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Original Article

Analysis Testing of Sociocultural Factors Influence on Human Reliability within Sociotechnical Systems: The Algerian Oil Companies

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ABSTRACT

Background: The influence of sociocultural factors on human reliability within an open sociotechnical systems is highlighted. The design of such systems is enhanced by experience feedback.
Methods: The study was focused on a survey related to the observation of working cases, and by processing of incident/accident statistics and semistructured interviews in the qualitative part. In order to consolidate the study approach, we considered a schedule for the purpose of standard statistical measurements. We tried to be unbiased by supporting an exhaustive list of all worker categories including age, sex, educational level, prescribed task, accountability level, etc. The survey was reinforced by a schedule distributed to 300 workers belonging to two oil companies. This schedule comprises 30 items related to six main factors that influence human reliability.
Results: Qualitative observations and schedule data processing had shown that the sociocultural factors can negatively and positively influence operator behaviors.
Conclusion: The explored sociocultural factors influence the human reliability both in qualitative and quantitative manners. The proposed model shows how reliability can be enhanced by some measures such as experience feedback based on, for example, safety improvements, training, and information. With that is added the continuous systems improvements to improve sociocultural reality and to reduce negative behaviors.

1. Introduction

Humans have always occupied a significant place in the design, exploitation and maintenance of industrial systems. With technological advances, systems have become more sophisticated and complex. This complexification requires some abilities (cognitive, sensorimotor, and intellectual) and knowledge that sometimes exceed the limits of human operators. For example, the human operator could be failing on more than one criterion (saturation, loss of vigilance, tiredness, error, etc.).To that is added the constraints inherent in operator unsuitability to the technology of these systems that are conceived within sociocultural setting with no relationship to the local context. Such human failings are often the origin of incidents that evolve into catastrophes and sometimes have dramatic consequences not only for the operators and the installations but also to nearby populations and even to the environment. To prevent risks related to human error, several approaches to human reliability have been developed.

Since the 1950s, safety studies of industrial systems started to take an interest in human error with the purpose of establishing a quantifiable assessment allowing the calculation of the reliability of the human operator as a simple component of the system. Thus the first quantified estimates of human reliability were developed by Sandia National Laboratories, New Mexico, Albuquerque, USA in 1952 [1], with the purpose of quantifying the human error probabilities to build up evaluations, *ex ante*, of human reliability and using these data to calculate the overall system reliability.

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In the 1960s, the French Academy of Sciences accepted human reliability as a discipline belonging to the engineering sciences. Since then, studies have tried to build databases containing human error rates. Within this context, the human error rates method of prediction, technique for human error prediction was created in 1964 [2], followed by several similar methods such as technica empirica stima errori operatori (TESEO) [3], success likelihood method index (SLIM) [4], human error assessment and reduction technique (HEART) [5], and human cognitive reliability (HCR) [6]. These constituted the first generation [7] of methods based on human error, by considering the human as a simple component of the system characterized by failures that one can evaluate by probabilistic approaches. The second generation of these methods—cognitive reliability and error analysis method (CREAM) [8], a technique for human event analysis (ATHEANA) [9], and méthode d'evaluation de la réalisation des missions opérateur pour la sûreté (MERMOS) [10]—were developed from the 1990s and were focused on cognitive processes to try to predict and explain human failures. These methods tried to take into account some contextual factors within the framework of a systemic approach. The third generation—functional resonance analysis method [11], barrier and operational risk analysis [12], and other similar methods that developed from the end of the 1990s—were concerned with the organizational environment of work and its role in the genesis of human error.

The technicist approach—based on the improvement of a system's overall reliability by the increase in the reliability of each one of their components—considers the human a simple element of the system, hoping to evaluate the human's reliability as one evaluates the reliability of any system component. This approach appears to be outdated. This is in spite of their positive and undeniable contributions in the assessment of human reliability in terms of error prediction and quantification, especially their contribution to the improvement of maintainability and availability of systems. The technicist approaches had reduced the accident effects and the accident frequencies.

