Safety by context

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The paper is presenting the results of a research developed in order to understand and use the work context in order to improve safety at work. Even if it seems that the context of work is rapidly changing, the changes could be assessed inside a global, safety context assessment mechanism that was put into place by the research. The paper offers a model for the understanding and the assessment of the work (safety) context and also a methodology developed using this model.

The research was done focusing on the development and testing of a Safety Context Conceptual Model (SCCM) that is at the basis of the development of a Safety Context Assessment System (SCAS) - done and implemented in more than 500 work environments in construction, manufacturing and process industries.

Keywords: occupational context, safety, safety by context

Why research safety context?

Any task took place in a specific context. The context is influencing not only the quality of work but also the safety and health at work. Context is described sometimes as" the important small things that we don t observe, do not take into account or are not doing" (Delano, 2013)

The development of better safety at the workplace could be significantly improved by the assessment and the analysis of the day to day work context, of the safety context assured by the enterprise management at every step and also the context of safety culture at the workplace. An efficient safety culture in which:

- Workers and work teams take responsibility for accident prevention initiatives and safety performance improvements;
- Staff safety specialist is employed as a safety coordinator and support function;
- Executive and senior management provide strategic leadership for safety strategy. Content and initiatives left to workers and work teams; and
- Total integration of safety performance into all job responsibilities and accountabilities would be based heavily on the optimal manipulation of the work context.

By context we understand generally the social context- defined as "Availability and expectations of significant individuals, such as spouse, friends, and caregivers. Also includes larger social groups which are influential in establishing norms, role expectations, and social routines" (AOTA, 1994)

Safety context assessment is involving as main actors:

- context provided by the employer (Maciejewski, 1997), including the commitment of the employer- at all the management levels- for safety and health at work;
- context provided by the employee including the physical state of the employer, its general and on the work training, his/hers satisfaction with the work being done, his/hers real commitment with personal/team/overall safety at work;
- context provided by the task needed to be executed;
- context provided by work environment, community and society as a whole determination of some activities (for example using cyanides in gold mining); Figure defines the occupational (work) context that is analysed in this research.

Occupational (and safety) context is intimately related to occupational performance- described as" The ability to carry out activities of daily life. Includes activities in the areas of occupation: activities of daily living (ADL also called BADL and PADL), instrumental activities of daily living-IADL, education, work, play, leisure, and social participation. Occupational performance is the accomplishment of the selected activity or occupation resulting from the dynamic transaction among the client, the context, and the activity. Improving or enabling skills and patterns in occupational performance leads to engagement in occupations or activities. (Law, 1996)

Performance is also related to performance patterns- that could be described as" Patterns of behaviour related to daily life activities that are habitual or routine" (Mosey, 1996).

As could be seen in the figure 1 that describes the safety context model, the main elements of safety context analysis are:

- Human Factor- that could be interpreted here as" "A composite definition of the self which identifies the work being done, the safety measures being adopted and includes an interpersonal aspect (e.g., our roles and relationships, such as mother, wives, occupational therapists), an aspect of possibility or potential (who we *might* become), and a values aspect (that suggests importance and provides a stable basis for choices and decisions)…" (Christiansen, 1999). Human factor in this interpretation could be also viewed as:
    - The developers and implementers of the task- management or Employers;
    - The executors of the task- or Employees

- Task- that Includes specific activities needed for performing the activities of the enterprise – task also should define: Employment interests and pursuits; Employment seeking and acquisition and Job performance (Mosey, 1996). Task should be considered in the following main elements: design, reception and execution.
- Work environment- that includes elements like organizational and safety culture. Work environment should be interpreted as immediate or mid and long term.

Figure 2 details all these elements together with the two categories of influences – outer influences- determined by the community and society as a whole and inner influences- determined by the employers and employees in achieving a common degree of adaptation, seen here as" Relates to the ability to anticipate, correct for, and benefit by learning from the consequences of errors that arise in the course of task performance" (Fischer, 2001). Figure shows two kinds of possible interventions – mitigation of the safety context and improvement- as interventions are perceived here as Specific strategies selected to direct the process of safety improvement that are based on the client's desired outcome, evaluation date, and evidence. Interventions should comprise in every approach:

- Create/promote (health promotion)
- Establish/restore (remediation/restoration)
- Maintain
- Modify (compensation/adaptation)
- Prevent (disability prevention) (Moyers, 1999)

