

MODERN RISK ASSESSMENT TOOLS-THE FUZZY APPROACH

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RISK AND A FUZZY WORLD

When dealing with a real world problem we can rarely avoid uncertainty. At the empirical level, uncertainty is an inseparable companion of almost every event, resulting from a combination of inevitable errors in observation, measurement, computation and resolution limits of the observers.

At the cognitive level uncertainty emerges from the vagueness and ambiguity inherent in natural language. [1].

At the social level, uncertainty has strategic uses and its often created and maintained by people for different purposes (privacy, secrecy, property). [2]

Being disseminated through all the levels of the socio-economic field,[3] uncertainty is a major companion of the incidents produced at the workplace.

All the studies being done about causes of occupational accidents indicate that human errors are the triggers in 70..95% of events. [4].

Risk is a very peculiar thing. Apparition of risk, its action and its outcomes could be rarely previsioned. Risk is closely connected with uncertainty.

In an ideal world, risk could be modeled through a set $D(X)$ where the probability P of obtaining a reward in the range $[0..x]$ is determined by a cumulative distribution function $F_u \in D(x)$, the number F_u being interpreted as the probability of receiving an amount less or equal to x .

$$\forall x \in X : F_u(x) = P([0..x]) \quad [1]$$

$$\forall F_u \in D(x) : V(F_u) = \sum_{i=1}^n u(x^i) p^i \quad [2]$$

In the real world, regarding especially occupational risks, there are many risk actuators. For example, at the workplace level the erroneous relations between the actors within and between the human operators and the other components of the man-machine system may result in deficient individual and team behaviour that in certain instances is leading to incidents and accidents [5].

Risk assessment should include, in our opinion, a forecast or general prognosis about the development of risks on short or middle term; in this respect, it should include also the assessment of uncertainties-representing these uncertainties using intervals or more exactly fuzzy intervals has a justification considering the many influencing factors and the expert opinions.

Kosmowsky [6] gives a very interesting formula regarding the success index SI , considering the risk control options at workplace RCO . Having a basic option, BO :

$$\Delta SI^{RCO,BO} = SI^{RCO} - SI^{BO} \quad [3]$$

The risk reduction is expected when $\Delta SI^{RCO,BO} > 0$ [4].

Developing this formula we could write the following equations:

$$SI = SI^{audit} + SI^{prevention} \quad [5]$$

considering the two phases of the assessment process and

$$SI^{audit} = SI^{risk\ identification} + SI^{risk\ parameters} + SI^{risk\ interaction} + SI^{effects} + SI^{risk\ prognosis} \quad [6]$$

Incident occurrence probability could be estimated as $Iop = FI/SI$ [7]

where FI is a failure index defined by parameters that are the adverse residual conditions after the prevention measures.

Unfortunately, our workplace is not an ideal world, where we could exactly estimate all the parameters for the success index but a more vague world, where most of the assessed parameters could be described by data like in the following table.

Table 1 Example of qualitative discriminators and their fuzzy rating

Symbol	Choice	Result	Fuzzy variable range
In	Insufficient	Intolerable	0..1
Po	Poor	Inappropriate	1..2
Av	Average	Conditionally accepted	2..3
Go	Good	Accepted	3..4
Vg	Very good	Excellent-Ideal	4

As seen in the precedent table, it could be established a connection between qualitative statements and quantitative variable values.

These statements could be used as choices in fuzzyfication.

It is possible to represent the system in which the risk factors are acting as an incomplete system of events and to do an event analysis based on random variable model and to employ the results of operational modes and effect analysis, of the reliability analysis and of fuzzy (uncertainty) analysis.

System redundancy and robustness are considered as uncertainties due to the fact that a number of events (example: cure/aggravation of patient's situation), expressed by the entropy concept in probability theory, conditioned by operational and failure modes.

The goal of modes analysis applied to complex systems is to determine all or, at least, the most important observable operational and failure modes, as well as their relations.¹

The entropy concept expresses the uncertainty of systems of events.²³ Moreover, the maximal entropy principle is proposed to derive the form of minimally prejudiced probability distributions of random variables-probability distributions leading to the global and unconditional minimum of entropy of unconstrained systems or subsystems of events or the resulting probabilities are as flat as the constraints follow.⁴

The event oriented system analysis (EOSA) combines system reliability and the uncertainty of complete or incomplete audited systems of operational and failure modes.

