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HUMAN FACTOR AND PREVENTIVE ENGINEERING

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Abstract. *In this paper human error analysis and reduction and same of curent human factor and preventive engineering reserch models: the iceberg model, the organizational model of accident, SHEL model, the model of safety problems, and complex model of risk evaluation, are shown.*
The preventive engineering education and training and an integrated approach towards preventive engineering is also shown.

Key words: *human factor, preventive engineering, risk, accident, human error*

1. INTRODUCTION

Development of progressive strategies for interpolete of human factor in preventive engineering has it's times curent.

In the 60' and 70' preventive engineering were focused on minimizing tehnical failures, increasing the realibility of engineered safety devices and barriers. In 80' after airlines accidents in 1974. and Three Miles Island in 1979. the focus was on the fallible human component; better training, improved human – computer interfaces, decision support systems were the answer to minimizing and avoid the propagation of "human error". Finally, in the 90' after the wide spread of the several empirical evidences (Chernobyl, Zeebruggs, King's Cross, Bophal, etc.) the central importance of socio-technical factor and organizational failures in safety - critical system has been acknowled ged.

The task of preventive engineering is, by using analithic-sinthetic models, which are used in different researched systems, to provide optimal working and living environment quality for performance of human activities, at the same time reducing to lowest possible level appearance of accidents or minimizing concequences which it causes.

In realisation this tasks human factors and the management of human knowledge are playing an increasing relevand role, beacase the massive introduction of automation and

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computational tools demands a human contribution, to productive processes based almost exclusively on knowledge (Rusmussen et al 1994.). Often organisations have the information they need, but they do not know, or, are not able to find it, and recent works aim at collecting and organising the workers knowledge and expirience, to make it available for the organisation as a whole (Conklin, 1996.).

2. Human error analysis and reduction

There are five types of human-system interaction which the analyst should consider with respect to an incident scenario (Spurgin et al., 1987):

– maintenance / testing errors affecting safety system availability (latent errors),
– operator errors initiating the incident,
– recovery actions by which operators can terminate the incident ,
– errors (e.g., misdiagnosis) by which operators can prolong or even aggravate the incident, and
– actions by which operators can restore initially unavailable equipment and systems.

Consideration of these types of interaction, and discussions with the system risk analyst at the problem definition stage will enhance the smooth integration of the human reliability analysis into the system risk analysis.

Once human error probabilities have been quantified, the system risk, can be calculated and compared to an acceptable level to see if improvement is necessary. If human error cannot be reduced to an acceptable level, even with additional hardware recommendations, then significant redesign of the system and/or its operation will be required. Usually however, an effective combination of human and hardwere modifications can be found to achieve an acceptable level of risk.

In the case of specific identified critical errors there are several ways of reducing their impact on the system (Kirwan, 1994.):

– Prevention by hardware or software changes: use of interlock devices to prevent error; automate the task etc.
– Increase system tolerance: make the system hardware and software more flexible or self-correcting to allow a greater variability in operator inputs which will achieve the interded goal.
– Enhance error recovery: enhance dection and correction of errors by means of increased feedback, checking procedures, supervision and automatic monitoring of performance.
– Error reduction at source: reduction of errors by improved procedures, training, and interface or equipment design.

The first two measures require collaboration between the ergonomist or human reliability analyst and system design personnel, and may well prove expensive. Improved error recovery probabilities are often the simplest to implement but maynot reduce erroe likelihoods by a sufficient, amount, and may not be feasible with all critical errors. Error reduction at source therefore may well be the primary means of improving human reliability.

A second additional analysis of the results will be possible only with quantification methods which use a structured performance shaping factor (PSF) approach (e.g., SLIM, IDA, HEART, THERP, TESEO). With these approaches it is possible to determine the contributions of individual PSFs to human error goals. For example, the most significant PSF in a particular scenario may be "qualiti of procedures" and, therefore, error reduction measures aimed at improving the quality of procedures will be most effective at reducing error likelihood. Furthermore, if for example quality of procedures is the most important PSF for a number of human errors, this then suggests that a single global error reduction strategy generally to enhance performance can be specified. This type of investigation of the results will enable the cost effectiveness of potential error reduction strategies to be assed (Grozdanović, Savić,2001.).