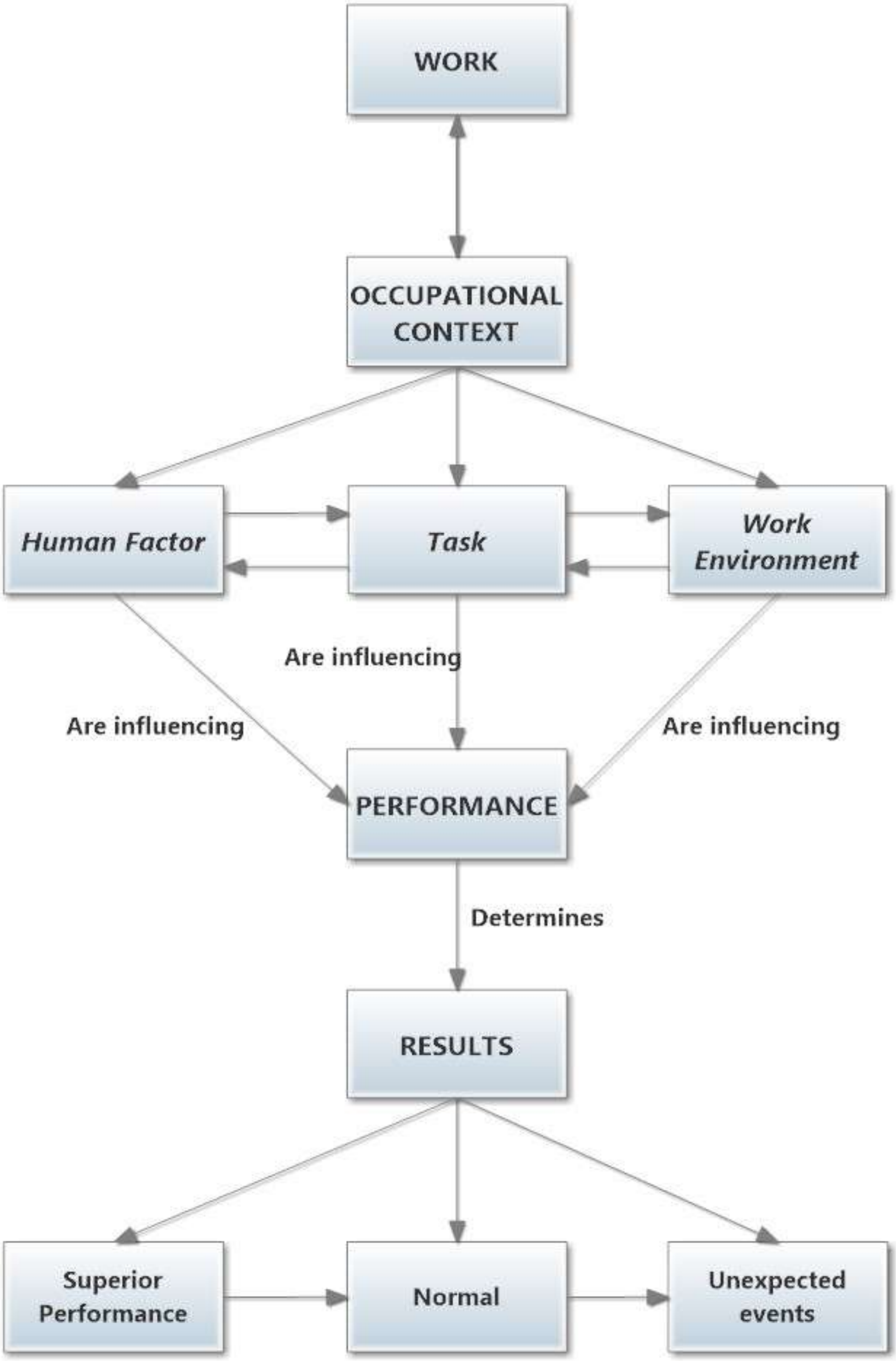

Figure 1. Safety context conceptual model

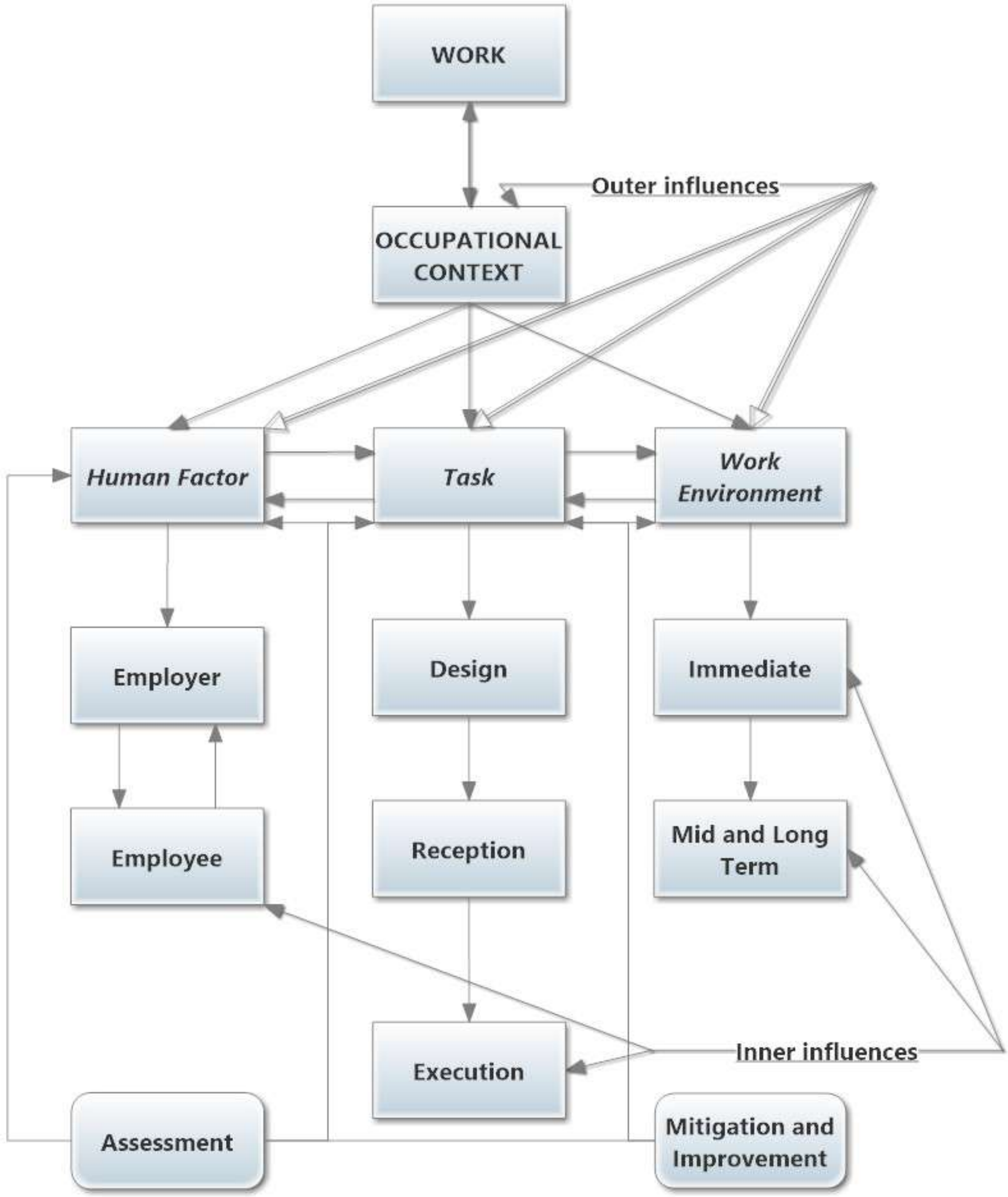

Figure 2. Context main elements

Developed methodology

The SCAS system was designed as a simple yet efficient tool to perform the following main actions:

- to identify context patterns in the development of Unexpected Events at the workplace; such identified patterns could lead to the optimization of lessons learned- for example, an identified context pattern in one of our implementations was the formal endorsement of the safety culture at the workplace by a management that considers other aspects more important than safety- mainly in the construction area. A number of unexpected events occurred in this pattern, finalized with two severe occupational accidents.
- to analyse the main elements that are composing the work context and to see if they are ensuring the desired safety level; for example, the analysis of task element inside a processing facility in the city of Iasi revealed that there was no task recording- more relevant no recording of the unexpected outcomes- even if such outcomes were leading to significant financial loss. The pair analysis- performed in the pair Human Factor- Task- had shown that the safety context of the above mentioned process facility was significantly altered by the indication given by the management of the facility- not to give

importance to unexpected events that are just loss producing- if the value of the loss is below 1000 Euro/month. This was in fact leading to a non-corresponding training of the human operators that were shift leaders- together with the absence of significant task outcome recordings for unexpected situations

- pair analysis of the context main elements- in order to be able to develop safety scenarios based on the context- to plan the mitigation and improvement processes;
- to see if there is a certain unbalance between a referential level of safety in (occupational) context and the actual state of things;
- to assess safety performance- as given by the safety context; this performance could be considered as the static component of the general safety performance;

The different types of dependencies that can occur include the following:

- functional dependencies,
- physical dependencies,
- human interaction dependencies,

Functional dependencies between safety measures, systems and components can arise when the function of one system or group of components depends on the function of another system or component. These can arise due to a number of causes including the following:

- shared components,
- common actuation systems,
- common isolation requirements, and
- common support systems, i.e. power, cooling, indication and control, ventilation.

Functional dependencies include physical interaction between measures, systems and components which can occur when the loss of function of a system or component causes a physical change in the environment of another system or component — for example, a loss of trace heating on a section of pipe that allows it to freeze in cold weather. Physical dependencies can arise in two ways. Firstly, an initiating event can cause the failure of a safety measures, systems and components and failure of some of the safety systems or components required to provide protection. Secondly, an internal hazard (such as a fire or a flood) or an external hazard (such as extreme environmental conditions, a seismic event, etc.) can cause an initiating event and failure of some of the safety structures, systems or components required to provide protection. It is important to analyse the interaction between the progression of the physical process and the performance of the required measures, systems and components. To correctly incorporate the effects of physical processes on the accident sequences, the operability of the required systems must be assessed, i.e., the effect of accidental environmental conditions on the engineering safety features and their support systems must be analysed in detail.

One example of how physical processes may influence the progression of events can be found by considering the loss of the heating, ventilation and air conditioning system. Increasing temperature and humidity may affect the functioning of mechanical or electrical equipment, the ability of operators to take appropriate action and the quality of information provided to the operators.

