Proceedings of the 6th European Conference on Industrial Engineering and Operations Management
Lisbon, Portugal, July 18-20, 2023

Analyzing the Benefits of Incorporating Human Factors in Socio-Technical Systems

Mfundo Nkosi
Department of Mechanical and Industrial Engineering Technology
University of Johannesburg
South Africa
mnkosi@uj.ac.za

Abstract

Human factors engineering aims to optimize socio-technical systems to enhance systems performance and human well-being throughout the systems lifecycle. The aviation industry is one of the sophisticated and influential industries that popularized human factors engineering principles in response to aircraft incidents and accidents. Now, there has been a slow pace in applying human factors in the lifecycle of socio-technical systems beyond the aviation industry. Lack of understanding of human factors benefits has been alluded to as one of the factors that hinder the application of human factors in other industries. A number of studies focus on the development and application of various human factors models, but there seems to be no study that adequately shortlists, discusses and presents the benefits of applying human factors. The aim of this paper is to uncover, examine and classify the benefits of applying human factors engineering principles in sociotechnical systems, especially in the era of 4IR. A narrative literature review methodology was adopted to analyze and synthesize various conference and journal articles on the application of human factors. The study revealed and classified the benefits of human factors according to performance, wellbeing, safety, quality, cost, and other operational benefits. The study's main contribution is making the benefits of applying HFE in various systems and processes visible to potential adopters and researchers involved in the application of HFE. Human factors such that they are visible to researchers and industry practitioners. Thus, it sets an agenda for future debate, discussion and research.

Keywords
Application, implementation, benefits, human factors, HFE, socio-technical systems

1. Introduction

Human beings continue to contribute significantly in engineering systems' design, manufacturing, operation, maintenance and programing. In the era of The Fourth Industrial Revolution (4IR) there are new interactions between human and technology/systems. Thus, there is a serious need to continue researching and addressing human factors engineering (HFE) in relation with technology, engineering systems and processes. Human factors are key to industrialisation, specifically in moments there is an occurrence of new levels of interconnection between humans, machines, materials and objects or interconnections in a socio-technical system (Longo et al. 2021). It is in the nature of human to make errors. In a technical setting these errors occur during the design, manufacturing, installation/assembly, inspection, operation and maintenance phase (Dhillon & Liu 2006). It is believed that system failures, incidents and accidents that stem from human errors constitute bout 70-80% (NOPSEMA 2015; Wiegmann and Shappell 2003; Pons and Dey 2015). HFE was established to with a human-centred approach to design, operate and maintain equipment, technology, systems, processes and procedures. HFE is viewed as "the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance" (International Ergonomics Association 2018). The studies and initiatives on human errors and HFE have made a considerable contribution that has led to enhancement of safety, quality, well-being and productivity (Long at al. 2021). A detailed analysis and presentation of benefits of HFE application will be discussed in detail under literature review.

HFE is based on a system approach that focusses on the environment under which human operate with the intention to develop defenses to avoid errors or alleviate their impact (Reason, 2000). It is widely believed that human factors and ergonomics studies and application took effect during World War II (Wickens and Hollands, 2000). However,

HFE was made popular by the United States aviation industry in a gradual development that became more visible in early 1990s to address a series of aircraft incidents and accidents (Peach, et al., 2016). Since then, there are a number of human factors engineering frameworks and roadmaps established with an intention to examine, understand and manage human errors in associated with mismatches in a human-technical system. The application of HFE models especially in design, manufacturing and maintenance of technical systems has led to the achievement of various benefits. However, these benefits are hidden within the papers that address the human error and human-machine or human-technology interactions without communicating benefits as the primary objective of the research. Many designers, engineers and management are still unconvinced of the benefits of using HFE (Pinder 2015). One of the comments that few participants made from the energy industry was that, they would like to know and understand the benefits of the application of HFE to influence HFE adoption in power plants (Nkosi, 2020).

Objectives

The study established the following objectives:

- To identify, analyze, shortlist and classify the benefits of incorporating human factors in socio-technical systems.
- To discuss how these benefits were obtained and make recommendations.

This study contributes to the research of human factors specifically the adoption of HFE by identifying and shortlisting the benefits. It can assist potential adopters to understand the nature of the benefits that are realized by adopting human factors in socio technical systems. Thus, contribute increasing the pace of adopting HFE beyond aviation and nuclear plants.

