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Industrial Design Evolution in the Context of Ergonomics and Industry 5.0

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Abstract

The role of humans in both production systems and commodities purchase is crucial, in this regard considering people's requirements as workforces in the industrial sectors, and as customers in terms of marketing issues are important. Therefore, both ergonomic design and industrial design which concern human beings and users' needs play key factors in every development. Furthermore, the new generation of industry entitle Industry 5.0 as a progressed form of Industrial 4.0 focused on a human-centric approach in industrial systems in which ergonomics has a crucial place. As industrial design also emphasizes a human-based process not only in product development but also in-service design, the success of this discipline depends on ergonomics consideration and following the rules of Industry 5.0. This new generation of the industry has a wide scope in which some sorts of multidisciplinary science should be involved i.e. humanities, life sciences, engineering, environmental and social sciences. Undoubtedly, merging these areas together and making an appropriate connection between mentioned different fields especially human factors, engineering, and industrial design thinking will be ended in better outcomes in this descriptive informative paper (mentioned fields are focused).

Keywords

Ergonomics, Industrial Design, Industry 5.0, Product Design, Human Factors.

Introduction

Humans play a critical role in the process of development of innovation and technology. Undoubtedly, occupational health considerations are known as essential interventions in working systems; in fact, Health, safety, and performance are maximized if equipment, workstations, and work methods are designed to meet the capabilities and limitations of the employees in industrial sectors (Baba et al., 2021; Sadeghi Naeini, 2015). Also, industrial sectors are known as one of the main components of societies, and the transformation of the industry is a prominent action toward community evolution (Leng et al., 2022).

Therefore, making effective communication between humans as a workforce and manufacturing systems is essential for development. Undoubtedly, Industrial evolution is an important process to achieve the mentioned development. Industrial development in the form of fast industrialization makes some side effects on workers' health and safety, in this regard Industry 4.0 framework should be sustainable (Leng et al., 2022).

However, the root of the industrial revolution goes back to some centuries ago and the age of the invention of Steam power, then step by step some sorts of evolution took place such as the electronic age, IT generation and so on (Leng et al., 2022; Xu et al., 2021). Industry 5.0 has a wide scope in which some sorts of multidisciplinary science should be involved i.e. humanities, life sciences, engineering, environmental and social sciences. Undoubtedly merging these areas together and making an appropriate connection between mentioned different fields will be ended in better outcomes (Leng et al., 2022).

The significance of human beings and sustainability emphasis on the fact that human-centric logic should be considered in the industrial-based evolution, in fact instead of system-centric which concerns cost reduction and productivity, the human-centric approach plays a crucial role (Lu et al., 2022). End users as the customers of products, and workers as the human resources in the manufacturing process play the main role in product development and marketing. Utilizing the appropriate technologies in the product or service design to make innovative and effective products based on users' needs is also known as a vital factor in every development.

What can technology do for us? rather than, *What can we accomplish with new technologies?* (Namrata Prakash et al., 2021). Surely, new and modern technologies such as robots, smart machines, the Internet of Things (IoT), artificial intelligence, and big data will still be vital for marketing and different businesses; however, the role of workers' skill development, self-sufficiency, adaptability, and all the feature which are related to technology are becoming more perceptive and efficient (Namrata Prakash et al., 2021). In this regard, in this paper, the significance of product and service design in the context of the new generation of technology and based on ergonomics consideration are focused. Actually, in this period of industrial evolution, product and service designers should pay attention to design for people based on Industry 5.0 circumstances, as a matter of fact, industrial designers' success depends on the following of Industry 5.0 rules.

Ergonomics

Nowadays, human beings play a critical role in every movement, society, situation and place because humans involve some factors such as humanity, politics, economics, social health, sustainability, and so on. One of the multidisciplinary sciences which concerns human well-being, user satisfaction, health, safety, as well as efficiency and productivity, is Ergonomics or human factors engineering (Sadeghi Naeini, 2015; 2020; Sadeghi Naeini & Zolfaghari, 2020), as it is able to help managers, decision-makers, and authorities in terms of making a proper fitting between systems' situations and users' requirements.

