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Anticipating impacts of change on individual behaviors within a perspective of safety management

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ABSTRACT: Technological or managerial changes aim improving a dimension of performance of sociotechnical systems, generally productivity, profitability or quality. In some circumstances changes can affect, as a side effect, system safety properties and facilitate occurrence of crisis situations or by decreasing system ability to mitigate crisis situations. Anticipating potential consequences of change on sociotechnical systems safety properties requires knowledge, method and tools covering the complexity of sociotechnical system. Objective of this paper is to present and apply a methodological framework aiming supporting the identification of impact of a change on individual and collective behaviors within the perspective of safety management.

1 INTRODUCTION

Organizational changes, defined as a “process of radical or marginal transformation of structures and skills that punctuates the process of evolution of organizations“(Grouard et al. 1998) or “any relatively permanent modification in a subsystem of the organization, provided that such modification can be observed by its members or people who are related to this system" (Collerette *et al.* 1997) are omnipresent in enterprises.

Among the diversity of these changes, some are injunctions coming from the strategic apex with a strong constraint of realization and relatively weak margins of manoeuvre (Autissier et al. 2012). Consequences of these injunctions are the launch of change management project aiming to transform the organisation as whished by the strategic apex.

Changes can affect safety performance of the system. Consequently safety management systems required a risk analysis to be performed in order to guarantee the level of safety. Despite those precautions, several examples can be found of occurrence of negative and perverse effects affecting negatively the performance of the organisation. Those negative effects can be related to the non-compatibility, to the inefficiency of the new system, to its rejection by the operators, to the creation of new dependencies or to the loose of flexibility and of margins of manoeuvre to perform tasks.

Technology assessment (Westrum 1991) aims considering the potential consequences of new technological system. Several methods and tools exist to support such assessment. In the context of safety and security, traditional risk assessment methods such as FMECA or THERP are often used with the purpose to identify potential risks related to the adoption of a new technology. Such approaches allow considering a set of consequences but present some limitations regarding, among others things, to consider the complexity of human behaviours, of socio-technical systems and of large-scale socio-technical systems.

Objective of this paper is to present a methodological framework aiming supporting the identification of impact of a change on various dimension of the human dimension of a socio technical system.

First section is related to the framework developed for supporting the identification of potential impacts of a change on system safety performance. The different phases of the associate method are presented and the diversity of assessment modules to be developed is discussed.

Second section presents dimensions to be considered by the assessment of potential consequence of a change on human performance. These dimensions are firstly innovation societal and practical acceptance issues then the variability of observe, interpret, plan and communicate functions, and finally stress and fatigue.

Third part describes methods that can be used to conduct process of identification of potential consequences of changes. Focus group and a set of situation-awareness assessment methods are presented.

Some lessons of the realization of assessment on different cases are summarized in the conclusion and perspectives of development are presented.

2 THE IMPACT FRAMEWORK

The IMPACT method aims providing a set of recommendations for a change process management before, during and after its realisation. It is based on an analysis of the potential consequences and opportunities or risk. Consequences are identified through the application of an assessment strategy that is defined alongside an examination of the change considered.

Application of the method is based on methodological guidelines describing the different steps to be achieved and a toolbox describing data acquisition processes and performance indicator assessment guidelines.

2.1 *Methodological guidelines*

The IMPACT method is based on four phases.

- **Phase 1**: *General Outline*. This phase describes the knowledge necessary to understand the technological change studied and defines a strategy dedicated to the identification of its potential consequences. The strategy is based on the selection of a set of relevant assessment targets.
- **Phase 2**: *Consequence identification*. The purpose of this phase is to identify potential consequences of the change in question by applying the assessment strategy defined in the first phase. The result of this phase will be a list of potential consequences.
- **Phase 3**: *Risks and opportunities analysis*. This phase evaluates the risks and the opportunities associated with the change in question. The set of consequences identified in the previous step is looked at and a list of potential risks and opportunities is defined.
- **Phase 4**: *Recommendations for decision-making*. The purpose of the last phase is to define a set of recommendations for change design and management processes based on the analysis of the set of risks and opportunities identified in the previous step.

