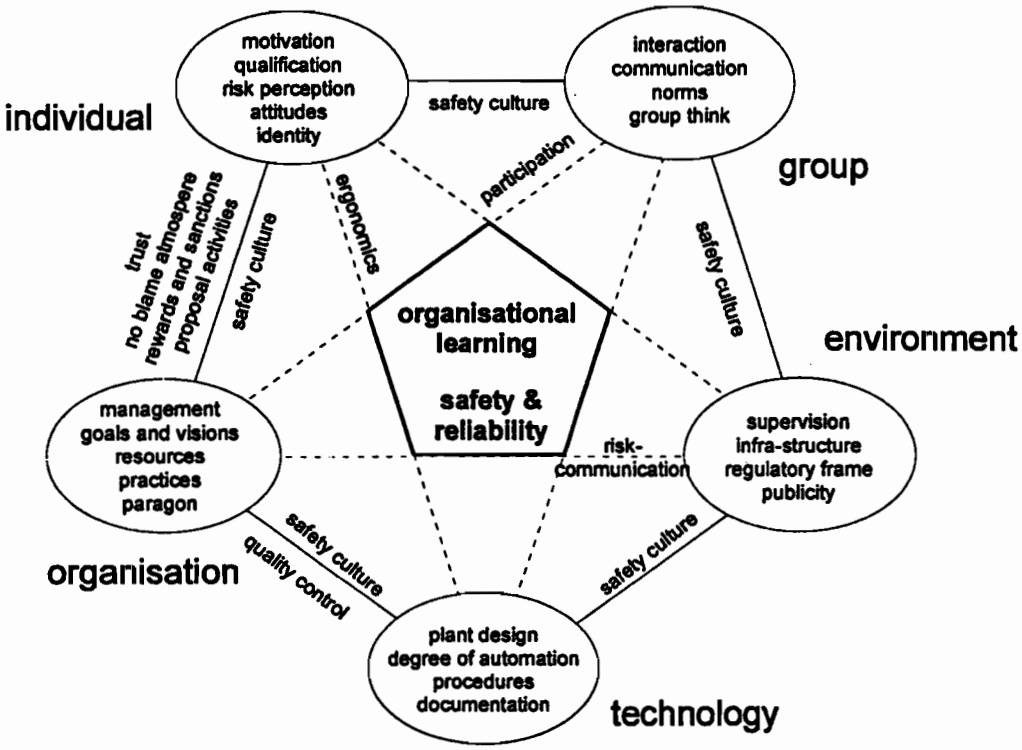

Figure 4. A model for different subsystems in an NPP.

Human reliability is not the only part in PSA affected by COFs. Maintenance efficiency is a good example of work processes affected by them – if the things are not well, fixing (or getting information about, finding spare parts, getting workers for...) a fault simply takes more time. Thus, component and system unavailability may manifest poor situation with regard to COFs. Similar effects may take place in other plant processes.

Let us take a basic reliability engineering example. We have a stand-by component that is tested and maintained in regular intervals. Obviously, in addition to how well the

component is manufactured also the way it is used often affects the failure intensity λ (i.e. using a component outside its intended environment etc.). Similarly, the test (f=1/T) and routine maintenance frequency (f_m) affect the unavailability - faults are discovered and fixed, but sometimes T&M also causes unavailability (T_M) and errors may be made (Q). The maintenance organisation effectiveness also is reflected by the duration of repair T_R, especially if the component / system is critical.

Table 4 presents some basic formulas for the unavailability of a stand-by component / system. The parameters listed above also represent the organisational decisions made and the plant practices and culture considered as organisational factors. Depending on the role of a component / system, they may affect either safety or/and economy. Thus, organisational factors have a much wider influence than human reliability analysis only.

Table 4. Calculation of unavailability of a stand-by component (from /PAAN 98/)

Periodically tested components	$\overline{U} = \overline{U}_1 + \overline{U}_2 + \overline{U}_3 + \overline{U}_4$
i) Unavailability owing to hardware failure between tests λ:failure rate T: mean time between tests	$\overline{U}_1 = 1 - \frac{1-e^{-\lambda T}}{\lambda T}$ if T<<1 $\overline{U}_1 \cong \frac{1}{2}\lambda T$
ii) Unavailability owing to repair of detected failures T_R: duration of the repair	$\overline{U}_2 = \frac{\frac{e^{-\lambda(T+T_R)} + \lambda(T+T_R) - 1}{\lambda(T+T_R)}}{1+(1-e^{-\lambda T_R})e^{-\lambda T}} + \frac{1-e^{-\lambda T_R}}{e^{\lambda T}+1-e^{-\lambda T_R}}$ if $(T+T_R)<<1$ $\overline{U}_2 \approx \frac{1}{2}\lambda T + \lambda T_R$
iii) unavailability owing to routine maintenance/tests f_m: frequency of maintenance T_m: duration of maintenance	$\overline{U}_3 = \overline{U}_2 \frac{1}{1+f_m T_m} + \frac{f_m T_m}{1+f_m T_m}$ if $f_m T_m<<1$ $\overline{U}_3 = \overline{U}_2 + f_m T_m$
iv) unavailability owing to errors in maintenance/tests Q_{M1}:prob. of a human failure Q_{M2}:prob. of recovery	$\overline{U}_4 = \overline{U}_3(1-Q_{M1}Q_{M2}) + Q_{M1}Q_{M2}$ $Q_{M1}Q_{M2}<<1$ $\overline{U}_4 = \overline{U}_3 + Q_{M1}Q_{M2}$

3.3 Performance indicators

Reliability parameters may, in some cases, be used as indicators of organisational performance and their comparison may reveal areas of improvement needs. One has to be, however, aware of the fact that the parameters are rather insensitive to changes

and only long term analyses make sense. Sometimes it is useful to study the way the organisation is performing before the reliability parameters are affected (see also section 2 about individual response). Here, other types of performance indicators (PIs) may be used. PIs are valuable tools in systems where actual performance builds on several interdependent characteristics connected by long time constants and complex interactions.

Performance indicators can in a way be said to provide feedback on future performance before trends can be seen in actual performance. NPPs use various systems of performance indicators which include mainly "hard" technical indicators such as fuel reliability index, radiation doses, accident rate, number of significant events, maintenance backlog, turnover and load factor. In the consideration of organisational factors one needs to define "soft" PIs, i.e. indicators suitable for assessing individual commitment, organisational efficiency and in detecting weak signals of organisational deterioration. Examples of such indicators are staff qualification rate, training hour rate, need for repeated maintenance, administrative delay in safety related actions, temporary modification rate, personnel turnover, number safety related initiatives (+their treatment rates), surveillance efficiency, maintenance ambition index etc. Also behaviourally anchored rating scales (BARS) may be used to rate performance (some analysts consider only such PIs as soft enough). A good collection of performance indicators is presented, e.g. in /LEH 95/.

PIs can be collected as a continuous process or the data for their calculation can be collected at regular intervals. Their definition preferably builds on existing relationships between actual performance and the indicator value. To be feasible, PIs should be accepted by their users, difficult to deceive, reflect true performance and be changed according to needs to be useful. They often are well suited to normal situations, but they are not adapted to the analysis of incidents (note that different things may be important during them than during the normal operation).