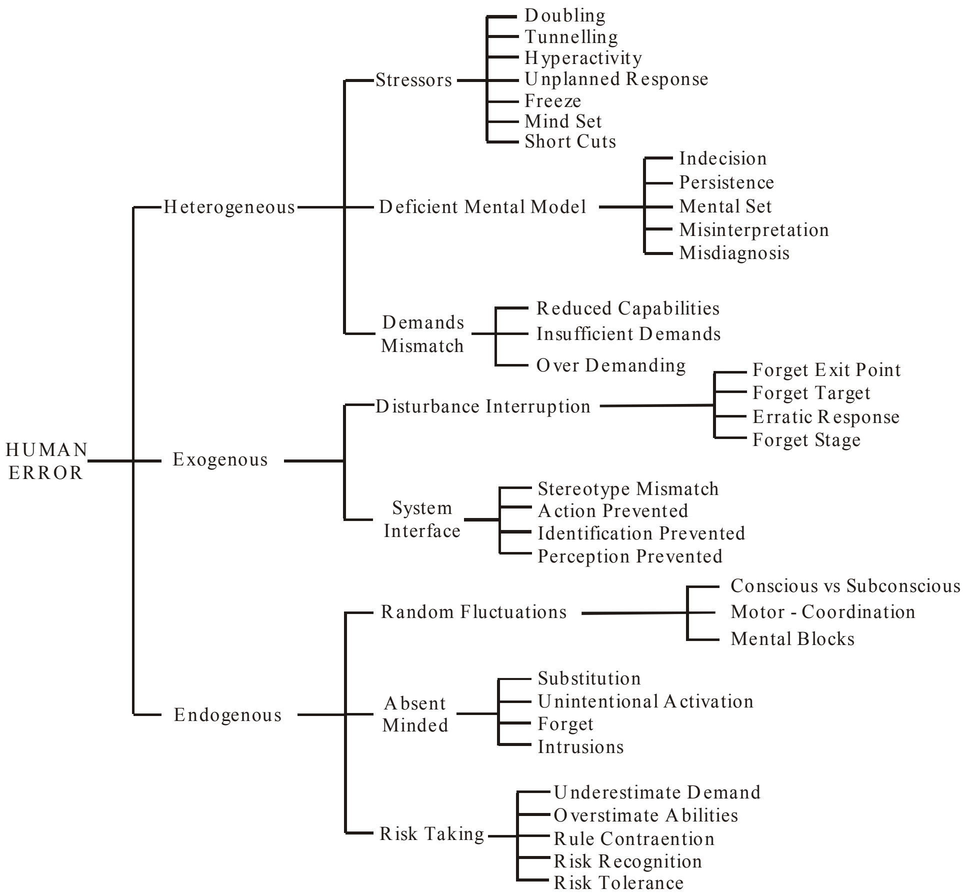

Fig. 1. Error causes grouped by error mechanisms

Another method for human error analysis is embedded within the systematic Human Error Reduction and Prediction Approach (SHERPA). This human error analysis method consists of a computerized question – answer routine which identifies likely errors for each step in the task analysis. The error models indentified are based on the "skill rule and knowledge" model, and Generic Error Modeling System (GEMS: Reason, 1990).

Computerized system is the Potencial Human Error Cause Analysis (PHECA) system (Whalley, 1988). Figure 1. shows the error causes and mechanisms interent in the model and Figure 2. show the major performance shaping factors which interact with the error causes (Grozdanović,1999.)