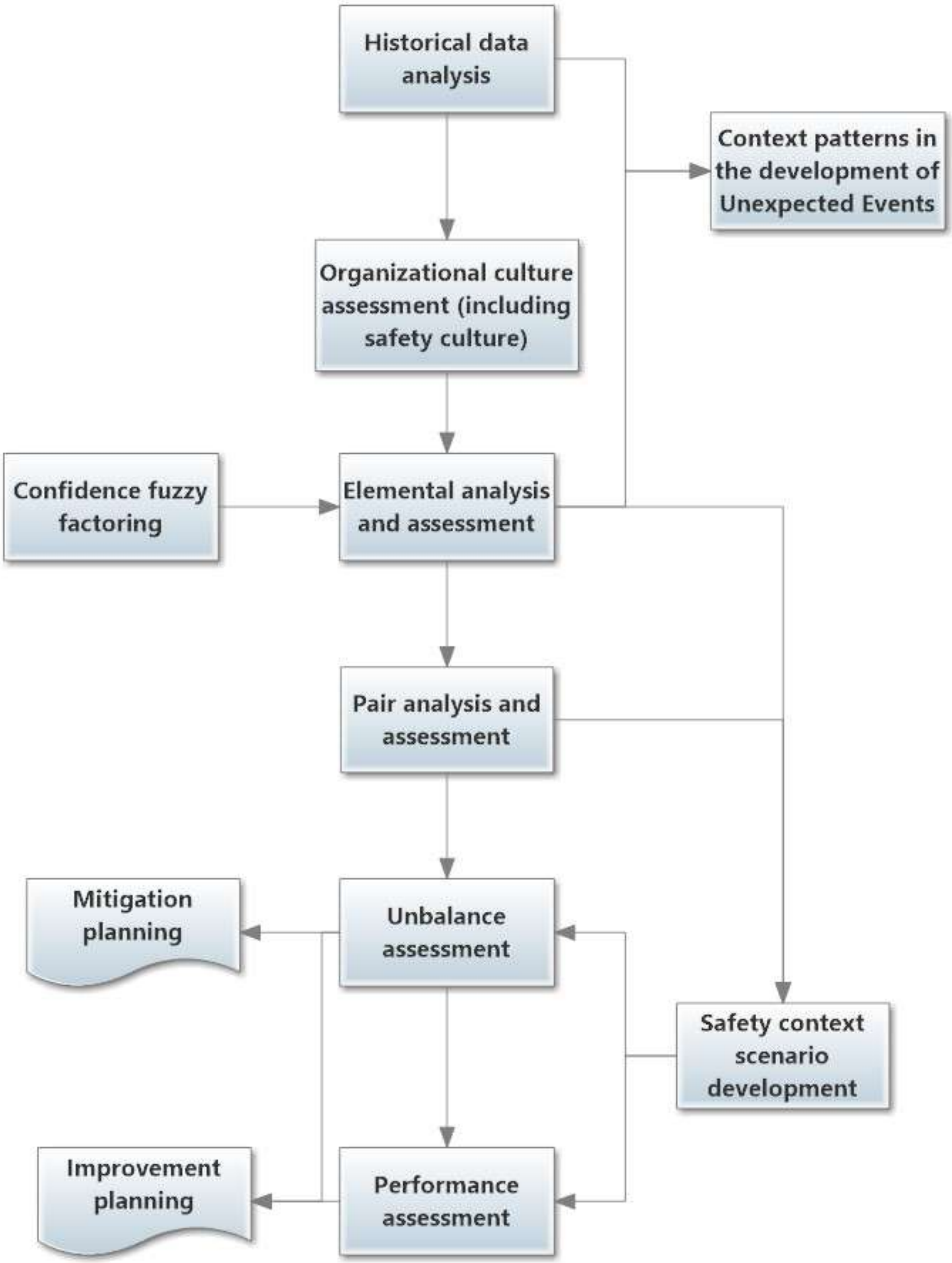

Figure 3. SCAS

Figure 4 details the pair analysis.

