Human Factor in Technical Systems and in Supply Chain

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In social studies, the human factor plays the dominant role and is the main topic of these studies. In the technical field the situation is somewhat different. The authors of this study have concentrated on the influence of the human component in reliable supply chains. A supply chain is treated as a complex technical-organizing system whose aim is to produce and supply a product that is readily available for use by the consumer. The aim of the article is to produce a critical analysis of the publications put forward a the ESReDA seminar, which was dedicated to the human component in technical systems as well as the referencing of publications with regards to the human component in supply chains.

Keywords: human factor, supply chain, technical system.

1. INTRODUCTION

In Social studies, the human factor plays a dominant role and is the main topic of these studies. In the technical field the situation is somewhat different. An analysis of the publications from the ESReDA seminar as well as articles that have been published in professional technical journals reveal that the human factor is commonly treated as an element of a technical system and thus the human factor is analysed analogically to the technical elements of an infrastructure. It is thus not difficult to disagree that the human factor is much more complicated and thus requires a specialized analytical approach, specifically during the process of risk analysis of some given system.

The authors of this study have concentrated on the influence of the human component in reliable supply chains. A supply chain is treated as a complex technical-organizing system whose aim is to produce and supply a product that is readily available for use by the consumer. The aim of the article is to produce a critical analysis of the publications put forward a the ESReDA seminar, which was dedicated to the human component in technical systems as well as the referencing of publications with regards to the human component in supply chains. Thus, an analysis was conducted of the technical literature that references the meaning of the human component in technical systems. Next, an analogical analysis was conducted on literature referencing the human component in studies of supply chains. The conclusions as well as implications for further studies in this field are based on the above mentioned results

2. HUMAN FACTOR AND IRREGULARITIES IN A TECHNICAL SYSTEM

A fact that should be highlighted is that in some definitions of technical systems, the human factor has been avoided. As an example, the following definition [Ditrich 2011] by which „a technical system is a joining technical abilities (expertise) that allow mass, energy and information to be processed". Yet, without the human factor it is impossible for most technical systems to function effectively.

In recent years, research into technical systems has focused on the topics related to risk management and reliability of technical processes. The human component should in essence play a crucial role in such processes, especially in the reliability of the studied process. It suffices to make a statistical analysis of work related accidents that have been reported by industries who fit the definition of a technical system as stated above.

Table 1. Victims of accidents at work in chosen PKD areas in 2015.

PKD AREA	TOTAL	ACCIDENTS		
		deaths	critical	mild
agriculture, forestry, fishing	1296	22	23	1251
mining and mineral extraction	2261	16	15	2230
industrial processing	28351	78	207	28066
production and processing of electrical, gas, steam and hot water	709	5	5	699
water supply, wastewater management	2224	14	21	2189
construction	5776	69	84	5623
trade, vehicle service and repair	12006	14	27	11965
transport and storage	6262	49	39	6174
information and communication	532	3	2	527

Based on: www.stat.gov.pl *Wypadki przy pracy w 2015r* [access: 15/04/2016].

In each of the above mentioned work related accident, some form of disruption occurs in the technical system with the human involved in some way being the cause. This disruption could be mild in character such as in cases where the injury is mild i.e. stopping production machinery for a period of a couple of minutes to an hour. However, in some cases, especially where the effect is death, a system could be stopped for a couple of days to a couple of months(i.e. mining catastrophes). In some sectors such as the mining sector, studies conducted by the Higher office for mining show that in most cases the cause of a catastrophe are human error. They are often the result of insufficient training of the crew and tolerating unsafe work practices.

3. HUMAN FACTOR PRESENTED ON ESReDA SEMINAR

The importance of the human factor has been highlighted by the organizers of the ESRADA seminar, which was organized in November 2015 and was dedicated to the topic of *Human Factor in Risk Assessment and Maintenance*. ESReDA is a European Association provides a forum for the exchange of information, data and current research in Safety and Reliability and a focus for specialist expertise. One may conclude that the publications presented are in line with the latest trends that are mandatory in Europe. Thirty two papers were presented on seminar from different scientific disciplines, and from different European researchers. But, despite the subject of the seminar, only few of the articles were strictly connected to the topic of Human Factor. I would like to present that few to show what type of reaction does HF have in European science.