The operation of series systems may be represented by a subsystem O with one mode:

$$O = (E, P(E)) \quad [8]$$

Where E are random events occurred in the system

The failure of series systems can be presented by the F subsystem of all the failure modes:

$$F = (E_1..E_n, p(E_1)..p(E_n)) \quad [9]$$

The audited system in which risks are acting can be presented as

$$S = (O + F) \quad [10]$$

System's entropy can be computed as

$$H_N^1(S) = H(S)/p(S) \quad [11]$$

Redundancy of the system may be viewed as:

$$RED(S) = H_{N0}(S/O) \quad [12]$$

Robustness of the system may be expressed as:

$$ROB(S/F) = H_{Nf}(S/F) \quad [13]$$

¹ Barlow R.B., Proschan F., Mathematical theory of reliability, New York, Wiley, 1965

² Khinchin A., Mathematical foundations of information theory, N.Y., Dover Publications, 1957

³ Kulback G.S., Information theory and statistics, N.Y., Pergamon Press, 1969

⁴ Tribus M., Rational description, decisions and designs, N.Y., Pergamonn Press, 1969

Redundancy and robustness system parameters could be very useful in the development of fuzzy audit instruments or fuzzy

PREMISES FOR THE RESEARCH

The research activity regarding the development of expert systems in INCDPM is a success story. Various expert systems were developed in the 1996-2003 period, mainly as assistants for PPE's selection, dangerous substances and products handling, safety devices design and so on.

Fuzzy approach is a relatively new approach. Research regarding fuzzy action upon unexpected events was developed after factual findings regarding fuzzy influence in the occurrence of incidents and accidents. Unofficially, about 75% of the recorded incidents and accidents could be considered as fuzzy in occurrence and also in the development of the event. In this respect, the fuzzy approach is the most close to reality of the event.

About 87% of the severe accidents could be connected with fuzzy actuators and developers. In the chemical industry, this percent could reach 92..93. Chemical risk is very fuzzy determined. Apparently safe installations are breaking apart in a fuzzy manner, normal chemical processes are behaving in a fuzzy way and so on.

FOLLOWED GOALS

The main goal of the research was to introduce uncertainty and fuzzyness into risk assessment.

The fuzzy approach shall change fundamentally the actual risk image, giving new starting points in risk assessment.

Fuzzy approach will take into account the most significant aspects of a would be event, starting with occurrence possibilities, researching development paths and ending with effects upon man and machinery.

In this respect, a theoretical model for fuzzy based events was developed together with a stochastic one, in order to introduce fuzzy elements into the risk assessment activities.

The stochastic model follows the three main aspects of the event:

Occurrence→Development→Conclusion

A fuzzy expert system prototype was developed afterwards, in order to serve as an assistant to the assessment process.

ASPECTS REGARDING THE DESIGN AND DEVELOPMENT OF A RISK ASSESSMENT SYSTEM BASED ON FUZZY CONCEPTS

Fuzzy instruments

There are many fuzzy instruments that can be introduced in the system to be used in safety and health improvement. The main classes of the instruments already in use by the system are shown in the next figure.