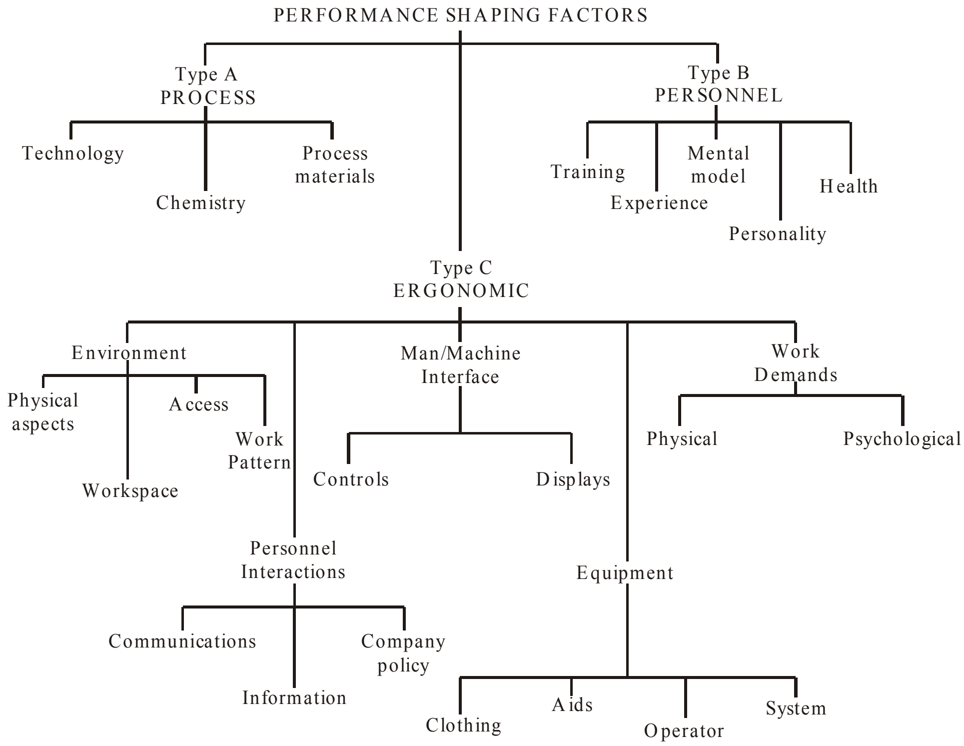

Fig. 2. Major sections of the performance shaping factors classifications structure

Where possible, the positive effects of the error reduction strategy adopted should be factored back into the quantitative analysis and it should be checked that the HEPs and overall system risk calculated become acceptable. This requires not only the precise operational definition of each aspect of the error reduction strategy is properly implemented and maintained throughout the remaining life of the plant. This is part of the quality assurance phase.

3. PREVENTIVE ENGINEERING RESEARCH MODELS

In this paper are shown same of current human factors and preventive engineering research models, because traditional methods which analise only reports on accidents, without reestablishment of corelative realations between relevant factors of causes and concequences of accidents, can not propose adequate solutions.

3.1. The iceberg model

The iceberg model shows the relationship between accidents, near – misses, unsafe acts. There is a double correlated trend in learning from experience in the safety domain. From one side, organizations are trying to learn not just from the more visible and less frequent events such as accidents and incidents. They are paying attention also to less visible but much more frequent event such as near – misses and unsafe acts.

Experts belive that the latter are the key components that combined in an unlucky pattern may lead to the former, as depicted in Fig. 3 by the familiar iceberg model. Then, feedback from the analysis of near – misses and unsafe acts are supposed to help in preventing or reducing incidents and accidents. Reason quotes several factors for considering accident, incident, and near- misses reporting system as having too little and too late effect. Two of them are quite compelling:

- A very conservative estimate by an experienced unsafe act observer (Groeneweg, 1991) was 7 unsafe acts per hour. In a company emplaying 6000 people, this wold yield approximatety 6 million unsafe acts per year. Not only eliminating but even meosuring these 6 million unsafe acts would be an impossible task.
- The likelihood of an accident is a function of the type and number of latent failures within the system. The more higher in the management level of the organization and the more frequent they are, the greater is the probability that some of these latent failures will encounter just that combination of local triggers necessary to produce an accident. This view demants quite a different calculus then that employed in conventional probabilistic risk assessment produced by backtracking analysis or linear causal models.

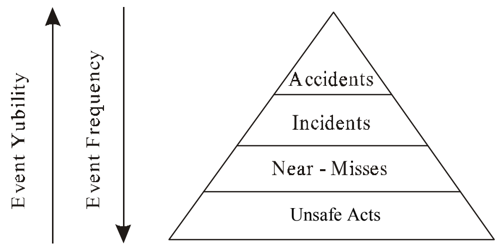

Fig. 3. The iceberg model

3.2. The organizational model of accident

The organizational model of accident (Figure 4.) provide a good representation of the shift from tehnical to organizacional issues in modelling accidents. Again this is a shift from more visable to less evident as also stressed by the two main components of the model active and latent failures.