Performance indicators can be used in the control of the organisation by bringing them in as a management tool. They can be incorporated into the goals as targets for improvements. Ideally performance indicators should be linked to company values which can give them a valuable position in internal discussions. Performance indicators are sometimes used to create additional incentives within the organisation through a bonus

system, but care has to be taken in order not to cause distortions in personnel performance. The actual performance and not the indicators should be controlling the path of organisational development.

4 Approaches to include organisational factor in PSA

In this section, approaches to include organisational factors in PSA are presented. This normally means that we are more interested in the outcome than modelling organisational processes themselves. However, as many references e.g. /DAWA 94/ and /HAWS 98/ show, the approaches using models like SADT may serve in both purposes.

There is a wide variety of methods that could be presented, here, and picking one and not another is a difficult task. Fortunately, a representative collection of non-PSA related approaches for analysing organisations has been presented, e.g. in /WIL 00/. A framework for proactive risk management including a comprehensive collection of COFs has been presented, e.g. in /RASV 00/. Furthermore, reference /ØISK 00/ discusses six different approaches to include organisational influences in PSA.

We briefly discuss three examples in the following (although their development has not been totally independent). From the clearly HRA related "outcome" approaches, the Accident Prevention Group (six step) one /MOOR 94/, /ORMJ 93/ is selected. WPAM /DAWP 94/ also aims at studying work processes and, thus, is presented as a dual approach with some extensions to technical failure parameters. Finally, the I-risk /PAAN 98, HAGB 98/ approach seeks to take the organisational influence into account in the whole risk analysis framework and combine it with company safety management audits. Other recent methods dealing with the effect of COFs on HRA/PSA are, e.g. ATHEANA /COET 96/, SOCRATES /GEET 98/, SAM /MUPA 96/, ISM /MOMW 92/, e-factor /MOGS 97/, MACHINE /EMB 92/.

4.1 The Six step HRA approach

A systematic approach has been developed by /MOOR 94/, /ORMJ 93/ for incorporation of organisational factors into human reliability estimates to extend the applicability of PSA to safety culture improvement and integrated risk management. The approach is based on use of decision trees, expert judgement, empirical data on human error (if available) and information collected on organisational factors (OFs) in the form of ratings.

The proposed method also addresses the dependence between multiple operator actions in an accident scenario due to common organisationally grounded influence factors. A methodology for incorporating the common influence of organisational factors particularly into estimates of control room crew reliability in PSA was presented by the Accident Prevention Group in PSAM II.

The approach consists of six steps:

Step I: Develop a Causal Model of the Control Room Crew Reliability
Step II: Develop a Decision Tree For Control Room Reliability
Step III: Determine Ratings for Organisational Factors
Step IV: Calculate Organisationally Grounded Ratings for Influence Factors
Step V: Assess Probabilities (or Weigths of Evidence) for Influence Factors
Step VI: Incorporate Influence Factors' Weights of Evidence Into Decision Tree

The approach uses a simplified causal model (Step I) of the control room operating crew reliability. The three main categories of influence factors (**IFs**) for crew reliability are:

1) knowledge, skill and ability (**KSA**),
2) tools and resources (**TR**), and
3) motivation and morale (**MM**).

Each of these categories of IFs are mutually influenced to varying degrees by higher level organisational factors (**OFs**) through plant departments and programs. The used five groups of OFs (decision making, communications, administrative knowledge, human resource allocation and culture) are presented in Table 3. The departments taken into account were operations, training, licensing, QA, engineering, safety and maintenance (I&C, MECH and ELEC).

Step II includes drawing a decision tree for estimating human error probabilities (HEPs), using the three categories if IFs, *i.e.*, KSA, TR and MM and their degrees of influence on human reliability. For example, let us say that the degree of influence of KSA on HEP is assessed to be 10. In such a case, the probability of operator failure to perform a required action is multiplied by a factor of 10 when the KSA level is judged to be "poor" (compared to the case where KSA was judged to be "good").

OFs can be measured, or rated, by using various instruments (step III). In cases where they cannot be measured, as very often, Behaviorally Anchored Rating Scales (BARS)

may be used, i.e. rating the factors on an integer scale, for example, between 1-7. Results of applying BARS and other instruments produce a set of OF ratings (5 OFs and their detailed dimensions Table 3) for each NPP department which are taken into account in the analysis. Finally, an average is calculated for each OF / department.

The degree of influence on the HEPs varies among different departments. For example, one may argue that the operations and training departments have the greatest influence on the operating crews' KSA compared to the other departments. Next, the departments' OFs are weighted for their degree of influence (step IV) as follows:

$$R_i = \Sigma_j W_{ij} * R_j \tag{1}$$

where

R_j = average rating associated with jth department considering all OFs
W_{ij} = weighting factor indicating degree of influence of jth department on ith IF; $0 \leq W_{ij} \leq 1$ and $\Sigma_j W_{ij} = 1$
R_i = rating associated with ith human reliability influence factor (KSA, TR or MM).

Ratings for the weighting factors of the three IFs may be assigned by using structured methods such as trade-offs common in decision analysis, Analytic Hierarchy Process (AHP) /SAA 80/ etc.

The objective of the step V is to convert the OF ratings R_i on human reliability influence factors (*i.e.*, R_i) into probabilities or weights of evidence (*i.e.*, p_i). A simple linear model is suggested:

$$p_i = a + b * R_i \tag{2}$$

Assuming:

p_i = Pr(Quality of ith IF is good) = 1, if $R_i = 7$ (all the relevant department are doing very well)

p_i = Pr(Quality of ith IF is good) = 0, if $R_i = 1$ (all the relevant departmenst are doing really bad) (3)

Using these conditions in equation (2) yields, according to /ORMJ 93

$$p_i = \Pr(\text{Quality of } i\text{th IF is good}) = -0.17 + 0.17 * R_i \tag{4}$$

The last step (VI) incorporates the information on quality of organisational factors, departments and crew related IFs into decision tree to produce unconditional human error probabilities (HEPs). Based on the organisationally grounded rating values given in Table 3 for the influence factors KSA, TR and MM, an estimate for HEP is obtained: 0.17.

Also the dependence between multiple operator actions due to common organisational factors may be addressed in the decision tree framework. Although both of the two operator actions are dependent on the same OFs, their weights may be different.

4.2 THE WORK PROCESS ANALYSIS MODEL (WPAM)

In an attempt to link organisational factors to the activities carried out at nuclear power plants, and recognising that work processes are central to the conduct of these activities, the Work Process Analysis Model (WPAM) has been developed /DAWP 94/. This is in addition to be able to assess the effect of organisational factors on safety and economy. The strength of WPAM is that it models the way in which plants actually conduct work.

WPAM consists of two parts: WPAM-I for each work process, and WPAM-II for each accident sequence.

The approach has several aims, such as to:

- Link specific organisational deficiencies, i.e., weak organisational factors, to specific tasks within a work process
- Guide analysts to specific organisational factors depending upon within which task an error occurs
- Guide analysts to other work processes based on the type of errors identified
- Have a mental model of the plant's coordination and execution of work
- Identify latent conditions by tracing errors back to their organisational roots

WPAM-I consists of a three-step procedure as follows: (1) conduct a task analysis of each work process, (2) define the organizational factors matrix for each work process (Table 3), (3) determine the relative importance of the organizational factors for each task.