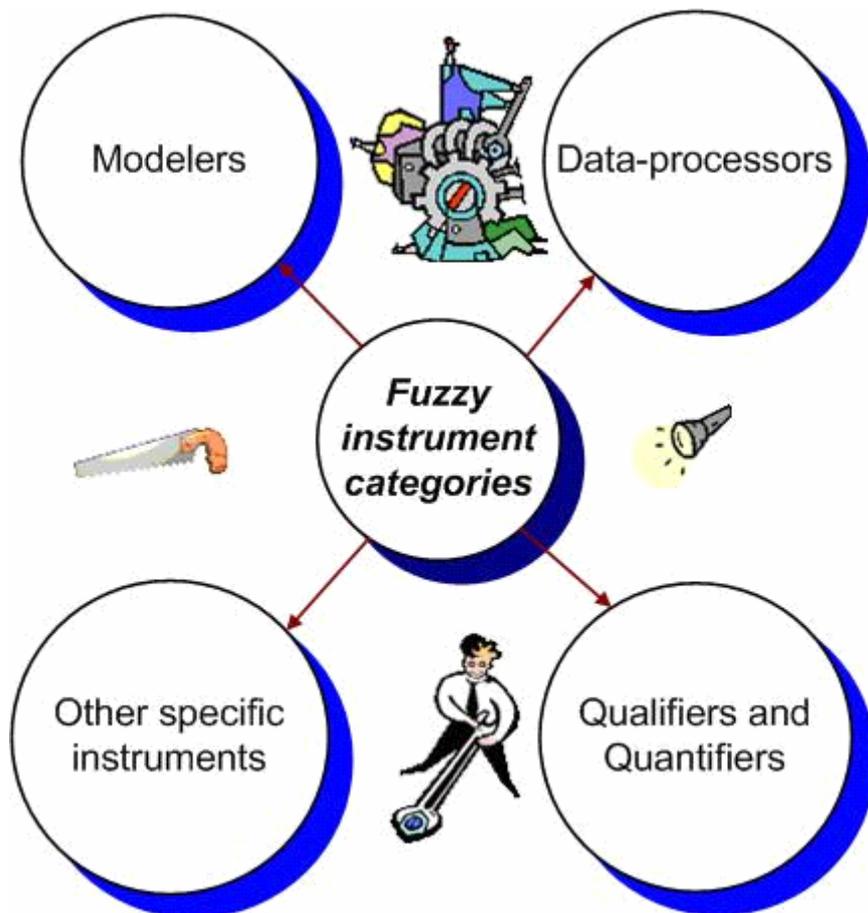


Figure 1-Fuzzy instrument categories

The next figure shows in detail some aspects about various fuzzy instruments that were developed by our research team [7] and by other research teams in Europe in the 1999-2002 period. [8,9]

Why fuzzy instruments ?

- to capture more exactly the forgotten or neglected aspects of reality [10];
- to be able to understand and use fuzzy data;
- to identify the fuzzy patterns in collected data in order to process correspondingly this data so that no unexpected events occur [11];
- to model more exactly the reality, so that the main safety and health aspects are captured by the model;
- to develop more precisely safety and health audit instruments [12];
- to develop more precisely prevention tools that could eliminate/reduce at admissible levels the risks for health and safety;

