Effects of Industry 4.0 on Human Factors/Ergonomics Design in 21st Century

Manutchanok Jongprasithporn[1(✉)], Nantakrit Yodpijit[2], Chanakamon Phaisanthanaphark[2], Yotsuda Buranasing[2], and Teppakorn Sittiwanchai[2]

[1] Department of Industrial Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand
manutchanok.jo@kmitl.ac.th, mjongpra@gmail.com
[2] Center for Innovation in Human Factors Engineering and Ergonomics (CIHFE^2), Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Abstract. The fourth industrial revolution as known as Industry 4.0 becomes a big part of the digitized economy in the 21st century. Industry 4.0 considerably drives the entire supply chain through digital infrastructures and significantly changes work systems. There are many new jobs and work opportunities available for workers with different skill levels due to society and technological changes. Understanding user needs and new technologies is a key factor for the design and development of products and systems where human exists. It is to ensure that the operation and maintenance of such systems are compatible with human abilities and limitations. The purposes of this paper are to explore theoretical and empirical concepts of Industry 4.0 influencing the design of work systems and present factors affecting human factors/ergonomics design in terms of physical, cognitive and organizational perspectives.

Keywords: Human Factors/Ergonomics · Industry 4.0 · Physical, cognitive and organizational perspectives

1 Introduction

Nowadays, the business competition is quite high. Companies must find appropriate ways to develop business in order to increase productivity, work efficiency, and cost reduction. Technology is one of major roles to help companies with high success. Therefore, industries have been changed with significant utilization of computers and automated systems since 2011 into the fourth industrial revolution (Industry 4.0) [1]. Industry 4.0 applies different technologies to change human living and create the business opportunities. Internets and technologies are integrated in the digital and physical world for monitoring and controlling in manufacturing systems for the improvements of productivity and work efficiency [1] and [2]. The main concept of Industry 4.0 is smart factory [1] and [3]. Before Industrial 4.0 implementation, workers are required to understand work systems and their responsibility. As such, understanding the effects of industry 4.0 is very important to help companies achieve business success.

G. Di Bucchianico et al. (Eds.): AHFE 2020, AISC 1202, pp. 437–443, 2020.
https://doi.org/10.1007/978-3-030-51194-4_57

Human Factors/Ergonomics (HF/E) concerns with the relationship between the user, equipment, and environment or fitting a job to a person. It is to ensure that the operation and maintenance of such systems are compatible with human abilities and limitations. HF/E is defined by The International Ergonomics Association (IEA), it concerned with the collaboration between humans and other elements of system for development quality life and overall system performance [4]. The field of HF/E is characterized into three domains of specialization: physical, cognitive, and organizational [4–6] and [7]. Understanding user/operator needs and new technologies is a key factor for the design and development of products and systems where human exists. Proper HF/E design leads to the improvement of work systems and the prevention of repetitive strain injuries and other musculoskeletal disorders in Industry 4.0 era.

Due to significant changes in activities of daily living, new technologies have been designed and developed to meet user needs. The main purposes of this paper are (1) to explore theoretical and empirical concepts of Industry 4.0 influencing the de-sign of work systems, and (2) to present factors affecting HF/E design in terms of physical, cognitive and organizational perspectives.

2 Methodology

This research concentrates on Industry 4.0 and HF/E characteristics. The project has been conducted with the following research methods.

2.1 Background of Industry 4.0

In sum, the first industrial revolution refers to steam power in term of decreasing worker and animal workload. The second industrial revolution involves electrical power for mass production. The third industrial revolution concerns with computer and automation. The fourth industrial revolution as known as Cyber-Physical Systems (CPS) and defines by the use of internet and technology to integrate the digital and physical world. It applies the technologies in all parts of factory as called smart factory to support entire supply chain and meet customer demand. Industry 4.0 is the technology revolution. It consists of Internet of Thing (IoT), Cloud, Big Data, Augmented Reality (AR), Additive Manufacturing (AM) and Autonomous Robots as shown in Table 1 [1–3] and [8].

Table 1. The definition of the technologies enabling Industry 4.0.