José Sobral, Edgar Serrano, Luis Ferreira in their *Methods, Techniques and Tools to Understand Human Error in Industrial Activities* writing about human reliability. They are referring it to reliability in meaning a probability of success. In fact, reliability is defined by them as "the ability of an item to perform a required function under given conditions for a given time interval and may also be defined as a probability" [Sobral 2015]. Human reliability is described in this article as a wider and more complex concept. Authors are citing Meister [Meister 1993] states that "human reliability is linked to the probability of a work or task to be accomplished with success in a given time". Kirwan [Kirwan 1999] says that "human reliability is a discipline of Ergonomics based on the knowledge of reliability and risk analysis". A more complete definition of human reliability is mentioned by Pallerosi: "it is the probability of a person not to fail on the accomplishment of a required task (action), when demanded, in a given period of time, under adequate environmental conditions and with available resources to perform it" [Pallerosi 2008]. The team also writing about human failure in accordance to Pallerosi. Human failures are classified into different categories as errors (slip and mistakes) and transgressions (deliberate and unintentional). the most common cause of human failures is error. These errors are dependent of operator capability, stress factors, motivation and environmental conditions. Mistakes usually happen due to fatigue or stress or even bad environmental conditions or person's aging (natural loss of capabilities) but the main reason is due to lack of training for a specific activity. Sometimes physical characteristics can also influence the accomplishment of certain tasks. "Human sensory and cognitive stimuli play an important role on the probability of failure when doing an activity. Although the importance of five senses (vision, hearing, touch, smell and taste), it is extremely crucial the existence of auxiliary sensors (external) and human intelligence capability when performing an activity. Human's memory can store and reactivate a huge quantity of data using three basic systems: sensory memory, transient memory and permanent memory" [Sobral 2015]. Authors also concentrate on the subject of man-machine interaction, where man is the system supervisor. To control the human error they presenting few technologies, methodologies and tools to minimize human error probabilities: Human Error Rate Prediction (THERP), Accident Sequence Evaluation Program (ASEP), Human Error Assessment and Reduction Technique (HEART), Standardized Plant Analysis Risk - Human (SPAR-H), Cognitive Reliability and Error Analysis Method (CREAM), A Technique for Human Event Analysis (ATHEANA). None of them taking into account any cultural differences between people all over the world. It can be observed from the previous paragraphs, the estimation of the probability of human error is a complex task, once it can be influenced by several factors. But none of those factors were social, political or cultural. Just technical and environmental ones were taken into account.

Human Error Views: A Framework for Measuring the Distance between Academia and Industry, and Benchmarking Organizations by Nektarios Karanikas from Amsterdam University of Applied Sciences was another article with HF in it. Author made its research about the distance in the context of safety and human factors thinking had not been previously quantified. He explains that: "certainly, any measured distance is not self-explanatory; thus, it must be seen as a stimuli for exploring the underlying reasons. Resistance to change, limited access to state-of-the-art literature, misbelieve in academic research, pressure for compliance with established standards might comprise few of the reasons on the industry side. Lack of effective and continuous communication with the industry, the suggestion of extremely complex and resource demanding tools and models, and inadequate on-field experience of academics could be some of the factors that might have negatively affected the relation between academia and practice" [Karanikas 2015]. In his methodology and study we still couldn't find any differences in the definition and methods of HF.

Another article referred to the subject of HF is Sébastien Picand's *Application of HEART (Human Error Assessment & Reduction Technique) methodology to assess the human risk factor – nuclear power plant context.* He began his researches with the description of HEART methodology. The author describes the 3 HEART methodology steps that allow us to assess the human failure probability for a specific task. To ease the methodology description, let us follow a virtual example: "A plant operator failing to achieve the task of isolating a plant bypass route as required by procedure. The operator is fairly inexperienced in fulfilling this task and therefore typically does not follow the correct procedure. The individual is therefore unaware of the hazards created when the task is carried out." [Picand 2015]

To fine the analysis, he adds the following assumptions about the work context (if available) [Picand 2015]:

- the operator is working a shift in which he is in his 7th hour,
- there is talk circulating the plant that it is due to close down,
- it is possible for the operator's work to be checked at any time,
- local management aim to keep the plant open despite a desperate need for re- vamping and maintenance work; if the plant is closed down for a short period, if the problems are unattended, there is a risk that it may remain closed permanently.

