Real time dynamic simulations and delayed time static simulation in human factors specialist's toolkit: two different ways for evaluate productivity and safety in process design

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Abstract. Simulation is a tool required in any process of technical and organizational design. Depending on project goals, simulation may have different levels of realism, involve more or less resources (technical, time, economic, etc.), multiple goals (quality, safety, training, etc.) and can be used in a wide range of sectors and areas of design (architectural, computer, industrial, purely organizational, etc.). However, the whole range of simulation methods could be described according to different models. In this presentation we will describe two of those models of simulation processes used in the design of high-risk environments.

Keywords. Real time simulation, anticipatory simulation, human and organizational factors, safety.

1. Introduction

Simulation turned out to be an essential tool for ergonomists and human factors specialists. Even though it is recommended for every design process whose role is to improve productivity, it is indispensable when an organizational or technical modification presents safety issues (Daniellou, 2013: 48 y ss.). This is especially true for socio-technical changes in the field of high-risk activities (energy, transports y aviation, medicine, etc…).

In this paper, we describe two types of simulation corresponding that may be used in this field. On one hand, **real time dynamic simulation** is frequently used in new IT tools implementation projects in air traffic control. On the other hand, **anticipatory static simulation** is used in organizational changes in continuous process industry (chemical and petrochemical).

2. Real time dynamic simulation: the case of air traffic control

Air traffic control industry has been using this kind of simulations for decades, for controllers' training and for new control tools' evaluation and validation. Both kinds of projects are long, expensive and complex. Preparation of this process has to be completed with much anticipation, and has to be structured around several "groups" of persons involved in specification, development and test of the new system (controllers, pseudo-pilots, engineers, human factors specialists). All these "actors" are coordinated by a *simulation director*, whose role is to lead activities in **real scale simulator**.

Below, we'll describe experimental conditions as well as evaluation criteria used in the simulation process.

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2.1 Experimental conditions and evaluation goals

The first stage of an evaluation process lies in ensuring that collected information will be reliable and complete, by means of:

- **Representativity of involved controllers:** demographic, organizational, geographic, functional, etc.
- **Training of controllers and pilots**: this guarantees "quality" of work in the simulator and quality of controllers' assessment during interviews, focus groups and when completing questionnaires. **Documentation** used for the training is a key factor.

Simulation run and features.

a. **Quality and adaptation of scenarios and exercises based on air traffic samples as a simulation "support":** exercises and scenarios have to match with the features of evaluated functions
b. **Operational mode** definition: in order to be assessed, new functions have to be used in *a certain way*, called *"operational mode"* (procedure describing actions sequence, tasks division in control team, etc..).
c. **Activity's realism in simulator**: simulator has to be as close as possible from a real control center (acoustics, movements, people's location in the room, etc..)

The assessment process aims at evaluating **new system's usability**, that is, in other words, *"the degree of efficacy, efficiency and satisfaction a product may be used with, by specific users to reach precise goals, in a specific use context (ISO 9241-11)"*.

2.2 Efficacy assessment: safe and fluent operation with the new system

Efficacy may be described in this standard as "the accuracy and the degree of achievement users reach established goals with".

If we consider air traffic safety and fluidity as the **primary** goal, parameters such as number of assumed airplanes, percentage of solved conflicts, average delay, effects of atmospheric disturbances on assumed airplanes, etc. have to be evaluated.

Efficacy-related data will be collected with **system internal recording tools** (actions' frequency and duration, radar data, communications, etc…) and **notes** collected in real time situation by Ergonomics and Human Factors specialists (Bisseret, A., Sebillotte, S. y Falzon, P.,1999).

2.3 Efficiency assessment: safe and fluent operation with the new system

Efficiency will be measured as a relation between **efficacy** and **spent resources** to reach the goals. We consider that primary objective of efficiency in our case is to minimise controller workload, organisational, training and technical resources necessary to reach the established levels of **safety** and **fluidity**.

- **Workload criterion**: the main workload for air traffic controller is of mental nature. It may affect the individual on both cognitive plan (for example, troubles when treating or memorizing information) and psychic functioning (for examble, insecurity or uncertainty caused by the system). The question of "measuring" mental workload is a very controversial topic in the field of Ergonomics and Human Factors (Villena, 2006). Several "methods" exist to assess this kind of workload, but each of them has some limitation (based on physiological rates, on subjective scales, on evaluation of *performance*, etc...). In any case, this question hasn't been solved yet, neither in the field of air traffic control nor in any other area. In our case, workload evaluation is based upon **behavioural information** (operating modes' variation in work activity - Sperandio, 1971, Falzon y Sauvagnac, 2004, Leplat, 1965- information is collected with Actopalm and Actogram device, audio/video recording and self-confrontation) and **standards** (heuristic and recommendations from research institutes as INRIA-).

- **Organizational resources and Training criterion:** the question looks easy, but it is highly relevant: how many controllers are necessary to run the new functions of the system? Is it more or less than in the current system? What training do they need to run the new system suitably?
- **Technical resources criterion**: every assessment concerning new tools' efficiency has also to include an estimation of necessary technical resources for **development, test, evaluation, maintenance and re-specification** of the new tools.

2.4 Evaluation of controller satisfaction with the new system

Satisfaction indicates how users feel free of "discomfort" when using the new tools during the simulation. Satisfaction can be assessed on objective and subjective measures:

- **Objective measures** can be based either on users conduct observation (for example, postures, body movements, spontaneous expressions) or on their physiological reactions' analysis.
- **Subjective measures** of satisfaction may be reached by quantifying users' reactions and opinions intensity thanks to multiple-choice questionnaires and interviews lead by Ergonomics & Human Factors specialists.