In order to support the application of the method, a set of methodological guidelines related to the information acquisition process and the performance dimension assessment is suggested.

2.2 *Toolbox*

The IMPACT toolbox consists of two types of guidelines: data collection processes and performance indicator assessment processes. These processes provide assessment modules to be applied during the consequences assessment phase of the method.

Three types of data collection processes are suggested:

- **Risk assessment**. Traditional risk assessment processes based on different methods (FMECA, HAZOP, THERP, CREAM, etc.).
- **Focus groups**. Focus groups is an approach that consists of asking a group of people about their feelings, opinions, and beliefs concerning an idea, a concept, a product, etc.
- **Simulation**. Simulation can be an efficient way to identify the consequences of a change on a system. Simple role-playing games or more elaborate simulations using technological facilities such as bridge, flight or crisis management simulators can be used in order to acquire information about the consequence of a change by, for example, comparing the execution of a given scenario with and without the application of the change.

Four levels of performance indicators are suggested:

- **Risk based consequences**. Consequences related to technical, human or organisational failure modes.
- **Human- and organisational-based consequences**. The consequences related to human and organizational factors approaches include: change acceptance, non-technical skills definition and assessment; research and development activities, e.g. situation awareness, decision-making, communication, teamwork, leadership, stress, fatigue **(**Flin et al. 2008); control performance assessment (Hollnagel & Woods 2005); and risk governance e.g. pre-assessment, management, appraisal, characterization, evaluation and communication (Renn & Walker 2008).
- **High Reliability Organisations (HRO) and Resilience Engineering-based consequences**. Consequences identified by safety science research include: organizational resilience capabilities, e.g. Respond, Learn, Monitor and Anticipate (Hollnagel et al. 2011); HRO abilities for the management of unexpected situations, e.g. Preoccupation with failure, Reluctance to simplify interpretations, Sensitivity to operations, Commitment to resilience, Deference to expertise (Weick & Sutcliffe 2001); and the Efficiency Thoroughness Tradeoff model i.e. Work ETTO, Psychological ETTO, and Organizational ETTO (Hollnagel 2009).

Research and development activities are conduct with the perspective of developing a first prototype of assessment module dedicated to the assessment of impact of change on human behaviour.

3 HUMAN - BASED CONSEQUENCES OF CHANGE ASSESSMENT INDICATORS

Objective of the framework is to support assessment of impact of a change on the diversity and complexity of individual behaviors. Development of two preliminary assessment modules is conducted:

- **Societal and practical acceptance of change.** This module aims assessing the potential of the change to be at the origin of rejection by people for general or practical concerns.
- **Individual characteristics.** This module aims assessing the potential of the change to affect individual characteristics (stress, fatigue, etc.) and behaviors (observe, interpret, plan, etc.).

For each dimension, a list of preliminary indicators is proposed.

3.1 *Societal and practical acceptance of change conceptual model*

Societal and practical acceptance of change issues concern mainly innovative technology and are related to the question of acceptance of a technology.

3.1.1 *Societal acceptance of a new technology*

Societal acceptability is related to the potential of an innovation to be at the origin of a social problem. Social problem can be defined as "a condition that undermines the well-being of some or all members of a society and that is usually a matter of public controversy" (Macionis 2005) or as "the activities of individuals or groups making assertions of grievance and claims with respect to some putative conditions" (Spector & Kituse 1977). Social problem life cycle can be structured with six phases (Best 2008):

- **Claims making**. People make claims that there is a social problem, with certain characteristics, causes and solutions.
- **Media coverage**. Media report in claims makers so that news of the claims reaches a broader audience.
- **Public reaction**. Public opinion focuses on the social problem identified by the claims makers.
- **Policymaking**. Lawmakers and others with the power to set policies create new ways to address the problem.
- **Social problem work**. Agencies implement the new policies, including calls for further changes.
- **Policy outcomes.** There are various responses to the new arrangements.

In order to assess the potential of a change to be at the origin of social problems, a set of dimensions are considered. The following table presents dimensions that are considered.