From this research it's possible to describe and valuate the HEART methodology, but still the problem of HF is treated as one without any cultural differences.

Multinational team from Serbia and Greece: Evanthia Giagloglou, Panagiotis Antoniou, Ivan Macuzic and Panagiotis Bamidis presented the game of safety. Their *Improving Safety through gaming: A serious game's application for risky professions* [Giagloglou et al.2015] proves that among the most efficient training methods, targeted to high risk professions, are the Serious games applications. The current research project aims to investigate the mental state and the cognition of professionals under stressful situations, for the purpose to deeply understand the human behaviour and mental state during high risk tasks. The experiments to be done involve electrophysiological recording while the subjects play the game. Those one was the first article taking into account cultural differences among human.

Predicting the Optimal Testing Strategy for Maintenance Procedures (by Magnus Karlberg, Yang Zhang, Sean Reed and John Andrews) produces a methodology to identify the tests for errors to perform in a particular maintenance process. It first of all discusses a systematic way in which the possible tests can be identified. By selecting any subset of tests they can be integrated within the maintenance process model in order to predict the expected time to complete. By embedding this process within a Genetic Algorithm the optimal selection of tests can be established. To demonstrate the approach, the sequence of tasks used to make a cup of tea is used as this is well understood and has all of the features which would occur in a maintenance process. But only in those example can be observed the “standard procedure of making a cup of tea”. There is no sight of what tea. When or who is preparing it. Even in the EU there are many differences in preparing a cup of tea. Say nothing about overseas cultures [Karlberg et al. 2015].

Alberto Petruni, Ivan Mačužić from Faculty of Engineering, University of Kragujevac were writing about fuzzy logic and human factor. The Fuzzy Logic [Zadeh 1965] is the method that most fit the necessity of transfer human judgement in a mathematical model. The experience of experts from several industries and areas are employed to define the weight values of parameters and factors of the model. Fuzzy logic is a type of multi-valued logic that uses an approximate rather than a definite reasoning. The fuzzy approach to human logical thinking attempts to describe the human language and to duplicate the human tolerance for incompleteness, vagueness and uncertainness in decision making processes. The main fuzzy logic feature is the capability to manage the concept of partial truth as values between "entirely true" and "entirely false" [Zadeh 1965]. The influence factors need to be identified and quantified. The identification is done by analysing standards, paper, work instructions and direct observations. The expected result of authors research work is to obtain an effective tool for an industrial application. The effectiveness regards its usability, the time that its use requires and the reliability of its outputs. If these objectives are achieved, the model can be considered a practical support for the man-workplace management decision. In particular, the model should supply information about the health and safety condition of the workers in the different workplaces, in order to assist the decisions regarding the job placement. Furthermore, the model should be able to suggest the possible actions to be taken to make a safer work position. These countermeasures concern both the equipment and the environment that the workers, and the relation between them. The different solutions can be seen as horizontal and vertical improvements. The simplest horizontal solution is to combine the workers with the workplace that most fit their needs, and for the adequate period of time. The vertical enhancements can be split in two groups. One is about the training of workers to improve their characteristics and their ability. The other includes measures to reduce the level of risk due machineries employment and to increase the comfort conditions of the workplace. Methodology based on interviews, direct observation can point out the cultural differences between people.[Petruni 2015]