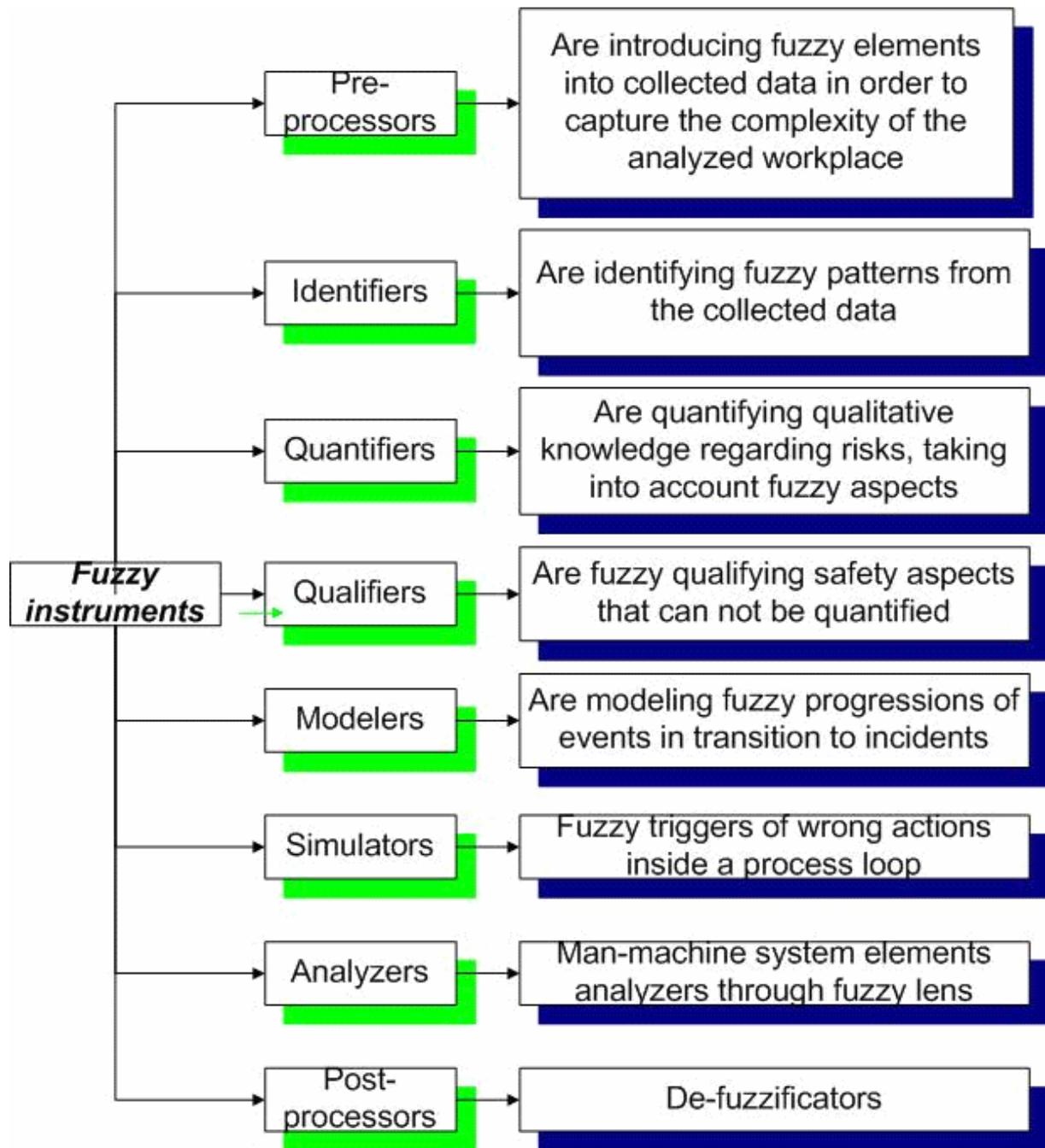


Figure 2-Fuzzy instruments

Design problems

The main question is where in the assessment process could be used the fuzzy concepts so as to contribute at the risk assessment success [13]. The obvious answer is that fuzzy concepts could be used successfully in most of the cases.

A global fuzzy approach of the risk assessment [14] process will be not recommended at this moment because of the processing problems and also because of the necessity to develop a coherent theory, so that the fuzzy assessment system could offer pertinent explanations regarding its actions and conclusions.

Development of the prototype

An expert system based on fuzzy concepts was developed by our research team, using the Exsys Developer V. 8.0 Demo version. Our aim was to catch all the risk assessment parameters that are not directly measurable and are usually estimated by the auditor, using checklists (example: “Estimate the influence of an unquantifiable specific stressor on the human operator working 9 to 5 on a specific machine” using some descriptors like inadequate, below average, poor, etc. –see also the precedent table or “On a 0(Very poor) to 5(Excellent) scale evaluate..”