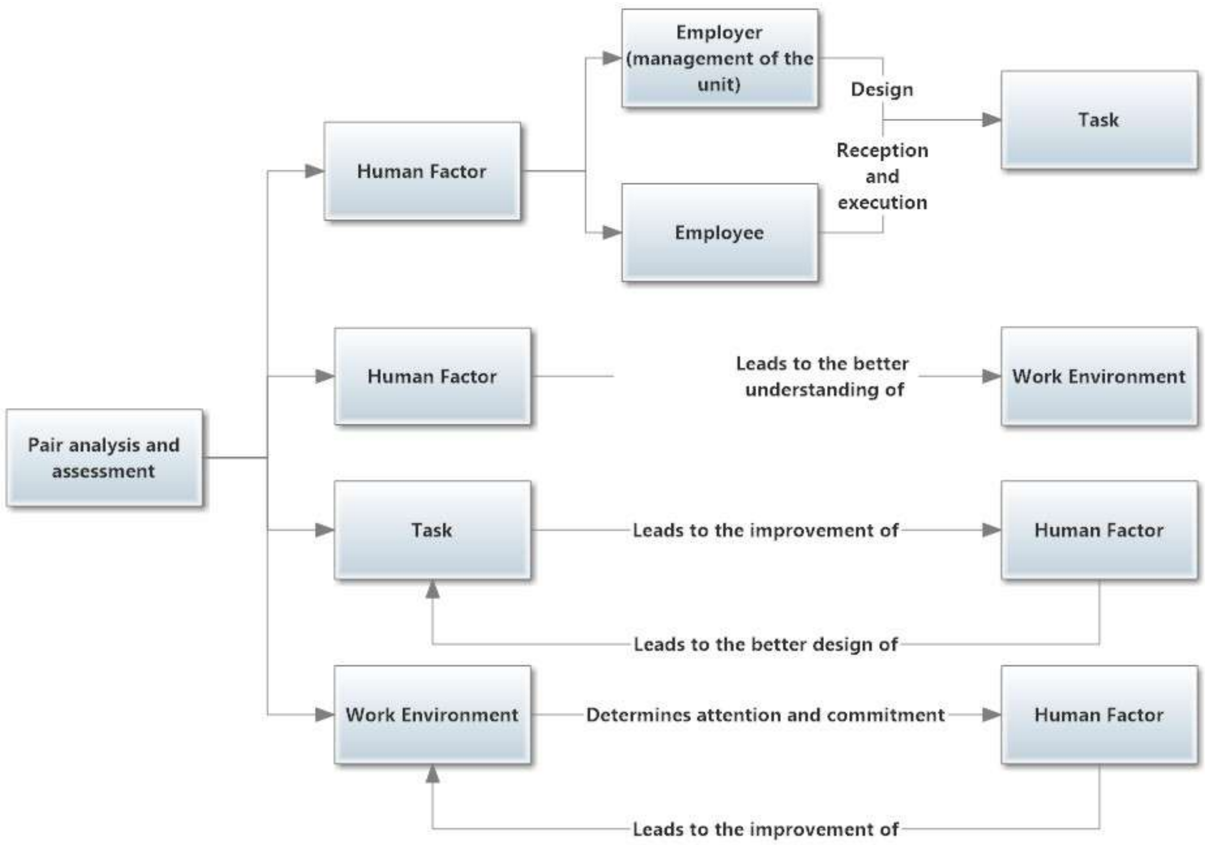

Figure 4. Pair analysis

Safety context performance metric

A **performance metric** is that which determines an organization's behaviour and performance. Performance metrics measure of an organization's activities and performance. It should support a range of stakeholder needs from customers, shareholders to employees. While traditionally many metrics are finance based, inwardly focusing on the performance of the organization, metrics may also focus on the performance against customer requirements and value. In the analysis of the occupational context performance metrics would imply the measuring of following main criteria: safety, mitigation and improvement costs, resources and quality. Developing performance metrics usually follows a process of:

1. Establishing critical processes/customer requirements
2. Identifying specific, quantifiable outputs of work
3. Establishing targets against which results can be scored

In general, an occupational context has multiple weaknesses. The risk of exploitation in each weakness i is given by the product between likelihood of apparition and impact.

Assuming that the potential exploitation of a weakness is statistically independent of others, the system risk is given by the summation of individual risk values:

Occupational Context Risk $_{\text{Element Specific}}$ = Li x Ii (1)

Where Li is the likelihood of exploitation of weakness i and Ii is the corresponding impact.

The individual risk values shall be computed by the assessment of each main element (and eventually of supplemental elements if this is the case). For each element a cover value of Li and Ii should be established and OCR computed.

We could consider an adapted formula- where CEWLi is Context Element Weakness Likelihood and CEI Context Element Impact , so:

OCR (Occupational Context Risk) $=\sum_{1}^{3}(CEWLi\ x\ CEIi)/c_f$ (2)

c_f being a correction factor that would give OCR a canonical form in the following domain

OCR = (1...5) (3)

where 5 is maximum occupational risk and 1 means no occupational risk.

CEWLI and CEI are parameters that should be assessed individually for each element inside the context using a scale like the one given in the next tables.

Table 1- CEWL scale

Context Element Weakness Likelihood	0...10%	11...20%	21...50%	51...75%	76...100%
Assessment value	1	2	3	4	5

Table 2 CEI scale

Context Element Impact	Very Low	Low	Medium	High	Very High
	1	2	3	4	5

For example, in one process facility there were assessed (on the basis of historical data and direct plant assessment the following values for context elements:

Human Factor

$CEWL_{Human\ Factor}$=3 – stating that at an unexpected event could be determined by the employees on a scale between 21...50%

$CEI_{Human\ Factor}$ =2 – the possible impact is low

$OCR_{Human\ Factor}$ = 3

Task

$CEWL_{Task}$=4- states that the likelihood to happen an unexpected event in the plant- event connected with the context of tasks being defined, transmitted and executed being between 51% and 75%

CEI_{Task} =4 – maintenance tasks and other auxiliary tasks could be dangerous in this case.

OCR_{Task} = 4

Work Environment

$CEWL_{Work\ Environment}$=4

$CEI_{Work\ Environment}$= 3- there could be a medium impact.

