



Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Review Article

The Fourth Industrial Revolution and Its Impact on Occupational Health and Safety, Worker's Compensation and Labor Conditions

Jeehee Min¹, Yangwoo Kim¹, Sujin Lee¹, Tae-Won Jang², Inah Kim², Jaechul Song^{2,*}

¹ Department of Occupational and Environmental Medicine, Hanyang University Hospital, Republic of Korea

² Department of Occupational and Environmental Medicine, Hanyang University, Republic of Korea

ARTICLE INFO

Article history:

Received 2 July 2019

Received in revised form

18 September 2019

Accepted 22 September 2019

Available online 27 September 2019

Keywords:

Fourth industrial revolution

Occupational health and safety

Workers' compensation

Workers' health

ABSTRACT

The “fourth industrial revolution” (FIR) is an age of advanced technology based on information and communication. FIR has a more powerful impact on the economy than in the past. However, the prospects for the labor environment are uncertain. The purpose of this study is to anticipate and prepare for occupational health and safety (OHS) issues.

In FIR, nonstandard employment will be common. As a result, it is difficult to receive OHS services and compensation. Excessive trust in new technologies can lead to large-scale or new forms of accidents. Global business networks will cause destruction of workers' biorhythms, some cancers, overwork, and task complexity. The social disconnection because of an independent work will be a risk for worker's mental health. The union bonds will weaken, and it will be difficult to apply standardized OHS regulations to multinational enterprises.

To cope with the new OHS issues, we need to establish new concepts of “decent work” and standardize regulations, which apply to enterprises in each country, develop public health as an OHS service, monitor emerging OHS events and networks among independent workers, and nurture experts who are responsible for new OHS issues.

© 2019 Occupational Safety and Health Research Institute, Published by Elsevier Korea LLC. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Klaus Schwab predicted a new industrial revolution to begin in the near future in the World economy forum Global Challenge Insight Report (The Future of Jobs-Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution [FIR] in 2016) [1]. Experts say that the FIR needs to be prepared because it will change the way people work, how they consume, and even how they think [1].

The industrial revolution led to changes in the labor market with machines replacing human labor. The first industrial revolution replaced manual work with the invention of a steam engine and the second industrial revolution enabled mass production using electric energy [2]. The tertiary industrial revolution started the automation era with informatization based on computers and the Internet [3]. In the future, the super intelligence revolution based on the Internet of things, cyber-physical system, and artificial intelligence (AI) will greatly change human intellectual labor [4].

The technologies that will lead the FIR are diverse. Artificial intelligence based on high-speed networks and interfaces would change the production process [4], and business models based on big data will be popular [5]. The speed actory in Germany, which produces Adidas-personalized sneakers, is a typical example of the innovation of the production process [6].

The world has overcome differences of time and space by the development of information and communication technology, which has developed into a single economic system. The social network system has already changed the way people communicate. In the future, operational technology or cyber-physical system devices will monitor, coordinate, and integrate information in real time [4]. Operational technology will lead to a hyper-connectivity society, with human-machine, machine-machine, and human-human connections [5].

If human labor is replaced by machines, the labor market will be greatly affected [7]. As technology develops, labor productivity increases, and new jobs are created. According to the US Department of Labor, American's factory workers declined by two-thirds from

* Corresponding author. Department of Occupational and Environmental Medicine, Hanyang University, Sungdong-ku, Seoul, 04763, Republic of Korea.
E-mail address: jsong@hanyang.ac.kr (J. Song).

1960 to 2014, but productivity has increased dramatically [8]. In addition, the average hourly wage from 1973 to 2014 increased by 85% [7,9], and new jobs were created in new industries. During the third industrial revolution, manpower shifted from the manufacturing sector to the service sector. The FIR is likely to change what kind of work needs to be performed, not just the number of jobs [7]. For example, the role of product marketers is changing because of the emergence of big data, which is a core technology in the FIR [10,11]. Instead of market research using current surveys, the use of big data is increasing [12]. Therefore, it is necessary to hire professional staff to collect, store, analyze, and distribute big data [11,13]. Specifically, spending on the big data in information technology market worldwide has doubled from \$27 billion in 2011 to \$54 billion in 2016 [14].

It is a global trend to change government systems to e-government, which automate administrative tasks and make it possible for services to be performed online [15]. For example, the Austrian Administration Service provides information (<https://www.oesterreich.gv.at/public.html>) [15]. This change can increase productivity and reduce environmental pollution by avoiding unnecessary documentation and business trips [16].

At the national and whole industry sector levels, the FIR may have little impact, but it will reduce employment in local economies and individual industries [18,19]. According to Acemoglu and Restrepo [20], introducing a single robot in a multinational corporation reduces the employment rate by 0.37 per 1,000 workers. By industry, the largest number of robots were introduced to the automobile industry, followed by the electronics industry and the raw materials industry [21]. Robots were adapted more frequently in developing countries than in developed countries. In particular, the rubber and plastics industries, which are major industries in emerging countries have adapted 10 times more robots than developed nations (Table 1). Therefore, in emerging countries, low-skilled low-salary jobs would be threatened by automation [21].

Future jobs will be polarized according to the nature of the jobs and whether robots can be used or not [20,22]. A study by Frey and Osborne [23] predicts that 47% of the jobs in the US labor market will be replaced by computers in the next 10 to 20 years (Fig. 1), (Table 2). In the same way, Republic of Korea is a high-risk country, where 57% of all jobs are likely to be replaced by machinery [24]. In

2016, 18 million people, or 70% of the total workforce of 25.6 million in Republic of Korea, are in high-risk jobs [25]. In particular, the rate of substitution for cleaners and kitchen assistants is close to 100% [25]. High-risk jobs range from blue collar, white collar, salespeople, to simple labor. Jobs that require performing repetitive tasks such as mathematical operations, data classification, and management are endangered [26]. For example, salesclerks could be replaced by a system like the currently commercial "Amazon go" [27]. The FIR could reduce the employment of low-skilled service workers and cause mass unemployment [7,25,28].