2. Literature Review Research Approach

This study followed a narrative literature review approach which is about a detailed commentary and summaries of work published in various scholarly writings such as journals, conferences, books and reports. The study reviewed, synthesized and made summaries of existing studies focusing on the application of human factors engineering in socio-technical systems. The aim was to identify, shortlist, classify and present benefits for the application of HFE to help potential adopters and researchers interested in the application of HFE. Furthermore, to create an agenda and debate for future research. The existing studies were accessed from open access databases and those that the university of the researcher/s subscribe to. The papers were used based on their relevance, which means they must have documented benefits of applying HFE, and methods used that led the realization of those benefits. The abstracts were read and if they met the criteria, they formed part of the shortlisted studies. After careful reading and analysis of papers, only 15 papers made it to the analysis. It must be remembered that this study followed a traditional (narrative) literature review which identifies and reviews existing studies in a broad manner relative to the topic. This type of literature review was adopted to assist the researcher in identification of HFE benefits and locating the research within the existing body of knowledge.

3.1 Literature Review

This section presents the benefits of integrating HFE with technical systems. It also discusses the initiatives that were taken leading to the realization of these benefits. In some cases, it also reports on the challenges that may be encountered when introducing HFE in technical systems that might hinder the realization of benefits.

The study by Longo et al. (2021) done within the Oil and Gas industry with the main focus on the new levels of socio-technical interaction between humans, machines, materials and objects in the era of Industry 4.0, revealed a number of benefits. These benefits were minimized risk, enhanced process safety, enhanced productivity, enhanced quality, enhance workers' well-being and simplified cognitive activities (Longo et al. 2021). In their study, they associated these benefits with the use of technology and cognitive solutions to minimise the risk of deign-induced human errors. The challenges of integrating technology or digital solutions with HFE that may lead to insufficient realization of these benefits could be inadequate management of change and insufficient training on human factors.
Incorporating HFE principles into production and logistics (P&L) systems has led to a number of benefits such as enhanced performance, enhanced quality, enhanced well-being, enhanced psychosocial performance and enhanced (Vijayakumar et al. 2021). Furthermore, Vijayakumar et al. (2021) stated the importance of incorporating HFE in design and management decisions and mentioned that overlooking HFE is likely to lead to adverse consequences such as operator fatigue, discomfort, and even injuries and poor operator and system performance (Vijayakumar et al.,

2021). The challenge that they faced during this is that there is insufficient literature concerning the application of HFE in P&L systems specifically focusing on job design and layout design.

The study performed by Alanano et al. (2021) focussed on redesigning workstations to remove and avoid risks of musculoskeletal disorder under the hype of HFE referred as ergonomics. Their study revealed that the new workstation designs that incorporated HFE aspects led to prevention of risks, enhancement of personnel health, enhancement of wellbeing, enhancement of working conditions, reduction of cost and enhancement of productivity (Alanano et al., 2021). Furthermore, they believe that the focus on continuous improvement of the working condition, reduction of cost and enhancement of productivity are fundamental goals of manufacturing organizations.

One of the studies integrated HFE and technology for overall manufacturing processes with an aim to gain organisational and technological excellence (Reiman et al. 2021). In their study, they indicated that, the integration of HFE and technology leads to improved compatibility, improved effectiveness, enhanced performance, improved human well-being, and improved quality of life (Karwowski, 2005 cited in Reiman et al. 2021). Now, the adoption of HFE in bigger processes of organisational development need a comprehensive understanding of sociotechnical structures (Reiman et al.2021). The challenge is that the data gathering may need new approaches such as digital systems and big data analytics something in rare in other organizations and not easily accessible. There has already been an introduction of new methods of gathering deeper knowledge on performance and worker wellbeing through digitalization (Reiman et al. 2021). Ensuring the privacy of data for employees is key, thereby enhancing trust.

The companies that strengthen employee involvement and human-centred design in their journey of adopting new digital technologies and Industry 4.0 technologies will sufficiently enhance their operational performance (Kadir and Broberg 2020; Tortorella et al. 2018). Employee engagement is one of the critical aspects of HFE principles and it plays a major in the readiness to successfully apply HFE in technical systems (Nkosi, 2020). The results from the study of Kadir and Broberg (2020) revealed that enhanced human well-being and enhanced entire system performance are the benefits that were realized through the incorporation and maximizing employee involvement. The successful adoption of Industry 4.0 technologies in organizations requires that employees to have adequate information concerning changes to be made and proper comprehension of the proposed digital technologies specifically on how they will affect their jobs and future responsibilities within the organization (Kadir and Broberg, 2020). Furthermore, workers should be given the training and education that will equip them adequate knowledge and skills to perform their new or modified duties adequately.