Nevertheless these tools had shown some limitations, because they adopt reductive and mechanist views [13]. Their application is heavy and complex, because they are based on arbitrary task division in elementary operations without taking into account the interactions between the tasks [14] and the probabilistic assessment is based on expert views and database extracts which differ in context to one another.

Thus these tools were centered on assessment rather than on reduction of human error risks because they are unaware of the human operation-specific characteristics and did not focus on the human operator negative aspects, hiding the operator's positive role especially in the recovery of incidental situations [15].

Many studies have highlighted the positive role of the human as a reliability agent [1], such as the ability to innovate and to invent new solutions according to situations, the expectation and recovery of failures, the adaptation to various unusual situations, the fast selection of relevant information, and the ability to synthesize and reason. Therefore, any reliability approach must bypass the comprehension of the human, in its thinking, its representations, its interactions with its environment, and its reactions when faced with constraints.

The comprehension of human conduct requires taking into consideration several factors such as personality, affectivity, cognitive function registers, cognitive styles, culture, training, and social environment.

The approach should tackle the issue of human reliability within a widened framework, by considering the studied system as being an open sociotechnical system on the external environment (social organization, economic, cultural, etc.) because this approach will not have to be limited to negative aspects (errors, maladjustment) but will have to be focused on operator strengths (recovery, correction, expectation).

In this article, we will try to emphasize the relevance of the influence of sociocultural factors on the operator reliability of the human–machine system within an open environment because the interactions of the elements composing the system cannot be considered within a closed system. We have limited these factors to six main ones in order to consolidate our in-site survey. This choice is justified by the theories of social psychology, the sociology of organizations, and by the works of the French Foundation for Industrial Security Culture. The selected factors are: standards and social values; group culture; commitment, mobilization, and culture of safety; socioeconomic environment; resistance to change; and the influence of the use of new information and communication technologies (NICT).

2. Materials and methods

For the site survey, we chose two major Algerian oil companies with large workforces. They were Sonatrach/DP Hassi Messaoud, Algeria, and ENTP (National Company for Oil Wells) Hassi Messaoud, Algeria. In accordance with the objective of the research, we initially adopted a qualitative approach centered on work cases. These observations let us foresee deviations in operator behavior when executing prescribed tasks. We also considered the statistical analysis of incidents/accidents which occurred following human errors and semistructured interviews with some of the managers that are accountable on managing systems showing all significant risks.

In order to consolidate the study approach, we made a schedule, through which we tried to be unbiased by supporting all workers categories according to their age, sex, education level, prescribed task, accountability level, etc. This schedule is made up of 30 items, each item comprises two parts: one closed question (yes or no) about the adoption of such behavior towards a given situation; if the response is positive then the operator is called to choose the sociocultural factors having motivated his behavior.

The sample took into consideration 300 workers distributed as shown in Table 1.

The average age of the executive managers was 38 years, that of the supervisors was 44 years, and that of the skilled workers was 46 years. The executive managers were from specialized institutes or from universities, supervisors were from certain specialized institutes and skilled workers came from training centers or institutes.

While choosing standard measurements to calculate the percentage of the behaviors adopted by the operators (positive and negative) and the part of the sociocultural factors which justified the adoption of such behaviors, it became quantitatively foreseeable to estimate the behaviors that are revealing in the assessment of human reliability and that are likely to be influenced by the sociocultural factors characterizing the local context.

Table 1
Schedule consistency and distribution

Companies	Studied workers			Sex		Nature of tasks		
	W1	W2	W3	M	F	T1	T2	T3
Sonatrach	50	50	50	138	12	62	58	30
ENTP	50	50	50	144	06	55	56	39
Total	100	100	100	282	18	117	114	69

T1, supervising and monitoring; T2, operation; T3, maintenance; W1, executive managers; W2, supervisors; W3, skilled workers.