Some sorts of disciplines are also related to ergonomics i.e. industrial design, occupational health and safety, industrial engineering, industrial psychology, architecture, interior design, and so on (Naeini, 2019; Naeini & Mosaddad, 2013; Sadeghi Naeini & Zolfaghari, 2020).

According to this vast communication, there are some definitions for ergonomics in which all of them show the significance of human health, well-being, and productivity. *The definition of ergonomics (or human factors) adopted by the International Ergonomics Association (IEA) in 2000 is the scientific discipline concerned with the understanding of 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*.

The author defines ergonomics as a multidisciplinary science concerning designing, redesigning and/or modification of the environment, task, and equipment to fit them to the abilities and limitations of humans to achieve the dual goal of health, and productivity (Sadeghi Naeini, 2020).

Considering the abovementioned scope for ergonomics, as a matter of fact, this discipline has a firm association with sustainability, and plays a crucial role in sustainable development. Both ergonomics and sustainability are known as the human-centered fields (Lin et al., 2019; Sadeghi Naeini, 2020).

Apart from the product design process, the main target place of ergonomics interventions are industrial sectors, workplaces, and workstations. Furthermore, there is no boundary between human factors engineering and industrial-based evolution. Hence both of Industry 4.0 and 5.0 have some sort of common areas with ergonomics, especially Industry 5.0 as is known as a human-centric approach, so ergonomics plays a vital role in its development.

The International Ergonomics Association divides ergonomics and human factors into three main domains, *physical ergonomics (working postures, repetitive movements, material handling, safety, and health), cognitive ergonomics (mental workload, decision-making, skilled performances, motor response, training, and human–computer interactions), and organizational ergonomics (organizational structures, design of working times, processes, communication, and cooperative work* (Zizic et al., 2022), and all the mentioned fields work in both Industry 4.0 and 5.0, however, workforces are oriented as the core of manufacturing fields in the Industry 5.0 (Battini et al., 2022).

Industrial Revolution

According to the evolutionary history of Industry X.0 (Figure 1), some stages can be defined, for instance, Industry 1.0 and 2.0 are remarked by the *Steam Age*, and *Electric Age*, respectively. The information technology development highlights the third generation of industry, and Industry 4.0 merges IT and Operational Technology (OT) in a cyber-physical system manner for mass customization/personalization with intelligence. Industry 5.0 as a newborn generation makes an efficient connection between human as a workforce and smart technologies in which problem-solving of the mismatch between manufacturing and social needs is considered (Leng et al., 2022; Xu et al., 2021).