Farid and Neumann (2019) explored application of system dynamics (SD) modelling as an instrument for assessing the effects of human factors with regard to low back injury, productivity, quality and performance parameters for production workers. The benefits of this study are more on how SD can help organizations measure so that they can take proper decisions related to the production floor. Thus, the results of study helped managers, designers and relevant personnel to gain understanding on the impact of human factors risk factors that can be imposed on operators' health and manufacturing system performance (Farid and Neumann 2019). Furthermore, this can lead to enhanced health, decreased errors, enhanced quality and enhanced production rates. Their model during a 5 year simulation could be able to show them an increase of 1.3% on reported low back pain, increase of 40% on reported human error rates and a drop of 0.2 on reported production rate. The incorporation of HFE and system dynamics (SD) modelling helped the organizations get adequate and honest reports on errors and issues so that they could resolve matters adequately and apply their efforts on actual problems, rather than in cases where issues are hidden and the organization resolves symptoms instead of actual problems.

García-Alcaraz et al. (2019) studied the impact of effects on just in time benefits as a consequence of integrating human factors (HF) and lean techniques. In their study they reported the integration of human factors (related with managers, operators and suppliers) and techniques of lean manufacturing led to successful implementation of Just in Time (JIT). The benefits that were realized through an integrated approach were shorter lead times, increased productivity and reduced levels of waste (García-Alcaraz et al. 2019). Furthermore, they indicated that managerial commitment is key to integrating HF and lean technologies to successfully adopt JIT. Management commitment is key in the application of HFE in sociotechnical systems.

Positive effect on performance, enhanced quality, improved productivity, improved efficiency and effectiveness as well reduced defect rate and minimized human error were revealed as benefits of HFE application in a study of

production quality and HFE (Kolus et al. 2018). These benefits were related with operational performance and could be achieved by including HFE aspects at each phase of operation systems design and providing adequate guidance on reduction of human factors associated problems. Furthermore, there is a need for proper operation design, knowledge and understanding of HFE's impact on the performance of the system and the HFE thinking should be linked with the organization's overall strategy (Kolus et al. 2018). In addition, HFE should be considered in design, predictions and simulation stages of workstations and in virtual and augmented reality.

The study by Gaiardelli et al. (2018) proposed a comprehensive model that considers and link technical, physical, cognitive, organisational, social and performance variables associated with the adoption of lean management approach. The application of this model led to benefits such as reduced ask time, just in time delivery, enhanced process performance, enhanced productivity, enhanced safety, enhanced quality or conformance, improved delivery, enhanced dependability, enhanced flexibility, improved cost management, enhanced well-being, improved employee satisfaction and enhanced employee motivation (Gaiardelli et al. 2018). The operational outcome was achieved through lean practices and HFE aspects such as work environment, job design and employee behaviour outcome.
The research that stemmed from the fundamental notion of "human-oriented" proposed a methodology for studying, creating and assessing the manufacturing units layouts, enhancing integrated logistics and enhancing human factors to ensure layout design optimization (Li and Tan 2018). This has led to the benefits such as increased operation efficiency and decreased risk of physical and mental harm to workers. Furthermore, they enhanced flexibility, reduced the likelihood of accidents emerging from substandard operation, improved sustainability, enhanced safety, reduced area utilization and minimized costs related with logistics, re-layout, economy, material handling and production loss (Li and Tan 2018). Their study used an innovative approach that considered the concept of designing for people or human-centred design thereby addressing the one sided view of the previous methods by incorporating HFE in logistics and layouts (Li and Tan 2018). Furthermore, they argued that at some point industry and academia seemed to hold a notion that 4IR would not need human, which is contrary to what research continues to unpack that in fact human initiative plays a significant role in the advancement of 4IR.