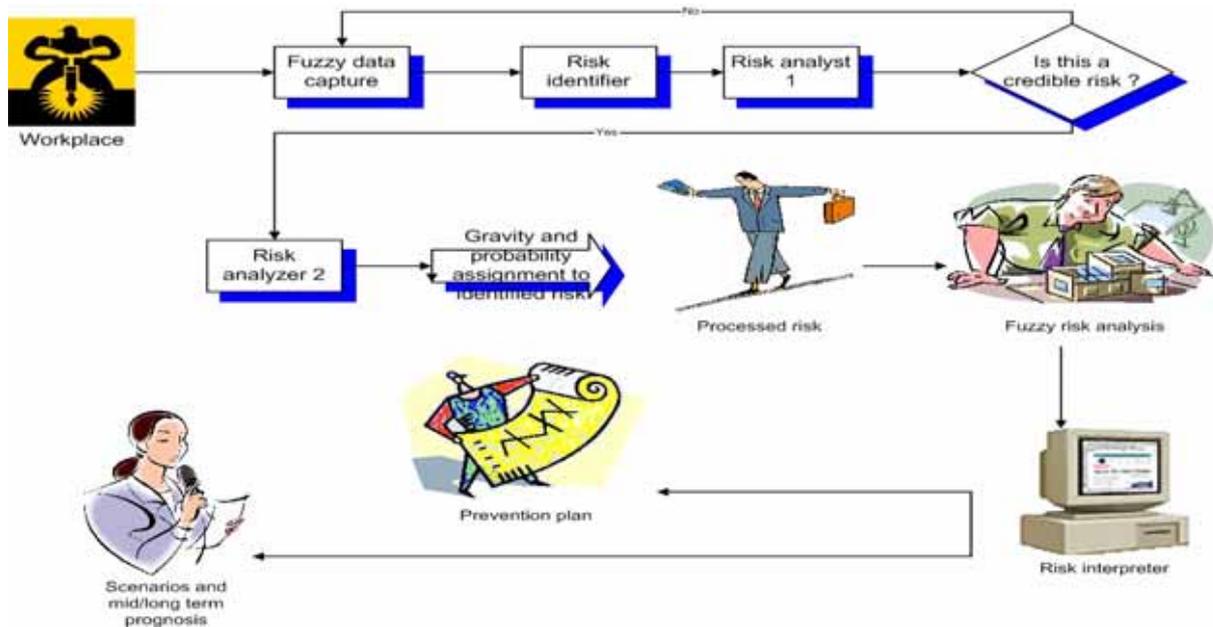


Figure 3.-General schema of a dedicated fuzzy expert system

Some pictures from the prototype system are presented below.

The risk and safety assessment systems currently used in Romania are generally semi-qualitative, semi-quantitative systems. Their results are strongly influenced by the subjective qualitative assessment.

Our theory follows the assessment of the man-machine system with the four main components Human Factor-Task-Machine-Work Environment. Generally, the Human Factor and Task components could be assessed just qualitatively.

The fuzzy approach allows the transposition of these qualitative assessments into quantitative ones.

Moreover, a fuzzy analysis instrument is on development now. This instrument will take into account fuzzy influences into the occurrence, development and ending of an specific event, in order to help the safety specialist to concentrate just on the prevention measures that could be usefull.

Till then, the fuzzyfication of the non-cantitative parameters will be extremely usefull in order to transpose them in a calitative assessment.