Table 2
Schedule counting showing the level of influence of sociocultural factors on worker behavior

Behaviors influencing reliability	Worker categories					Relative % of operators having noticed the influence of sociocultural factors on their conduct						
	W1	W2	W3	Total	%*	F1	F2	F3	F4	F5	F6	F7
Negative behavior												
Recourse to informal methods	35	48	52	135	45	52	45	35	40	47	2	7
Fatalism versus risk	11	27	70	108	36	60	55	30	35	42	0	2
Codes & languages misunderstanding	3	22	113	138	46	55	22	25	9	30	0	3
Bad awareness of risk	9	48	90	147	49	44	53	55	12	22	15	7
Inappropriate decisions	15	25	86	126	42	47	53	48	23	32	4	2
Prescribed rules breaking	12	36	85	135	45	62	58	53	54	57	11	5
Deviance floating	6	57	87	150	50	59	52	54	43	23	6	3
Risk taking	8	42	91	141	47	45	55	53	45	33	8	4
Demotivation & commitment lack	23	52	81	156	52	45	55	34	44	25	0	2
Leading new techniques to fail	12	24	75	111	37	49	48	33	12	52	0	2
Work botching	51	44	22	117	39	35	46	45	42	39	7	4
Distraction & loss of vigilance	55	56	51	162	54	12	11	35	10	12	44	3
Positive behavior												
Rules adaptation to ambient context	38	51	49	138	46	52	44	43	40	2	0	2
Anomalies recovery	39	29	64	132	44	23	25	55	45	0	5	3
Use of informal know-how	9	13	113	135	45	44	39	38	15	9	7	2
Cooperation & coordination	55	60	80	195	65	22	45	43	5	0	12	3
Collective strategy against risk	56	57	76	189	63	15	52	47	12	0	15	4
Communicating by informal codes	9	32	82	123	41	22	35	27	10	12	9	4
Commitment & mobilization	60	55	41	156	52	24	26	55	40	0	14	3
Skills transmission between colleagues	66	65	73	204	68	25	56	41	20	0	12	4
Discipline & self-control	68	65	44	177	59	22	35	45	22	0	15	3

* Percentage of operators having adopted this behavior.
F1, social values; F2, social group; F3, safety culture; F4, socioeconomic conditions; F5, the resistance to change; F6, new information and communication technologies; F7, another case being considered by the asked operator; W1, executive managers; W2, supervisors; W3, skilled workers.

3. Results

The schedule data processing summarized in Table 2 details the worker categories that participated and their stances with respect to the sociocultural factors having influenced their reliability. These results confirm clearly that there are certain deviations between the prescribed tasks defined by the system designers and the actual activity of the operators according to the collected answers. Thus, these factors are ascertained as a determinant of operator reliability.

3.1. Standards and social values

In a country such as Algeria, the industrial facilities are always imported in *turnkey* form; the issue of worker maladjustment arises because this technology is conceived elsewhere.

Through our on-site observations, we noticed that a huge part of the human errors at the origin of incidents having caused disturbances in work (quality defects, breakdowns, beginnings of fire, light injuries), are related to low awareness of risks, and of false representations on conducts when faced with a dangerous situation.

This can be explained by the individual acquired culture which determines its manner of acting when faced with a risk [16]. Thus, some workers minimally trained on risk prevention resort to antiquated beliefs, which reduces their ability to evaluate potential risks [1].

Standards and social issues that negatively influenced human reliability were: return to informal processes (traditional know-how); recourse to fatalism (religion, tradition) to reject the protection means; difficulties in comprehension due to language and code (knowing that the majority of the workers only speak Arabic); breaking of certain prescribed rules that appear to them as not in conformance with their culture; making poor decisions because of the representations which they had on the risky situations.

Factors positively influencing human reliability included using symbols and codes as shortcuts to simplify tasks, using workers' mother tongue to improve communication, and using traditional know-how.

3.2. Group culture

The group is seen as the most significant component in the working staff. Some is the educational level of the operator which tries always to belong to a group (trade unions, work colleagues, ethnic groups, and so).