The organizational model of accident and the organizational learning processes ask for a different view of documenting and analyzing safety issues. A view that consider the productive system as a whole and that does not concern just events with negative outcomes but also the vital signs of safety (Reason, 1994). This view is by not means new and it is theoretically well grounded in the distributed cognition approach (Hutchins, 1995).

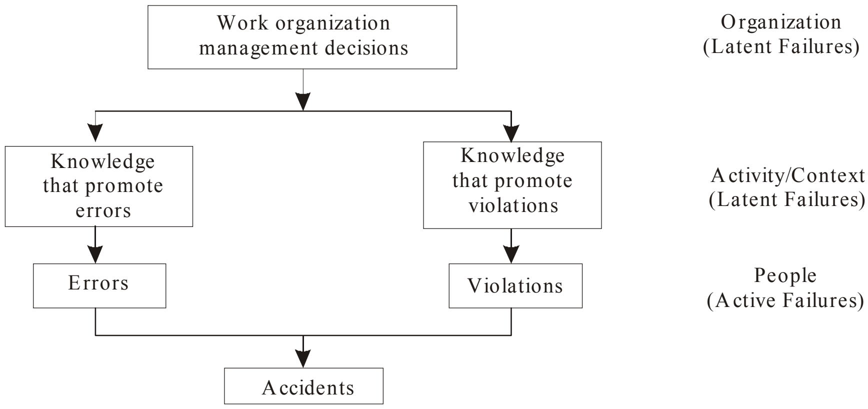

Fig. 4. The organization model of accidents

3.3 The framework for the model of safety problems

Analysis of safety problems should be based on the task aspects of the human-machine interactions that give rise to them. Our approach views every work task as a series of interactions between two sub-system : a human sub-system (the worker) and an engineering sub-system (machines, physical objekts in the environment, etc.). To achieve the common task-goals, these sub-systems should operate as one, in smooth coordination. In such a system there is an important division of responsibilities between the two components, where some of the tasks are performed by the worker, the others by his engineering counterpart. Ideally each performing those parts of the task for which it is best suited. Figure 5 shows theoretical framework for the model of safety problems.

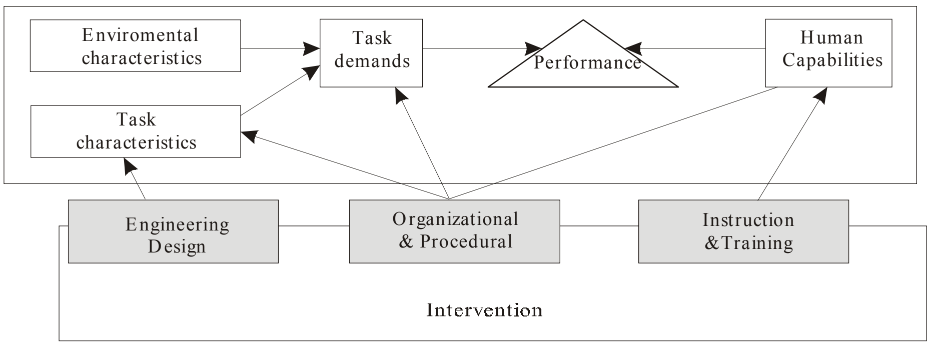

Fig. 5. The model of safety problems

In the analysis of each task we found it useful to examine four main dimensions (Greenshpat et al., 1997):

Environmental characteristics relevant to the task performed e.g. lighting, noise, floor conditions, etc.

Task interaction characteristics. We put special emphasis on such aspects as the level of activity structure, regularity and complexity; as well as periodicity and cycle duration, locus of control, extent of tolerance to human error and type and quallity of materials being hendled.

Task demands. Processing and response demands, derived from the characteristics of the environment and/or of the task with which the worker has to cope so that the system can function smoothly.We put special emphasis on such aspects as: the reliance of task performance on perceptual information (visual, auditory, tactile or proprioceptive); nature and level of skill and knowledge bases; complexity, accuracy, speed and coordination properties of motor responses; level of alertness; nature and costancy of attention demands over time and coping with mental load and the mobilization of resources in times of emargency.

Operator capability dimensions relevant to the task as: the physical characteristics (morphologic, anthropometric and biomechanical): perceptual capabilities; skill level and extent of relevant knowledge and energetic state during performance of the task.