In addition, professions currently enjoying relatively high wages and high employment stability are likely to be replaced by AI and robots [29]. Artificial intelligence Watson and remote telesurgery robots like Da-Vinci will replace human medical practices. Legal information can be easily accessed by the general public. In addition, standardized legal systems and the development of technology can threaten the work of lawyers [29].

There is also a concern that the inequality of labor income and capital income could deepen. According to Andrew McAfee (2012), productivity and employment rates were closely linked from the 1940s to the 1980s, but after the emergence of the Internet era in the 1990s, the employment rate did not increase as much as productivity growth (Fig. 2) [30]. In the FIR era, the adaptation of automation and robots would increase inequality.

As AI-based platform business spreads, labor is likely to be treated as content traded on the platform (Table 3) [31]. For example, "Uber" or "Airbnb" could significantly reduce transaction costs by directly connecting providers and consumers at the platform. They do not provide transformation services and accommodations by hiring employees or owning hotels [32,33].

Under the subcategorization concept of platform business, gig economy is an economic term in which a worker takes on temporary employment and contracts with several employers at the same time. Gig economy is categorized by crowdwork and work-on demand via applications. Crowdwork involves performing simple tasks like small-sized projects such as correcting website errors. Work on-demand via applications does chores for customers like purchasing clothes and retail items, and cleaning houses [33]. Ideally, independent workers in the gig economy can work freely without the constraints of the labor space by using the Internet

Table 1
Descriptive statistics of the changes of robot density by sector

Sector	World		Developed economies		Emerging economies	
	[*] Δ Robot density	[†] Labor intensity	[*] Δ Robot density	[†] Labor intensity	[*] Δ Robot density	[†] Labor intensity
	2014–2005	(2005)	2014–2005	(2005)	2014–2005	(2005)
Agriculture	13	0.009	14	0.001	9	0.029
Electronics	3,035	0.008	2,995	0.003	3,143	0.02
Wood & paper	-23	0.007	-39	0.004	22	0.013
Automotive	6,019	0.006	5,106	0.003	8,509	0.017
Construction	28	0.005	29	0.003	25	0.011
Textiles	3	0.004	-2	0.002	17	0.01
Rubber, plastic, & mineral products	733	0.004	201	0.002	2,183	0.008
Education/Research/Development	2	0.004	-21	0.002	64	0.008
Basic metals	1,172	0.003	1,257	0.003	940	0.005
Industrial machinery	249	0.003	-64	0.002	1,102	0.007
Chemicals	306	0.002	383	0.001	96	0.004
Food & beverages	749	0.001	878	0.001	397	0.003
Utilities	1	0.001	-1	0	8	0.002
Mining & quarrying	4	0.001	4	0	1	0.001

Labor intensity = Labor hours per week/Units produced per week (h/unit).

* Δ Robot density: Because introducing robots would be profitable in repetitive tasks, industries are willing to substitute workforce to robots. So Carbonero et al find out how much the impact of substitution of workforce. Robot density means one robot per 10,000 workers.

† Labor intensity is the relative proportion of labor, compared with capital, used in a process.

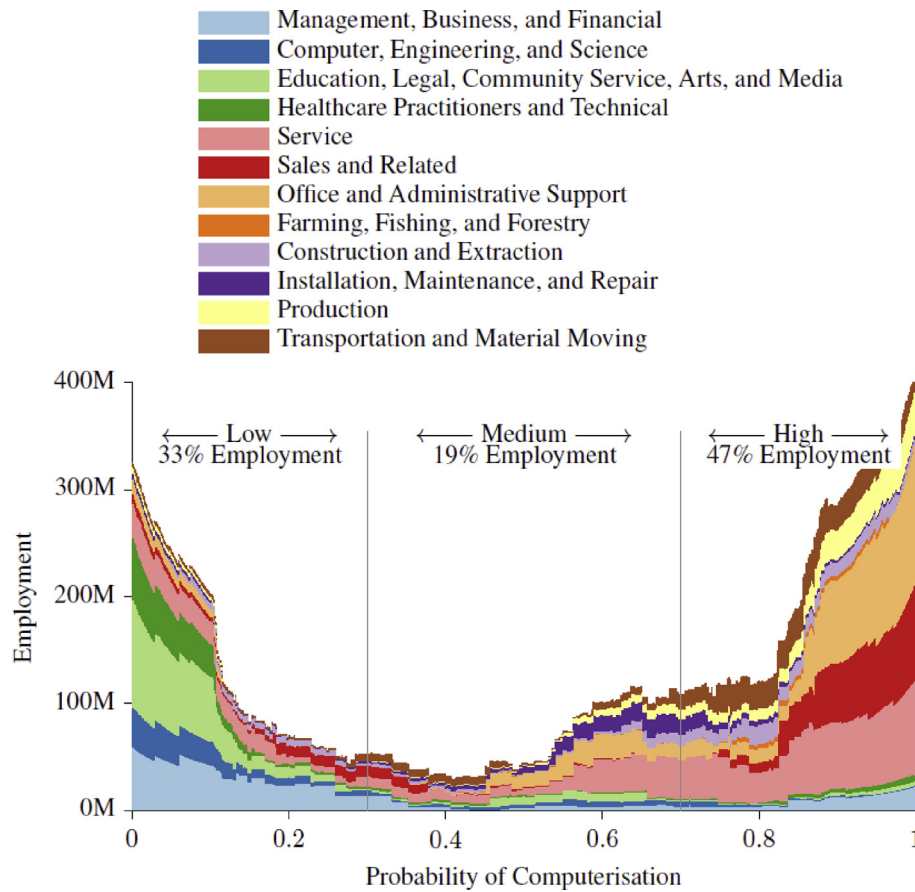


Fig. 1. The distribution of Bureau of Labor Statistics (BLS) 2010 occupational employment over the probability of computerization, along with their shares in low, medium, and high probability categories.