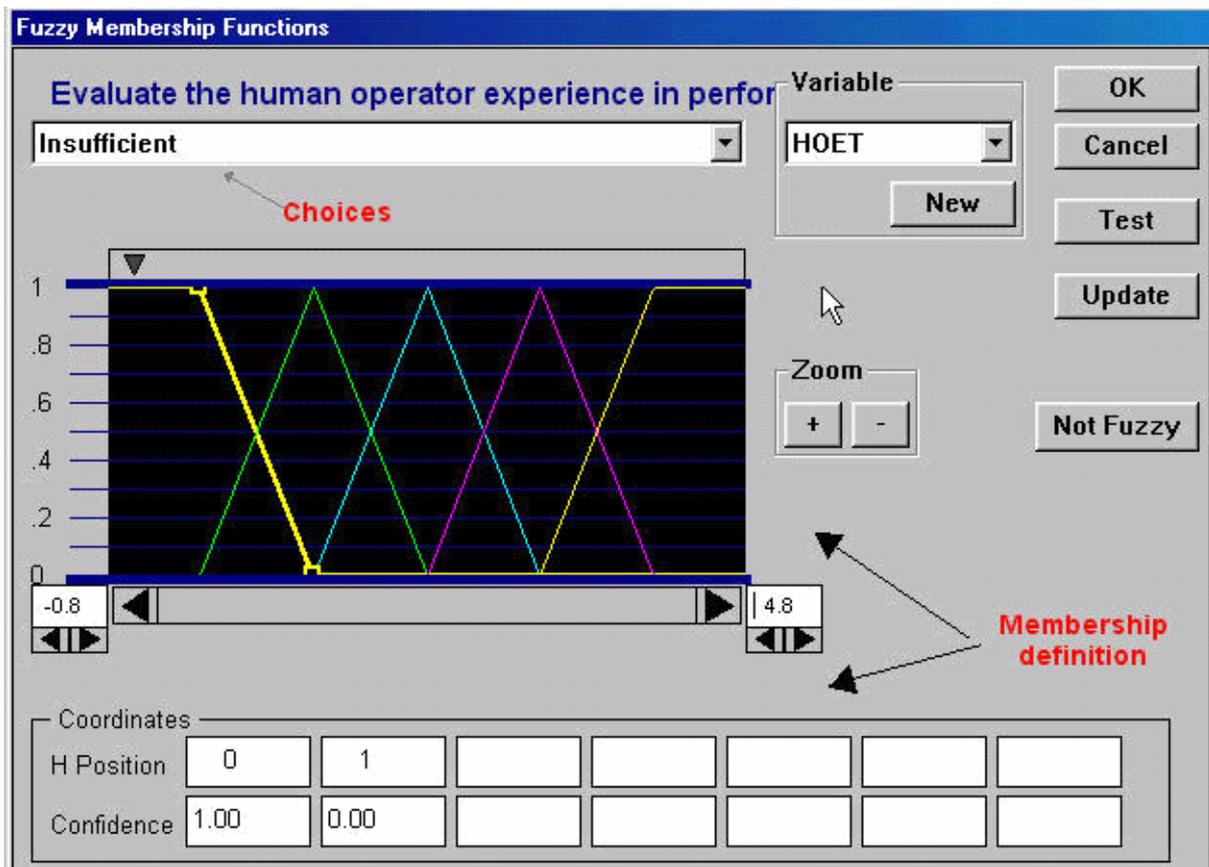


Figure 4 Developing a membership function for one of the system variables

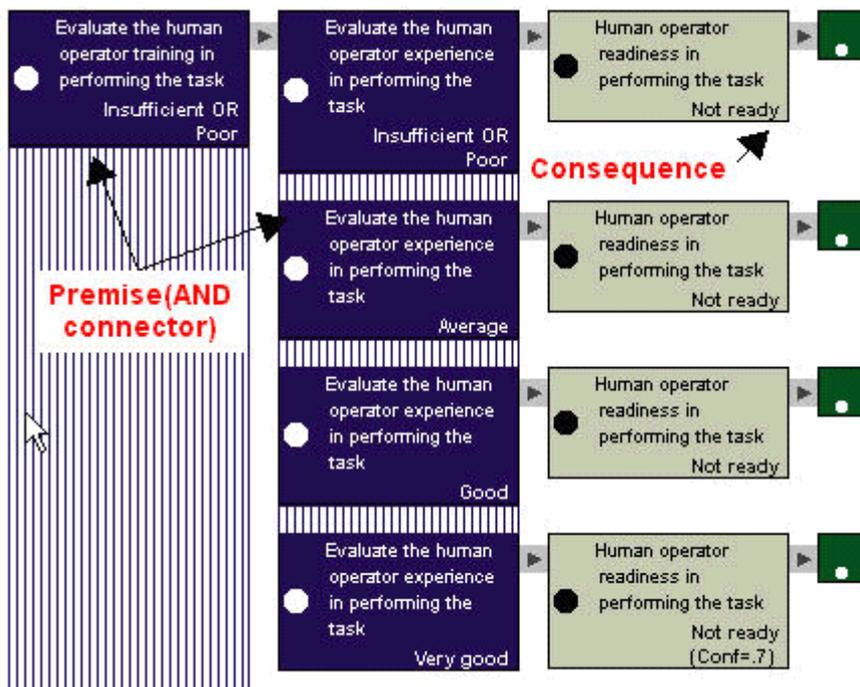


Figure 5 Developing the inference tree

The system is introducing uncertainty as a main risk component.

CONCLUSION

Obtainable information required for risk assessment is not complete and not perfect [15]-information deficiency is directing the assessment process towards a more or less degree of uncertainty.

Regarding this uncertainty, all the general types could be recognized in the risk assessment process:

- fuzziness [16] –resulting from the imprecise boundaries of the fuzzy sets-found in the assessment process;

- no specificity-imprecision-connected with sizes of relevant sets of alternatives-found in the assessment process and also in the establishment of prevention measures;

- strife –express conflicts among the various sets of alternatives-found in the design of prevention specific plans;

The fuzzy approach of the risk audit process is a more reality driven mode to assess risk at workplace, considering:

- the fuzzy environment and audit conditions that are offering incomplete, fragmentary, not fully reliable, vague, contradictory or deficient in some other way information and are leading to incomplete, fragmentary, not fully reliable, contradictory or deficient in some other way results;

- the fuzzy aspects of human operator audit;

- other fuzzy data (maintenance parameters, etc.)

Regarding the fuzzy expert system, uncertainty can occur:

- considering the meaning of words used in production rules [17];

- considering the consequent that is used in a rule;

- considering the input data;

- considering the control data;

Analyzing the fuzzy logic used to handle the expert system, it will be logic of the second type-which handles uncertainties by modeling the uncertainties. This is accomplished by blurring the boundaries of type 1 membership functions into “footprints of uncertainty”. These footprints could include the residual risks –providing new degrees of freedom in the risk analysis.

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