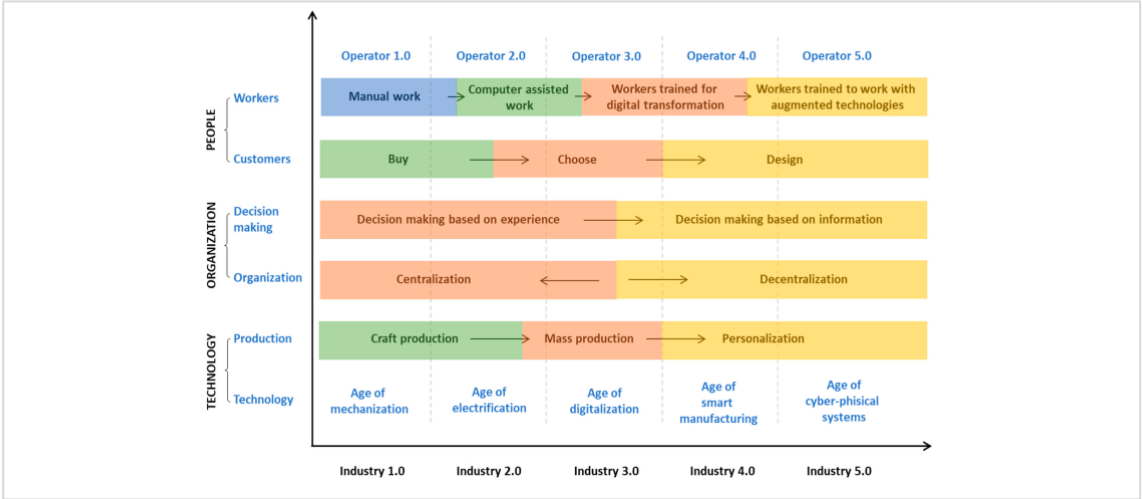

Figure 1: *Different industrial generations and characteristics (Zizic et al., 2022).*

Industry 4.0 and 5.0

Industry 4.0 is based on the concept of smart and technology-driven approach (Xu et al., 2021) in which modern technologies such as artificial intelligence, robotics, blockchain, 3D printing, Internet of Things are known as the core issues, however, these benefits face some challenges in terms of the role of the human in systems and workers related concerns such as health hazards, occupational health problems, job satisfaction and so on (Choi et al., 2022). Industry 4.0 which was introduced in Germany, became a worldwide issue during the past decade (Xu et al., 2021), and the main logic in Industry 4.0 is *digitalization* and using smart technologies instead of humans (Leng et al., 2022).

However, there are some different interpretations of Industry 4.0, all agree upon the Reference Architecture Model Industry 4.0 (RAMI4.0). This model was introduced by an Electronic Manufacturers' Association (ZVEI) in Germany. Figure 2 shows the three-dimensional RAMI4.0 model (Xu et al., 2021).

Industry 4.0 focuses on the digitalization of systems and considers fewer social and sustainability aspects of working systems, hence, the Industry 5.0 paradigm which is firmly related to Industry 4.0 approach (Battini et al., 2022) emphasizes the three main aspects of the sustainable, human-centric and resilient industry (Battini et al., 2022; Choi et al., 2022; Nahavandi, 2019; Xu et al., 2021). Figure 3 shows the mentioned three pillars of Industry 5.0. If we know Industry 4.0 as a technology-driven process, Industry 5.0 is value-driven and focuses on the role of workers as well as other aspects of Industrial 4.0 (Fonda & Meneghetti, 2022).

