2015

Human Factors Engineering at Design Projects for Process Industry - Challenges and Lessons Learned

Maria Chiara Leva
Technological University Dublin, maria.leva@tudublin.ie

Farzad Naghdali
Trinity College Dublin

Human factors engineering at design projects for process industry - Challenges and lessons learned

M. C. Leva [1], F. Naghdali [1]
[1] Centre for Innovative Human systems, Trinity College Dublin, Dublin, Ireland.
e-mail: levac@tcd.ie

Abstract
Human Factors Engineering (HFE) hasa key role in promoting the inclusion of human factors knowledge at design and construction phase of socio-technical systems so as to insure what is known about human performance drivers and limitations is appropriately catered for. The goal is to put the human at the core of the design and built the system to optimise the human contribution to production and minimise potential for design-induced errors minimising risks to health, personal or process safety and environmental performance.
This paper describes the cosnideration steming from the experience of the authors in design projects as human factors consultant. This experiences highlighted key gaps and requirements for an optimum human factors engineering.
Keywords
Human Factors Engineering; Design review; Human Machine interface; Cognitive Ergonomics

Introduction

Human Factors Engineering (HFE) hasa key role in promoting the inclusion of human factors knowledge at design and construction phase of socio-technical systems so as to insure what is known about human performance drivers and limitations is appropriately catered for. The goal is to put the human at the core of the design and built the system so as optimise the human contribution to production and minimise potential for design-induced human errors, and consequents issues with personal or process safety (OGP, 2011).

The ISO standard ISO 9241-210 (2010), Ergonomics of human-system interaction, requires that all new facilities projects apply the principles of Human Factors Engineering (HFE) during early design stages. In practice this means ensuring, as a minimum, that every new facilities project is screened in collaboration with the end users to identify whether there are any “hotspots” (risks, issues or opportunities) associated with the scope of the design project that justify further HFE activities. Further standards detail these activities, including physical and cognitive ergonomic assessments of the operator tasks, the equipment they will use to complete those tasks, and the environment in which they will be undertaken. However, the standards are only one of the elements required for implementation of human factors knowledge in the design of the systems. Other key factors such as level of knowledge organisational commitment, skills, budget and time are contributing factors to the overall results of the design with respect to the human factors knowledge implementation.

A recent Human Factors Engineering for a design project revealed that due to the complex nature of the tasks and presence of several influential factors, lack of very well structure approach to human factors will result in experiencing problems and barriers towards the implementation of Ergonomic principles.

The authors whom were involved in design projects as human factors consultant for providing input to the design project, have other similar experiences of several design projects in Oil & Gas industry and their previous studies presented that the human factors standards are in need of reform. A recent survey about Human Factors and risk assessment standards that was conducted during 2014 illustrated this issue from the point of view of industrial practitioners who participated in the survey (Naghdali et al. 2015). The survey asked the participants whether they feel the need for better HF tools and techniques or no. The results are illustrated in figure 1.

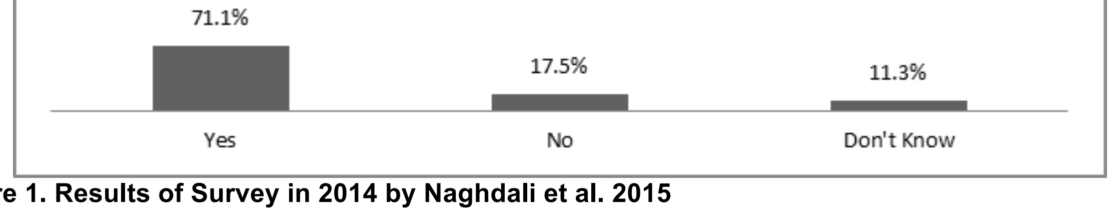

Figure 1. Results of Survey in 2014 by Naghdali et al. 2015

Human Factors Engineering at design stage has been considered very important and recently end-user companies in process industry started to include human factors engineering as a project requirement (Naghdali et al. 2014). In order to provide support for industrial practitioners s number of standards are available, however a review on few of such standards revealed that they lack a structured and concrete approach to facilitate the Human Factors Engineering activities during the design process (Leva et al. 2012).

A detailed study about human factors engineering at design stage and available standards and guidelines reviewed several international, national and industrial standards. The finding of that study is represented in table 1.