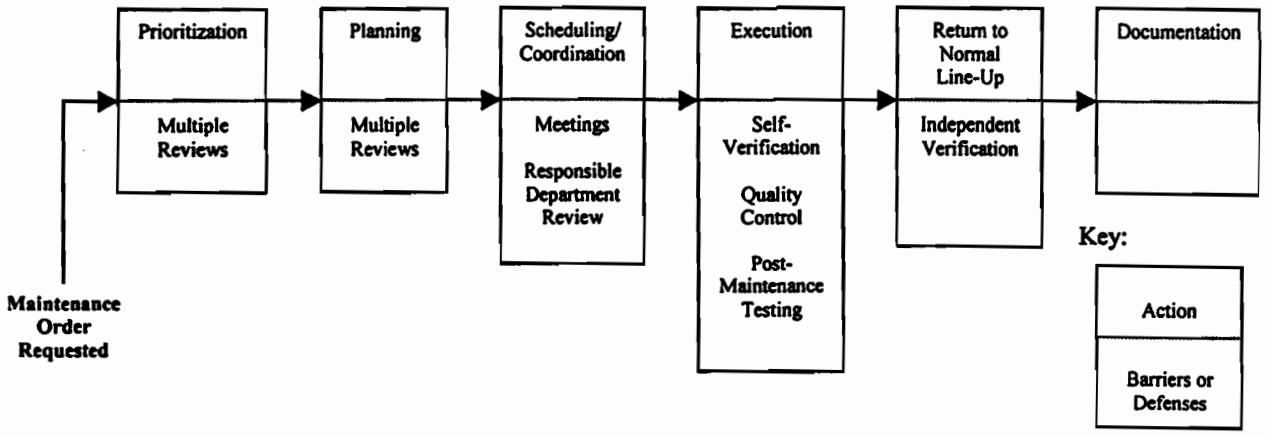

Figure 5. A flow diagram describing maintenance process /DAWP 94/.

Naturally, each task in a given work process is influenced by more than one organisational factor. Therefore, it is deemed necessary to rank the pertinent factors (also for a later use in WPAM-II). This is done according to their importance / influence on the tasks of the work process under analysis. As, in 4.1, this is done by using AHP /SAA 80/. In AHP sessions, the weights are obtained by using paired comparisons and eigenvalues of the resulting comparison matrix.

As shown in Figure 3, the corrective maintenance work process is made up of several tasks. Many maintenance related errors, according to incident investigations, occur in the execution task. However, the contributing factors may be present in other parts of this or other work processes. For example, if the work orders referenced in a work package are not appropriate for a specific task, and a maintenance error results, a contributing cause is an error that occurred in the planning task (inside this work process). Another example is when procedures referenced in work packages are deficient. In this case, a contributing cause is the deficient procedure. This indicates an error somewhere within the procedure writing work process (different work process).

Although the total number of work processes at plants is large, they are not all equally important with respect to performance. Maintenance, backfitting, (human) condition monitoring, and operating experience are examples of important work processes. A task analysis of them easily picks up several similarities between them. Invariably, they

all include a prioritisation and documentation task. Additionally, maintenance and backfitting work processes share planning and scheduling tasks. Other work processes exhibit a similar sharing of tasks. These similarities are important because organisational factors influence the successful outcome of several tasks. If an organisation is deficient in one factor, then errors in many work processes may follow affecting many different areas of the plant. This directly points to the possibility of common-cause failures of a different type than traditionally modelled in PSAs.

WPAM-II is used to estimate the impact of the organisational factors on plant risk. Only the pre-accident operations are typically considered; operator actions during a transient, for example, are not analysed (compare to section 4.1). This does not, however, preclude the analysis of dynamic situations which may have their roots in the routine operation of the plant. WPAM-II is composed of two basic steps: minimal-cut-set screening and quantification.

To address the dependencies among the parameters that are influenced by organisational factors, WPAM-II has modifies minimal cut set frequencies to include organisational dependencies in some PSA parameters. They are called **CPGs** (Candidate parameter groups) - groups of parameters whose numerical values might change due to the influence of organisational factors.

An examination of PSAs has resulted in the identification of six candidate parameter groups for WPAM. They are defined as follows: **RE** (failure to restore equipment to normal configuration after test/maintenance); **MC** (miscalibration of equipment); **UM** (unavailability due to maintenance i.e. down time of component); **FR** (failure to function on demand e.g. failure while running, failure to start, etc.); **CCF** (common cause failures due to factors other than human errors) and **TR** (available time for recovery).

The quantification takes place so that, first, work process analysis model-I (**WPAM-I**) is used to identify the organisational factors which may affect each CPG. Then, the success likelihood index methodology (**SLIM**) /EMET 84/, including a log-linear relationship between the PSF-factors and probability, is used to evaluate new frequencies for each MCS. This involves determining importance weights through the use of the analytic hierarchy process (**AHP**), determining ratings for organisational factors by tools such as behaviour-

ally anchored rating scales (**BARS**), and determining calibration constants for the probabilities of similar and dissimilar events.

4.3 The I-RISK approach

The I-RISK project /PAAN 98, HAGB 98/ was a project belonging to the EU IV-framework programme especially directed towards applications in chemical industry and major hazard installations to comply with Seveso-II directive.

The basic idea was to give a basis for controlling the interactions between failures that occur at different levels of the socio-technical system (and which have been repeatedly observed in accidents). The objectives were to: develop and integrate technical and management risk control and risk monitoring model, incorporating the models into an Integrated Quantitative Risk Assessment (I-QRA) approach, developing management "corrosion" probes to assist in monitoring the state of the risk management system and testing the created approach. This was done by integrating research results from engineering risk assessment; management systems; safety culture concepts and organisational structures.

A specific objective of the I-Risk project also was to quantify the effect of the safety management system (SMS) of an installation on risk. In this case the risk of Loss Of Containment (LOC) of hazardous substances was studied. Two general models were developed and quantified: **A *technical model*** incorporates the aspects of risk assessment that are directly affected by the existing hardware along with the associated operating, maintenance and emergency procedures (master logic diagrams were used). **A *management model*** incorporates the aspects of the organisation and management of the installation that may affect the performance of people, and indirectly of the hardware. An interface procedure was generated for integrating risk so that the management model modifies the various parameters of the technical model. The latter then provides the modified risk measures. The *technical model*, *management model* and *interface* comprise the key components of the I-Risk model.

The basic principles involved in building an I-Risk interface can be summarised as:

1. Identifying the relevant parameters in the technical model that determine the quantification of the probability or frequency of events.
2. Specifying the nature (underlying assumptions) of the technical parameter data so that the management aspects to which the data are sensitive can be identified. In other words, what aspects of the data specification are modifiable and what not. For example, generic equipment repair times that are found in databases do not include the waiting time for spare parts. Or, the generic failure rate of a component does not include consideration of changes in assumed internal conditions.
3. Specifying how the use of management delivery systems can affect the parameters of the technical model.
4. Quantifying the relative importance of the delivery systems in terms of the effects on the delivery system.