network as a self-employed status. Also, enterprises can easily achieve professional outcomes at lower prices [33]. However, this represents the extreme form of the fissured workplace, whose characteristic is personal outsourcing. A lack of relevant regulations could exploit the labor force without limits and undermine employment stability [33,34].

Platform economy could aggravate worker environments by deepening job fragmentation. Job fragmentation refers to separating jobs to enable a product by outsourcing to a subcontractor or offshore to developing countries as well as digitalize or automate to reduce costs [35,36]. As the fragmentation of labor progresses, “standard employment” the safe employment type, would decrease and nonstandard employment defined as dispatch jobs and freelancers will increase greatly [37]. According to the Katz and Krueger data, between 2005 and 2015, the proportion of nonstandard employment in the United States increased significantly from 10.1% to 15.8% [34].

A platform economy can exacerbate precarious work conditions. Subcontract workers are apt to be isolated from occupational health and safety (OHS) coverage. This is because that the size of the business is usually too small and subcontractor workers are employed with short-term contracts. According to data from the Ministry of Employment and Labor, there were 28 accidents that more than 3 people were killed. For these 28 accidents, 109 workers died, and 93 people of 109 dead (85%) were subcontractors [38]. Another data from Occupational Safety & Health Research Institute in Republic of Korea, as 2015, the numbers of workers who died due to industrial accidents per 10,000 workers was 0.39 in

subcontracts, whereas the same ratio was 0.05 in main contract, which was eight times higher [39]. Recently, safety accidents of subcontractors have become a social issue in Republic of Korea. The International Labour Organization (ILO) has already worried that nonstandard employment, such as subcontractors, daily workers, and freelancers, could threaten worker health and the stability of their lives [40].

Thanks to globalization, accelerated by the FIR, multinational corporations could easily exploit the workforce and the environment of developing countries [41]. Over the course of history, multinational corporations have established manufacturing factories in developing countries because of low incomes and lenient environmental regulations [42]. As a result, the employment rate of the manufacturing sector in developed countries declined by 19% for 37 years [42,43]. However, plants result in socioeconomic problems in many developing countries because they are based on loose labor regulations and low wages [44].

In the era of the FIR, manufacturing will be developed in small quantity production systems of various kinds. Factories in developing countries are no longer attractive because low-wage workers can be replaced by automated robots. Rather, it is advantageous to place the production plant near the main market to quickly produce and distribute products [43]. This is called “re-shoring”. In an Adidas Speed factory equipped with this system, AI-based robots perform most of the shoe manufacturing work. Some accessories were made with 3D printers, which reduced employment from 600 people to 10 people [6]. If the re-shoring phenomenon continues, the power of economic development in developing countries will

Table 2
Probability that computerization will lead to job losses within the next two decades, 2013* (1 = certain)

Job	Probability
Recreational therapist	0.003
Occupational therapist	0.0035
Physicians & surgeons	0.0042
Elementary school teachers, except special education	0.0044
Mental health counselors	0.0048
Computer system analysts	0.0065
Curators	0.0068
Athletic trainers	0.0071
Preschool teachers, except special education	0.0074
Clergy	0.0081
Career technical education teachers	0.0088
Teachers & instructors, all other	0.0095
Makeup artists, theatrical & performance	0.01
Pharmacists	0.012
Firefighters	0.17
Actors	0.37
Health technologists	0.40
Economists	0.43
Commercial pilots	0.55
Machinists	0.65
Word processors & typists	0.81
Real estate sales agents	0.86
Technical writers	0.89
Retail salespersons	0.92
Accountants & auditors	0.94
Telemarketers	0.99

* "1" means that the job definitely substituted by computerization in the future.

be lost and developing countries will endure a poor and risky working environment to secure price competitiveness [6].

The development of technology is a double-edged sword. You need to be prepared not only for the bright future that technology will bring, but also for the problems that will arise. The purpose of this study is to anticipate and prepare for OHS problems for workers in the era of the FIR.

Table 3
Principal platforms and applications in the gig economy

Name	Field	Size of workforce (person)	Operating areas
Uber	Transportation	160,000	International
Lyft	Transportation	50,000	United States
Sidecar	Transportation	6000	Major US cities
Handy	Home services	5000	United States
TaskRabbit	Home services	30,000	International
Care.com	Home services	6,600,000	International
Postmates	Delivery	10,000	United States
Amazon Mechanical Turk	Crowdwork	500,000	International
CrowdFlower	Crowdwork	5,000,000	International
Crowdsorce	Crowdwork	8,000,000	International
Clickworker	Crowdwork	700,000	International

2. Changes in OHS expected in the FIR

2.1. Positive aspects in the workplace

New technologies can be used to create a safe working environment by excluding humans from harmful workplaces. For example, by applying a deep-learning algorithm to detect human behavior patterns by security cameras, it is possible to monitor for chemical leaks or worker accidents in real time [45]. If a dangerous situation is recognized, the relevant system can alert the operator, safety officer, or responsible department immediately to prevent the accident in advance [45]. In fact, in the New Boliden mine in Sweden, robots can be used for safe work [46]. The use of virtual reality technology and smart glass in safety education can enhance the effectiveness of education [47,48]. It is also possible to prevent musculoskeletal disorders by wearing a wearable robot that supports human strength [49].