Table 1. GAPS in th guidelines provided for HFE applied to design

HFE Area of Design	Related existing standards / best practices	Possible issues/ gaps
Design of physical built environments	ISO 6385 (2004) Ergonomic principles in the design of work systems	The standards do not provide any practical guidance on how to actually review the built environment at the design stage involving users (such as 3D reviews)
Design of machinery / electrical systems	ISO 12100 (2010) Safety of machinery / EEMUA 178 (1994) A design guide for the Electrical Safety of Instrument Control Panels	The standards are seldom applied in the industry and they do not specify to what machinery they should apply
Design of control rooms, HMI for information systems	EEMUA 201 (2010) / ISO 9241-210 / ISO 11064 (2006) Ergonomic design of control centres	How to review the mimics of control centres is not specified and the use of task analysis is not clearly suggested
Design of information systems and alarms	EEMUA 191 (1999) / ISO 11064 (2006)	As above
Workload assessment for design	ISO 11075-3 (2004) Ergonomic principles related to mental workload	Not really applied in the industry
Design of manuals and procedures	ISO 12100 (2010) / ISO 18152 (2010) Ergonomics of human-system interaction – Specification for the process assessment of human-system issues	The standards specify how to assess processes but not how to translate them in to good instructions and procedures
Risk assessment at design stage	ISO 31010 (2009) Risk management – Risk assessment techniques	Little guidance on what standards are available for human reliability analysis

During the case study project different aspects of the system were reviewed according to the predefined design review methodology with in the project minimum requirements. One of the studies required was the HMI design review in which mainly focuses on the control rooms design. The two main criteria of human factors engineering were physical ergonomics of control room and the cognitive ergonomics of control room. The control room is also referred to as an important HMI in oil and gas industries and on the other hand there is high level of human and machine interaction in control rooms, therefore the required input from the HFE were more demanding and crucial (EU-OSHA, 2006).

Case Study description

The project was about the design of a Gas processing plant as an extra unit in an existing plant. Human Factors Engineering was a project requirement but the late involvement of the Human Factors team resulted in providing recommendations that were not well timely sequenced and therefore resulted in potential delays and some of them resulted not easy to implement (some reccomendatiosn for instance should have been included in the procurement contracts for some of the suppliers while they arrive at a stage where the supplies were already bought). The project benefit from an initial Human Factors screening the tool used was aligned with OGP recommendations(see, OGP, 2011) however these standards lacked a set of more concrete guidelines for human Factors Engineering activities.Out fo the screening anyhow the basic needs that emerged for the use of HFE principles applied to that design project were the following:

Ergonomic Review for Physical layout and plants area: As part of the HFE work a review of the layout of the new unit, the position of critical items for normal, emergency or maintenance operator activities (such as the positioning and orientation of manual valves on the plant, the space around them, and provision of access walkways, lay-down areas, possible issues with Escape routes/

congested spaces, maintainability of equipment etc.) needed to be performed, this was achieved by reviewing the 3D model of the new unit at 30%, 60% and 90% stage of finalization using a checklist designed on the basis of the ISO 11064-4, and the MIL-STD-1472F.

Ergonomic review of control room and Human Machine Interface: The Ergonomic Review will also take into account those cognitive and physical aspects important for the control room operator to be able to effectively control the plant through the information provided by the control panel. This review will be based on the guidelines provided by ISO 11064-5 which presents principles and gives requirements and recommendations for displays, controls, and their interaction, in the design of control-centre, and the ISO 9241 on the Ergonomics of Human Computer interactions (superseding the old ISO 13407 now withdrawn). The checklist(s) was used to evaluate the available documentation for the design of the graphical displays for the plant in collaboration with the potential end users of the plant. A suggestion about the manning level can also be presented as part of the review. All the actions resulting from both reviews and form the human reliability analysis will constitute the main content of the improvements recommended by the HFE study to be included in a Basic Ergonomic Review Report.
The following documents need to be issued at least “for comments” as they are basic inputs to the activity:

- 3D model of the plant at various level of completion
- Control room Layout (for control room basic ergonomic review)
- DCS Graphics Print Out (for control room basic ergonomic review)

Alarm Study: An Alarm Rationalization Study is recommended to provide requirements and give recommendations for the management of alarm of plant monitoring and control systems to reduce information overload and human errors in the operation of plants. The objective of the alarm study is to capture and document all information relevant to the proper design of an alarm system and to define alarm suppression strategies. An alarm system cannot be designed in isolation by the instrument engineer as most information will not be readily available. Therefore, a team study shall be undertaken.
In light of Human Reliability analysis human intervention should only be assumed to provide a limited reduction of risks. A process plant typically requires the following types of alarms:

- Process alarms;
- Trip (IPF) alarms;
- F&G alarms;
- Common alarms from packaged units;
- Diagnostic systems.