A safety problem is defined as a mismatch between task demands, and the worker's ability to meet them.

3.4. SHEL model

The Shel model (Figure 6.) is to consider human as integrated and not separable component of the productive system. Shel is the acronymic of Software, Hardware, Environment and Liveware. According to this view any productive process is always defined by a specific combination of hardware, software and liveware resources wich can be represented as the three axis of a three-dimensional space. In this model human error are the product of breakdowns in the interaction betwen the humans, the hardware, the software.

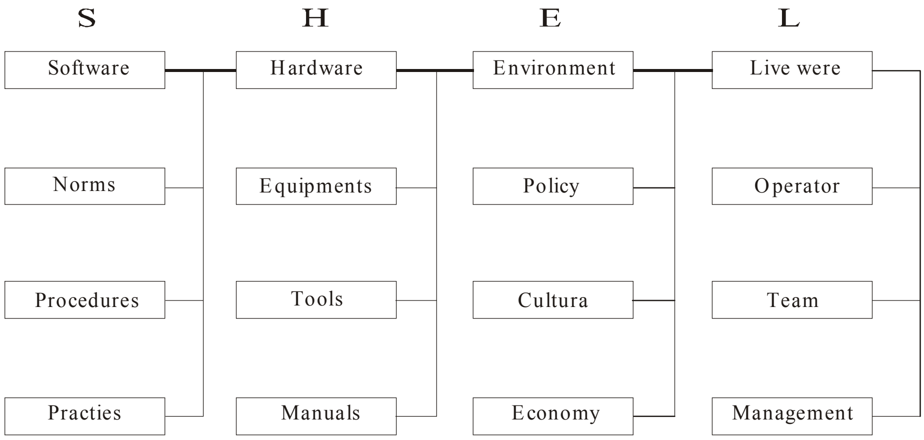

Fig. 6. The SHEL model

Following this model, a taxonomy of the critical issues (named SHELS) had been developed and many of the classes included in the taxonomy are similar to that proposed by other tools as the General Failure Types proposed by Reason or the Human Error Analytic Taxonomy previously developed by some of us (Bagnara et al, 1989) or the Project Evaluation Tree put forward by Stephenson (1997).

3.5. Complex model of risk evaluation

The principle of this model consists in point evaluation of each important factor of final risk level. After the point evaluation of each components is computed final risk value and compared with the value of acceptable risk. This method was developed in the section Machines safety-working group for mechanical, physical and chemical risk (Sinay et al, 1998). The main application area for this method are human risks. Method integrates several basic components of human factor analysis and also enables the clasification of risk level of working area and working subjekt.

Method consit of next computations:

a) computation of risk factor caused by technical device, i.e. risk factor of machine M is given:

$$M = S \cdot Ex \cdot P \cdot Pr$$

where:

S (1 – 10) is velue of possible damage
Ex (1 – 2) is exposure ho hazard
P (0,5 – 1,5) is probability of accident
Pr (0,5 – 1) is possibility of prevention

b) computation of environment influences, i.e. risk factor of environment E is given:

$$E = Wr + Erg + Ni$$

where:

Wr (0,5 – 1) – is arrangement of working area
Erg (0,3 – 0,6) – are ergonomical conditions
Ni (0,2 – 0,4) – are other negative influences

c) computation of human factor H is given:

$$H = Q + Ps + O$$

where:

Q (0 – 10) – is degree of personal qualification
Ps (0 – 3) – is personal psyhological ability
O (0 – 5) – is level of work organization

Using above mentioned computation the final risk value is given:

$$R = M \cdot E \cdot H \cdot (M/30)$$

The main goal of this computation is to control the risk, to minimize all negative influences, for example illness, health injury, dead and also technical consequences. All necessary demants on the technical safety are integrated in two basic legislation products of EU:

- Direction 89/391/EU – Increasing of Safety and Health Protection in Working Conditions
- Direction 89/392/EU together with its amendments 93/44/EU, 93/68/EU – Machine Safety – Approximation of Member States Legislation.