Throughout our observations of various task execution within the various activities of Algerian oil companies, we noted that 45% of operators are influenced by their group's informal standards. This caused the companies to adopt some behaviors affecting the system reliability negatively: neglecting some prescribed rules to observe certain unwritten rules that are adopted by the group; informal distribution of tasks among the group members [17]; and risk taking and standardization of some deviances, with an aim of taking shortcuts to save time and effort.

However, the group influence can have positive effects on human reliability, such as: skill transmission by interactions between the group members; cooperation in the recovery of the anomalies; ease of communication and information exchange; and apprenticeship of some positive values that can improve safety.

3.3. Commitment, mobilization, and culture of safety

The companies are social systems, which are characterized by specificities shaping their cultures. Then, each company endeavors to develop a strategy aiming to channel energies in order to mobilize individuals with adhesion to its collective project.

During the survey, we noted that the operators mobilization degree to the company safety policy goals differs according to factors such as the size of the company and the operator's experience, age, and training level.

In large companies such as Sonatrach, most operators are convinced by the safety requirements and show their interest in the observance of these rules and guidelines. This can be explained by: the implication of the hierarchy to setting up of the culture of safety [18]; the climate of safety that reigns in workplaces; the influence of the work staff, which exerts a kind of informal control on newly hired workers; and operators' positive commitment thanks to the positive role played by the representative authorities such as the Health and Safety Commission and labor unions.

By contrast, in other companies such as ENTP, we found that few of the operators are convinced by the utility of the safety requirements. The others think that these rules and guidelines are barriers to their actions. This can be explained by a weak culture of safety, a lack of training and information on risk prevention, especially for young workers, and a hierarchy that shows little interest in prevention programs.

3.4. Socioeconomic environment

Several studies (Tavistoc Institute, Faverge, France) [19] consider the company as an open sociotechnical system, organized in interindependent elements. The company's external environment (geographical situation, sources of natural or different risks) as well as the internal situation (financial position, hiring mode, social policy), exert a real influence on the operators' behaviors towards risks.

During our work, we realized that in the small companies that perform some work by subcontracting with Sonatrach the workers, considering their unsteady state (the majority are on fixed-term contracts), try to save possible company expenditure with regard to setting of actions related to risks prevention or to facilities maintenance.

Among these behaviors, we found the following: ignorance of prescribed deadlines concerning installation maintenance, such as changing of crane cables, tires, or fuel dumps; adoption of risky operations in order to save time; not carrying some protection equipment to save expense; and intervention on moving machines to maintain them while not disturbing the production process.

This situation is worsened by the absence of a representative from the Health and Safety Commission, occupational medicine service, or labor union intervening in the safety and health at the work site.

Another important social aspect that influences the workers' reliability and performance is working far from the family location. We found that the majority of the workers lived far from their places of work. They work 12 hours per day for 4 weeks without interruption and then rest for the next 4 weeks. Working away from family is a source of psychosocial disorders, resulting in potentially risky behavior, (nervousness, excitation, tiredness, stress, depression).

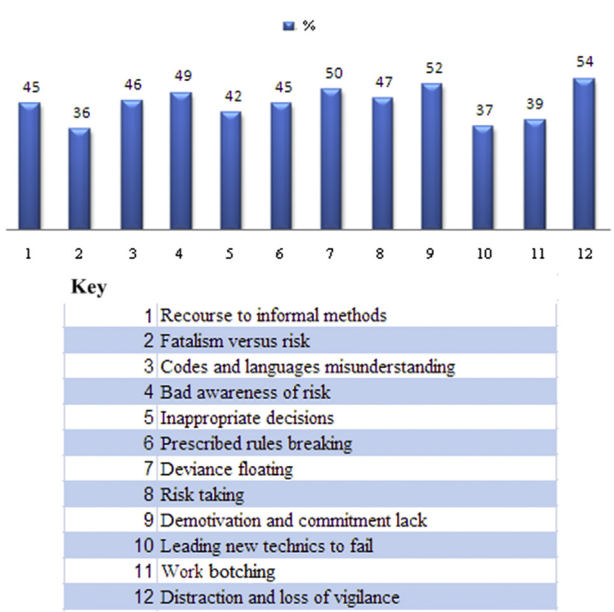

Fig. 1. Relevance of negative behavior adopted by workers.