On the other hand, Peruzzini et al. (2017) argued that the Sustainable Manufacturing (SM) generally paid attention to enhancement of environmental and economic features while overlooking the human aspect of performance, whereas the costs of industrial plant, plant performance and quality are highly reliant on the individual human performance. Their study was based on human-centred approach to redesigning workstations within the pipe industry with the purpose of addressing HFE aspects such as the personnel's perceived comfort, the nature of the physical and mental workload, simplified activities and personal satisfaction (Peruzzini et al. 2017). Furthermore, considered the impact of hazardous positions and uncomfortable activities on company's costs. Their mixed reality simulation modality served as a progressive move towards digitization of present-day organizations in connection with human-centred manufacturing. This enabled workplaces to be improved and reproduced with the human-system interconnection in a comprehensive manner without requiring high effort to produce high results quality (Peruzzini et al. 2017). This approach was of benefit since it was evident that it supports proper re-design activities through the prediction of the evaluation of human factors within the design phase by including real users, validating the plant layout and enhancing the entire process quality (Peruzzini et al. 2017).

To address the human factors issues associated with the laborious and time demanding nature of order picking (OP), relevant HFE aspects were adopted in the internal logistics of an organization (Grosse et al. 2017). The incorporation of HFE (Cognitive, Organizational, and Physical) aspects into the design of an order picking system led to the realization of benefits such as enhanced quality, improved worker health, enhanced safety, improved performance, enhanced time, improved efficiency, enhanced customer satisfaction, enhanced service levels, reduced errors and enhanced well-being (Grosse et al. 2017). These benefits were reaped through the consideration of HFE aspects such as human strengths and limitations, imaginative, cognitive, physical, psychosocial, work environment, job design, and design of layouts as well as focussing on cost efficiency goals and its direct determinants (Grosse et al. 2017). Furthermore, they confirmed that human aspects are usually not taken into consideration even though they are a critical determinant to successful performance of an OP system.

Dode et al.(2016) developed and validated a model that supports the incorporation of HFE at the design stage of a production system, through a proactive and simultaneous event simulation approach to performance and human wellbeing. There was a reduction of human resource utilization, enhanced productivity index, reduction in defective

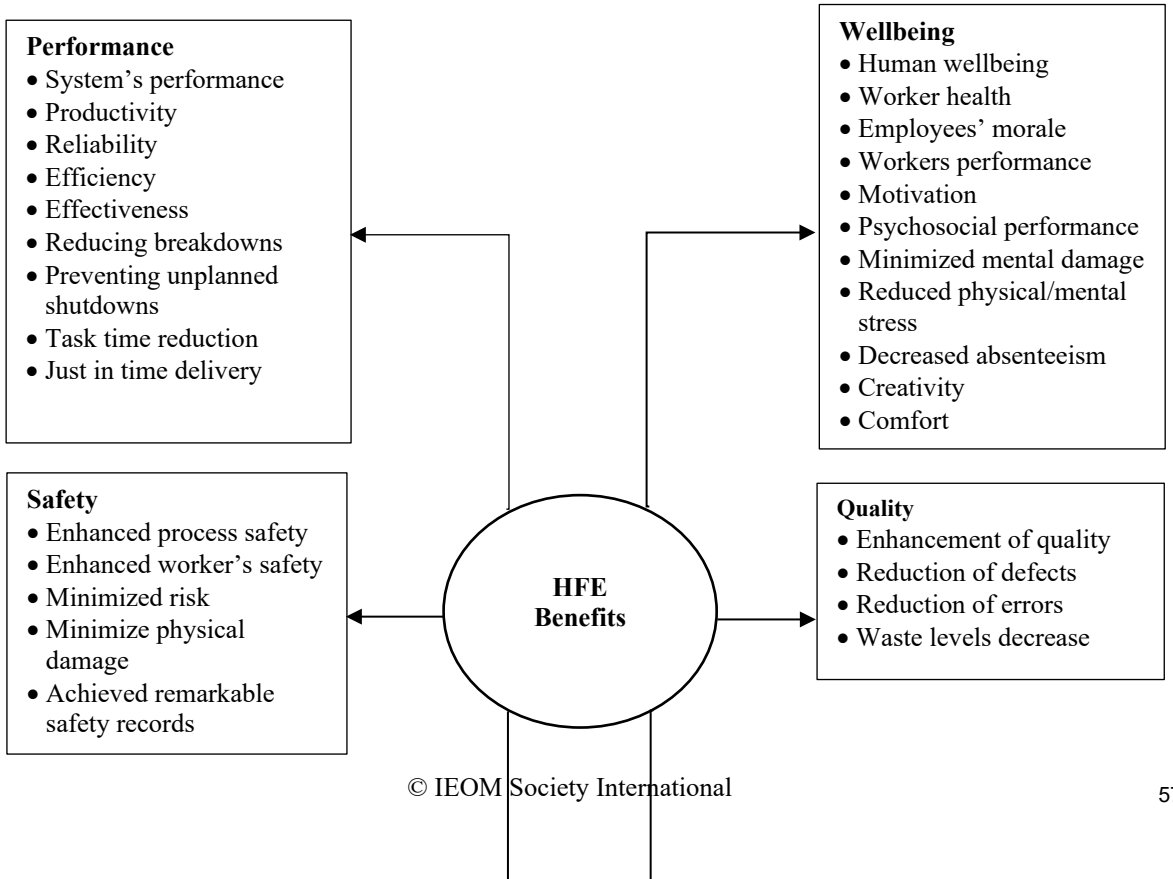
units, cost savings, enhanced well-being, improved return on investments and enhanced productivity after the incorporation of HFE in a design phase (Dode et al. 2016).

