 

# HUMAN OPERATOR ASSESSMENT-BASIS FOR A SAFE WORKPLACE IN THE PROCESS INDUSTRY

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The human operator is the core of good functioning for almost every technical installation, in the civil or military field. About 75% of the occupational accidents are provoked by the human operator. Assessment of the human operator from the safety point of view will be the first step toward a safer workplace. Unfortunately, the assessment process of the human operator is a very subjective job, considering the mostly subjective parameters that are defining him.
This paper shows aspects of the design and application of a better and objective safety assessment system for the human operator, considering all the definitory categories for his/hers safety, like training, physical state, psychical state, stress, attitudes and so on. The system was built on the basis of operational analysis, robotics theory and also the most advanced information instruments available. Searching the space state of the man-machine system in its workplace instance, there could be defined optimum state functions that are balancing the need for efficiency with the safety requirements. The assessment system is using checklists to compute these functions and then is cross-checking these functions against reference values. On the basis of the calculated optimum values, a general score for the human operator is calculated, being compared then with reference scores for various activities inside the process industry. The general score and optimum state functions offer indications about actions that must be taken to improve the safety of the human operator, and actions like a better training, moving to another workplace and so on. The system has a multilevel architecture, starting with base level-basic assessment, done by complex checklists, a middle level for assessing the safety of process specific activities and a final level for assessing the operator's safety at his workplace.
The implementation of this system has started in pilot centers from Romania's process industry, till now being obtained very promising results. Some of these results are also presented in this paper.
**Keywords**
Human operator assessment, optimum state functions, safety functions, safety assurance

## GENERALITIES

Incidents and occupational accidents are taking place into the workspace. Here, because of the human error or because of the malfunctioning of the various installations accidents occur. So, in developing a human operator assessment system, the starting point will be the workplace.
There could be defined two categories of state functions, considering the man-machine environment:

-Workplace state functions

 

-Human operator state functions

Optimum of workplace state functions is given by the parameters of machine and working environment
The human operator(HO) is merely "forgotten" from the safety assessment because of the mainly subjective analysis results that are obtained. But, sadly, the human operator is the main or indirect cause of the most incidents and occupational accidents.
"Static" HO states are defining the readiness of the human operator in performing in safe conditions.
"Dynamic" HO states or functions are defining the dinamic activity developed by the operator to perform his task. Dynamic HO functions could be delimited in:
-Threshold functions: are defining the (succesfull) end of a task and start-up of another task
-Performance functions:are defining the safety performance in doing one specific task .These performance functions could be considered as beeing optimum driven towards optimum workplace state functions
Considering the subjective trend of the most human assessment systems, the main goal of the common research developed by the two Romanian National Institutes, INCDPM and INCDT COMOTI RA [1]was to develop a more objective safety assessment system for the human operator involved in process activities. In doing that, we meet the necessity to define some theoretical basis of human operator analysis inside work space. The existing theories were centered around the human performance at the workplace, the safety aspect being neglected or treated not so well. Our secondary goal was to test our assessment system in real conditions and to develop it so as to became an efficient tool in safety assessment. Some aspects of this research are presented in this paper.

## WORKPLACE STATES AND THE ASSESSMENT PROCESS

The assessment process and its consequences are presented in Figure 1.

 