4. EDUCATION AND TRAINING FOR THE PREVENTIVE ENGINEERING

Education and training for the preventive engineering were greatly developped in most countries with a view to guaranteeing a sufficient protection against risks of damage to helth, to integrating within mentalities – and this as soon as possible – positive attitudes and behaviour towards safety. Figure 7. shows the concept of education and training for the preventive engineering.

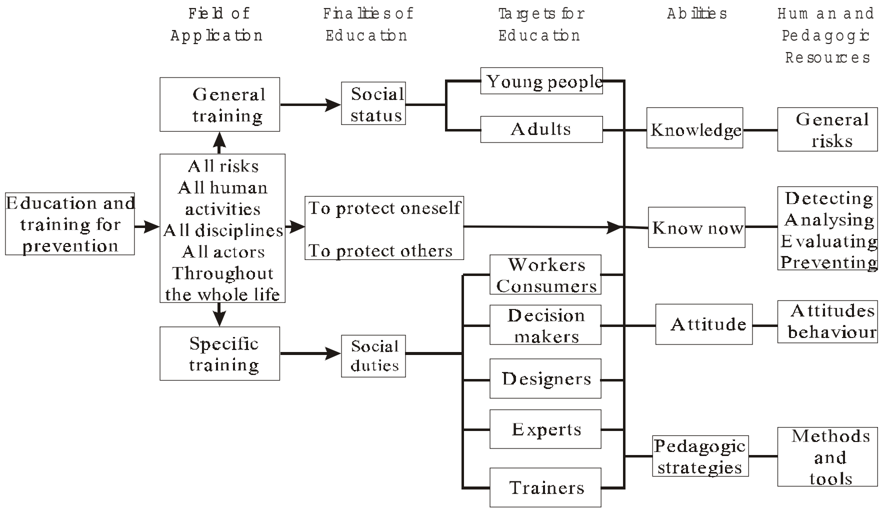

Fig. 7. Concept of education and training for preventive engineering

Principles, bases and aims of education and training for the preventive engineering are (Jerome, 1997):

- Prevention, rehabilitation and compensation are closely inter-linked strategies in the development of a real social policy.
- The systemic approach to occupational risk prevention opens up the possibility of developing a global prevention concept..
- Combining these factors provides education and training programmes with objectives, content, programmes, trargeted audiences and specific resources.
- Education and training models incorporate acquisition of knowledge about existential risks. This equips the individual to recognize dangers and adopt personal protection behaviour patterns.
- States and social insurence agencies, together with all the actors involved, have a decisive role to play in facilitating the development of safety and health education and training.

In order for education and training to be instrumental in the development of a safety-health behaviour in all human activities, these education and training must be a priority in all prevention actions in order to allow the global control of risk with the active participation of the persons concerned.

– This education and training for prevention should start in childhood and continue troughout life. It should make all citizens more aware of the risks confronting them or which they contribute to create for themselves or others and to make them capable of participating in their prevention.
– This education and training should develop abilities to detect, anticipate and evaluate risks, reduce or remove these risks, control persistent risks and limit the seriousness of the consequences of an accident or a residual risk which could not be prevented.
– In order to develop these skills, all citizens shoud be able to acquire knowledge, know-how and social skills with respect to prevention.Education situations should allow acquisition of general knowledge, the use of a methodology, the application of what has been acquired for both themselves and for others and take into account the real activity of the persons concerned.
– To achieve these objektives, support should be obtained from all scientific and human disciplines and from human attitudes and behaviour.
– The State, social insurance institutions, public and private enterprises, employers associations and trade unions, consumers' and environmental associations, professionnal associations of experts, employees or citizen, each and everyone should, in their own sphere, take every step to:
  - institute, or act through the relevant institution for, compulsory requirement for education and training for the prevention of general and specific risks so that global control of these risks becomes effective.
  - apply of have applied, help and develop, control and participate in this obligation within the framework of principles, foundations and objectives of the study from which these present contributions have emanated.

These principles, foundations and objektives, and the resulting recommendations, are, according to us, the necessary conditions for education and training for the prevention of safety-health hazards to have an influence on man's behaviour, whatever the levels of industrial development in which education and trainong take place, the locations at which they are provided, the situations which drive or orientate them.