In the research that focussed on the application of HFE in system design and analysing the practices and standards aimed at encouraging the use of HFE at the design stage of a system revealed benefits such as quality improvement, machine performance improvement, plant risk minimization, errors minimization/avoidance, decreased cost and minimised outages (Leva et al., 2015). It also led to other benefits such as enhanced probability for business continuity based on decreased outages, decreased duration to fulfil maintenance requirements thereby, enhancing results through avoidance of production loss. Furthermore, to achieve these benefits or successful inclusion of HFE, it is crucial to make certain that ensure HFE standards are compatible with the applicable technical/engineering standards. Thus, ensuring that designers receive guidance that is without conflict from these two sets of roadmaps. The main goal of their research project was to establish an adequate roadmap for properly incorporating HFE into the Total Quality Management (TQM) within the organizations that formed of testing during this project (Leva et al. 2015).

Shanmugam and Robert (2015) revealed that enhanced safety records, reduced human errors, enhanced maintenance performance, enhanced reliability, enhanced quality assurance, accrued tangible and intangible results based on investments made on training, and enhanced worker productivity are benefits for incorporating HFE in aircraft maintenance. In addition to these benefits were minimized sick leave, decreased body damage, enhanced wellbeing, enhanced communication, improved creativity, enhanced productivity, reduced absenteeism, reduced employee compensation for accidents and improved turnover, enhanced health, improved safety, enhanced comfort and enhanced effectiveness of employees and prevention of workplace accidents (Shanmugam and Robert, 2015). These benefits were obtained through addressing HFE, accumulating understanding of human errors and performance, and conformance to HFE regulations such as International Civil Aviation Organization (ICAO) guidelines through which the scope for establishing Safety Management System (SMS) and cause-effect risk analysis is set upon (Shanmugam and Robert, 2015). Furthermore, the organizational and job structure, maintenance training, adequate recruitment, and developing the employees' competences support the successful inclusion of HFE in maintenance of aircraft. The sufficient incident report systems, proper maintenance planning and scheduling, and adequate inspection activities serve as a foundation for satisfactory maintenance performance and reduction of errors.

4 Key Findings and Classification of HFE Benefits

The study identified, discussed and classified the benefits of incorporating HFE in socio-technical systems through the review of scholarly writings. Figure 1 and Table 1 below present the classification of the benefits of HFE application.