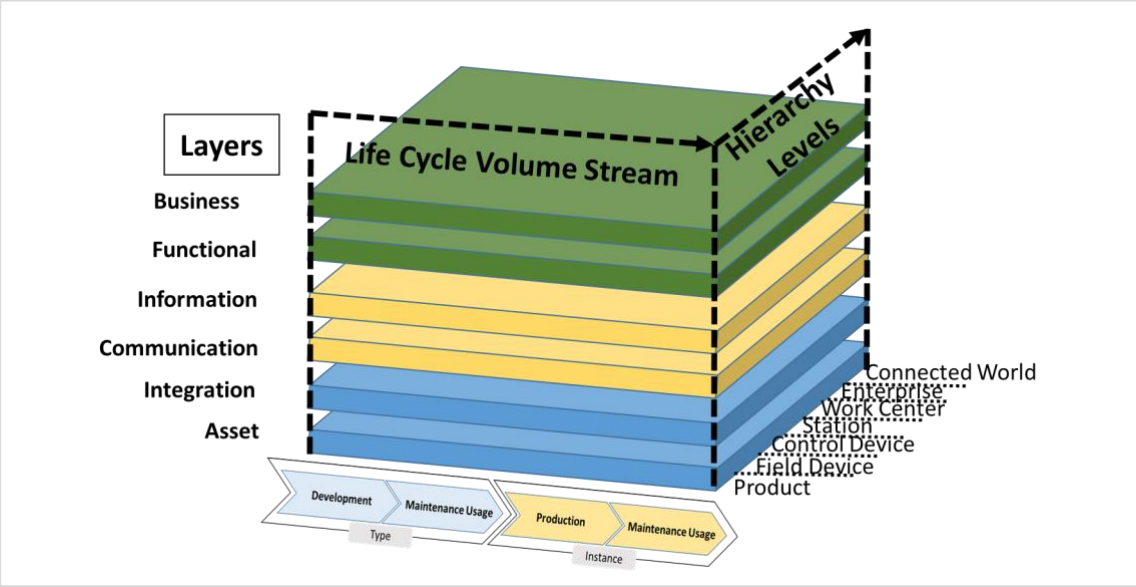

Figure 2: *RAMI 4.0 Model- Adapted from Xu et al. (2021).*

There are some opinions about Industry 5.0, for instance, some of the researchers emphasize on industry 5.0 as a future of the manufacturing/production system based on aspects of human-centric, sustainable, and resilient, or someone believes that in Industry 5.0 both workers and equipment are working together toward more efficiency based on human creativity and brainpower (Leng et al., 2022; Nahavandi, 2019). The concept of resilience as one of the three aspects in the fifth generation of the industry relies on the role of workforces.

A Resilient Manufacturing System is defined as *a system with the ability to adjust its functioning prior to, during, or after operational changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions*. The Resilient Operator 5.0 focuses on building *self-resiliency*, and *system resiliency* towards systems optimization (Xu et al., 2021). These two mentioned concepts have some specific scope, per se. Self-resilience considers occupational health and safety and the prevention of workers' exposure to hazardous agents, as well as productivity.

System-resilience focuses on making a good communication between humans and machines toward appropriate productivity (Leng et al., 2022). Considering this new generation of industry, and according to the essential of following its rules and considerations, all of the related disciplines should be involved and adapted, in this regard, involvement of industrial design as a discipline which is related to both manufacturing and commodities' usage by customers is inevitable.

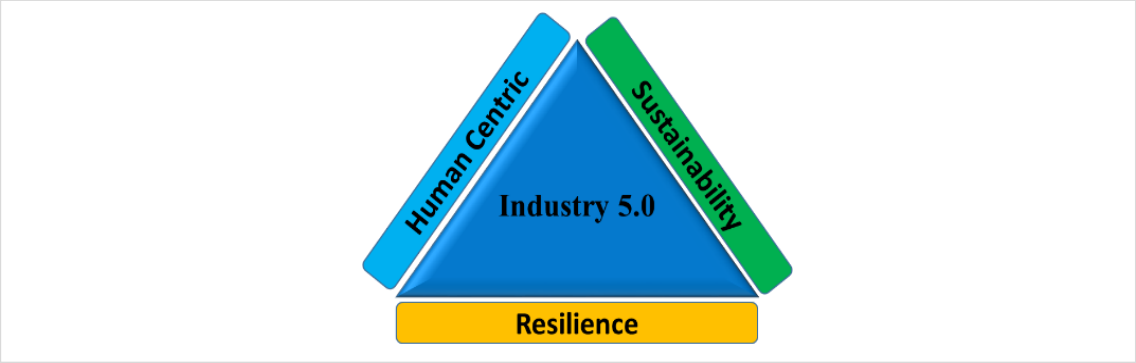

Figure 3: *Industry 5.0 with three key drivers.*

Industrial Design

Design as a multidisciplinary worldwide field concerns the product and artifacts creativity, artworks visualization, product development based on manufacturing systems, and service design in which some aspects of social, sustainability, commercial and business, and culture are focused more than in previous decades. In fact, one of the primary goals of design is to prepare some new ideas and to develop proper options and different choices for people based on their needs and requirements (Jonas, 2020).

Nowadays, industrial design as a sub-branched of design (as a general term) plays a critical role in product and service design in which a dual goal is followed, users' satisfaction as the customers of commodity, and productivity as the main concern of producers and industrial sector managers.

State-of-the-art industrial design is not limited to the appearance and surfaces of tangible products, in fact, other prominent features such as the design of material and social artifacts toward meeting the users' and communities' requirements are considered (Krippendorff, 2007).