2.2. Negative aspects in the workplace: globalization

Globalization is a pre-existing concept, which existed before the debate of the fourth industrial evolution. As a result, it is a

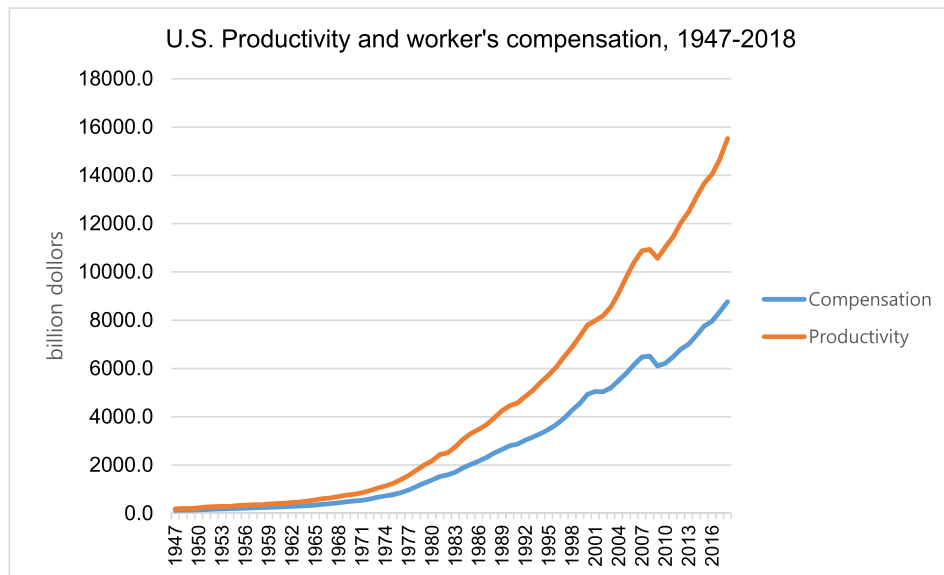


Fig. 2. US productivity and worker's compensation, 1947–2018. Note: Productivity means that current dollar output (billions of current dollars) of production in the nonfarm business sector. Compensation means compensation of workers in billions of current dollars. Source: Division of Major Sector Productivity, Bureau of Labor Statistics

precondition of the FIR with the development of information and communication technology and AI technology. Friedman [50] states that “the world is flat,” in which the social and cultural standards of individual countries are unified into global standards through the proliferation of financial capitalism as well as the development of transportation and communication. Globalization would be accelerated by the FIR and eventually, it would affect working conditions [51].

Because multinational corporations take advantage of loosening labor regulations in developing countries to increase productivity, workers in developing countries work in hazardous workplaces without proper welfare. Child labor and forced labor, which are prohibited in most developed countries, occur in developing countries. There are often no provisions for minimum wages and maximum working hours. As a result, the ILO proposed the “Rule of the Game” as a global standard in 2014, but it was not enforced and could not be introduced into industrial sites in many countries [44].

Globalization affects working time, where shifts or night shifts increase. Birth [52] describes time–space compression as a change in the concept of time due to globalization. Human time is divided into the local time, an individual's biological time, and social time, which constitutes labor conditions. Because of globalization and the development of information and communication, time–space compression adapts to the time of work, not the biological time of the person. At this time, the biological cycles for a location on the globe and the time of his work are desynchronized, which causes many problems [53].

2.2.1. Shift work and daily rhythm disturbance

According to the statistics of Republic of Korea's labor environment survey in 2011 and 2017, 9.1% of service workers worked shifts in 2011 and it increased to 15.7% in 2017. In 2011, only 6.5% of sales workers were shift workers, but it increased to 15.1% by 2017 [54,55]. Shift work causes circadian rhythm disturbances by change of melatonin [56].

2.2.2. Shift work and cancer risk

Breast cancer is the most common cancer associated with shift work. The relationship between shift work and breast cancer was confirmed by two prospective cohort studies (Nurse Health Studies I and II) conducted for nurses in the United States. Both studies were executed by large study population, respectively, 78,562 and 115,022 nurses for more than 10 years. And they coincidentally assessed risk of breast cancer as 1.36 to 1.79 (95% confidence interval [CI]: 1.06–3.01) when at least three shifts were performed at least once a month for more than 20 years [57,58]. In addition, many epidemiological studies have been conducted in Europe and Republic of Korea, which showed that shift work consistently increases the risk of breast cancer [59].

In addition, there are epidemiological studies investigating the association between shift work and other cancers, colon cancer and prostatic cancer, even though the relative risks were lower than breast cancer [60,61].

2.2.3. Shift work and the risk of other diseases

Shift work is known to increase the risk of cardiovascular and cerebrovascular diseases. In a systematic review and meta-analysis of 34 studies conducted by Canadian researchers in 2012, the odds ratio (OR) of myocardial infarction in shift work was 1.23 (95% CI: 1.15–1.31) and the ischemic stroke rate was 1.05 (95% CI: 1.01–1.09). The population attributable risks of shift work in Canadian were estimated to be 7.0% of myocardial infarction, 7.3% of coronary heart disease, and 1.6% of ischemic stroke [62].