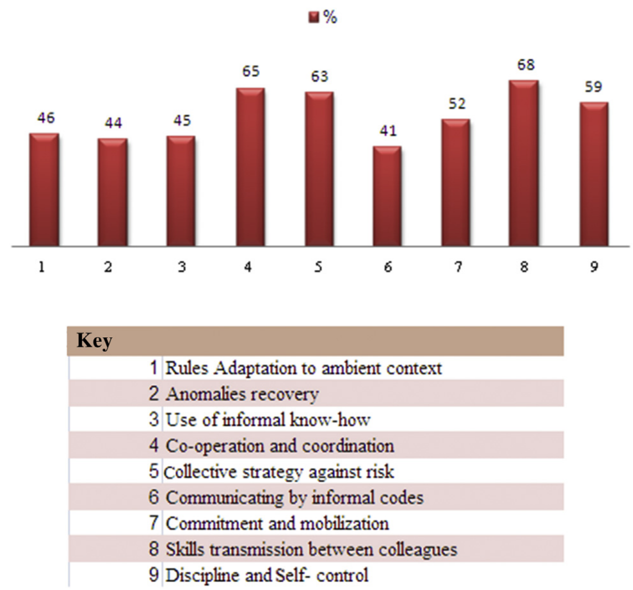

Fig. 2. Relevance of positive behavior adopted by workers.

3.5. Resistance to change

The resistance to change is a phenomenon characterizing individual and group behavior. This phenomenon is an expression of rejection of all that is new. Maurers [20] considers this phenomenon as a natural one and is a current attitude, he considers it also as the least-known source and the most significant in the change failure.

In Algerian companies in general and the oil companies that were the subject of our study, we realized that a majority of workers see change as a symptom of a questionable future, of destruction of the existing and of a confrontation with the unknown.

With regard to our subject, the resistance to change can result in the following: the rejection of new more automated and protected working methods, to remain bound to old methods that are much focused on the manual operator intervention; the refusal to carry new protection equipment and continued use of old equipment; the development of defensive strategies by all the working staff in order to fail the new safety requirements; and the adoption of some passive behavior in anomalies recovery to prove the inefficiency of the new procedures.

We can adhere to the ideas of Coch and French [21]: "the resistance to change results from one combination, at the same time, of the individual reactions, related to a frustration feeling and collective reactions resulting from the group induced forces."

3.6. The influence of the use of NICT

Generally there are positive results from the use of NICT and of the internet in particular on an organization's operation. These tools made it possible to facilitate information exchanges in a large quantity efficiently [22]. Indeed, their advantages are many and difficult to quantify such as: the avoidance cost, collective creativity and the cooperative work; the contacts widening; and access to real information sources.