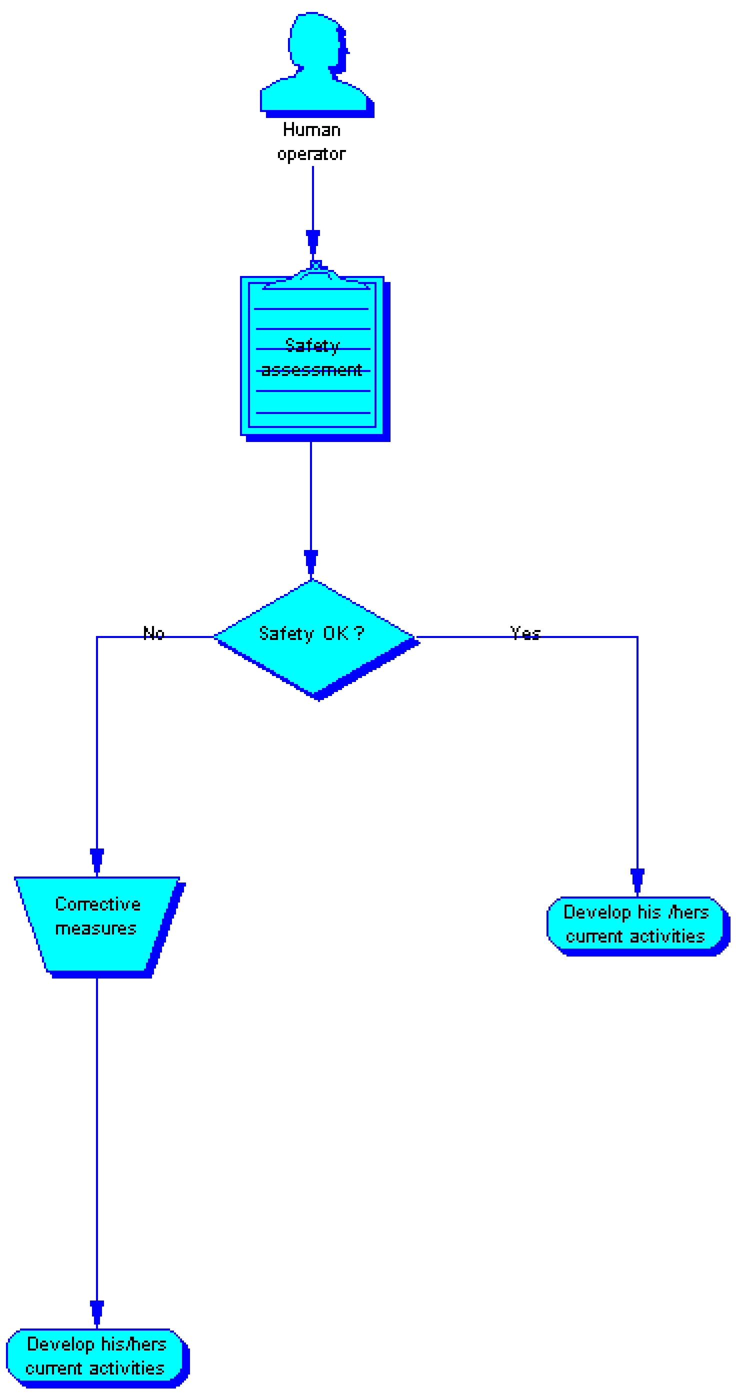


Figure 1-Safety assessment of the human operator and its consequences

The space of workplace's states [2]is a very interesting thing to analyze; practically, these states are leading to a normal functioning of the system or toward occupational accidents. By analogy with robotics it is possible to define at the workplace, two distinct areas:
-the main activity area, in which the human operator is moving so as to perform the process;
-the auxiliary area, in which the human operator is moving for auxiliary tasks, for recreation or for other reasons;

 

Considering these areas and the canonic activity [3] of the operator imposed by the task being done, it is possible to think at the operator's activity as a collection of distinct states. The characterization of these states could be done on different criteria.
Currently, from our point of view, there are two main interesting classes of states inside the workplace:
-safety states;
-current activity states;

## SAFETY AND ACTIVITY STATES-COMPUTING THE OPTIMUM FUNCTION

The safety states are exemplifying for the activities being done. If the safety state is not sufficient then accidents may occur.
Analyzing the safety states, there could be separated three main ones, presented in the table 1:

Table 1-Main Safety States

| State name | Transition | Description | Reference values |
|---|---|---|---|
| Ideal Safety State (ISS) | –>all the other states are moving toward this state in case of unlimited safety resources<br><–all the other states are departing from this state in really functioning | Describes the 100% safe functioning of the system | 9...10 |
| Normal Safety State (NSS) | –>towards ISS in the condition of safety supply;<br><–towards USS in the condition of system decay; | Describes the normal(current) functioning of the system | (5) 6..8 |
| Un-desired Safety State (USS) | –>toward NSS in the condition of safety supply | Describes the critical(from the safety point of view) functioning of the system | 0...4(5) |

Considering a 0..10 evaluation scale with 0-most negative and 10 most favorable ,we could define reference values for these safety states as shown in the above table.
The reference values are useful in analyzing the results of checklists against these values.
Safety states could be given by statistic data [4] for various activities, analyzing the accidents, incidents and near incidents on a five to ten years period. This analysis could be refined selecting just the events produced by the human operator. For example, considering the reference values presented above, these could be connected to specific events like in the table below.