Table 1: Societal acceptance indicators

Indicators	Description
Privacy	Concern over our accessibility to others: the extent to which we are known to others, the extent to which others have physical access to us, and the extent to which we are the subject of others' attention'
Confidentiality	Status accorded to data or information indicating that it is sensitive for some reason, and therefore it needs to be protected against theft, disclosure, or improper use, or both, and must be disseminated only to authorised individuals or organisations with a need to know"
Safety	Condition of being protected against physical, social, spiritual, financial, emotional, occupational, psychological, educational or other types or consequences of failure, damage, error, accidents, harm or any other event, which could be considered non-desirable.

3.1.2 *Practical acceptability of a new technology*

Practical acceptability is related to the perception by users of the utility of a technology for achieving their goals. This perception can be studied "a priori", assessment is based on the subjective representation of the technology and characterized its acceptability. It can be studied with an experimental use of the technology and characterized its acceptation. Finally it can be studied once integrated in users activities and characterized its appropriation (Terrade et al. 2009).
In order to assess the potential of acceptability, acceptance and appropriation of a change a set of dimensions are considered (cf. Table 2).

Table 2: Practical acceptance indicators

Indicators	Description
Utility	Utility is related to the total or partial correspondence between functions provided by the innovative system and actual and future users' needs.
Usability	Usability is related to a set of dimensions characterizing the ease of use of system functionalities (efficiency, ease of learning, man machine interface, errors prevention, satisfaction, etc.).
Acceptability	Acceptability is related to users' attitude and the correspondence between users' values and the innovative technology properties.

Dimensions to be considerate by a diagnostic of a change potential of acceptance or of reject by society and end users have been presented in this section. These dimensions can be used, as basement by data collection processes.

3.2 *The Individual perspective*

This is related to the presentation of a set of factors to be used for the diagnostic of potential impacts of a change on individual functions and characteristics.

Four individual functions are firstly considerate: Observe, Interpret, Plan and Communicate. Then individual characteristics of human stress and fatigue are discussed.

3.2.1 *Observe, Interpret, Plan and Communicate*

Observation function aims gathering information by perception in the current situation (Endsley 1995, Flin et al. 2008). Failure modes of observation process are (Hollnagel 1998):

- **Observation can be missed**. A signal, an event or a measurement is missed.
- **A false observation can be made**. A response is given to an incorrect stimulus or event, an event or some information is incorrectly recognised or mistaken for something else.
- **Wrong identification can be made**. A signal or a cue is misunderstood as something else, the identification of an event or some information is incomplete or incorrect.

Information gathered by the observation process has to be processed to make sense of the situation in order to understand what is going on and the significance of data observed (Flin et al. 2008). Failure modes of interpretation process are (Hollnagel 1998):

- **Diagnosis is false**. Diagnosis of the situation is incorrect or incomplete.
- **Reasoning is false**. Induction or Deduction reasoning process lead to invalid results, Selection among alternatives is achieved with using incorrect criteria, hence leading to incorrect results.
- **Decision is false**. Agents are unable to make a decision; decision is wrong, decision does not completely specify what to do.
- **Interpretation is delayed**. Identification is not made in time or not made fast enough.
- **Prediction is incorrect**. A change not anticipated occurred, event developed in the main as anticipated but some side effects has been missed, speed of development has been misjudged.

Interpretation and prediction of the evolution of the events to be controlled information is used for planning decisions and actions to be performed (Flin et al. 2008). Failure modes of planning process are (Hollnagel 1998):

- **Plan is inadequate.** Plan is not complete, does not contain all the details needed or is wrong.
- **Selection of goals is wrong.** Priorities followed are wrong and goals have been wrongly selected.

Communication refers to the exchange of information, feedback, response, ideas and feelings. Failure modes of communication process are (Hollnagel 1998):

- **Communication failed**. The message or the transmission of information did not reach the receiver, the message was received, but it was misunderstood.
- **Information is missing**. Information is not being given when it was needed or requested, the information being given is incorrect or incomplete, there is a misunderstanding between sender and receiver about the purpose, form or structure of the communication.