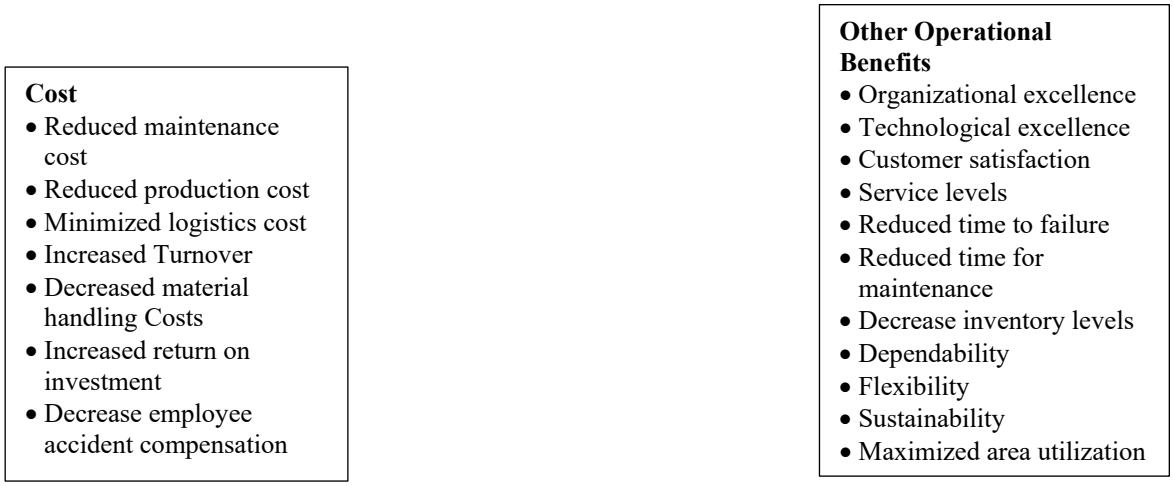


Figure 1. Classification of benefits of HFE

The authors that perfectly addressed the benefits of applying HFE in technical systems are summarized in Table 1 below.

Table 1. Classification of benefits of HFE according to reviewed papers

Item	Paper	Initiative	Performance	Well-being	Safety	Quality	Cost	Other operational benefits
1.	(Longo et al., 2021)	Integrating technology or digital solutions with HFE	✓	✓	✓	✓	.	✓
2.	(Vijayakumar et al., 2021)	Incorporating HFE principles into production and logistics	✓	✓	✓	✓	.	.
3.	(Alanano et al., 2021)	Redesigning workstations	✓	✓	✓	✓	✓	.
4.	(Reiman et al., 2021)	Integrating HFE and technology in manufacturing processes	✓	✓	✓	✓	.	✓
5.	(Kadir and Broberg, 2020)	Incorporating employee involvement and human-centred design for digital and Industry 4.0 technologies	✓	✓	.	.	.	.
6.	(Farid and Neumann, 2020)	System dynamics (SD) modelling to assess effects of human factors	✓	✓	.	.	.	.
7.	(García-Alcaraz et al., 2019)	Human factors (HF) and lean techniques on just in time	✓	.	.	✓	.	✓
8.	(Kolus et al., 2018)	HFE aspects at the operation systems design phase	✓	✓	.	✓	.	.
9.	(Gaiardelli et al., 2018)	A model linking technical, physical, cognitive, organisational, social and performance variables with lean management	✓	✓	✓	✓	✓	.
10.	(Li and Tan, 2018)	Human-oriented manufacturing units layouts integrated with logistics	✓	✓	✓	.	✓	✓
11.	(Peruzzini et al., 2017)	Sustainable Manufacturing (SM) through human-centred approach to redesigning workstations	✓	✓	.	.	.	.
12.	(Grosse et al., 2017)	Incorporation of HFE into the design of an order picking system	✓	✓	.	✓	.	.

13.	(Dode et al., 2016)	HFE in production system design simulation approach	✓	✓	✓	✓	✓	✓
14.	(Leva et al., 2015)	HFE in system design and analysing the practices and standards	✓	✓	✓	✓	✓	✓
15.	(Shanmugam and Robert, 2015)	HFE in aircraft maintenance and conformance HFE regulations	✓	✓	✓	✓	✓	✓

It was observed in Figure 2, that 100% of papers that explicitly listed the benefits of applying human factors in socio-technical systems mentioned system's performance as a benefit. Of these papers, 93% mentioned human wellbeing, 73% quality and 60% safety. These are in line with several definitions and objectives of human factors or human factors engineering stating that, human factors engineering aims to improve human-system relationship, thereby enhancing performance, well-being, quality and safety (International Ergonomics Association, 2018; Long at al., 2021; Vijayakumar et al., 2021). Then cost and other operational benefits scored 40% and 47% respectively. Future studies should look closely to cost benefits since cost reduction is one of the aspects that get scrutinized during the adoption of interventions or new ways to doing work. Figure 2 below presents the classification of benefits of HFE.