 

Table 2-Reference values and number of events at the workplace

| Safety State Name | ISS | NSS | USS |
|---|---|---|---|
| Reference values | 9..10 | 6..8 | 0..5 |
| Number of near incidents in the latest 5 years | 0..1 | 2..15 | more than 15 |
| Number of incidents in the latest 5 years | 0 | 1..5 | more than 5 |
| Number of accidents in the latest five years | 0 | 1..3 | over 3 |

Analyzing the activity states, is possible to identify three main states, presented below:
-preparation state: in which the process is prepared;
-process state: execution of activity;
-disposal state: in which the by-products are eliminated;

By mapping [5] the safety states on the activity states and taking into account that the main safety problems are in the process sate, we obtain table 3.

Table 3-Mapping of the safety states on the activity states

| Activity State/Safety State | Ideal Safety State | Normal Safety State | Un-desired Safety State |
|---|---|---|---|
| Preparation State | 9..10 | 5..8 | 0..4 |
| Process State | 9..10 | 6..8 | 0..5 |
| Disposal State | 9..10 | 5..8 | 0..4 |

Returning to the human operator, we could identify some main attributes of his safety at the workplace, as these attributes could increase or decrease the safety level; in this paper we are proposing a shorthand list of attributes, presented in table 4:

Table 4-Human operator specific attributes

| Attribute name | Describes |
|---|---|
| Training | Specific safety training of the human operator |
| Physical state | Physical state of readiness of human operators |
| Psychical state | Psychical state of readiness of human operators |
| Stress | Stress level imposed by a specific activity |
| Attitudes | Attitudes required to perform a specific activity |
| Conformism-dynamism | Conformism to the activity being done; tendencies to overreact or to do something |

 

| Attribute name | Describes |
|---|---|
| | else in case of a monotone activity |

These attributes are caught using complex checklist systems, so as to be as objective as possible. When completed, the checklists are giving specific scores for all these attributes; these scores are converted into a safety state parametric functions, specified as fs(attribute)=value and also in an activity parametric function specified as fa(attribute)=value that combined together give the optimum state function.
The optimum [6]function will be computed as

fopt=optimum(fs,fa) [1]

This optimum function could also be analyzed on a 0 to 10 scale. Our experience in implementation of the system shows that a satisfactory range of values would be between 7..9.

**DYNAMIC HUMAN OPERATOR FUNCTIONS**

Using a probabilistic approach it is possible to define a general safety function as

Gsafe=f (X1,X2,...Xn) [2]

where X1= exposure to the risks;
X2..Xn-1= exposure variables;
Xn represents the specific safety function slope factor;

Regarding the performance of the worker at his workplace it is possible to define two distinct types of safety functions that could contain the safety aspects of the human operator's activity.
-THE SAFETY PERFORMANCE FUNCTION SPF is directly connected to a specific task or subtask and is describing the safety needs from the human operator, so as to safely perform the mentioned task or subtask;
-THE SAFETY THRESHOLD FUNCTION STF is a connector that describes the safety links between a task and the next one, so that if task n-1 is performed safely task n could start but if task n-1 ended in failure task n will not start.
This alternation between safety performance functions and safety threshold functions is presented below in figure 2.