3.2.2 *Stress and Fatigue*

Stress is a "particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being" (Lazarus et. al. 1984). Two types of stress are considered (Flin et al. 2008). Acute stress is sudden, novel, intense and of relatively short duration. It disrupts goal-oriented behaviour and requires a proximate response (Salas et al. 1996). Chronic stress is related to reactions of individuals of the variability of its environment such as an increase of the demand or a perception of having not enough time or resource to perform goals correctly.

With the perspective of assessing impact of change on stress of individual, source, symptoms and effects of stress are considerate (Flin et al. 2008).

Factors related to activities, demands, individual perception or work and general environment of the individual can create stress (cf. Table 3.).

Table 3: Stressors factors

Indicators	Description
Job demands	Too much, or too little time to complete tasks Too little or too much training for the job Boring or repetitive work, or too little to do Working environment (temperature, noise, etc.)
Control	Lack of control of work activities Lack of involvement in decision making
Superviser / Manager	Lack of support from manager and co-workers Unrealistic goals
Relationships	Poor relationships with others Bullying, racial or sexual harassment
Role	Uncertainty about work objectives and lack of clarity about responsibilities Staff feeling the job requires them to behave in conflicting ways
Change	Uncertainty about what is happening at work Fears about job security Restructuring of the job
Home: Work interface	Family problems Dual-career marriages Life crises

Stressor Factors can create both individual and organisational symptoms. (cf. Table 4.).

Table 4: Symptoms factors

Indicators	Description
Individual	Behavioural (absenteeism, abuse of drugs or alcohol, hostile behaviour, apathy, distracted, etc.) Emotional (anxiety, cynicism, depression, irritability, etc.) Somatic (decline in physical appearance, chronic fatigue, infections, health complaints, etc.) Thinking (lack of concentration, reduced attention, difficulty in remembering, failures in planning, etc.)
Organizational	High absenteeism High labour turnover Poor quality control

Effects of stress can also be both individual and organisational. (cf. Table 5.).

Table 5: Effects of stress factors

Indicators	Description
Individual	Physical ill-health Mental ill-health Burn out
Organizational	Apathy Chronically poor performance Frequent / severe accidents Prolonged strikes

All these indicators can be used to assess potential impacts of a change on the stress of individuals.

Fatigue can be define as " the state of tiredness that is associated with long hours of work, prolonged periods without sleep, or requirements to work at times that are 'out of synch' with the body's biological or circadian rhythm" (Caldwell et al. 2003). With the perspective of assessing impact of change on individual's fatigue, cause and effects of fatigue are considerate (Flin et al. 2008).

Table 6: Fatigue Cause and effect factors

Indicators	Description
Cause of fatigue	Long hours of work Lack of sleep Stress Temperature extremes Noise Physical work Vibration
Effect of fatigue	Cognitive performance (reduced ability to cope with unforeseen rapid changes, less able to adjust plans, tendency to adopt more rigid thinking and previous solution, acceptability of lower standards of performance, etc.) Motor skills (less coordination, poor timing, etc.) Communication (difficulty in finding and delivering the correct word, speech is less expressive, etc.) Social (become withdrawn, more acceptance of own errors, less tolerant of others, neglect smaller tasks, less likely to converse, increasingly irritable, distracted by discomfort, etc.)

All these indicators can be used to build assessment process for assessing potential impacts of a change on human performance variability.
Next section will be dedicated to the presentation of a set of data collection process that can be used to structure assessment.

4 HUMAN - BASED CONSEQUENCES OF CHANGE ASSESSMENT MODULES

Indicators characterized in the precedent sections can be used as basement for realizing assessment modules.

Three types of assessment are considered:

- **"Before change" assessment**. Identification of potential consequences of change on system safety performance is realized before the occurrence of the change. Identification process of potential impact is based on systems' experts and end users perceptions of the change and of its potential consequences.
- **"During change" assessment**. Identification of potential consequences of change is realized during the change management process. Identification is based on the study of systems' experts and end users perceptions after the start of the change process or on the conduct of a pilot study.
- **"After change" assessment**. Identification of potential consequences of change is realized after the change management process. Identification is based on the study of systems' experts and end users perceptions after the change.