The reliability parameters in the technical model affected by management and organisational factors were those presented in

Table 4. In addition, also repairable and constantly monitored components were included in the analysis. The approach is applicable to **both normal operation and disturbances**, as seen from the parameters mentioned in Table 5.

Table 5. Basic Event Parameters of the I_RISK Technical Model

f_i: Frequency of external events
λ_s, λ_o : Failure rate of unmonitored (standby) or monitored components
T: Time between testing
Q_{M1}: Error in test and repair
Q_{M2}: Failure to detect and recover previous error in test and repair
f_M: Frequency of routine maintenance
T_M: Duration of routine maintenance
T_R: Duration of repair
Q_{O1}: Probability of error in operations or emergency
Q_{O2}: Probability of not detecting and recovering error

The primary business functions (compare to work processes & programmes) which the model considers are: **operations, emergency operations; inspection and testing, maintenance and modifications**. Based on a literature review, the modelling experience gained in the project and the systematic logic imposed by the SADT technique,

the management & organisational factors were grouped into generic delivery systems. They are: **competence, availability, commitment, interface and modifications, spares, internal communication and coordination, conflict resolution and finally procedures/output goals and plans.** Also the feedback and learning loops were considered.

In the I-Risk interface model, the output of the management system is the result of a series of management processes that are assessed and quantified for each **delivery system.** The final output of the management system is calculated including the local feedback and adjustment processes for task executions. For each of the 10 parameters shown in Table 5, the basis of the technical model data has been defined in I-Risk, for example whether it was generic (such as for λ) or plant specific (such as for T). The relevant management aspects were identified, for example, whether the maintenance frequency specified originally is kept to or whether delivery systems increase or decrease it.

Then, at a much more detailed level for each parameter, **the parameter-influencing factors** (PIFs) were identified and grouped according to the relevant management delivery systems. For example, for the routine maintenance frequency, fm, the **Communications** delivery system influences communication of schedules, priorities, and unambiguous instructions on scheduling.

Table 6. Delivery systems (of a common mode management system) that affect basic event parameters with their weights ($\Sigma_i W_i$=1)

	Basic event parameters										
Delivery systems	*Qo1*	*Qo2*	*Qm1*	*Qm2*	*fi*	*λ*	*T*	*fm*	*Tr*	*Tm*	*Total*
Availability	0,06	0,05	0,08	0,05	0,1	0,08	0,05	0,05	0,12	0,12	0,76
Commitment	0,15	0,14	0,19	0,13	0,2	0,12	0,24	0,21	0,07	0,08	1,53
Communication	0,07	0,05	0,06	0,05	0,1	0,12	0,14	0,16	0,21	0,21	1,17
Competence	0,16	0,21	0,14	0,22	0,1	0,08	0	0	0,09	0,08	1,08
Conflict resolution	0,18	0,21	0,14	0,18	0,1	0,08	0,28	0,32	0,10	0,12	1,71
Interface	0,20	0,20	0,08	0,18	0	0,08	0,05	0,05	0,19	0,17	1,2
Procedures	0,18	0,14	0,17	0,15	0,4	0,16	0,19	0,16	0,10	0,08	1,73
Spares & tools	0	0	0,14	0,04	0	0,28	0,05	0,05	0,12	0,14	0,82

These PIFs were different for each parameter, and the number of factors varied between delivery systems for each parameter. Counting the number of PIFs factors for each parameter, and then expressing the number for each delivery system as a proportion, enabled every delivery system to be weighted in importance for each parameter. The result is shown in Table 6, and it provides a conversion table for apportioning the quantified outputs of the management system deliveries to the parameters.

5 Discussion and concluding remarks

Cultural and organisational factors (COFs) are important components in nuclear safety. Unfortunately, there is no commonly agreed and validated method for their assessment, neither inside nor outside the scope of PSA. Neither can generic recommendations given about how to improve COFs at an installation. This is due to that all plants, cultures and organisations have their specific features. In nuclear sector, organisational processes are periodically reviewed by regulatory agencies. This makes them easily more formal than in some other industries.

The area of COFs is very delicate, although during the past few years we have learned to talk about human reliability and human errors. Consequently, a great deal of experience, discretion and a wide perspective is required to understand the mechanisms of COF influences, ways they affect safety and economy and the practical possibilities to take measures in a real organisation.

Fortunately, there are many practical things that one may do. For example, the different points of views on COFs lead to a rather similar outcome: the COFs consist of action and communication processes taking place on a higher than the shop floor level (or before). The feasible approaches to analyse COFs are highly dependent on the purpose and the target of the analysis. However, the points and principles presented in sections 2 and 3 provide a reader with a collection of tools to start with.

The practical approaches presented in this paper (section 4) for the inclusion of COFs in PSA are quite alike and based on the same research pedigree. This harmonious view also may include a danger that the readers should be aware of – there are many sources of major uncertainty in modelling and subjective data used. A constructive data oriented interaction between theory and practice is necessary to validate models. It is recognised that this may be a long term endeavour and very plant specific data may be required.

Undoubtedly the used models and laws simplify the reality very much. On the other hand, using simplifications is not a flaw in itself – probably using too complex models (that would be speculative, anyway) would be much worse. We have seen that on other areas of PSA that could not have developed without starting with major simplifications.

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APPENDIX: ORFA CLASSIFICATION

The ORFA project was a Concerted Action (Contract No. ERB FI4S-CT98_0051) among seven partners in Germany, Finland, France, Switzerland, Spain, Sweden and the United Kingdom /WAH 99/. The project was started in August 1998 and it ran to the end of 1999. The main purpose of the ORFA project was to join scattered European efforts of research in organisational factors of nuclear safety and to establish a common frame for future research. The scientific objective was to identify key components of an organisational theory, which is practical enough to be used in addressing safety, related issues of organisation and management at nuclear power plants. Also a need to create methodologies and tools by which managers at the plants can develop their own programmes for organisational development was identified during the project. A concerted action like ORFA was too limited to solve the large problems it studied, but a basis for further research co-operation was built.

The organisational factors that were identified as feasible are relevant from this lecture point of view. In ORFA literature survey, several methods to assess organisational performance were reviewed. This review produced some 160 organisational factors, which are highly overlapping. These factors could be finally structured into seven general categories, (1) Inter-organisational Relations, (2) Vision, Goals & Strategies, (3) Supervision and Control, (4) Operation Management, (5) Resource Allocation, (6) Performance, (7) Technology which provide a generic view of important organisational relationships. These categories were used to collect experiences of nuclear utilities and regulatory bodies about them and their influence on different NPP objectives (e.g. safety, good publicity, competitiveness, profitability) in ORFA. In the lecture text, some relationships between the factors and different levels of function are presented.

(1) Inter-organisational Relations
This category relates to all extra-organisational factors, organisations or institutions which interact with nuclear power plants and which have an impact on its internal operations, such as political events, regulatory bodies, manufacturing companies, design companies and research institutions. It seems self-evident that such relations will affect organisational aspects of nuclear power plants. For instance, regulatory demands may force certain reporting and documentation activities or re-arrangements of intra-organisational responsibilities.