Although relatively difficult to study, the possibility of a relationship between shift work and type 2 diabetes has also been

suggested [63]. In cross-sectional studies conducted in Republic of Korea in 2016, artificial light at night exposure was associated with obesity (OR 1.24, 95% CI: 1.14–1.35) [64].

Shift work also has a negative impact on incidence of depression disorders. A study based on the 2009 British Panel Survey found that the OR for complaints of depressive symptoms when working for more than four years was 6.08 (95% CI: 2.06–17.92) [65]. In a study of nurses' health in Republic of Korea in 2015, a study of 9,789 nurses with severe depression showed that the OR of shift workers was 1.52 (95% CI: 1.38–1.67) [66].

2.2.4. Prevention of negative health effects

Unless we stop the number of increasing shift workers, occupational health services should minimize the measures taken to minimize adverse effects [67].

First, to minimize circadian rhythm disturbances, it is necessary to maintain a normal biological clock. It is recommended to take melatonin to adjust light and to use stimulants such as caffeine as needed. Bright light above 10,000 lux keeps the circadian rhythm set to awake. Exposure to bright light for more than 30 minutes in the morning will help restore a normal circadian rhythm [68]. On the other hand, when shift work ends, it is also recommended to avoid exposure to bright light by using sunglasses or blue light filters [69]. It is also necessary to provide sleep hygiene education and health checkups to shift workers as well as establish a monitoring system for negative health effects [70].

2.3. Negative aspect in the workplace: automation

When automation or robots replace simple and repetitive tasks, workers feel uneasy about employment and their livelihood. Work insecurity refers to “fear of unemployment and difficulty of re-employment” [71]. The ILO has extended work insecurity beyond the level of employment and wages to a comprehensive concept [40]. In addition, it is difficult to maintain an individual work–life balance without negotiating working conditions such as working hours, wages, paid time off, and improving the workplace with an employer. ILO redefines job insecurity. In addition, when social safety nets such as public pension payments, sick leave, annual leave, and maternity leave are not guaranteed, when there is no opportunity for job turnover or promotions, or when basic human rights such as discrimination or joining unions willfully are ignored, employment instability is affected [40].

Increased employment instability can increase mental illness. 2012 and 2014 automation workers in high-risk occupations complained of anxiety and poor health [72]. In particular, workers feel insecure about their jobs if they feel that their jobs are a substitute for robots and experience worsening poverty and health as wages decrease and welfare benefits of employers decrease [73].

Also, automation introduced to increase productivity and quality of life would paradoxically result in increased human labor time. For example, if an autonomous vehicle is introduced, it would be possible to enjoy leisure activities instead of driving during travel. However, humans could be forced to do more work to improve productivity. In this case, driving stress may be replaced by work-related stress [74].

Human beings could be in charge of tasks with poor working conditions. For example, if an automation machine malfunctions, the worker should repair the machine manually. Most industrial accidents occur during this time such that it is demanded that all machinery should be shut off and worker's security should be guaranteed. However, in many cases, safety checks are carried out without stopping the machine for upkeep. Recently, there was a death in Republic of Korea, where a worker who was directly

checking the conveyor belt in a thermal power plant was killed by the belt.

2.4. Negative aspect in the workplace: on-demand economy

In the on-demand economy, workers are independent contractors and it is difficult to earn a certain income because “demand” changes every day (sometimes every hour). In the on-demand economy, workers need to find work day-by-day or even every hour as independent contractors. Therefore, they endure the risk of fluctuating revenue, which was a primary role of corporations. In this situation, workers cannot avoid stress and instability [75]. Like most people with temporary jobs, on-demand economy workers rather than by choice, often choose on-demand jobs because they do not have a fixed job.

Because they are treated as private businesses, legal protection as a worker is difficult. Currently, independent workers are not part of the “worker” class defined by labor laws and on-demand employers are not obliged to provide welfare including pensions, insurance, paid time off, maternity leave, and sick leave. This is because, through the platform, the consumer and supplier of labor interact and provide labor outside the supervision and direction of the employer. This type of economy has the advantage of creating new employment opportunities and enabling flexible work, but it is hard to distinguish between individual operators and workers. Therefore, it is hard to provide legal protection for OHS [75]. In the case of employment relations, platform companies must provide various pensions, insurance, and leave based on labor laws, but in the platform business, employers are not obliged to provide welfare [75]. Therefore, they are not subject to restrictions regarding wages and working hours guaranteed by various labor laws in the employment relationship. As a result, it is difficult to receive social insurance benefits. In the United States, there was a lawsuit in which Uber drivers argued that they should be treated as Uber employees and they demanded payment of the cost of doing business on the premise of an employment relationship. In the United Kingdom, there was a lawsuit raised by Uber drivers claiming the right to a minimum wage and vacation. Also, in Republic of Korea, there was a lawsuit case that injured delivery man who are enrolled in delivery agency received compensation. And Republic of Korea Worker’s Compensation & Welfare Service collects compensations from the delivery agency, but agency filed a lawsuit for cancellation of the taxation. They declared that worker was not their employees, and the delivery agency do not have any responsibility for the delivery man [75]. As such an example, it is hard to adapt traditional concept for employment to new employment. To respond to new employment relations, the Korean government has recently extended the concept of “workers” in the Industrial Safety and Health Law as “those who provide work for wages to businesses or workplaces of any kind” [76].

In on-demand economy employment, independent workers contract with employers directly. Platform vendors can exploit platform worker labor in dominant positions [77]. In addition, for independent workers, unions are hard to form. In platform businesses, one independent worker registers on multiple platforms and provides labor individually according to the consumer’s needs, so there is little sense of belonging to the workplace and little sense of solidarity with colleagues. As on-demand economy becomes more common, the sense of community will be deteriorated by our me-centered society. Unstable employment tends to negatively affect health status [78] as it causes psychological and physical health risks, such as low mental health, dissatisfaction with physical health, anxiety, or high blood pressure.