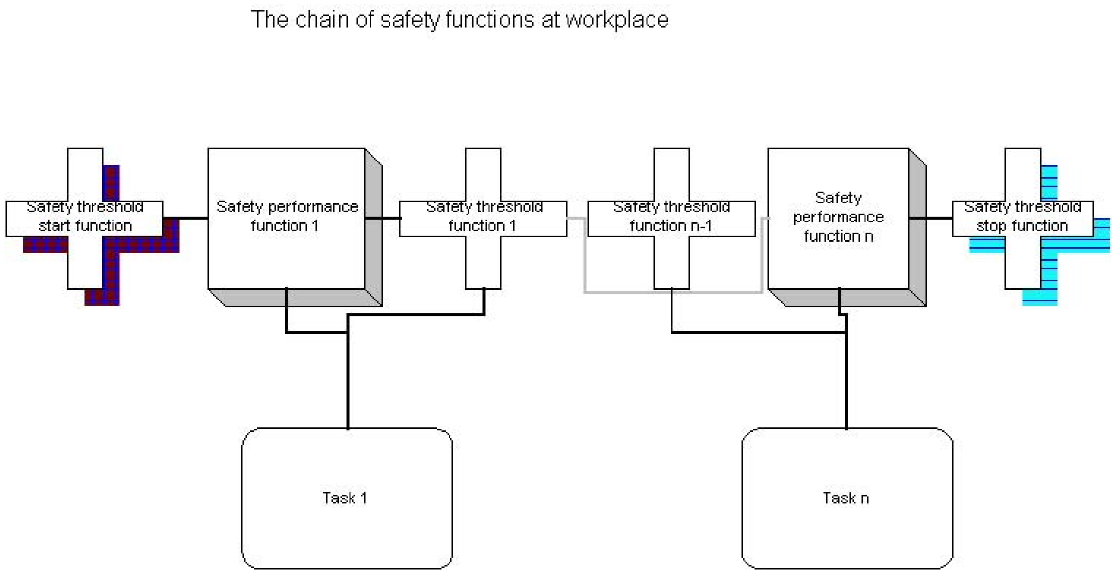


Figure 2 The chain between safety performance functions and safety threshold functions

It is possible to see that, the performance functions are co-responding to a specific task and the threshold functions are gateway functions between the tasks.

## SAFETY PERFORMANCE FUNCTIONS (SPF)

The safety performance function is directly mapped to a specific task [7]. For example, at a lathe, the first task is to start the machine. For doing this, the worker:
-1. must be able to carry on and load the material to be processed into the lathe;
-2. must verify the active zone of the lathe so as, at starting up, no materials will be caught and projected into the worker or his/hers colleagues;
-3. must verify the material being processed, so that this material is solidly fixed into the rotating part of the lathe and could not be projected at start-up;
-4. must verify the processing tool, so that is the required tool for the material being processed, this tool is solidly fixed and is not touching the material at starting the machine.
-5. must verify the existence of oil in the oil reservoir and also the functioning of oil pump;
-6. must verify if the lathe is plugged in and if the alimentation cord is safe;
-7. must know on which button to push;
Considering all these auxiliary activities needed to start the lathe, we could define some specific states describing the safety of the human operator.
These states could be evaluated by an auditor on a 0..10 scale, so as 0 is equivalent to extremely bad and 10 to ideal from the safety point of view .
We can imagine these states as safety filters between risks and the human operator, as shown in the figure 3.
In this example, we are considering the states presented in the table below-their assessment was done so as to assure a minimal safety:

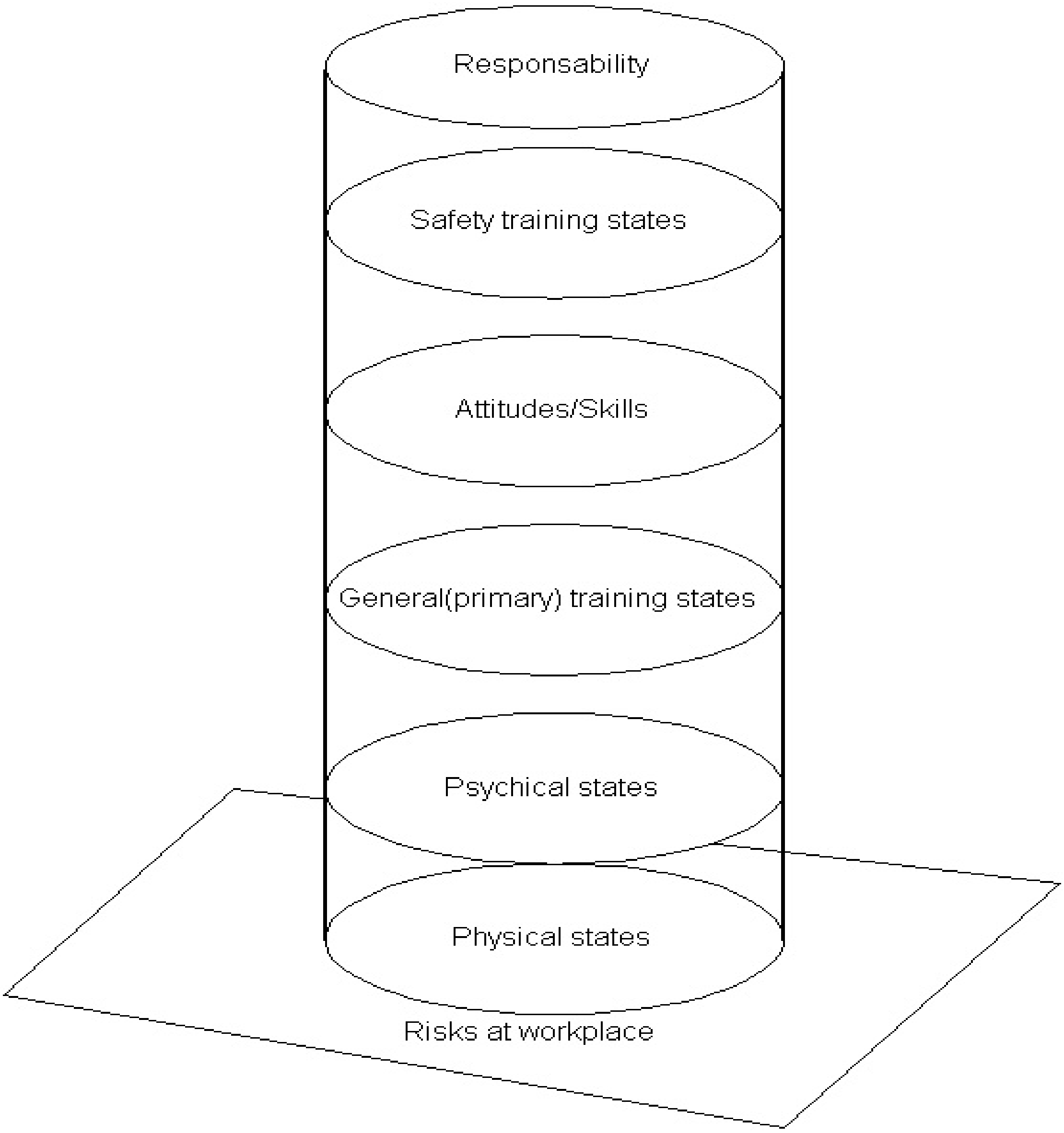


Figure 3 The safety states filter between risk and human operator

A mapping of the safety states on the activities presented in this example is shown in table 5.

Table 5 Safety states vs. activity

| No | State | Example activity no. | Safety Estimation |
|---|---|---|---|
| 1 | General training | 2..7 | 5..6 |
| 2 | Safety training | 2..7 | 6 |
| 3 | Physical | 1 | 6 |
| 4 | Psychical | 1..7 | 5 |
| 5 | Skills | 2..6 | 6 |
| 6 | Attitudes | 2..6 | 5 |
| 7 | Responsibility | 1..7 | 6 |

 

A special attention must be given to the Responsibility State. The table 6 is detailing its components