(2) Vision, goals and strategies
All strategic or policy objectives decided at the highest corporate or nuclear power plant level, may be placed in this category as they may relate to entrepreneurial or safety issues. These aspects must be considered important indicators of safety commitment of top management, and so aspects of organisational and safety culture find expression in this category as well.

(3) Supervision and control
In this category all those features of nuclear plants that relate to leadership and managerial functions such as employee monitoring, incentive and reward structures, definition of responsibilities, work flow co-ordination, training programs were assembled. The way in which such functions are conducted will undoubtedly have consequences for the

internal organisational climate and trust, which are the foundations staff organisational commitment and safety related activities.

(4) Operations management
All those organisational arrangements which ensure an adequate and safe work flow within nuclear plants are grouped under this heading. They cover such functions as planning, quality management, operations feedback, procedures, maintenance management, performance auditing and review.

(5) Operations performance
Specific aspects of the 'task performance' of individual staff in nuclear plants such as: work practices, violations, work protection, stress management and housekeeping were grouped under this category.

(6) Resources
Factors that enter this category consist of tangible and intangible resources from which the organisation of a nuclear plant may draw in order to guarantee safe and reliable operations. These include financial resources, information resources, labour relations, communication, staff attitudes and commitment, team spirit and staff competence.

(7) Technology
This last category covers all the technical features of the nuclear plant's hardware and software such as component quality, design and construction, defence–in-depth, physical working conditions and technical support.

It must be assumed from theory, as well as from practical experience, that the seven main categories of organisational factors described above do not operate independently of each other in impacting outcomes of nuclear power plants such as safety and reliability. In fact, complex interactions among them must be assumed. Further, it must be borne in mind that the 160 odd factors from the 13 models that were analysed were ascribed to generic categories by way of a consensus process among safety experts. One may rightly debate the adequacy of the seven categories identified as well as the validity of the grouping of individual factors within one of the seven groups. Nevertheless, it seems useful to summarise and visualise the potential interrelations among the seven categories and their influence on nuclear plant outcomes (e.g. safety. reliability, competitiveness, profitability), as an eighth category.

The effect of organisational factors on risk

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Summary of the lecture

- Introduction to cultural and organisational factors (COFs) + safety culture
- How they affect safety (and economy)
- Selected approaches used to study organisational influences and processes in PSA
- Discussion: state-of-art (where are we?)
- Conclusions

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1 Introduction

- Accidents are usually attributed by human and organisational factors (sub-optimal performance)
- Increasing awareness of significance of interdisciplinary analyses of MTO (man-technique-organisation)
- Demand has led to an amount of studies (see references)
- Confusion about defining organisational factors - very different points of views may be taken
- This lecture mostly looks at the issue from PSA point of view
- The message to the audience: yes, the area is complex but there are tangible things one may do

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2 Organisational factors and safety culture

Six views on the organisational factors:

- process-outcome point of view
- primary / secondary action point of view
- structure and communication channel point of view
- top-down and bottom-up point of view
- time point of view
- organisational process and individual response point of view

They lead to a rather harmonious synthesis!!

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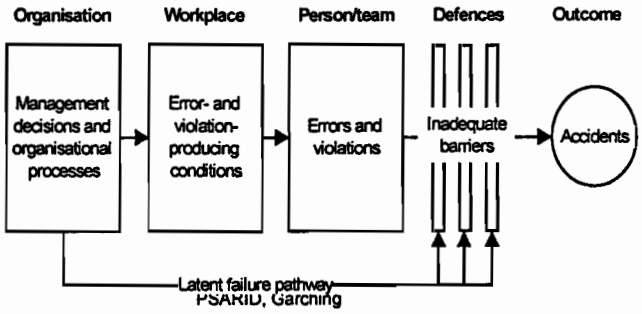
2 Organisational factors and safety culture

- Process-outcome point of view: there are processes with inputs and their outcomes (example: communication)
- It is often easy to find problems in the outcome - finding a remedy requires an investigation of the processes themselves.
- We may either study the processes or their outcome (PSA) depending on the current need / sufficient level of analysis

J. Reason:



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2 Organisational factors and safety culture

- Primary versus secondary actions: organisational processes consist of (from PSA point of view secondary) human actions - their outcome affects primary (shop floor) actions.
- Operation, maintenance, modifications and (often) testing are primary actions, where man is in direct touch with the process and equipment
- For example, planning, design, supervision etc. are secondary supporting activities
- Supports process-outcome point of view!

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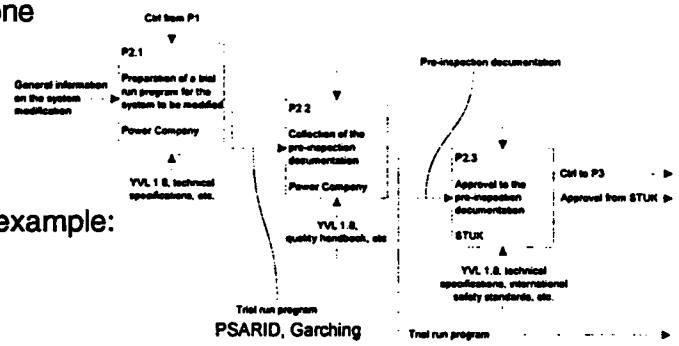
2 Organisational factors and safety culture

•Structure and communication channel point of view - presents information flow inside the organisation
•Representations: static organisation box chart or more dynamic flow diagrams / Petri nets / SADT etc.
•There also may be a formal organisational structure and an informal one

A SADT example:



2 Organisational factors and safety culture

Top-down and bottom-up approaches:

•The bottom-up approaches look at organisational factors from the shop-floor human action perspective (PSA)

•The top-down perspective attempts to study and explain organisational factors starting from the upper level, i.e. safety culture, organisational learning, organisational "types" etc.

Time point of view:

•Results (outcome) of organisational processes (control room design, organisational structure, policy, training, procedures etc.)

•Dynamic events during the disturbance having an impact on behaviour (managing situation with system faults (maintenance) and information about them, arriving communications, resources available etc.)

2 Organisational factors and safety culture

•Organisational processes and individual response: especially in short term bad organisational support does not have to lead to a catastrophe

•No organisational support makes up lacking personal skills and motivation - even in case of a perfect organisational support and good workers accidents happen (bad luck).

This is an add-on point of view to PSA related study of organisational support

	Human performance (indicators)	
Organisation (secondary activities):	positive	negative
supportive	indicators tell that the shop floor actions are going well organisation supports performance acceptable long term situation	indicators tell that the shop floor functions are not satisfactory staff incapable of using the organisational support or bad luck
disruptive	1 no direct indicators pointing at less qualified organisational support (good luck ?) 2 good staff, improvises and compensates for lack of support (short term)	indicators tell that the shop floor functions are not satisfactory the organisation does not support shop floor activity unacceptable long term situation

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2 Organisational factors and safety culture

Safety culture (INSAG):

•"...safety issues receive the attention warranted by their significance"

•"individual attitudes and competencies, organisational culture, and all of the organisational structures required to safely operate a plant"

•"a prudent questioning attitude towards safety related matters".