Job insecurity is a complex and multifaceted problem, but there are some ways to improve it. Governments can filter out false contracts and enforce long-term contracts through labor-hire licensing [79]. To ensure an independent worker’s status, the government provides minimum social safety nets such as unemployment payments. It is also a possible solution to establish a market, which can afford to pay for it, for example, permitting only limited areas of flexible labor [80]. In reality, to recognize platform labor, alternatives such as basic income, basic labor rights, and social security; direct ownership and operation of government or local government platforms; and the formation of platform labor unions have been suggested [81].

2.5. Who should be responsible for providing OHS to on-demand business?

The Korean Occupational Safety and Health Act imposes OHS obligations on the government, employers, and workers. The government has the responsibility for disaster prevention of workplaces such as establishing and enforcing OHS policies, research and development of technology for safety and health, and the installation and operation of facilities. The employer is obliged to comply with the Industrial Safety and Health Act, the standards for the prevention of industrial accidents, and to provide a comfortable work environment and working conditions. Workers are obliged to observe the precautions necessary to prevent industrial accidents and to observe measures to prevent industrial accidents [82].

At present, the social security system for some special independent workers as worker is the only worker’s compensation insurance in Republic of Korea. However, if a worker works for several companies, he/she can only partake in a voluntary subscription scheme where he/she pays a 100% premium [83]. Under current law, it is impossible for an employer to pay workers compensation insurance for platform workers. In addition, because the employee is not a worker (a worker under the Labor Standards Act) for a single employer, the employer’s liability and obligation regarding OHS services is not imposed. Therefore, it is difficult for platform workers to manage chronic diseases, work-related diseases, and occupational diseases due to difficulties in health examination and health care.

3. Missions of OHS to prepare for the FIR

3.1. Re-definition of decent work

Labor is indispensable. Even if a machine replaces labor, human labor is indispensable. Labor is also necessary for the development of human beings, both culturally and psychologically. Labor is also needed to contribute to society and to protect the dignity and value of individuals [84]. In a world where jobs are scarce, employment opportunities must be fair. In other words, it is necessary to discuss who is going to perform decent work and bad work. It is also necessary to renew the definition of working hours in the situation where fragmented labor is universalized and globalization causes social time constraints to gradually disappear.

To date, ideal jobs have been thought of as stable jobs where workers receive fixed salaries. However, as nonstandard employment becomes popular, it is necessary to re-establish the concept of stable jobs and good jobs. In the “Declaration of Social Justice for a Fair Globalization” adopted in 2008, the ILO “convinced that in a world of growing interdependence and complexity and the internationalization of production: the fundamental values of freedom, human dignity, social justice, security and nondiscrimination are essential for sustainable economic and social development and efficiency” [85]. Decent work should involve many dimensions. It

means not only productivity, fair income, and workplace safety, but also guarantee of social security for the family, individual self-development and social integration, freedom of individual expression, and participation of union labor in the workplace. In other words, the concept of decent work is a set of values that go beyond fixed, high wages, stable working hours, and stable employment conditions [85].

3.2. Paradigm shift of OHS

An occupational disease is a disease caused by the working environment or conditions for the purpose of livelihood. Occupational diseases are not limited to specific organs, so treatment is difficult. Therefore, OHS emphasizes prevention and reward rather than focusing on treatment or rehabilitation. Occupational medicine originated from industrial medicine centering on occupational diseases in manufacturing and it was extended to occupational medicine, which encompasses the entire occupation.

Currently, most of the OHS services are in business units. However, as the employment relations change with the FIR, the units and responsibilities for managing workers exposed to harmful factors become unclear. Currently, OHS services in asbestos business units cannot take care of independent workers employed on a project-by-project basis. In other words, OHS services should be changed from an employer-centric to a public health approach, as set out in the WHO's Health and Safety Convention [86].

The same is true of industrial accidents. In case of working as a project unit, it is difficult to apply the present system that estimates and compensates based on exposure to harmful factors. In other words, in the age of the FIR, labor is not continuous or constant. In such a working environment, there is a lack of grounds for judging whether an individual's illness is caused by a certain occupation. Even if there are many problems in the current industrial accident compensation systems, in the current systems, there are the consensus that specific jobs must have specific risk factors in common. So, it was possible to assess job hazard analysis by job groups. However, when constant and continuous jobs are scarce, and people have more than one job by their needs, it was hard to assess risk of jobs. Furthermore, in this situation, current industrial accident compensation system cannot protect independent workers. Therefore, this should also be changed from an employer-centered approach to a public-health approach [86].

Each country has to make institutional arrangements and broad legislative measures to ensure that the ILO's international labor standards apply equally to its own regulations and policies [44]. International labor standards cover basic agreements. The Equal Remuneration Convention seeks to ensure that a worker who provides equal value is not discriminated on the basis of sex, race, color, religion, political opinion, socioeconomic status, social origin, or age. Particularly, the freedom of association, the right to collective bargaining, OHS, and the protection of employment and discrimination are necessary. Wages of temporary workers should not be lower than those of other workers who do the same or similar things. In addition, temporary workers should be provided with maternity protection, paid leave, paid holidays, and sick leave [40].