Not all alarms and messages should necessarily be routed to the operator. Other recipients of alarms and messages should also be considered. To do this a Variable Table Construction (via Initial Setup - ISU) shall be used in order to:

- Understand the boundaries of the process
- Setting the safe operating limits correctly
- Provide sufficient time to respond
- Adopt a consequence based approach

Alarms are always linked to human follow-up. Therefore, the foremost principle in reviewing alarm is recognition of the human task and the human factors involved. Avoiding a situation with huge information overloads. The human may also make mistakes or act too late. That is why a Human Reliability analysis needs to be performed for those task identified as critical as follow up to important alarms.

The following documents need to be issued at least “for comments” as they are basic inputs to the activity:

- I/O List
- Alarm Philosophy
- DCS architecture

Human reliability Analysis: As a follow up on the alarm study a Human Reliability analysis needed to be performed for those task identified as critical within the HSE case or as follow up to important alarms. In light of Human Reliability analysis possible actions able to reduce the conditions leading to the scenarios requiring the intervention or improving the condition for its successful outcome should be addressed. In general however human intervention is assumed to provide a limited reduction of risks. The human reliability analysis in this case was only qualitatively performed as a review of main critical possible errors. The output of the study was a report specifying possible recommendations aimed at reducing Human Error or mitigating its effects.

As part of the Human Reliability Analysis an initial task criticality screening and a more detailed task analysis for highly critical tasks was carried out. The following documents were used as basic inputs to the activity:

- Main operation procedures or operating philosophy and Start up and shut down procedures for the facility
- Main maintenance procedures or maintenance philosophy for critical equipment
- Interview with process engineering designing the plant to capture elements not described in the above documentation or to elicit the information if the documentation above is not available
- Main control room and or field operator actions expected in response to critical alarms (information that can be derived from the alarm study)
- area that requires modification and providing them with possible mocked up solution.

Using a standards method (HSE, 1999) the tasks were reviewed and ranked based on criticality level. The final result was a critical task inventory, with recommendations on each critical task to be used for further screen and input into the design of manuals and procedures. The identified tasks that are ranked critical could be further analysed for procedural reviews and for special training purpuses.

Lessons learnt form the experience

The overall outcome of the HFE intervention in the design project was a report covering different aspects from physical ergonomics to work load assessment and maintainability of the system. The project time span was over 40 months. The HFE was included in the project requirements since the beginning however the actual involvement of the HFE team was delayed until detailed design stages.

One of the main drivers of the HFE inclusion in the project was the direct request of the client. Such attitude in organizations provides evidence that the benefits of HFE screening at design stage is becoming more and more evident to the industry. However it is up to Human Factors practitioners to deliver added value to projects by getting involved at the right moment with the right resources/ support in the design projects from the early beginning.

One of the elements that authors identified was a structure for communication of results integrated with the results form the safety studies.

An example with regards to illustration standardisation is the HMI review. The HMI system will use graphical pages were the operators will be able to get required information and select functions. A common approach by HF practitioners was to annotate the screen shots with the HF issue to be addressed on the graphical interface.. The HFE team decided to use the experience and tacit knowledge of the end-user company operators and personnel and produce some mock up of the graphics to illustrate desired best practices for the overview pages, the alarm report pages etc. The results of this parallel work were shared with the instrumentation engineers providing them with some detailed suggestions. The HMI design review spans from Alarm management, control room design review to graphical pages review, and can also include the participation to the Factory Acceptance Test (as it was in this particular case). Parts of these studies overlap each other and have to be considered together. For example the Alarm management study can be an input to HMI design review but this point is not clearly mentioned in any of the available standards. Also some of the information needed for the Human Factors Engineers to make useful recommendations may be embedded in technical documents not easy to read without background knowledge of instrumentation engineering and they are document often not shared with the HFE team (such as the process control narratives and the Logic diagrams)

By considering the Human task approach and collecting relevant information from other HFE studies during the project, the team was able to screen and identify a considerable amount of issues during the design. The experience of the HFE study was not optimum due to the late involvement in the project and the lack of integration with the design team, however the HFE input was well appreciated by both the Design team and the end users. During the Factory Acceptance Test in fact some of the criteria that was brought once again to the attention of the design team and of the end user was that a good DCS system has two purposes: to serve the process controls and to serve the operator who is supposed to supervise the process, the instrument engineering team often seems to focus only on the first with detrimental effects on the latter.

