Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 38 (2015) 94 – 99

www.elsevier.com/locate/procedia

The Fourth International Conference on Through-life Engineering Services

Human Factors Engineering in System Design: A Roadmap for Improvement

M. C. Leva*, F. Naghdali, C. Ciarapica Alunni

Centre for Innovative Human systems, Trinity College Dublin, Dublin, Ireland.

* Corresponding author. Tel.: +353 86 16 13570;. *E-mail address:* Levac@tcd.ie

Abstract

This paper summarises current industrial practices and standards promoting Human Factors Engineering (HFE) at design stage and revise them with an action research approached based on the concrete case studies performed during a European project called TOSCA. The paper highlights how HFE can significantly impact the costs and risk associated with a plant lifecycle and the current gaps and issues encountered. The gaps identified are used to guide industrial practices and standards towards a more valuable inclusion of Human Factors knowledge in structured system design processes to support human performance and reduce the potential for human errors in operations and maintenance.

Peer-review under responsibility of the Programme Chair of the Fourth International Conference on Through-life Engineering Services.

Keywords: Human Factors Engineering; Maintainability; Human Machine interface; System Safety Engineering

1. Introduction

Human Factors Engineering (HFE) has a key role in promoting the inclusion of human factors knowledge at design and construction phase in socio-technical systems. Several research projects and programs [1] on system safety engineering and Quantitative Risk Analysis in the last 40 years have offered very strong evidence of the crucial role that human and organizational factors (HOFs) play in major accidents.

A coherent definition of HFE is provided by the International Association of Oil and Gas Producers (OGP), which states that HFE is a discipline exploiting a multidisciplinary approach that focuses on the integration of five elements ("star model"): people, work, work organization, environment and equipment [2]. In other words a suitable HFE application framework should address the whole collection of these contributors with respect to the specific case study, so as to support the human inputs to production and reduce potential for human errors for Occupational Safety and Process Safety. HFE can be interchanged with the terms "Human Factors" and "Ergonomics". In the Process industry the demands for safe and efficient operations has increasingly shifted the role of the human in the system from primary actor to supervisor of an automated process [3]. This increase in the role of automation highlights the need to properly consider possible hidden hazards when interfacing automation with the process to be controlled and the operators supervising them. In the past the development of new technology was much slower than it is at present and it did allow enough time for the hazards to emerge [4]; hazards that may also originate in the lack of adequate support for operator's cognitive processing at a rule-based level or at a knowledge-based level [5]. What is now more and more crucial are supports for the diagnostic capabilities of the operator to properly identify deviations in the process, to suitably fix eventual problems coherently with the severity of expected consequence/s. When the complexity of the system increases in fact the ability of the human to control the system and intervene in foreseeable and or unforeseen circumstances with even manual functions such as corrective maintenance) it's still crucial in helping the system to recover from abnormal conditions [6]; hence the need for Human Factors consideration in designing for operability and maintainability. Simple yet effective choices at both organizational and technical level can be observed to enhance human performance, prevent human error and improve safety and maintainability [7][8]. In relation to Process Safety, a well performed HFE method should account for two different aspects: resilience to human error, and enhancement of human

Peer-review under responsibility of the Programme Chair of the Fourth International Conference on Through-life Engineering Services.
doi:10.1016/j.procir.2015.08.091

performance which means support for direct intervention of operators whenever their tasks are required (e.g. maintenance intervention, calibrations etc.) providing them with better understanding of system dynamics and implications of their tasks. The quality of the human-machine interface (HMI) is critical in this sense. There have been several attempts to tackle this aspect with approaches supporting Human-Centred design [9], intelligent human-machine interface design [10], user needs analysis [11], Safety by Design [12] and Human Factors Integration [13]. Design practices have improved over the years also thanks to the lessons learnt from past accidents and incidents [14]. HMIs need to be carefully designed to meet the operator requirements and provide information and procedural guidance to support his or her diagnostic capability [15]. Boy and Schmitt [16] pointed out the necessity of consideration of human factors at design stage and consideration of the user's needs with new sophisticated methods because safer design requires iterative participation of the operators. Currently the availability and usability of human factors guidance provided by standards for designers and the maturity of practice is an issue [16]. Unfortunately the contribution of safety and human factors experts can only be effective if they can understand the choices made by designers and the reason behind their decisions [17]. That is why participation of designers and human factor/safety experts as a team to enforce knowledge exchange and cooperation can positively impact the quality of the outcome [18]. The value of early HFE integration in design projects is currently supported by some companies in the process industry, which have started to include Human Factors Engineering as a project requirement at procurement stage. In this sense, a EU funded research project TOSCA (Total Operation Management for Safety Critical Activities) [19] has proposed a comprehensive framework for the inclusions of Human Factors knowledge in structured system design processes and a roadmap for further improvement.