2.5 Results presentation for dynamic simulation

Information collected during the simulation enables to identify **ítems affecting future system's usability**. Ergonomics and Human Factors specialists, in cooperation with System Engineers and project managers have to propose **specific solutions** for every identified issue. Corresponding changes will then have to be validated **before new tools implementation**.

3. Anticipatory static simulations

3.1 Goals

Anticipatory static simulations may be used before implementing transformations concerning team organization, workplaces layout, work position design, tools & machines design, procedures redaction. It may also be used for feedback (REX) on specific operations like sensitive operations for safety.

In any case, simulations are performed to test and compare several options or scenarios, considering a sample of "simulated" work situations, in a room, by means of a static representation of the reality (drawings, pictures, diagrams, charts, mock-up).

3.2 Examples

In this paper, we will use the case study of a technical and organizational transformation in a refinery unit. In this project, anticipatory static simulations were used to help decision makers implementing safe and reliable system (organization, machines, procedures, etc.)

In order to increase and improve its production, a petrochemical company decided to extend an existing unit by purchasing and implementing an additional process. The company planned to change unit's organization to cope with the future process. New organization had to ensure unit's safety and reliability operation.

The company studied one organizational scenario, based on both a modification of tasks division between shift supervisor and shift supervisor assistant and a new division of field and panel operators' perimeter in the unit.

3.3 Simulations

One field operator, one panel operator, one shift supervisor and one shift supervisor assistant working in the current unit were gathered in a room. They were presented the main features of the project (machines to be purchased, workplace design at this stage, main operations to be performed). Future unit was presented on drawings, placed on a table, in front of the workers. The organizational scenario considered was presented by the project manager, before the Human Factors specialists lead several simulations of "activities":

- « Normal » or daily situations: on a board, the time schedule of a « standard day » in the future unit was written by the Human Factors Specialists with workers' cooperation, step by step, considering the main tasks to be completed during the day, from arrival at the unit until departure, considering instructions transmission, routine rounds, work permits signature for subcontractors, samples collection and analysis, lockout and tag-out operations, changeover time, etc… Precise operations were simulated, both on drawings and time scale, including changes due to new equipment and organization. As an example, the future detailed routine rounds were plotted on the drawings « without raising the pen" and their duration was estimated, for each role in the future organization. The goal was to evaluate how reliable and safe the considered scenario was regarding the future unit operation.
- Incidental and emergency situations: several realistic incidents were chosen (power cut, fire), one of them had previously been observed in real situation by the Human factors Specialists, in the field. The same method was used, drawing each operator's displacements in the unit, considering real path to follow (gangway, crinoline scale, etc.). The goal was to evaluate the ability of the organizational scenario to put the unit in a safe state in an assigned period (fixed with unit Safety Engineer).

3.4 Results

Simulations highlight the strengths and weaknesses of the considered scenario (low availability of field operators on certain critical periods, inability to put the unit in a safe state in a satisfactory duration, long operation on manual valves at the very opposite of the unit center, lack of operators to turn off a manual safety valve, communication uncovered areas, etc.). From this conclusions, several modifications (organization, equipment, procedures) are identified as a preliminary condition for ensuring safety and efficiency of the future organization.

4. Discussion and Conclusion

Both anticipatory static simulations and dynamic real time simulations show satisfactory results for new system (organizational, technical, interface) evaluation and solutions research. Their use at both early and advanced design stage makes possible to identify unexpected troubles and solve them before implementation, what is also a key point for projects economic scale. Generally, both kinds of simulation favours the design of processes, tools and interfaces that meet users' requirements and therefore lead to safe and efficient use, in normal operations as well as incidental situations.

However, several differences and key factors may be identified comparing the two types of simulations:

- First of all, realism of anticipatory static simulation can't be as good as it is in dynamic real time simulation. Therefore, participants' preparation is a critical point for anticipatory static simulations. As the future reality is not directly presented on a real scale position / unit, group leaders have to "create" conditions to make users project themselves in the future organization, with the new machines. Introduction's quality and teaching skills are key factors. Documentation has to be as clear as possible and built on users' representation mode to favour quick and deep comprehension. Drawings have to be on scale, big enough to work together around a table, with pictures and 3D plans. The meaning of drawing codes (symbols, colours) has to be previously explained to the participants.

- Second, simulation's methodology is significantly different in the two kinds of simulations. In anticipatory static simulation, Human Factors specialists has to lead the simulation and lead participants to future real work "projection ». Several tools are used to achieve it. Questioning is one of the most important : « when you have to operate this valve, what do you start with ? Where do you go first? What's the way? Do you have to carry specific tools ? Do you have to coordinate with panel operator ? Do you operate it by yourself ? When do you consider it to be finished? Once it's done, what do you do? At the same time, participants are invited to plot their path on drawings without raising the pen, and write their activity on a time scale, so that no step is forgotten.

As a conclusion, the two kinds of simulations use two different ways of representing the future situation. One is more realistic and interactive than the other, but also much more expensive. Methodology, more than supports and resources, is the key point to achieve results in both cases. **Scenarios definition is the key point**: an excellent simulator, used in unrealistic situations won't lead to any useful and reliable conclusion.

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