Undoubtedly, product design and commodities production are associated with society, hence, considering the impacts of products on end-users and the community are important. To optimize the product design process and product development, some main factors should be assessed such as engineering characteristics, sustainability, manufacturing, user-centered design and ergonomics (Lin et al., 2019)

Industry 5.0 efforts to bring human technicians back to the industrial sector and making productivity based on human creativity in the context of appropriate interaction between workforces and machines (Mourtzis et al., 2022), in this regard, the role of design thinking and industrial design based on ergonomics, and human-centricity approaches are noticeable.

According to European Commission, there are six main technologies and industrial-based fields in Industrial 5.0 (Namrata Prakash et al., 2021; Xu et al., 2021):

1. Customized human-machine communication.
2. Bio-inspired technologies and smart materials.
3. Digital Twins and simulation to model entire systems.
4. Technologies for data transport, storage, and analysis.
5. Computerized Artificial Intelligence (AI).
6. Technologies for energy efficiency, renewables, storage and autonomy.

According to the abovementioned wide range of related industries, there are plenty of potentials and opportunities for industrial designers.

Result & Discussion

The Industry 5.0 paradigm indicates a worldwide shift in industries, in which human beings and workforce's health and safety play as key factors in the manufacturing systems (Leng et al., 2022). In this age of industry, the approach of Human-centric production systems manufacturing is mandatory for industrial authorities to have a more agile, productive and robust system, and making an appropriate combination between workers and technology is a key factor toward productivity (Leng et al., 2022).

In the context of mass individualization requirements, not only human resources cannot be replaced by robots and equipment, but also digitalization and automation are not accomplished without humans (Leng et al., 2022) in fact, workers play key factors in the process of decision-making (Shiroishi et al., 2019). Besides, in Industry 5.0 making an appropriate and optimize harmony between the production system and productivity based on the human presence (Namrata Prakash et al., 2021).

However, Industry 5.0 is still in its preliminary stage and more studies should be done (Fonda & Meneghetti, 2022; Leng et al., 2022; Namrata Prakash et al., 2021).

According to the fast development of science and technology, the next industrial revolution might be called cobots as the next generation of robots that are so smart to do tasks and give robotic productions a human touch (Leng et al., 2022), so the role of ergonomic design for people and the new lifestyle become more and more crucial. However, considering human performance and making a proper relationship between man and machine is one of the undertakings in the design process, in this regard, appropriate communication between ergonomists and designers as members of a team is so important (Pazell & Burgess-Limerick, 2021).

Besides, the fast development of new technologies makes this essential fact that ergonomics interventions should have some vital evolution to cope with new and modern technologies, for instance, artificial intelligence (AI), machine learning, augmented reality, and so on are changing our environments, also human-machine interaction in the near future may make some dissonance between cycle time of human and equipment (Hancock, 2020), in this regard, human factors engineering should innovate to support users in coping with these new technologies and autonomous systems. In this regard, however, Industry 5.0 is still fancy, ergonomics and service design approaches should be revised and up to date (Lau et al., 2020). Furthermore, there is a reciprocal communication between Human-centered Design and Futures Design toward new design development (Udoewa, 2022), actually, there is no boundary between the two mentioned themes.

In this regard, industrial designers also should pay more attention and conduct two main fields:

- Service design based on new technology and digitalization
- Ergonomic design as a key factor in the industry-related human centric approach

Undoubtedly, some conflicts and limitations will occur, if the industrial designers ignore the Industry 5.0 logics and rules, for example:

- They will miss the main career role in the product development
- The evolution and generation in the Iranian manufacturing systems will be affected by the missing crucial role of designers, not only in system design but also in the product and service design process
- The role of related institutes and educational centers that involve industrial design training will get some side effects
- Industrial designers have an important role in ergonomics development in industrial sectors decision making, so the absence of their authority makes some negative impacts on the place of ergonomics
- The competition process among industrial sectors at both national and regional levels is affected

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