Affected by *(see Schein 1992)*:

•artefacts (visible entities in organisational processes e.g. occupational safety department)

•norms & values (strategies, goals and philosophies)

•underlying (unconscious) assumptions

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3 Organisational influences on safety - HRA

- There is not one and only valid approach or linking function (loglinear, logit ..) to include COFs in safety assessments.

  $\log(p) = \Sigma_i W_i * R_i + b$
- They are actually (note!) very often taken into account <u>in human reliability analysis (HRA)</u> by performance shaping factors (PSFs or PIFs):
- See lecture 6!

THERP[1]	HCR[2]	SLIM[1]	CREAM[1]
Situational characteristics Task and equipment characteristics Psychological stressors Physiological stressors	(1)Operator experience (2)Stress level (3)Quality of operator / plant interface Time [(4) median / available]	Procedures available / Requires diagnosis Stress level Time pressure Severity of consequences Complexity Requirement for teamwork	Adequacy of organisation Working conditions Adequacy of MMI and operational support Availability of procedures / plans Number of simultaneous goals Available time Time of day Adequacy of training and experience

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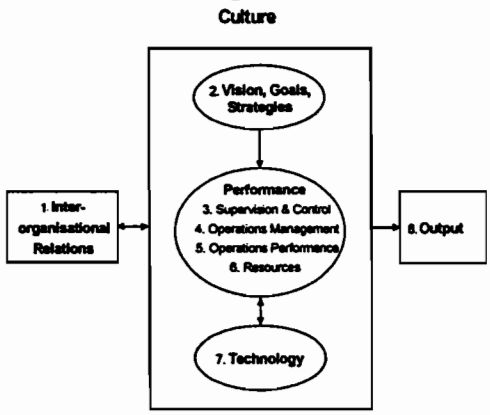
3 Organisational influences on safety - outside HRA

- COFs may be studied more extensively than for HRA purposes only (PSFs)
- Examples about what the COFs are e.g. Jacobs & Haber (1994)
- A hierarchical ORFA view on COFs for a plant:



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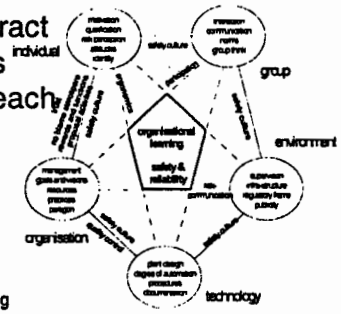
3 Organisational influences on safety outside HRA

Five different subsystems 1) the environment in which the NPPs are operating, 2) the technology used in their construction, 3) the individuals working at the plants, 4) the groups and their norms of behaviour and 5) the organisation with its structure and work processes.

•ORFA:These five subsystems interact and there are organisational factors important for nuclear safety within each of the subsystems and at their interfaces.

•Safety culture permeates all interactions between the five subsystems.



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3 Organisational influences outside HRA

- For example, maintenance efficiency affected by COFs
- Similar effects may take place in other plant processes.
- Effects on safety, economy, ...

Periodically tested components $\Gamma = \Gamma_{i} + \Gamma_{ii} + \Gamma_{iii} + \Gamma_{iv}$

i) Unavailability owing to hardware failure between tests $\Gamma_{i} = 1 - \frac{1 - e^{-\lambda T}}{\lambda T}$

λ: failure rate

If $T \ll 1$ $\Gamma_{i} \approx \frac{1}{2}\lambda T$

T: mean time between tests

ii) Unavailability owing to repair of detected failures $\Gamma_{ii} = \frac{\frac{e^{-\lambda(T+T_r)} + \lambda(T+T_r) - 1}{\lambda(T+T_r)}}{1 + (1 - e^{-\lambda T_r})e^{-\lambda T}} + \frac{1 - e^{-\lambda T_r}}{e^{-\lambda T} + 1 - e^{-\lambda T_r}}$

If $(T + T_r) \ll 1$ $\Gamma_{ii} \approx \frac{1}{2}\lambda T + \lambda T_r$

T_r: duration of the repair

iii) unavailability owing to routine maintenance/tests $\Gamma_{iii} = \Gamma_{iii} \frac{1}{1 + f_m T_m} + \frac{f_m T_m}{1 + f_m T_m}$

f_m: frequency of maintenance

If $f_m T_m \ll 1$ $\Gamma_{iii} \approx \Gamma_{iii} + f_m T_m$

T_m: duration of maintenance

iv) unavailability owing to errors in maintenance/tests $\Gamma_{iv} = \Gamma_{iv}(1 - Q_{m1}Q_{m2} \ldots) + Q_{m1}Q_{m2} \ldots$

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3 Organisational influences on safety - PIs

- Reliability parameters are rather insensitive to changes
- It is useful to study the way the organisation is performing before the reliability parameters are affected

Performance Indicators (PIs):

- "Hard" such as fuel reliability index, radiation doses, accident rate, number of significant events, maintenance backlog, turnover and load factor.
- "Soft" PIs, such indicators are staff qualification rate, training hour rate, need for repeated maintenance, administrative delay in safety related actions, temporary modification rate, personnel turnover, number safety related initiatives (+their approval rates), surveillance efficiency, maintenance ambition index etc.
- Also behaviourally anchored rating scales (BARS) may be used to rate performance ("really soft")

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4 Approaches to include organisational factors in PSA

- A wide variety of methods exist - a representative collection given in the references

Three examples discussed in text:

- the Accident Prevention Group (six step) method for post-IE human actions and COF influence on them
- WPAM also aims at studying company work processes and COF influences on (pre-accident) failure parameters of systems by using SLIM/AHP/BARS.
- I-risk approach seeks to take the organisational influence into account in the whole (pre- and post IE) risk analysis framework and combine it with company safety management audits

In the following, some slides are presented about the six step approach (the methods have partly the same pedigree)

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4 The six step approach

Step I: Develop a Causal Model of the Control Room Crew Reliability

Step II: Develop a Decision Tree For Reliability

Step III: Determine Ratings for Organisational Factors

Step IV: Calculate Organisationally Grounded Ratings for Influence Factors

Step V: Assess Probabilities (or Weigths of Evidence) for Influence Factors

Step VI: Incorporate Influence Factors' Weights of Evidence Into Decision Tree

The three main categories of influence factors (IFs) in step I are:

- 1) knowledge, skill and ability **(KSA)**,
- 2) tools and resources **(TR)**, and
- 3) motivation and morale **(MM)**.

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4 The six step method

- Step I:a COF influence model through plant departments and IFs to HEPs

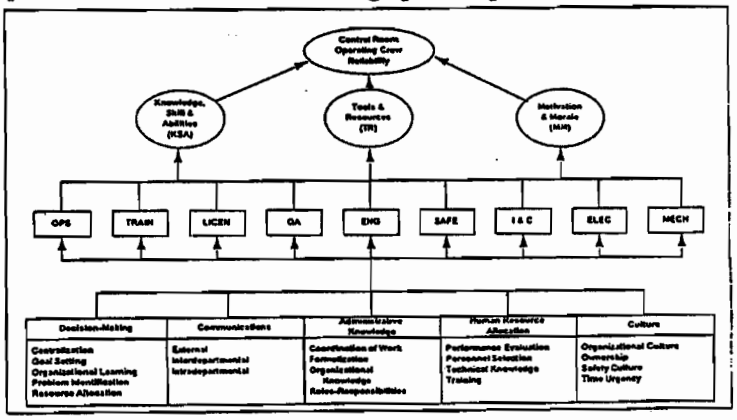

Figure 1. Influence of Organizational Factor Through Departments on Control Room Crew Reliability [5].