Frederik Mohrmann (from National Aerospace Laboratory in Amsterdam) and John Stoop (from Kindunos Consultancy, Gorinchem) presented their ideas of meaning of the behaviour of the Human Factor. In their *Behavioural yoga for pilots: Enabling good airmanship as a resilience strategy for civil flight operations* their notion the human error frequently is addressed as the main contributing cause of an accident. Despite the fact that in dynamic, open networks with a high level of technology and involvement of many stakeholders and actors with complex interactions, a single cause approach is irrelevant, such a focus on human error is still prominently present as an exclusive explanatory variable. Apparently, human error as a notion is a convenient vehicle for providing consensus on simple and comprehensible explanations for events that were unanticipated and which imposed unacceptable consequences. Authors have analysed human error from a psychological perspective, criticizing reactive approaches, compliance with procedural safety management and control. Despite their methodological and scientific critiques and alternatives for a popular use, the notion of human error is strong and alive, in particular in social media and public perception. It is used as evidence for the causation of major events such as the capsizing of the Costa Concordia, the high speed train crash at Santiago de Compostella, the disappearance of the MH370 and the crash of German Wings. Either the driver was wilfully and deliberately deviating from prescribed procedures, or had lost control over the situation. The notion of human error and subsequent risk control management mechanisms have been criticized by scientific and organisational experts, leading to a series modifications of the original notion of man machine interfacing. So called by authors yoga for pilots is the theoretical strategy to relies the short-period stress and emotional responses observed in the Man4Gen experiments. The authors are thinking about translate those philosophy concepts to a concrete strategy which pilots will be able to use in the cockpit. [Mohrmann and Stoop 2015]

Sameer Al-Dahidi, Francesco Di Maio, Piero Baraldi, Enrico Zio, team from Energy Department, Politecnico di Milano in *Supporting Maintenance Decision with Empirical Models Based on Fleet-Wide Data* were taking Human Factors (HFs) in maintenance as a element which play an important role for equipment reliability. For example, in 1985, 520 people were killed in a Japan Airlines Boeing 747 jet accident because of wrong repair [Dhillon 2009]. Moreover, in 1993, a study of 122 maintenance actions involving HFs reported that there were different types of maintenance errors: omissions (56%), commissions (38%) and others (6%). HE is the failure of the human to perform a specified task that could result in disruption of scheduled operations or damage to equipment. The errors of maintenance personnel can be the most visible aspects of maintenance HFs. HFs is the discipline that aims to optimize human well-being and overall system performance. The term includes all psychosocial and biomedical considerations, personnel selection, training principles and applications in the area of human engineering, human performance evaluation, aids for task performance and life support [Dhillon 2009]. In practice, the response to HEs involves two paths. First, the HEs probability can be reduced by identifying and counteracting error-producing conditions by involving attention to, for example human factors training and other actions directed at the HFs associated with these errors. Second, the implementation of an efficient PHM system can reduce (a) unnecessary maintenance actions, since it allows reducing unnecessary maintenance interventions and (b) predictable failures, since it allows anticipating the failure events [Zio 2012].

Towards the Integration of Human Reliability Analysis and Maintenance Prognostics within the Biopharmaceutical Industry defines Human factors (HF) as 'the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimise human well-being and overall system performance' [International Ergonomics Association 2000]. Performance shaping factors include factors external to the individual such as the environment in which the task is conducted, the work hours, the organisational structure, job and task instructions, equipment characteristics and task characteristics. More individually, psychological, e.g. time pressure, distractions, etc., and physiological, e.g. fatigue, hunger, radiation, stressors can also influence task performance and error rates. The base error rate for a particular task, such as installing valves, will remain constant for that task regardless of the individual valve. However, the PSFs vary according to the specifics relating to each individual valve and may influence the likelihood of correct maintenance actions.

The paper investigates human error in maintenance activities as a major cause of random failure events, using a case study from the biopharmaceutical industry. Elastomer failure data shows unexplained variability between the lifetimes of real components compared to accelerated lifetime testing in lab environments. Technician error during installation and maintenance activities of elastomers is one possible cause for this and this research explores in the first instance how these errors can be eliminated, reduced, and accounted for within the reliability modelling process. In this particular case study the first hypothesis was rejected as no significant association was found between the derived PSF metric and the incidence of component failure. The rejection of the hypothesis led to the discovery that non-compliance to training procedures during maintenance tasks may have been a confounding factor that could not be accounted for. For this reason it is the authors' belief that the developed methodology remains sound and such approaches should be considered and expanded on in future in instances of better controlled human-machine interactions during maintenance procedures.[McDonnell 2015]

Introduction of the human factor into the risk analysis describes human factor in many ways. Previously mentioned The Health and Safety Executive (HSE) guidance states [HSE 2005] that a simple way to view the human factor is to think about three aspects: the job, the individuals and the organization, and how they affects people's health and safety-related behaviour.