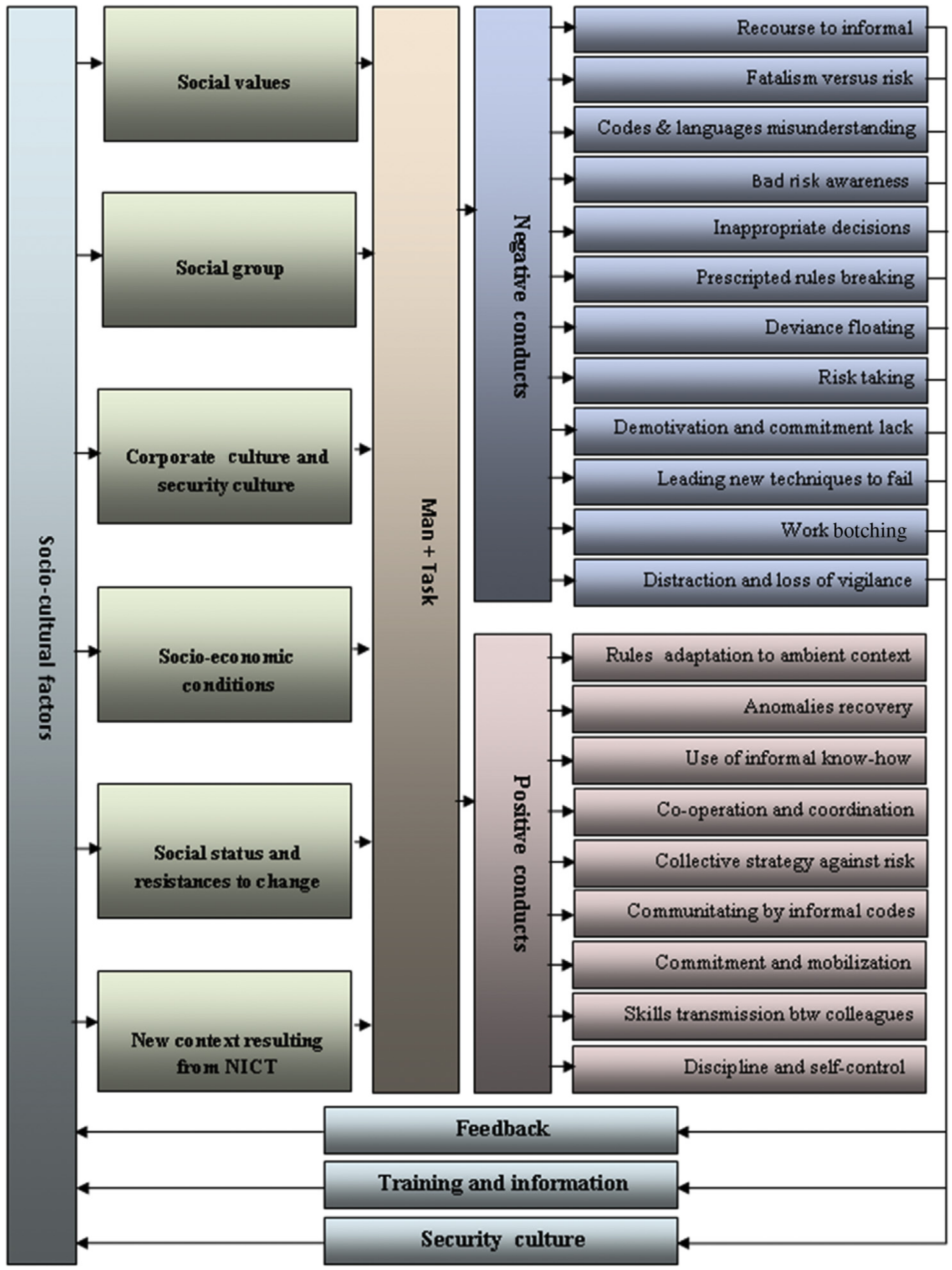

Fig. 3. Sociocultural systems design model.

Nevertheless, the NICT negative effects cannot be ignored. For example, intrusion risks and risk of data leakage, financial swindles and the spreading of fanatic ideas. Here, we focused on the influence of NICT, and especially that of social networks.

Thus, through our observations, and after the schedule exploitation, we found that a great number of the workers state to have used a mobile phone or computer internet service from their work station to reach social networks or to use the internet. In spite of the role of this gathering of useful information for the completion of work for certain tasks, nevertheless, the negative results of such use on operator reliability and performance are proven, which will be reflected on the total system reliability. Negative results include the waste of work time, the negligence of some alerts because of the operators focusing on these networks, the work botching in a hasty manner, which will influence quality, and the loss of attention and vigilance that will generate incidents, or even serious accidents.

4. Discussion

The results gained from the analysis of workers schedule answers confirmed the same trends as observed at the time of site surveys. These results showed that only the sociocultural factors are liable in 45% of cases, of some attitudes and negative conducts influencing the reliability of the human operator during the execution of its task. Among which one can quote adherence to old methods, rejection of new techniques, lack of attention and risk taking, the hasty decisions influenced by the context, disengagement and demotivation (Fig. 1). This does not exclude the positive contribution in 54% of cases of some sociocultural factors, for example, the setting of a positive safety culture, based on the cooperation between the working staff, the know-how apprenticeship, the imposing of certain positive informal rules within the group, the various adaptations and incidents recoveries (Fig. 2).