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4 The six step method

- Jacobs & Haber (1994) COFs used in step III
- Averaged BARS (non-measurable indicators) on scale 1-7 for departments' COF ratings

Table 1. Organizational Factor Quantification with Respect to Departments for a Plant [5].

DEPARTMENTS / FACTORS	OPS	TRAIN	LICEN	QA	ENG	SAFE	MAINTENANCE		
							I&C	ELEC	MECH
1. Communication	3	3	2	2	4	3	3	2	2
2. Administrative Knowledge	2	4	4	4	3	3	3	2	2
3. Human Resources Administration	3	4	3	4	4	4	3	3	3
4. Culture	2	3	3	3	2	3	2	2	2
5. Decision Making	2	4	2	2	2	2	1	1	1
Overall Ratings (R_j)	2.4	3.6	2.8	3	3	3	2.4	2	2

NOTE: Scale = 1 through 7, with 7 being the highest (best) score and 1 being the lowest (worst) score.

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4 The six step method

- The degree of influence on the post-IE HEPs varies among different departments.
- The departments' OFs were weighted for their degree of influence (step IV) on IFs by using Saaty's AHP as follows:

Table 2. Summary of Assigned Weighting Factors for Various Departments and Overall Ratings of Human Reliability Influence Factors [5].

WEIGHING FACTORS (W_j)	OPS	TRAIN	LICEN	QA	ENG	SAFE	MAINTENANCE			R_j^*
							I&C	ELEC	MECH	
KSA	0.3	0.5	0	0	0	0.1	0	0	0	3.2
Tools and Resources	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0	0	2.9
Motivation and Morale	0.6	0.3	0	0	0	0.1	0	0	0	3.6

* NOTE: Scale = 1 through 7, with 7 being the highest (best) score and 1 being the lowest (worst) score.

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5 The six step method

- Step V is to convert the departments' ratings into binomial probabilities (weights of evidence) of IF states (good or bad) through a simple linear model
- In step VI these binomial probabilities are used to multiply the decision tree (conditioned) outcome probabilities

Table 3. Summary of weights of Evidence (p_i) for the Three Human Reliability Influence Factors [5].

Influence Factor	Rating (R_i)	Influence Factor Scale	$p_i = -0.17 + 0.17 \times R_i$
Knowledge, Skill and Abilities (KSA)	3.2	Good	$p_1 = 0.37$
		Poor	$\bar{p}_1 = 0.63$
Tools and Resources (TR)	2.9	Good	$p_2 = 0.32$
		Poor	$\bar{p}_2 = 0.68$
Motivation and Morale (MM)	2.8	Good	$p_3 = 0.30$
		Poor	$\bar{p}_3 = 0.70$

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The six step method

Step II&VI: Conditioned and unconditional HEPs

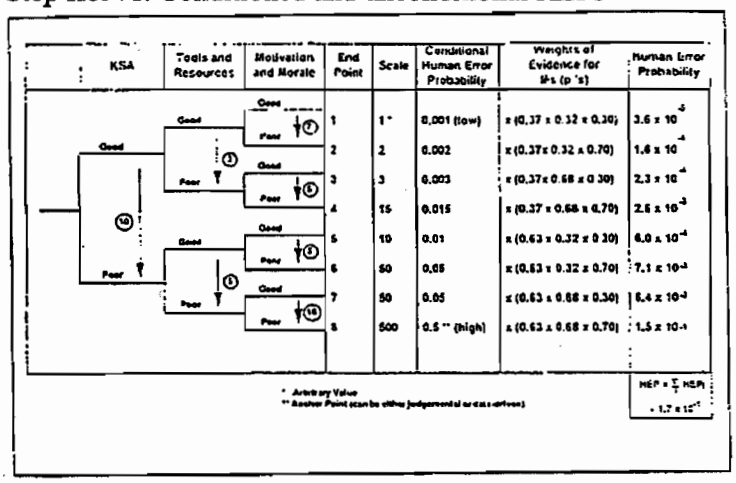

Figure 2. A Decision Tree to estimate Human Error Probability [5].

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Discussion and concluding remarks

- Cultural and organisational factors (COFs) are important components in nuclear safety.
- There is no scientifically validated generic method for their assessment, neither inside nor outside the scope of PSA -> A constructive data oriented interaction between theory and practice is necessary to validate models.
- Generic recommendations about how to improve COFs may be given but all installations and tasks have their specific features.
- Undoubtedly the used models and laws simplify the reality very much - on the other hand, using simplifications is not a flaw in itself
- The area of COFs and human reliability is still delicate and a great deal of experience, discretion and a wide perspective is required

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Discussion and concluding remarks

- There are many practical things one may do!
- COFs: consist of action and communication processes taking place on a higher than the shop floor level action (or before).
- The feasible approaches to analyse COFs are highly dependent on the purpose and the target of the analysis - this papers gives practical and thinking models to start with.
- The practical approaches presented in this paper for the inclusion of COFs in PSA are quite harmonious and based on the same research pedigree.
- An analyst has to judge what is the reasonable level of analysis so that evidence may collected to support suggested models and their quantification

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ANNEX 1: WPAM

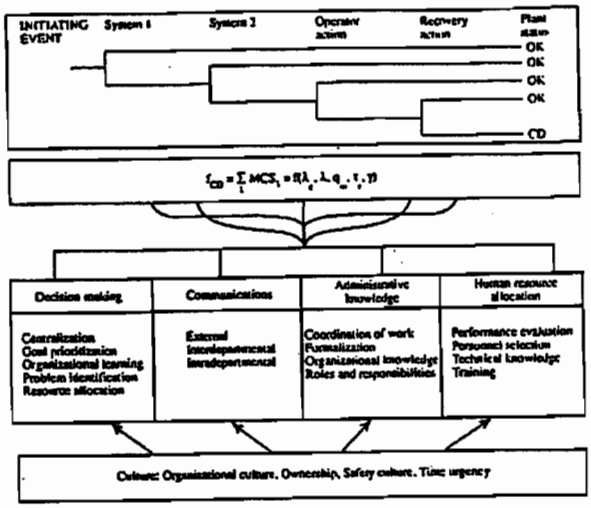

Figure 3. Incorporation of organizational impact into PSA [8].