Each country should also prepare for the labor market, which has no national boundaries because of the development of the FIR technology. International standard rules are required for working conditions. A labor market in developing countries should no longer be viewed in terms of being regulation-free. In 2019, the ILO describes labor standards in international markets under the title "Rules of the game" [44]. It must be ensured that labor does not interfere with personal freedom and safety, and does not undermine its dignity. In other words, labor standards of international

markets are being proposed so that the aim of human labor is to improve the life of humanity as a whole, not for economic development itself.

3.3. Need for a network replacing the traditional labor union to claim the new rights of independent workers

With the FIR, traditional unions have difficulty negotiating with their employers. The labor union participation rate in developed countries is decreasing compared with the 1970s [87]. As various work relationships such as suppliers, subcontractors, non-governmental organizations, and other labor relations are applied, and the characteristics of workers such as women, youth, and immigrants are diversified, labor organization innovation is needed.

As technology is developed, globalization promotes the decentralization of production. Multinational corporations now design and produce new products and manage production lines for workers in their home countries. This is a system which constructs and produces factories in middle-income or developing countries which are also consumer markets. At this time, workers in their home countries can demand a safe working environment by organizing labor unions based on relatively strong labor laws and social safety networks in developed countries. Workers in developing countries are likely to have little bargaining power in their relationship with employers because they cannot organize trade unions in their own countries, where social and legal infrastructures are lacking [84].

Thus, in the era of the FIR, where the on-demand business will become the dominant employment relationship, a new type of union is needed to represent the interests of independent workers. Unions based on a single workplace should also learn about the employment relationship between on-demand and platform businesses. The new union should go beyond the workplace to be a union of industrial units or a community-based union.

The new union should first demand the right of the independent worker and understand that industrial accidents caused by new technologies are unpredictable. In particular, the employer must disclose to workers all the health hazards that may arise in the event of a new chemical or physical process used at the manufacturing stage in a transparent manner. The nature of the employment relationship of the platform business is likely to be attributed to the individual independent worker. In addition to efforts to clarify responsibility, it is necessary to disclose information on harmful substances and harmful environments including trade secrets.

3.4. Government policy

Because of the effects of the FIR, a large number of jobs will be replaced by machines and new jobs will be created. There is a concern of mass unemployment in the transitional period of technological change. Capital income is overwhelmingly higher than labor income and mass unemployment is likely to make a society unstable. In addition, when nonstandard employment becomes mainstream, there is a concern that the number of workers who cannot be protected by the current labor law is likely to increase. Furthermore, there is a need for social security for those without capital. The gap between the rich and the poor is an element of social unrest. Therefore, redistribution of the profits of capital by means of a robot tax or basic income system is being considered.

It is necessary to reform the system to protect workers' health rights. With the expansion of platform business, on-demand business may make the business owner unclear and the entity that is responsible for providing the OHS service may disappear.

Therefore, to broaden the scope of OHS service and compensation, it is necessary to revise the definition of ‘full property’ or ‘worker character.’

We must establish a system to monitor the emergence of new forms of OHS issues, nurture experts to be responsible for changing OHS issues, and enact new labor laws and social insurance systems according to changes of the labor environment.

4. Conclusions

To cope with the emerging OHS issues in the fourth industrial revolution era, we need to establish new concepts of ‘decent work,’ and standardized regulations which apply to enterprises in each country, to develop public health as an OHS service, surveil emerging OHS events and networks among independent workers, and nurture experts to be responsible for new OHS issues.

Declaration of Competing Interest

All authors have no conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.shaw.2019.09.005>.