Table 6 Responsibility components

| No | Component (Responsibility for...) | Description |
|---|---|---|
| 1 | Supervision | The operator has supervision duties and must fulfill them in order to accomplish his task |
| 2 | Policy | Must follow the established policies of the company |
| 3 | Methods | Must follow established methods in order to accomplish his tasks and it is /it is not required to establish his own methods. |
| 4 | Materials and Supplies | Must efficiently allocate the required materials and supplies to perform the task |
| 5 | Confidence and Trust | From the supervisor and from his/hers co-workers |
| 6 | Contacts | For ordinary contacts, required by the work process and also from immediate contacts in emergency cases |
| 7 | Cooperative service and joint activity | Activity together with his/hers co-workers and also with third parties |
| 8 | Records and reports | Must record all the problems and report them to his superiors |
| 9 | Machinery and Equipment | Must use, preserve and maintain the machinery and equipment in an adequate state of safety |
| 10 | Safety for others | Must perform his/hers activity so as to preserve and improve other's safety |
| 11 | Personal safety | Must preserve and improve his/hers safety |

We could define Minimal Safety Performance Functions (MSPF) as, those safety performance functions that are just assuring safety against serious accidents ,developing into invalidity or death , without balancing with productivity and efficiency at work.

Analyzing this table, is possible to see that we can describe a Minimal Safety Performance Function, MSPF for this task of starting the lathe , by giving values to the component states, so as to assure the minimal protection against severe accidents. We could consider a MSPF for a Safety Estimation around 5 or 6.

A superior step, the Optimal Safety Performance Functions (OSPF) could be defined as the functions that are assuring safety against the majority of accidents (not including here the minor incidents or the occupational diseases provoked by stress or repetitive work) in co-relation with productivity and efficiency at work. Regarding the previous table, we could consider an OSPF if the Safety Estimation is around 8.

How will this estimation affect the productivity and efficiency ? Firstly, by lowering the time required to perform the task. Secondly , by raising the efficiency of the activity and thirdly by making the activity more secure.

 

## SAFETY THRESHOLD FUNCTIONS (STF)

STF's are the connectors between the tasks that are done at the workplace during the work process. On the simplest thought, STF's can be imagined as a 0..1 functions with the 0 value when the precedent task fails and 1 when the task is performed in safety conditions. This is the simplest way to imagine the threshold. However, in the real life, a task could fail but not obviously, so the next task could start even if the precedent ends in failure. So, it will be better to imagine the threshold functions in the fuzzy domain.
A more lucrative approach is to imagine the threshold functions at the workplace during a work process as coupled functions, the initial function-Safety Threshold Start Function STSTAF(as shown in Figure 2) starting with value 1. Depending on the outcome of various performance functions, this coupled function descends discretely towards the 0 value. When the threshold function is 0 then a serious event (incident, accident or technical error) occurs and the next performance function is not started.
The Safety Threshold Stop Function STSTOF acts a a safety report regarding the whole task. If STSTOF is less than 1 then something wrong happened and the process must be audited to see what went wrong.
The scope of threshold functions is to give a dynamic approach to the human operator problem and also to act as a guiding wire between the various activities being performed to execute a task.
The Immediate Threshold Safety Function ITSF describes the decision of the human operator to perform a potential dangerous task. ITSF could be described by the following values:
- 0 –when the human operator considers the task too dangerous and is not performing;
- 0< and >1 when the human operator performs conditioned the task; for example, being asked to polish a piece of iron at the polishing machine he asks for safety glasses and also for safety gloves.
- 1 –when the human operator is performing the task

This ITSF could describe the start-up point of accident building, considering just the human factor. Contrary to the other threshold functions ITSF is an aprioric function.
All the other functions could be considered as after event (aposterioric) functions.

## THE HUMAN ASSESSMENT SYSTEM

The developed safety system will be multi-level structured. This multi-level approach [8]assures an efficient assessment in accordance with the safety needs.
There could be defined three levels for the assessment.
*Immediate*-before entering the workplace, so as to be safe at the workplace-able to perform
*Mid-term*-to assure safety for him-able to work safely
*Long term*-to assure safety for him and his/hers co-workers; to be aware of the safety problems and to actively pursue safety-able to manage safety at workplace
In the following paragraph we are presenting some aspects of this system
The main idea is that we could scientifically design objective checklists, using the definitory attributes presented previously.
For example, we consider the training attribute.