2. Current industrial practices and standards in HFE

In order to provide support for industrial practitioners, a number of standards are available [20]. The standards could require, where appropriate, to take into account the physical and cognitive ergonomic assessments of the operator tasks, the equipment they will use to complete those tasks, and the environment in which the tasks occur. However, the standards need to be generic enough so as to avoid being tailored to any specific design process; this in turns generates a need for more specific guidance for different domains to concretely guide Designers, Operators, Risk Assessors and Project Planners. Safety critical domains such as aviation or nuclear industries, have often developed their own internal standards to provide more specific guidance on HFE assessment and safety by design issues. This section is aimed at providing a brief overview of the HFE standards most commonly used. The ISO: 6385– Ergonomic Principles in the Design of Work Systems [21] outlines how in the design of a work system, the design of the following components shall be addressed: *(a) design of work organization; (b) design of work tasks; (c) design of jobs; (d) design of work environment; (e) design of work equipment, hardware and software; (f) design of workspace and workstation...* Each design stage is described and appropriate ergonomic principles and methods for each stage are listed. The ISO 6385 is supposed to work as a menu to guide further choices but it's to be revised to provide a more comprehensive and structured list of available practices, for example it does not provide any reference to the standard ISO 11064 - Ergonomic Design of Control Centres [22]. This standard offers nine principles for the ergonomic design of control centres and guidance on specific aspects of control room design, including layout, workstation design, controls and displays, and environmental requirements. Another cross reference that is not mentioned in the ISO 6385 is the one to the standard ISO 12100 – Safety of Machinery [23] which suggests a five steps methodology to perform risk assessment at design stage and the overall strategy to take into account safety of machinery in the life cycle, considering usability, maintainability and cost efficiency. Outside the ISO group the EEMUA 191 [24] is an industrial standard developed by the Engineering Equipment and Materials Users' Association to support the design of alarm systems taking into account the requirements of the human operator receiving and responding to those alarms, while EEMUA 201 [25] is focused on the design of HMIs and gives guidance on areas such as display hierarchies, screen formats, and the attributes of the environment which may affect the use of the HMI. These standards define minimum requirements but their systematic approach is fairly generic and does not provide technical support for designers. They offer no guidelines regarding the methodology to conduct this verification. Rapid prototyping and participatory approaches are more and more becoming common practice in design review [18]. The use of 3D models reviews is also often undertaken with the involvement of the final users. The 3D model is a more natural representation that does not require decoding of 2D technical drawings and thus facilitates the operator in identifying potential issues regarding the proposed design. This approach can be considered a concrete example of human centred participatory design, and a more solid starting point for the designers to deliver a safer design. Such participatory design reviews should be facilitated as early as possible. The above-mentioned standards can be used in combination with 3D participatory review, however the process has not been detailed or suggested clearly in any of the before mentioned standards. So while on the one hand ISO 9241-210 [26], Ergonomics of Human-System Interaction, requires participatory human centered approaches it does not provide technical details on what specific aspects should be considered and how to concretely carry out such a process; again even this one does not even refer to more specific standards such as ISO 11064 [22] for the Ergonomic Design of Control Centers and or ISO 12100 [23] on Safety of Machinery. Integration of HFE principles within broader technical engineering and design standards may be one way to achieve assimilation. Too often, only human factors specialists are aware of the existence of HFE standards and the principles contained within them. It is also important to ensure that the HFE standards are aligned with the relevant engineering standards, to ensure that designers are not receiving conflicting guidance. Moreover, it is valuable to underline that the main best practice in HFE is to involve, as much as possible, the actual needs of the end-users in all the design phases to bring in a life-cycle perspective.