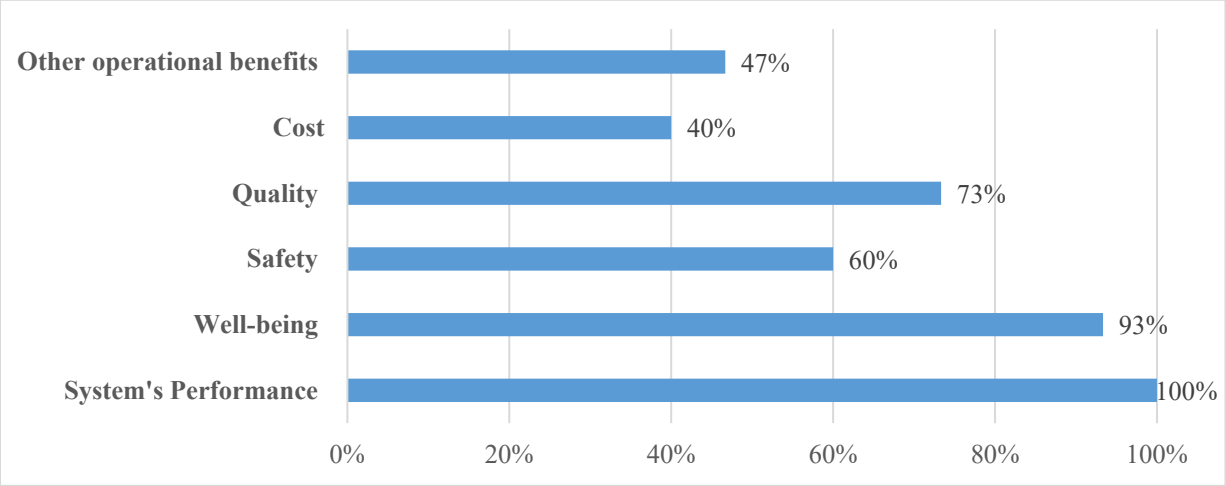


Figure 2. Classification of benefits of HFE

6. Conclusion

This study reports on the review of literature on the application of HFE in socio-technical systems, specifically the studies that listed and demonstrated the realization of the benefits of the successful application of HFE. The study classified the benefits of applying HFE according to system performance, human well-being, safety, quality, cost, and other operational benefits. System performance, well-being, quality and safety scored high on the benefits of applying human factors. In contrast, cost and other operational benefits scored low. Cost benefit should be given careful attention in the studies of HFE since it plays a significant role when deciding on an intervention or new ways of doing work. The papers that formed part of the review incorporated HFE aspects in digital systems, technology, Industry 4.0 technologies, lean management, manufacturing, maintenance, design, workstations and layouts, production logistics, etc. They demonstrated a need to continue pursuing studies in the field of HFE for future industries. At the pinnacle of the Industry 4.0 discussions, many people held a notion that Industry 4.0 technologies would replace human. However, it is evident that in the future of work there is still a considerable role to be played by human. Thus, determining interconnections between human and technology and managing these interconnections well would be key to success of organizations. The use of HFE specialists would also be necessary on the basis that there is still a rare integration of digital elements with HFE as well application of HFE in various industries. The study made the following propositions for future research:

- Making a comparative study between organizations that have adopted HFE and those that have not to determine significant differences.

- Developing a quantitative, survey study to solicit opinions of the organizations that have incorporated HFE with regard to benefits of the application of HFE.
- Conducting a study for the quantification of tangible benefits such as cost.

Acknowledgement

This work is supported and sponsored by the University of Johannesburg, South Africa.

References

Alanano, S.N.C., Caparas, H.A., Ferolino, J.C., Miranda, J.M.A. and Palattao, J.R.V., An Ergonomic Intervention on Metal Fabrication Workstations to Minimize the Risk of Developing Work-related Musculoskeletal Disorders.2021, page 4975-4986

Dhillon, B. S. & Liu, Y., 2006. Human error in maintenance: a review. Journal of Quality in Maintenance Engineering , 12(1), pp. 21-36.

Dode, P., Greig, M., Zolfaghari, S. and Neumann, W.P., 2016. Integrating human factors into discrete event simulation: a proactive approach to simultaneously design for system performance and employees' well being. International Journal of Production Research, 54(10), pp.3105-3117.

Farid, M. and Neumann, W.P., 2020. Modelling the effects of employee injury risks on injury, productivity and production quality using system dynamics. International Journal of Production Research, 58(20), pp.6115-6129.

Gaiardelli, P., Resta, B. and Dotti, S., 2018. Exploring the role of human factors in lean management. International Journal of Lean Six Sigma.