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ANNEX 1: WPAM

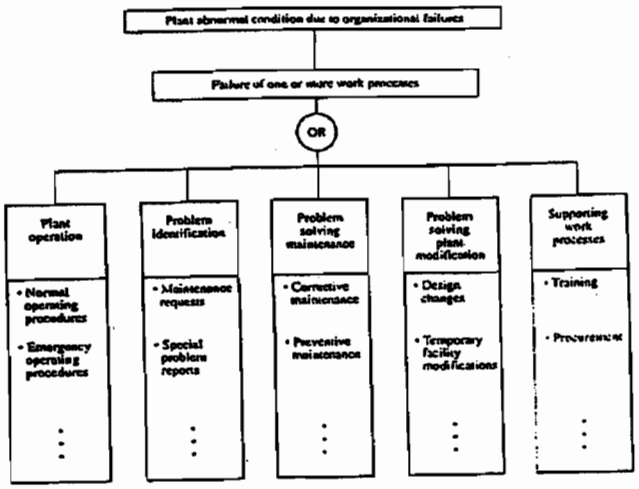

Figure 4. Front-line and supporting work processes [9].

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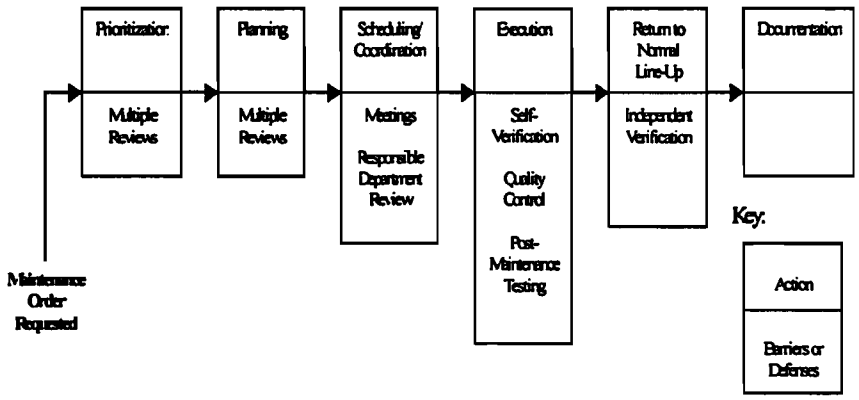
ANNEX 1: WPAM, tasks and barriers inside an example work process



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ANNEX 1: WPAM reference table example

Table 4. The cross-reference table for the corrective maintenance work process [9].

Task	Action/Barriers	Department	Personnel
Prioritization	Prioritization Reviews	Work Control Center (WCC) WCC/Operations	WCC Supervisor Shift Supervisor
Planning	Planning WCC Review Engineering Reviews Responsible Dept. Review	Maintenance/I & C WCC Engineering Maintenance/I & C	Planner WCC Supervisor System Engineer Mech./Elec./I & C Engineer
Scheduling/Coordination	Scheduling/Coordination Meetings Responsible Dept. Review	Planning Dept. Various Depts. Various Depts. (Operations for system tagging)	Scheduler Variable (Operations for Work Authorization)
Execution	Execution Self Verification QC Post-Maintenance Testing	Maintenance/I & C Maintenance/I & C Quality Control/ Quality Assurance Maintenance/I & C/WCC	Mech./Elec./I & C Mech./Elec./I & C QC/QA Engineer Mech./Elec./I & C
Return to Normal Line-Up	Return to Normal Line-Up 2nd Verification	Operations Operations	Control Room Operator Control Room Operator
Documentation	Documentation	WCC (Nuclear Plant Reliability Data)	Clerk

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ANNEX 1: WPAM

Table 5. The organizational factors matrix for the corrective maintenance work process [9.]

	Prioritization		Planning			Execution				
	Prioritization	Reviews	Planning	Reviews	Scheduling/ coordination	Execution	QC	Post-Maint. testing	Return to normal line-up	Documentation
Centralization	x	x	x	x	x	x	x	x	x	x
Communication-External			x							
Communication-Interdepartmental	x		x		x	x				
Communication-Intradepartmental	x	x	x	x	x	x	x	x	x	
Coordination of Work			x		x	x				
Formalization	x		x		x	x	x	x	x	x
Goal Prioritization	x				x					
Organizational Culture	x	x	x	x		x	x	x		
Organizational Knowledge	x	x	x	x	x	x	x			
Organizational Learning	x	x	x	x				x		
Ownership				x		x	x			
Performance Evaluation						x	x			
Personnel Selection	x	x	x	x	x	x	x	x	x	
Problem Identification		x	x	x		x	x	x	x	
Resource Allocation	x				x					
Roles-Responsibilities	x	x	x	x	x	x	x	x	x	x
Safety Culture	x	x		x		x	x			x
Technical Knowledge	x	x	x	x	x	x	x	x	x	
Time Urgency	x	x	x	x	x	x		x		
Training						x	x	x	x	x

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ANNEX 1: WPAM

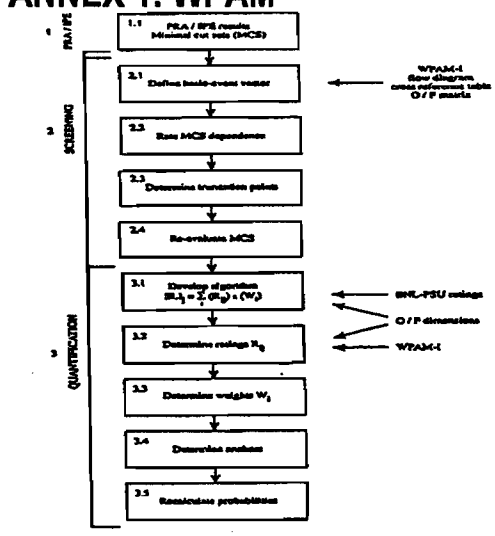

Figure 7. Work process analysis model-II (WPAM-II) [8].

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ANNEX 2: I-RISK

Table 1. Basic Event Parameters of the I_RISK Technical Model

f_i: Frequency of external events
λ_s λ_D : Failure rate of unmonitored (standby) or monitored components
T: Time between testing
Q_{m1}: Error in test and repair
Q_{m2}: Failure to detect and recover previous error in test and repair
f_M: Frequency of routine maintenance
T_M: Duration of routine maintenance
T_R: Duration of repair
Q_{o1}: Probability of error in operations or emergency
Q_{o2}: Probability of not detecting and recovering error

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ANNEX 2: I-RISK, weight of delivery systems wrg to reliability parameters

	Basic event parameters										
Delivery systems	*Qo1*	*Qo2*	*Qm1*	*Qm2*	*fi*	*λ*	*T*	*Fm*	*Tr*	*Tm*	*Total*
Availability	0,06	0,05	0,08	0,05	0,1	0,08	0,05	0,05	0,12	0,12	0,76
Commitment	0,15	0,14	0,19	0,13	0,2	0,12	0,24	0,21	0,07	0,08	1,53
Communication	0,07	0,05	0,06	0,05	0,1	0,12	0,14	0,16	0,21	0,21	1,17
Competence	0,16	0,21	0,14	0,22	0,1	0,08	0	0	0,09	0,08	1,08
Conflict resolution	0,18	0,21	0,14	0,18	0,1	0,08	0,28	0,32	0,10	0,12	1,71
Interface	0,20	0,20	0,08	0,18	0	0,08	0,05	0,05	0,19	0,17	1,2
Procedures	0,18	0,14	0,17	0,15	0,4	0,16	0,19	0,16	0,10	0,08	1,73
Spares & tools	0	0	0,14	0,04	0	0,28	0,05	0,05	0,12	0,14	0,82

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