Therefore, we can support previous research which shows the relevance of sociocultural factors in the individual's acquired culture, and in determining their way of thinking and acting towards risk [23]. Thus the improvement of human reliability should not be done without the assumption of liability of these factors, within the framework of a wider social organization regarding the company as an open sociotechnical system in the environment.

Finally, we can join the idea developed by Dejoy [18], according to which the individual's commitment to prevention programs is not solely determined by the threat against risks, but by the awareness of prevention programs, the application of these programs, the social environment in which they evolve, and by the level of the hierarchy involvement in setting of the safety culture. This limited study can be extended to a huge number of companies or to focus workers subcategories to highlight the main subcategory that is causing the most negative behaviors.

5. Conclusion

The explored sociocultural factors, considering the man as an unforeseeable element of an open sociotechnical system, are influencing its reliability both qualitatively and quantitatively. This was reached when noticing that technicist methods are limited because the human being is as such but not as a technical element of the system on which we can apply recovery loops in case of errors, for example. The human being is more than that: its behavior cannot be adjustable by a technical process and it has the ability to expect or to recover from itself. That is to say that the theory is very far from practice when the element is a human being because the latter is the holder of noticeable eigenvalues, such as resistance to change, that any other technical element cannot have because the technical element follows a strictly known path. Thus, this work highlights the most likely sociocultural factors influencing the human reliability as indicators (cues). They were determined by in-site observation, by incidents/accidents, and their influencing degree was estimated by a questionnaire.

With this intention, it would be advisable that the designers of sociotechnical systems do forecast the following: (i) experiment feedbacks to correct defects that will be detected during the production operation, while making facilities readjustment to the requirements of the parent population (e.g., anthropometry, language, religion, culture, climate); (ii) a safety management system, based on the development of a positive integrated culture of safety; (iii) error tolerant systems allowing anomalies recoveries; and training and information policy to improve risk awareness.

We propose the three-level model shown in Fig. 3, which clearly illustrates this influence. It operates in the following way. Level 1 depicts the most known sociocultural factors that influence the task–person interaction in two ways: a direct way that has an impact on behavior and conduct; and an indirect way which affects human thinking mode and its method of resolving issues. Level 2 depicts the consequences of these factors on task–person interaction that manifest themselves (positively and negatively) on human reliability. Level 3 feedback depicts the corrective actions and enhancements that could be done by supporting the training, the culture of security, and the information and adaptations that take into consideration the cultural specificities, for example, when conceiving systems.

This model can be useful when applying feedbacks, and thus can lead to the following: the success of technology transfer; the enhancement of systems design when adapting them to operator culture; a better design of user interfaces; and the anomalies recovery that makes systems more reliable.

On the human factors side, the model proposes only that actions, such as training and information, must be taken to dispose of resistance to change and other negative conducts conveyed by sociocultural factors. It proposes also the reinforcing of a culture of security to make operators pay more attention to rules and security orders.

Thus, we can state that taking into consideration the sociocultural factors in reliability studies will lead to a better mastering of risks that decrease incidents/accidents and shutdowns, decreasing the production cost and enhancing the quality. The work climate will be better and make communication easier, there will be improved cooperation and the coordination between workers, motivation will increase, and lead to fewer labor disputes (strikes).

Finally, although this analysis testing is limited, two major oil companies with large work forces were studied in order to explore the most responsible sociocultural factors. We hope that the analysis can be extended to a large number of companies and to more worker subcategories.

As a perspective, we foresee that this analysis will be a reference in human reliability research studies that should take into consideration these highlighted factors in various methods and tools to assess the human reliability.

Conflicts of interest

All authors have no conflicts of interest to declare.

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