García-Alcaraz, J.L., Realyvasquez-Vargas, A., García-Alcaraz, P., Pérez de la Parte, M., Blanco Fernández, J. and Jimenez Macias, E., 2019. Effects of Human Factors and Lean Techniques on Just in Time Benefits. Sustainability, 11(7), p.1864.

Grosse, E.H., Glock, C.H. and Neumann, W.P., 2017. Human factors in order picking: a content analysis of the literature. International Journal of Production Research, 55(5), pp.1260-1276.

International Ergonomics Association, 2018. www.iea.cc.Viewed 09 February 2018, http://www.iea.cc/whats/index.html.

Kadir, B.A. and Broberg, O., 2020. Human well-being and system performance in the transition to industry 4.0. International Journal of Industrial Ergonomics, 76, p.102936.

Karwowski, k. (2005). Ergonomics and human factors: the paradigms for science, engineering, design, technology and management of human-compatible systems, Ergonomics 48 436–463, https://doi.org/10.1080/00140130400029167.

Kolus, A., Wells, R. and Neumann, P., 2018. Production quality and human factors engineering: A systematic review and theoretical framework. Applied ergonomics, 73, pp.55-89.

Leva, M.C., Naghdali, F. and Alunni, C.C., 2015. Human factors engineering in system design: a roadmap for improvement. Procedia CIRP, 38, pp.94-99.

Li, J., Tan, X. and Li, J., 2018. Research on dynamic facility layout problem of manufacturing unit considering human factors. Mathematical Problems in Engineering, 2018.

Longo, F., Padovano, A., Gazzaneo, L., Frangella, J. and Diaz, R., 2021. Human factors, ergonomics and Industry 4.0 in the Oil&Gas industry: a bibliometric analysis. Procedia Computer Science, 180, pp.1049-1058.

Nkosi, M.S., 2020. Determining the Readiness to Implement Human Factors Engineering in Maintenance: A Special Case of Power Plants. University of Johannesburg (South Africa).

NOPSEMA, 2015. Human error risk reduction to ALARP, Perth: National Offshore Petroleum Safety and Environmental Management Authority.

Peach, R., Ellis, H. & Visser, J. K., 2016. A Maintenance Performance Measurement Framework That Includes Maintenance Human Factors: A Case Study From The Electricity Transmission Industry. South African Journal of Industrial Engineering, 27(2), pp. 177-189.

Peruzzini, M., Carassai, S. and Pellicciari, M., 2017. The benefits of human-centred design in industrial practices: Re-design of workstations in pipe industry. Procedia Manufacturing, 11, pp.1247-1254.

Pinder, A., 2015. Literature review: Barriers to the application of Ergonomics. Human Factors in engineering design. Health and Safety Executive, United Kingdom.

Pons, D. & Dey, K., 2015. Aviation Human Error Modelled as a Production Process. The Ergonomics Open Journal, 8(1), pp. 1-12.

Reason, J., 2000. Human error: models and management. Journal Digest, Volume 172, pp. 768-770.
Reiman, A., Kaivo-oja, J., Parviainen, E., Takala, E.P. and Lauraeus, T., 2021. Human factors and ergonomics in manufacturing in the industry 4.0 context–A scoping review. Technology in Society, 65, p.101572.
Shanmugam, A. and Robert, T.P., 2015. 2015),"Human factors engineering in aircraft maintenance: a review", Journal of Quality in Maintenance Engineering, Vol. 21 Iss 4 pp. 478 – 505
Vijayakumar, V., Sgarbossa, F., Neumann, W.P. and Sobhani, A., 2021. Framework for incorporating human factors into production and logistics systems. International Journal of Production Research, pp.1-18.
Wickens, C.D. and Hollands, J.G. (2000). Engineering psychology and human performance (3rd ed.). Upper Saddle River, NJ: Prentice-Hall.
Wiegmann, D. A. & Shappell, S. A., 2003. A Human Error Approach to Aviation Accident Analysis. Burlington: Ashgate.

Biography

Dr. Mfundo Nkosi is a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology, Faculty of Engineering and Built Environment, University of Johannesburg, South Africa. He completed his PhD in Mechanical Engineering from University of Johannesburg in 2020. He has a masters of philosophy in Mechanical Engineering from University of Johannesburg completed in 2014 and master's in business administration (MBA) from Concordia University St Paul completed in 2015. His research interests are in human factors engineering, change management, and maintenance technologies. He supervises masters and PhD students. He also review conference and journal papers.