$OCR_{Work\ Environment}$=3.5

The general OCR is given as

$OCR= (OCR_{Human\ Factor} + OCR_{Task} + OCR_{Work\ Environment}) = (3+3.5+4)/3= 3.5$

Interpreting this score by the reference scale (1...5) we could see that it is high and the context risk should be mitigated with respect to the task (that should be designed using safety best practice procedures, should be validated by a higher level manager- with experience in the process industries) and also by the work environment (a solid safety culture should be developed).

Evaluation by pairs takes a similar form- however here we have some correction coefficients.

$OCR_{HF-Task} = (0.6 \times OCR_{Human\ Factor} + 0.4 \times OCR_{Task)}$ (4)

$OCR_{HF-Work\ Environment} = (0.45 \times OCR_{Human\ Factor} + 0.55 \times OCR_{Work\ Environment)}$ (5)

The coefficient values are derived from extensive experience- they could be adapted if needed.

One essential question is how precise is the context elements evaluation- as the formulas presented above are general. In order to be as precise as possible- each element should be decomposed using topic mapping- based on ISO/IEC13250 that specifies a data model of Topic Maps.

The figure is showing some aspects from the definition of elemental topic maps. We have developed some specific topic maps for construction and process industry with more than 350 components to assess.

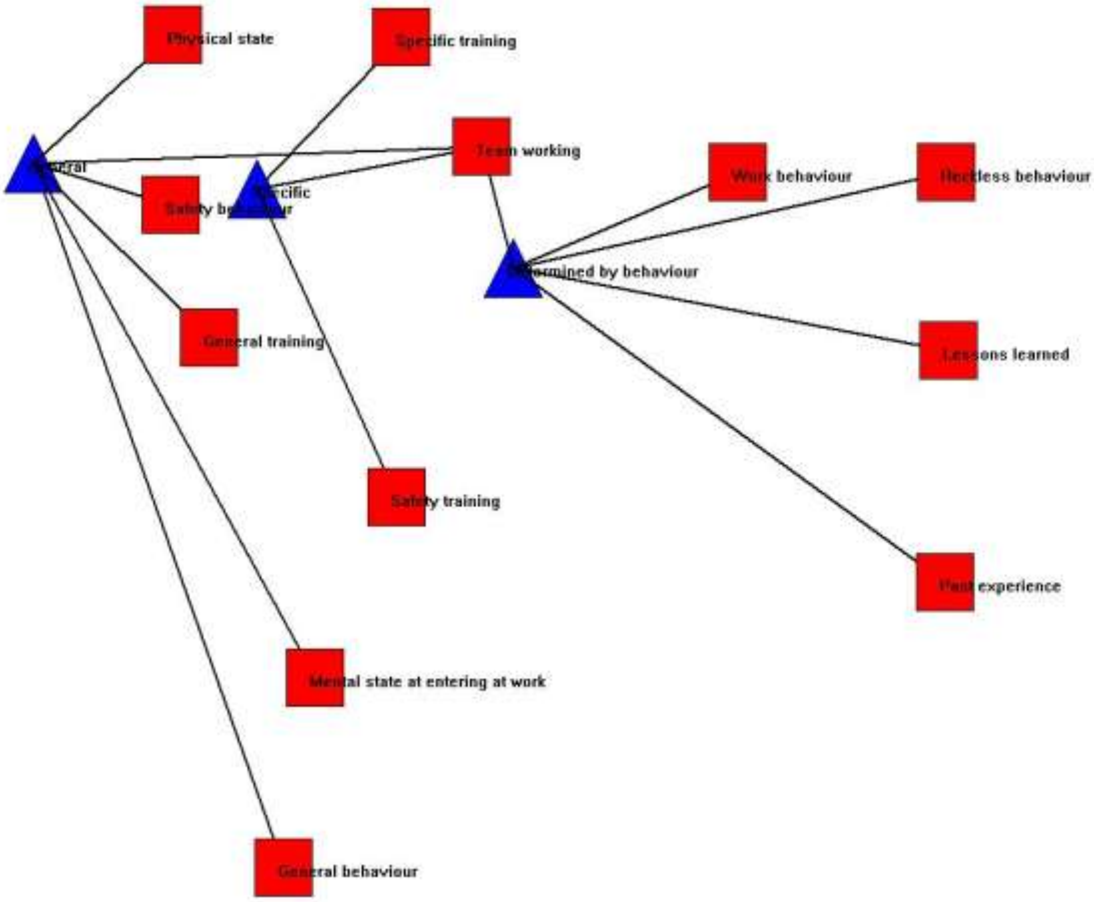

Figure 5 Human factor topic maps in the design mode.

Figure 6 is showing the same topic map in the view mode.