What are the goals desired from such an attribute ?
-First, we want that the worker, at his/hers workplace to have sufficient general training so as to perform correctly his/hers work tasks. So, we must check the general training.
-The safety training is an essential point. We must check the general safety training (knowledge of risks), the safety training specific to the main task, to the auxiliary activities and also to the transport duties.
-For a safe workplace is not sufficient that a single worker is safety prepared. All his/hers team fellows must share the same safety training. So , we must check out the safety training image of the fellow workers-in the idea that such workers exist.
The checklist sample for the training attribute is presented below.

Table 7- Checklist sample for the training component

| Question |
|---|
| 1. On a 0..10 scale, evaluate your general training, regarding the activities performed on the workplace |
| 2. On a 0..10 scale, evaluate your training, taking into account the main activity performed by you at the workplace |
| 3. On a 0..10 scale, evaluate your training, taking into account the auxiliary activities performed by you at the workplace |
| 4. On a 0..10 scale, evaluate your training, taking into account the general safety training<br>-Do you know the safety measures, rules and norms that are in usage in your activity ? |
| 5. On a 0..10 scale, evaluate your training, taking into account the general safety training-i.e. the knowledge of risks, general prevention measures, etc. |
| 6. On a 0..10 scale, evaluate your safety training, taking into account the main activity performed by you at the workplace<br>-Do you master the main activity ?<br>-Are you informed fully about the risks involved ?<br>-Do you know the usage of the personnel protective equipment and other safety equipment ?<br>-Are you ready to perform specific rescue activities and to give first aid if necessary ? |
| 7. On a 0..10 scale, evaluate your safety training, taking into account the auxiliary activities performed by you at the workplace<br>-Do you master the activities that are to be done , auxiliary to the main activity ?<br>-Do you know the risks involved in these activities ? |
| 8. On a 0..10 scale, evaluate your safety training, considering the transport activities performed by you |
| 9. On a 0..10 scale, evaluate the safety knowledge of your team colleagues regarding your main activity |
| 10. On a 0..10 scale, evaluate the safety knowledge of your team colleagues regarding the auxiliary activities developed at your workplace |
| 11. On a 0..10 scale, evaluate the safety knowledge of your team colleagues regarding the transportation activities |
| 12.On a 0..10 scale evaluate the possibility to be a work accident casualty , considering your actual training –lower marks for a greater possibility, higher marks for a low possibility |
| 13. On a 0..10 scale, evaluate the possibility to be a work accident casualty, considering the training of your colleagues –lower marks for a greater possibility, higher marks for a low possibility |

 

| Question |
|---|
| 14. On a 0..10 scale, evaluate the possibility to be a work accident casualty, considering your safety training –lower marks for a greater possibility, higher marks for a low possibility |
| 15. On a 0..10 scale, evaluate the possibility to be a work accident casualty, considering the safety training of your colleagues –lower marks for a greater possibility, higher marks for a low possibility |

The algorithm is relatively simple.

Nt = Kw* Nw + Kcw * Ncw+ Ks* Ns [3]

The media of worker's assessment [9] (Nw) is pondered with a coefficient (Kw) dependent on the worker's experience and previous work and safety results. The media of co-workers assessment-regarding a specific worker (Ncw) is pondered by a coefficient (Kcw) dependent on the team experience and results in safety assurance. The media of the supervisor's assessment (Ns) regarding the worker is pondered by a coefficient (Ks)dependent on his/hers experience and safety results. Some example values for this coefficients are presented in the table below

Table 8-Example of coefficients

| Case | Kw | Kcw | Ks |
|---|---|---|---|
| Apprentice with a normal team and a good supervisor (no accidents) | 0.44 | 0.2 | 0.35 |
| Apprentice with a normal team and supervisor (few accidents) | 0.55 | 0.15 | 0.3 |
| Worker with a normal team and a good supervisor (no accidents or few accidents) | 0.6..0.65 | 0.1..0.2 | 0.25..0.3 |
| Low qualified worker with a similar team and a good supervisor(no accidents or a few accidents) | 0.3..0.4 | 0.05..0.1 | 0.5..0.65 |
| High qualified worker with a similar team and a good supervisor (no accidents or a few accidents) | 0.7 | 0.1 | 0.2 |

Kw+Kcw+Ks=1[4]

The proposed system is developed as a pilot now and will be fully functional in the second part of 2002.

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