5. AN INTEGRATED APPROACH TOWARDS PREVENTIVE ENGINEERING

The integrated model towards safety management is a framework of an organizational development process. It supports and facilitates preventive Health, Safety and Environment (HSE) processes and structures to be integrated into organizations: HSE activities into the daily routines of managers supervisors, and employers, HSE standards and processes into the life cycle of products, services and work systems and finally human resource management principles to get the process running on a long term basic (Figure 8.).

A study of this model is being performed within the Chemical Industry. Three research groups are involved: one from Bochum University, one from Munich Polytehnical School, and a private counselling firm. The scope of the study is the identification of effective practices, proces and structures in HSE-related human resource management, in information management and systems in life cycle management of products, services and work systems, and in cultural aspects of organizations. Research questions address the completenes of components of the control cycle for each of the human resource and information management practices, and the kind of substitutes companies have developed to maintain an efficient feedback loop.

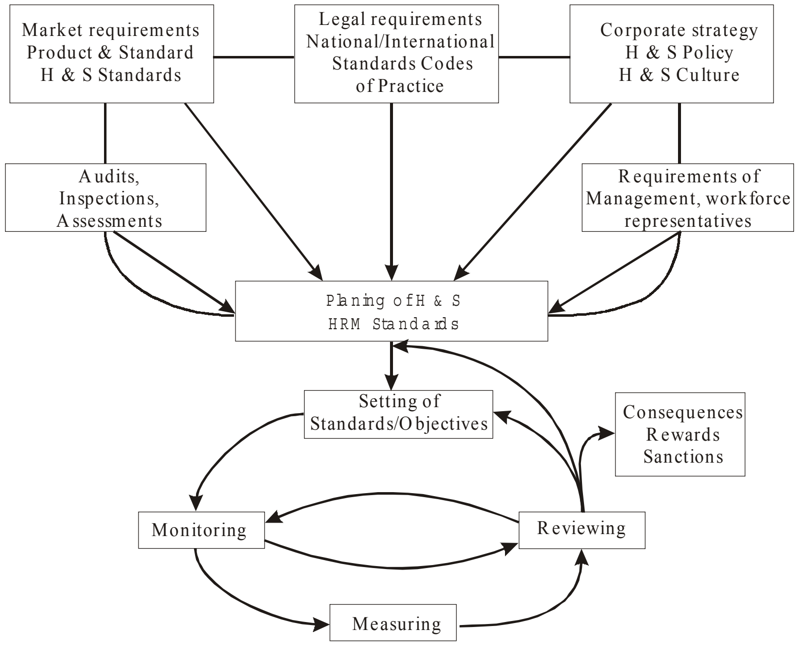

Fig. 8. Control cycle Human Resource Management

Setting difficult yet attainable HSE gools, reviewing HSE performance and achievements on a regularly basis, and reporting results to a monitoring function are essential prerequisites of the program (Locke & Latham, 1990). In order to get the whole process fuelled on a self-substained basis, performance appraisals, incentives and award programs with respect to HSE achievements must be integrated (Mc Afee & Winn, 1989).

6. CONCLUSION

In all fields all human activities there is a potential risk of damage occurrence. Due to that fact, and since ancient times, a man has been directing his activities to avoiding the occurrence of such damages or alleviating them. It represents the basic goal of presenting preventive engineering. In this context, preventive means integrated number of activities and measures, directed to preventing harmful events; reducing the possibility of accidents occurrence and alleviating the consequences if the harmful effect happens, anyway. The notion engineering means implementation of scientific principles and experiences in all stages of one project - from ideas giving to, preparation of studies, feasibility studies, and advice giving during the project realization and supervision.

The propose of this paper is to contribute to adequate realization of preventive engineering promoted goals by means of the methods presented.

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LJUDSKI FAKTOR I PREVENTIVNO INŽENJERSTVO

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U ovom radu predstavljeni su analiza i smanjivanje ljudskih grešaka i neki od aktuelnih istraživačkih modela ljudskog faktora i preventivnog inženjerstva i to: model "ledeni breg", organizacioni model nesreća, SHEL model, model bezbedonosnih problema i komplesni model istraživanja rizika.

Takođe su predstavljeni i edukacija o preventivnom inženjerstvu i integrisani pristup upravljanju preventivnim inženjerstvom.

Ključne reči: *ljudski faktor, preventivno inženjerstvo, rizik, aksident, ljudska greška.*