Technology	Definition	Reference
IoT	The use of internet for connecting human-human, human-machine, and machine to machine	[1–3, 10, 11] and [12]
Cloud	The storage of data that can assess in any time and place. Several small business, use Cloud for reducing cost as IT infrastructure	[1–3, 11] and [12]

(*continued*)

Table 1. (*continued*)

Technology	Definition	Reference
Big Data	Huge information that keep the various data for analysis. It helps for decision making and business opportunities	[1–3, 11] and [12]
AR	Technology that simulate the virtual objects in real environment	[1–3, 11] and [12]
Additive manufacturing	Making 3D objects from the drawing file for the simulation of the prototype	[1–3, 11] and [12]
Autonomous robots	The use of autonomous robot for decreasing human workload. It can work instead of human in hazardous industrial or monotonous work	[1–3, 11] and [12]

2.2 Overview on HF/E

HF/E is defined as the relationship between human, machine, environment, and its interaction in order to develop human well-being and system performance [4]. As noted by [5] and [7], HF/E concerns human beings, human capabilities and limitations for appropriate work systems design. The configurations of HF/E include (1) Physical Ergonomics deals with physical activity and human body (2) Cognitive Ergonomics concerns with metal processing for supporting human and machine functions, and (3) Organizational Ergonomics focuses on organizational structures, teamwork, and society relationship and communication [4–6], and [7].

Work system is the aggregation of various components that interact with each other to achieve the same goal [5]. Human–machine systems have been implemented in work systems for many decades. Human-machine systems have three domains as follows: (1) manual system considers of hand tools and other equipment using human physical energy for operating, (2) mechanical system uses human for controlling devices, and (3) automated system is unmanned working environment to get the job done [5, 6] and [7].

2.3 Data Analysis

From previous studies, this paper follows main pillars of Industry 4.0, as noted by [10], and three characteristics of HF/E: physical, cognitive and organizational, as defined by [4–6] and [7].

The analysis of the qualitative data of this research has three phases. The first phase focuses on reviewing and highlighting concepts of Industry 4.0. The second phase completes interviews on potential parties from various businesses. The third phase identifies the factors affecting HE/E design and refines the findings by the experts.

3 Results

3.1 Concepts of Industry 4.0

Industry 4.0 refers to Cyber-Physical System (CPS). It is the connection between physical world such as tools, machines, people, and cyber world via internet system, and the use of technologies for communication and real-time information sharing. Industry 4.0 has also focused on monitoring and controlling functions on machines and human for work agility, work efficiency, productivity, human error reduction and better decision making [2] and [10]. In Industry 4.0, the manufacturing system can produce products and provide services based on real-time customer demands using technologies to meet customer needs [2, 3, 8, 11] and [12]. The six pillars of Industry 4.0 are given in Table 2 [1–3, 11] and [12].

Table 2. The definition of the six pillars in Industry 4.0

Pillar of Industry 4.0	Definition	Reference
Virtualization	Technology that simulates physical world into digital form	[2, 10] and [13]
Inter collaboration	The connecting of components in system via internet	[2, 3, 10, 11] and [13]
Decentralization	The connecting of components in system though internet for appropriate decision making	[1–3, 10, 11] and [13]
Real-time communication	The real-time communication system that makes better decision making	[2, 3, 10, 11] and [13]
Service capability	The use of internet for internal and external organization management	[2] and [10]
Modularities	The flexible system that can change the condition by putting a module in or replace it	[2] and [10]

3.2 Interview of the Potential Parties

The data analysis is carried out through interviews with managers in higher management level. In-depth interviews are used to provide a broader view of the influence of Industry 4.0 on HF/E in companies. The managers explain the impact of Industry 4.0 on the design of HF/E in three following areas:

Physical HF/E

The implementation of Industry 4.0 concerns operator fatigue minimization, time reduction, productivity increase, cost saving, and work efficiency improvement. Benefits from applying physical HF/E include the decrease of sick leave of workers from hard working and the minimization of accidents from worker recklessness.

Cognitive HF/E
Most workers believe that if workers do not have enough knowledge and skills of new technologies, the company will lay off the workers. Workers do not have motivation for dealing with new technologies. Therefore, companies have to educate workers and put the right man on the right job.