Michaela Demichela in *New approach in the Food Safety Risk Management, involving Human Factor* wrote "Frequently the steps in the process which involve human factors intervention are the weak links in the process and quite often in validation work the human factors element is ignored while mechanical and technological aspects are studied in great detail"[Kieffer 1998]. Similar to other industries, within the food safety procedure, this issue is tangible as well, and it might originate from the fact that technical and instrumental aspects are covered by the HACCP in more details comparing to the human factors. Risk analysis can bridge that gap, but up to now few results have been presented in which the human factors is fully taken into account in the food risk management. To determine the human factors influence on safety, within European Community, Innovation thought Human Factors in Risk Analysis and Management (InnHF) project has been established. In this regard, the current study has been performed as a part of main research in Food Supply Chain Risk Management. Within the food safety field of research, there are very few studies considering the role of human factors and its effects on the final product and consumers' health, while most of the food process operations and controls perform by human.[Demichela 2015]

49th ESReDA seminar suppose to be about Human Factor. And for 32 presentations only 12 were trying to define what that human factor is. Most of the authors were based on the WHO definition, taking base definition from medical culture. Human Factor (called human error sometimes) were taken into account in different ways of researches. But most of the time treated as a point in the chain of the higher possibility of error. And unpredictable. Few authors were trying to deal with those unpredictability, by making project to protect against human errors, like yoga for pilots or special strategic games. But even those few didn't take into account differences among human. Their nationality, gender, culture, religion – which make huge differences in projects of preventing Human Errors.

It would be worthwhile to conduct research on the role of national culture and the effect it has on the management style of international supply chains. It is important to find the link between supply chain management behaviour to specific national settings.

4. HUMAN FACTOR IN SUPPLY CHAIN

Every man, bearing in mind their wishes and possibilities, selects occupation and any organization, keeping in mind the requirements of the environment and available resources will decide how to set up its organizational structure, define jobs and develop recognizable culture. Formation of certain structures of the company, except for activities with which it deals, depends on the willingness of old employees to adapt to environment changes and the readiness of new staff to embrace the culture of the organization. If appropriate organizational structure is established, its individual members and team activities can create a stimulating and pleasant environment, to educate, adjust and to reach their goals. Otherwise, undefined tasks, inability to self-decision making and the affirmation and unpleasant working atmosphere which results with dissatisfaction, higher staff turnover and poor business results [Jurcevic 2014].

The analysis of the human factor in the area of supply chain studies has a low priority. Literature review showed, that human resources are widely acknowledged as key elements that contribute to firms' success and performance [Karami 2004, Luthans 1997, Ding 2015]. The human factors can also have a major impact on the performance of the day-to-day operations of any organisation [Fraser 2013]. Many authors have noticed that supply chain technologies have evolved, practical and research interests initially have focused on the "hard" aspects of management, such as structural modelling, product design, process, and information technology. However, invariably, these efforts must be followed by the development of the "soft" human and leadership aspects of an organization [Reed 1996, Wilkerson 1992, Kanji and Wong 1999]. As [Pfeffer 1994] notes, the competitive advantages of the hard products, processes, and information technologies are transient. With the increasing pace of design and technical changes, such product, process, and information technology advances, despite patent or copyright protections, can erode quickly. Alternatively, the soft human knowledge and skills, and the supporting organizational variables are more regenerative and enduring as competitive advantages. Given the increases, both in number and range, of supply chain efforts, the strength of human resource and organization strategies and their alignment with the supply chain configuration notably reduces the potential for lost opportunities and risks of underperformance [Hunter et al., 1996]. Nevertheless, there is little in the literature that describes the relationship between human resource activities or organization variables and supply chain success [Shub and Stonebraker 2009].