The 3D model review also suffered form a lack of clear guidence on the structure and method to follow for a systematic and comprehensive review. The workshop was very time consuming and occasionally the participants could not focus on the most important factors. The Human Task view was not used in this part of HFE due to the fact that 3D model was not being led by a well informed HFE team.

Conclusions

The experience shows the following methods will have more chance to deliver the required improvements coming from applying HFE principles at design stage:

- A well -structured methodology
- A good inclusions of HFE in the design team
- A training for HFE engineers to read and interpret useful documentation such as process control narratives and logic diagrams for instrumentation design
- Predefined workshop to define the critical task inventory and feed the useful information ito procedure design

In Trinity College Dublin the Centre for Innovative Human system is currently working in two research project (TOSCA[1] and INNHF[2]) to map out best practices for HFE and its integration with Design engineering & Safety engineering to provide a road map for future implementations.

Acknowledgments

The above-mentioned research has received funding from the European Commission's Seventh Framework Programme FP7/2007-2013 under grant agreement FP7-NMP-2012-SMALL-6-310201 “TOSCA” and it is ©copyright of TOSCA project consortium)

References

EEMUA 178, 1994, A Design Guide for the Electrical Safety of Instrument Control Panels, EEMUA, London, UK.
EEMUA 191, 1999, Alarm Systems: A guide to design, management and procurement, EEMUA, London, UK.
EEMUA 201, 2010, Process plant control desks utilising Human-Computer Interfaces, EEMUA, London, UK.
EU-OSHA, 2006, European Risk Observatory Literature Review - The human machine interface as an emerging risk, European Agency for Safety and Health at Work, Bilbao, Spain.
Hale A., Kirwan B., Kjellén U., 2007, Safe by design: where are we now?, Safety Science, 45,1-2, 305–327.
ISO 10075-3, 2004, Ergonomic principles related to mental workload - Part 3: Principles and requirements concerning methods for measuring and assessing mental workload, The International Standards Organisation, Geneva, Switzerland.
ISO 11064, 2006, Ergonomic design of control centres, The International Standards Organisation, Geneva, Switzerland.
ISO 11075-3, 2004, Ergonomic Principles Related to Mental Workload, The International Standards Organisation, Geneva, Switzerland.
ISO 12100, 2010, Safety of machinery - General principles for design - Risk assessment and risk reductio, The International Standards Organisation, Geneva, Switzerland.
ISO 18152, 2010, Ergonomics of human-system interaction - Specification for the process assessment of human-system issues, The International Standards Organisation, Geneva, Switzerland.
ISO 31010, 2009, Risk management - Risk assessment techniques, The International Standards Organisation, Geneva, Switzerland.
ISO 6385, 2004, Ergonomic principles in the design of work systems, The International Standards Organisation, Geneva, Switzerland.
ISO 9241-210, 2010, Human-centred design for interactive systems, The International Standards Organisation, Geneva, Switzerland.Leva M. C., Pirani R., De Michaela M., Clancy, P., 2012, Human Factors Issues and the Risk of High Voltage Equipment: Are Standards Sufficient to Ensure Safety by Design?, Chemical Engineering Transactions, Vol. 26, 273–278. Bologna, Italy.
Naghdali F., Leva M. C., Balfe N., Cromie S., 2014, Human Factors Engineering at design stage: is there a need for more structured guidelines and standards?, Chemical Engineering Transactions, Vol. 36, Bologna, Italy.
OGP, 2011, Human factors engineering in projects, International Association of Oil and Gas Producers, Report No. 454, International Association of Oil and Gas Producers, London, UK.

[1] See http://www.toscaproject.eu/
[2] See http://www.innhf.eu/