Organizational HF/E
Work pattern is changed by integration new technologies. The companies have to change and determine the boundaries and roles of departments for supporting business operations.

3.3 Results from Qualitative Data Analysis

Physical HF/E
Autonomous robot is implemented in manufacturing systems for mass production. It supports human limitation such as working in dangerous places and lifting heavy parts, [2, 8] and [13]. The application of VR for plant layout simulation to improve workplace safety and productivity [2, 3, 8] and [13].

Wearable technologies such as smart phone, smart watch and smart glasses provide operator's real-time information on health condition and location. These are very useful for investigating operator's behavior, posture and activity while working [2, 8] and [13].

Cognitive HF/E
VR deals with simulation to make job safe and easy to perform. It is useful for decision making and real-time problem solving [2, 8, 10, 12] and [13]. VR reduces language limitation, work difficulty and stress, and supports migrant and old workers by displaying tasks in picture and large letters of working information [2, 3, 8] and [13]. Wearable technologies are used to investigate workers' stress at work [2] and [13].

Job allocation can be performed based upon skills of workers that are analyzed using Big Data features for matching worker skills to job tasks. Workers must have special skills and proper knowledge of new technologies, so they can work effectively with minimum stress [2, 3] and [13].

Organizational HF/E
After implementing new technologies, the organizational structure must be changed in the ways of work operation and management to fit with the technologies. It is very critical to identify the duties and organizational climates clearly. A new design of work system will contribute participation of all departments and adjust overall organizational structure including responsibilities and communications [2, 3, 8] and [13].

From the qualitative data analysis above, Industry 4.0 factors affecting HF/E design in the all three perspectives are shown in Table 3.

Table 3. The effects of Industry 4.0 on HF/E design.

Pillars of Industry 4.0	Physical	Cognitive	Organization	Application	Reference
Virtualization	✓	✓	✓	AR, and AM	[1–3, 9, 10] and [13]
Intercollaboration	✓	✓	✓	IoT, AR and Autonomous robot	[2, 3, 9–11] and [13]
Decentralization		✓	✓	Big data and IoT	[2, 3, 9–11] and [13]
Real-time communication	–	✓	✓	IoT, Big data and Cloud	[1–3, 9–11] and [13]
Service capability	–	✓	✓	IoT	[1–3, 9–12] and [13]
Modularities	✓	✓	✓	Cloud and IoT	[2, 3, 9–11] and [13]

Table 4 illustrates how industry 4.0 affects HF/E design on physical, cognitive, and organizational perspectives.

Table 4. The effects of industrial revolution on HF/E

Industrial revolution	Physical	Cognitive	Organization	Reference
Industry 1.0	• Human workload	–	–	[1–3, 8] and [13]
Industry 2.0	• Human workload • Fatigue	• Stress	• Profitability	[1–3, 8] and [13]
Industry 3.0	• Human workload • Fatigue • Comfortability	• Stress	• Profitability • Productivity • Work efficiency	[1–3, 8] and [13]
Industry 4.0	• Human workload • Fatigue • Comfortability • Safety	• Stress • Decision-making	• Structure of organization • Productivity • Work efficiency	[1–3, 8, 10, 11] and [13]

4 Conclusion and Discussion

Findings from this study present the effects of Industry 4.0 on HF/E design based on the six pillars (IoT, Cloud, Big Data, AR, AM, and Autonomous Robots) of Industry 4.0 and three perspectives (physical, cognitive and organizational) of HF/E. Industry 4.0 factors affect physical HF/E are Virtualization, Intercollaboration and Modularities with using IoT, AR, AM, Cloud and Autonomous Robot. The factors influencing cognitive and organizational HF/E are Virtualization, Intercollaboration, Decentralization, Real-time Communication, Service Capability and Modularities with using IoT, AR, AM, Big Data, Cloud and Autonomous Robot. The findings from this study supports a premise that Industry 4.0 is a central role in HF/E design influencing physical, cognitive and organizational approaches significantly and changes of HF/E design must be made substantially in 21st Century.

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