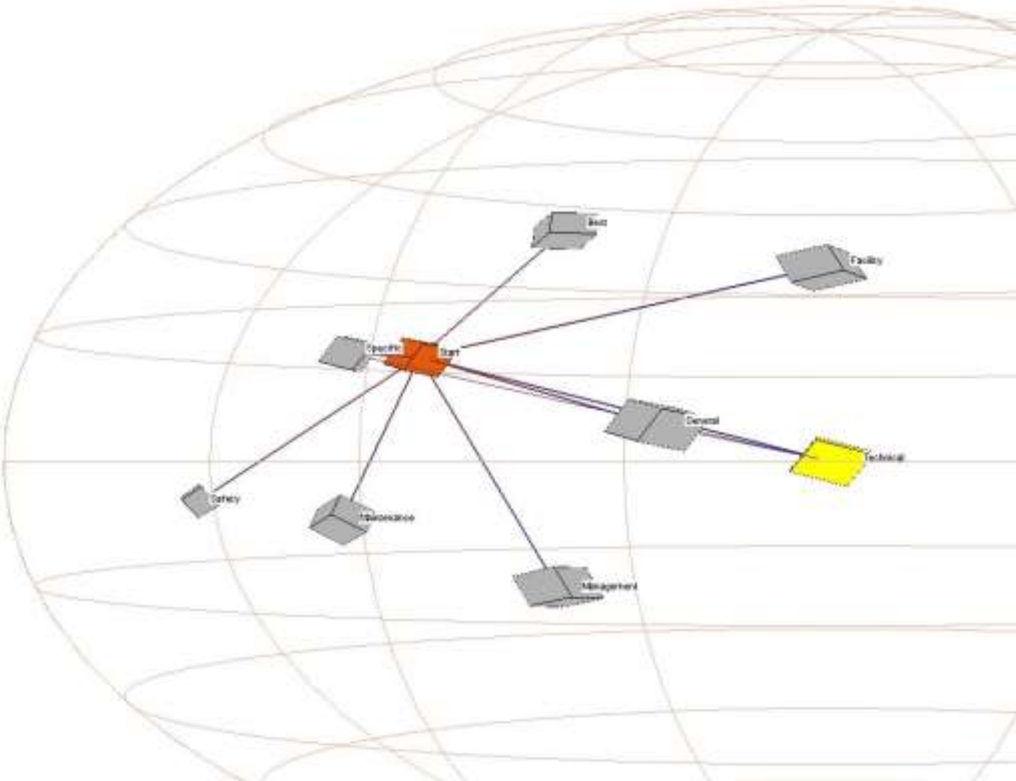

Figure 6 Topic map in the view mode

Modelling occupational context risk

Starting with the presented metrics it is possible to develop an operational model for the context. The developed model could be used:

- to interpret unexpected events that occurred already;
- to forecast dangerous developments at the workplace;
- training in safety;