Two types of methods can be used for building the assessment modules. Focus Group approaches definition is planned for the three types of assessment and existing human factors assessment methods for the second and the third assessment types.

4.1 *Focus Group*

Focus groups are structured, attentively moderated group discussions that reveal a target audience's conscious preferences, recalled experiences, and stated priorities (Goodman and all, 2012).

Focus groups are good for:
- Finding desires, motivations, values and firsthand experiences
- Understanding fundamental issues and perceptions
- Get attitudes and perceptions, thoughts and feeling
- Identify and prioritize features of a product
- Brainstorming

Focus groups are not good for:
- Getting general information on usability as this can vary much among individuals
- Getting numerical results which can be generalized to a larger public

There are four types of focus group interviews
- Exploratory (to get information on general attitudes, perceptions etc.)
- Feature Prioritization (to get information on what features are most attractive and why)
- Competitive Analysis (in comparison with another product; what attracts people/what makes them reject a product)
- Trend Explanation (used to help explain a certain behavior)

The organization of a Focus Group requires defining:
- **The schedule**. In order to be successful, a focus group requires time for preparation and time for data analysis. The definition of a schedule allowing appropriate time for each step is important.
- **The target audience and scope**. The selection of the people that will participate to the focus group and the definition of the groups are important to have a climate allowing free exchanges and discussions.
- **The topics**. The definition of the topics of the focus group, based on the strategy of assessment will support the writing of the discussion guide that will help the animation of focus group.

With the perspective of identifying consequences of change, focus group can be used to get people perceptions about the new technology, the new organization or the new regulation. Organizing Focus Groups with representative of the different activities of a domain allows collecting elements about their perception about the pertinence of the change, the potential change resistances forces or the complementary actions to be followed in order to support the change process.

Focus group dedicated to the identification of potential consequences of change can be completed with the application of specific human factors assessment methods

4.2 *Human factors assessment methods*

Various human factors assessment methods can be applied with the perspective of identifying consequences of changes. Situation awareness measurement techniques and discusses in this section

Situation awareness is related to the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future (Endlsey 1995a).

Different methods exist for studying situation awareness three of them are presented thereafter.

SART (Situation Awareness Rating Technique) method (Taylor 1990) aims to assess ten dimensions related to situation awareness: Familiarity of the situation, complexity of the situation, focusing of attention, variability of the situation, information quantity, arousal, instability of the situation, information quality, concentration of attention and spare capacity.

Participants of the assessment perform a scenario and at key moments they are asked to rate the ten dimensions with a scale of one (low) o seven (high).

SAGAT (Situation Awareness Global Assessment Technique) method (Endsley 1995b) aims to assess three key dimension of situation awareness: Perception of the elements, Comprehension of their meaning and Projection of future status. A set of questions is defined after a task analysis and participants are asked to answer to them during freezes time of a simulation scenario.

SACRI (Situation Awareness Control Room Inventory) method (Hogg and all 1995) is an adaptation of SAGAT method to assess situation awareness in control rooms. Assessment is based on three types of questions: Comparison between the current situation with that of the recent past, Comparison between the current situation with normal operations and Prediction of future situation developments.

Combination between Focus Group and assessment techniques is a first proposal of a framework for identifying potential consequences of a change.

5 CONCLUSION AND PERSPECTIVES

Focus groups dedicated to the assessment of potential impacts of change and simulation analyses based on human factors assessment methods has been experimented for the study of innovative technologies (Rigaud et all 2012, Zarea et all 2013a, Zarea et all. 2013b). Experimentations prove the utility of the approach. Nevertheless improvement areas have been identified.

Framework covers partially human related dimension, it has to be completed with other human related dimensions and with other dimension of system safety.

Results of assessment are qualitative and quantitative data about the likelihood of potential impacts of a change. This information has to be adapted in order to be used as a change management decision criterion.

Based on this experience, further developments are conducted aiming to complete the assessment module lists and to refine the global framework for making it relevant for a change management process.

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