In SCM case, the signification of human factor is absolutely perspicuous. Supply chain management bases on relationships hammered out between actors creating the whole complex system. These relationships are formed by people involved in the processes carried out at the interface of the companies [Akacum 1995]. Successful supply chain management is dependent on the performance of those people [Fisher 2010]. Therefore, organizations culture policy and human resource management seem to be extremely important in supply chain.

Culture is "the set of key values, beliefs, understandings and norms that members of an organization share" [Daft 2008]. Organization culture is a contributor to supply chain integration and performance [Mullarkey et al. 1995, Hunter et al. 1996, McAfee et al. 2002, Kanji and Wong 1999, and Kumar and van Dissel 1996]. It should be noted that the need for effective cross-cultural communication among sequential stages of the supply chain necessitates high levels of trust and suggests increased homogenization of the cultures [Hunter et al., 1996]. Correspondingly, [McAfee et al. 2002] cite the need for high levels of cultural consistency, both internally and externally, to assure the necessary trust and interdependence among sequential stages of the supply chain.

Human resource management function emerged as a dominant organizational function, which has a significant effect on organizational functions and performance [Zheng 2009]. Likewise, other organizational functions in human resource management proactively contributed to the emergence of supply chain success [Wellins and Rioux 2000]. On the other hand, supply chain management has direct and indirect effects on human resource management practices [Kinnie et al, 1999]. Many studies conducted in different working conditions reveal a strong correlation between HRM and SCM [Gowen 2003]. However, few studies have been available which reported the relationship between human resource management practices and supply chain management success [Khan 2013]. The examples of this research are results published by Othman and Ghani [Othman and Ghani 2008]. The authors provided evidence that there was a positive relationship between HRM practices and the SCM success. Moreover, they found some support for the contention that the adoption of SCM needs to be supported by specific forms of HRM practice. Likewise, in research [McAfee 2002] the authors have found that an important consideration in developing a supply chain strategy is a firm's human resource management strategy and its culture. It also suggests that a firm needs to examine the interaction between its human resource strategy and its logistics strategy. Failure to adequately address this strategic fit can lead to reduced optimization in the effective functioning of supply chain.

The importance of the human factor in supply chain management emphasizes the creation of such concepts as HRSCM. It is a new integrated model, which would combine suppliers, information systems, finance, employees, manufacturing and operations, sales and marketing, research and development, inventory management and customer relations, and integrate them into a single unified system which can be divided into different modules according to the flexibility of an organization [Kureshi 2009].

The focus of logistics executives must shift from managing assets and direct reports to creating a new vision of coordinated product flow, and implementing it by influencing the actions of others. Logistics professionals must learn to harness the power of human resources management to effect sweeping programs of change, not only in their own companies but in other companies in their supply and distribution channels as well. Farsighted top managers will see the huge strategic and financial gains of coordinated product flow and will give their logistics executive's new avenues of influence commensurate with their crucial responsibility. Perceptive logistics executives will realize that crafting company-wide HR policies is much more difficult than it might seem, and they will focus on acquiring this proficiency. Ultimately, the vision and savvy with which logistics professionals tailor companywide HR policies that drive coordinated product flow will go far to determine both their own effectiveness and their companies' long-run success [Jurcevic 2014].

5. CONCLUSION

A human factor is a specific element of a technical system that is being produced/created. The actions of humans are not always rational. A human cannot be programmed according to some accepted algorithm, is not fully controllable and the effectiveness of his/her work is dependent on many external factors that are above the influence of managers responsible for a given process. The characteristic workings of a human within the framework of a technical system as well as the influence on the reliability of a realized process should be the cause for more interdisciplinary studies that show the real complexities of humans.

The multi-criteria requirements of the conducted risk analysis is visible particularly in global supply chains. Adjacent to the technical and technological logistical systems, the lines between personal, organizational and communications established between the different links in the chain are blurred. These relations are built by teams of humans with different social norms, cultural differences, different levels of education and many other factors whose influence will shape the reliability of undertaken teamwork.

The analysis of select publications initiates studies currently conducted by the authors. Further analysis will focus on the workings of the human factor in other chains of supply in select areas of the economy as well as the social and cultural factors which influence the reliability of the elements involved in the economy.

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