The model is based upon equation (1) and its structure could be seen in figure 7.

```
UNATTACHED:
    DINAMIC__OCCUPATIONAL_RISK = PULSE(1,5,5)
UNATTACHED:
    Impact_OCRE = RANDOM(1,5,150)
UNATTACHED:
    Impact_OCRHT = RANDOM(1,5,110)
UNATTACHED:
    Impact_OCRT = RANDOM(1,5,130)
UNATTACHED:
    Likelihood_OCRE = RANDOM(1,5,140)
UNATTACHED:
    Likelihood_OCRHT = RANDOM(1,5,100)
UNATTACHED:
    Likelihood_OCRT = RANDOM(1,5,120)
UNATTACHED:
    OCCUPATIONAL_CONTENT_RISK =
    (OCCUPATIONAL_CONTEXT_RISK_ENVIRONMENT+OCCUPATIONAL_CONTEXT_RISK_HU
    AN_FACTOR+OCCUPATIONAL_CONTEXT_RISK_TASK)/3
UNATTACHED:
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Figure 7 The structural support for the model

The diagram of the model could be understood from figure 8.

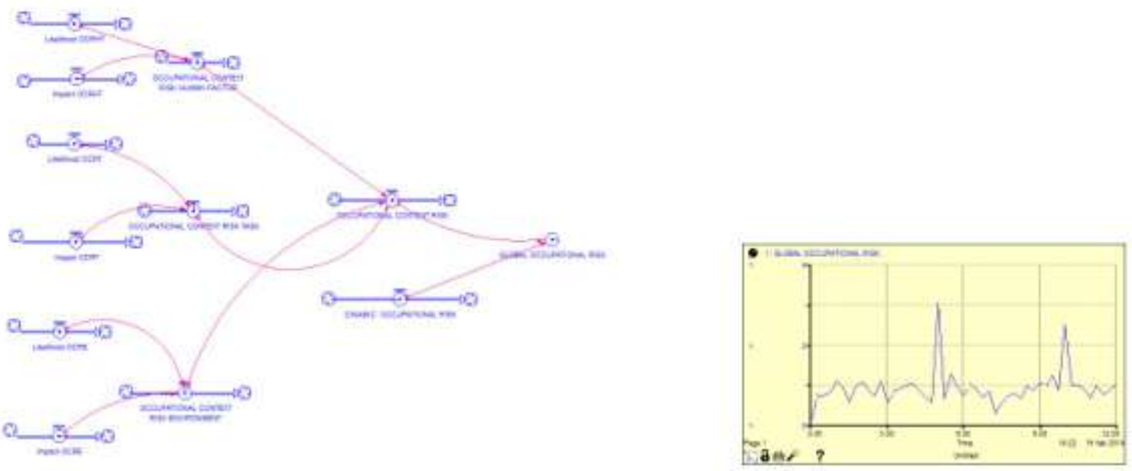

Figure 8 Diagram of the model

Pairs of likelihood and impact- modelled using fuzzy (random) functions are composing the occupational context elements- that are reunited into occupational context risk that is acting together with the dynamic risk upon the specific activities at the workplace.

Some results of the simulations developed using the model with various use case data could be seen in figures 9, 10 and 11.

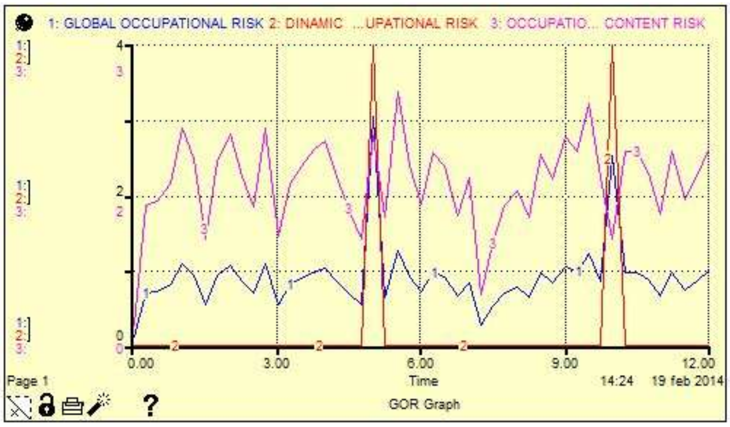

Figure 9 Simulation results-1

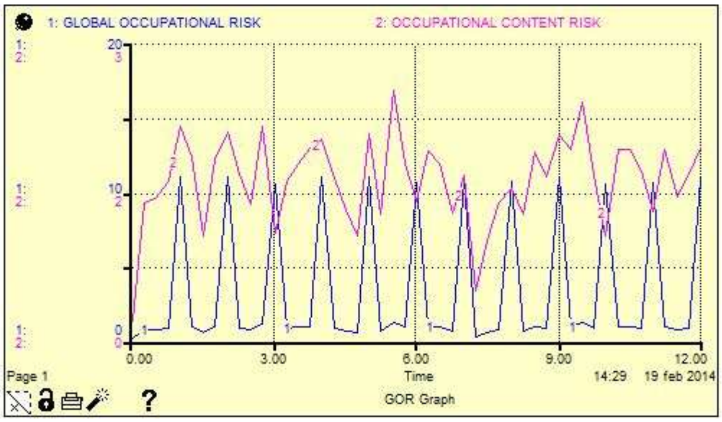

Figure 10 Simulation results-2

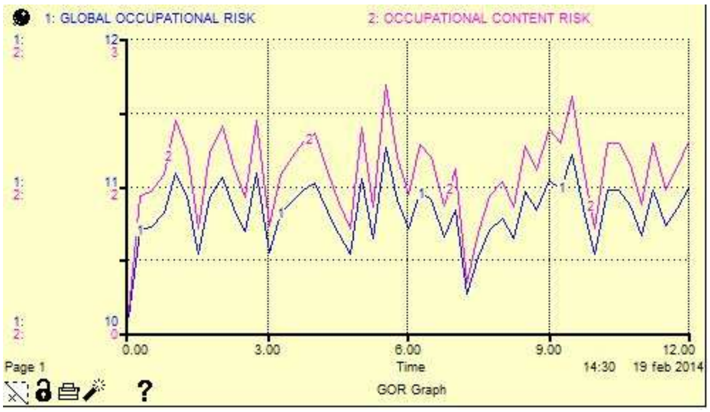

Figure 11-Simulation results-3

Obtained results conclusion

The research done was focused on:

- Development of the Safety Context Assessment System (SCAS);
- Test-up of SCAS in more than 500 work environments;
- Integration of SCAS in the existing safety assessment systems;
- Implementation of the new system;

SCAS was designed as an open, modular system focused on the assessment of the safety context for well-defined work tasks. A special add-on was designed also for not well defined tasks, using fuzzy support. SCAS works on the basis of safety ontology that gives the reference points needed to assess the context and to analyse the results.

As significant results could be mentioned:

- the optimization of the safety assessment process- by empowering SCAS to take over an important part of the assessment, based on subjective estimations made by employees and employers;
- easiness to use open interviews with employees, optimization of those interviews and the possibility to quantify these answers in partial results for the assessment;
- the safety mitigation process should start with the work context; employers and the management of the facility have (using SCAS) key points in which to apply challenge- and optimize their workplaces;

The SCAS was tested- in order to have a reliable and efficient instrument- in more than 500 specific work environments (and different contexts). We have found that using the context as a primary risk analysis base- we would obtain three important results:

- in risk study-a better risk analysis- as the input data for such analysis would be the outputs of the context analysis
- Safety improvement by context improvement- as the most context elements are direct connected with safety- so safety optimization at the workplace can be considered as 90% done by context improvement.
- Reduced costs- as safety context analysis is more affordable than a risk analysis and the identified patterns are constant during midterm and sometimes for long term.

Safety context could be considered as the static part of safety at the workplace. It is also the place where invested resources are giving a tangible impact.

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