References

- [1] Schwab K. The Fourth Industrial Revolution: what it means, how to respond. Foreign Affairs. 2016 [Internet], <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/>. Available from:..
- [2] Hull J. The second industrial revolution and the staples frontier in Canada: rethinking knowledge and history. *Sci Can* 1994;18(1):22–37 [Internet], <https://www.erudit.org/en/journals/scientia/1994-v18-n1-scientia3232/800373ar/>. Available from:..
- [3] Toffler A. The third wave, vol. 484. New York: Bantam books; 1980.
- [4] Bloem J, Van Doorn M, Duivestein S, Excoffier D, Maas R, Van Ommeren E. The fourth industrial revolution : things to tighten the link between IT and OT contents. Groningen Sogeti VINT 2014.
- [5] Gartner. Operational technology (OT). Gartner IT glossary. Available from: <https://www.gartner.com/it-glossary/operational-technology-ot/>.
- [6] Boute RN, Disney SM, Van Mieghem JA. Dual sourcing and smoothing under non-stationary demand time series: re-shoring with speedfactories. *Ssrn*; 2018. p. 1–42.
- [7] Ahn SH, Lee M-H. Fourth industrial revolution impact: how it changes jobs. *Korean Acad Soc Bus Adm Integr Conf* 2016;8:2344–63 [Internet], <http://www.riss.kr/link?id=A102057938> [In Korean]. Available from:..
- [8] Establishment Survey, 1960–2019. Bureau of Labor Statistics. Available from: <https://www.bls.gov/ces/>.
- [9] Labor force statistics from the current population survey. U.S. Department of Labor, Bureau of Labor Statistics, And Haver Analytics.
- [10] Erevelles S, Fukawa N, Swayne L. Big data consumer analytics and the transformation of marketing. *J Bus Res* 2016;69(2):897–904.
- [11] Dongmin B, Hyun-soo P, Kihwan O. Focus: big data trends and policy implications. *Inf Commun Broadcast Policy* 2013;(55):37–74 [In Korean].
- [12] Beyer MD. The importance of ‘big data’: a definition, vol. 21. Stamford: CT Gart; 2012. p. 2014–8.
- [13] Kelly J, Vellante D, Floyer D. Big data market size and vendor revenues. Report. Wikibon; 2012.
- [14] Beyer M, Lovelock J, Sommer D, Adrian M. Big data drives rapid changes in infrastructure and \$232 billion in IT spending through 2016. *Gart Res* 2012.
- [15] Schellong ARM. Benchmarking EU e-government at the crossroads: a framework for e-government benchmark design and improvement. *Transform Gov People, Process Policy* 2010;4(4):365–85.
- [16] Yildiz M. E-government research: reviewing the literature, limitations, and ways forward. *Gov Inf Q* 2007;24(3):646–65 [Internet], <http://www.sciencedirect.com/science/article/pii/S0740624X07000056>. Available from:..
- [17] Graetz G, Michaels G. Robots at Work. *Rev Econ Stat* 2018;100(5):753–68 [Internet], https://www.scopus.com/inward/record.uri?eid=2-s2.0-85058934283&doi=10.1162%2Frest_a_00754&partnerID=40&md5=58691772edc819f21acd008158b9728. Available from:..
- [18] Backer K De, DeStefano T, Menon C, Suh JR. Industrial robotics and the global organisation of production. *OECD Science, Technology and Industry Working Papers*; 2018.
- [19] Acemoglu D, Restrepo P. Robots and jobs: evidence from US labor markets. *Ssrn*; 2017 [October].
- [20] Carbonero F, Ernst E, Weber E. Robots worldwide: the impact of automation on employment and trade. *ILO Res Dep Work Pap* 2018;36.
- [21] Myung-bae Y. An economic-paradigm shift and new economic policy in the era of the 4th industrial revolution. *J Korean Natl Econ* 2018;36(4):23–61 [Internet], <http://kiss.kstudy.com/thesis/thesis-view.asp?key=3642077> [In Korean]. Available from:..
- [22] Frey CB, Osborne MA. The future of employment: how susceptible are jobs to computerisation? *Technol Forecast Soc Chang* 2017;114:254–80 [Internet] Available from: <http://www.sciencedirect.com/science/article/pii/S0040162516302244>.
- [23] Se-Um K. Analysis of high-risk employment ratio. *Labor Rev* 2016;49–58 [In Korean].
- [24] Ka-Yul P, Young Min C, Sung- Min H, Yongsu S. A study on the effects of jobs on technological change. *Policy Sci Technol* 2016 [In Korean].
- [25] Autor DH. Why are there still so many jobs? The history and future of workplace automation. *J Econ Perspect* 2015;29(3):3–30.
- [26] Amazon Go. Amazon Go. Amazon Go; 2016. Available from: <https://www.amazon.com/b?ie=UTF8&node=16008589011>.
- [27] Autor DH, Dorn D. The growth of low-skill service jobs and the polarization of the US labor market. *Am Econ Rev* 2013;103(5):1553–97 [Internet], <http://www.aeaweb.org/aer/>. Available from:..
- [28] Nelson SD, Simek JW. Future of the professions: how technology will transform the work of human experts. *The Res Gestae* 2015;59(Issue 9):40–1.
- [29] Viswanath P, Mathew M. Race against the machine: how the digital revolution is accelerating innovation, driving productivity and irreversibly transforming employment and the economy; 2009. p. 1–9. 2.
- [30] Srnicek N. The challenges of platform capitalism: understanding the logic of a new business model. *Juncture* 2017;23(4):254–7 [Internet], <http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%292050-5876/issues>. Available from:..
- [31] Wallsten S, Wallsten S. The competitive effects of the sharing economy : how is uber changing taxis. *Technol Policy Inst* 2015;22:1–21 [Internet], <https://techpolicyinstitute.org/wp-content/uploads/2015/06/the-competitive-effects-of-the-2007713.pdf>. Available from:..
- [32] Stefano V De. The rise of the just-in-time workforce: on-demand work, crowdwork, and labor protection in the gig-economy. *Information C. Comp Labor Law Policy J* 2015;37:471–504 [Internet], https://heinonline.org/HOL/Page?handle=hein.journals/cllpj37&div=34&sent=1&casa_token=&collection=journals&t=1561373725. Available from:..
- [33] Katz LF, Krueger AB. The rise and nature of alternative work arrangements in the United States, 1995–2015. *ILR Rev* 2019;72(2):382–416 [Internet], <http://10.0.4.153/0019793918820008>. Available from:..
- [34] Contractor FJ, Kumar V, Kundu SK, Pedersen T. Reconceptualizing the firm in a world of outsourcing and offshoring: the organizational and geographical relocation of high-value company functions. *J Manag Stud* 2010;47(8):1417–33.
- [35] Craig RL. Understanding taylorism. *Br J Sociol* 1978;29(2):185–202.
- [36] Kenney M, Zysman J. The rise of the platform economy. *Issue Sci Technol* 2016;32(3):61.
- [37] News Y. The Safety exam of Taean Thermal Power Plant was “Passed” at last October, which cause death accident. *yunhap news* [Internet]. Available from: <https://www.mk.co.kr/news/society/view/2018/12/782954/>.
- [38] Lee K, Kim Y. Statistics of integrated industrial accidents between main contract and subcontract; 2016.
- [39] Champeau M, Arsac M, Pineau P, Denyset F. Non-standard employment around the world, vol. 44. *ILO Cataloguing in Publication Data*; 2016. p. 1925–6.
- [40] Unicef Child Labour. UNICEF. 2017. Available from: <https://data.unicef.org/topic/child-protection/child-labour/>.
- [41] Mun-sub Y, Hyun-Dae C. A study on the reduction of manufacturing jobs and countermeasures by the entry of advanced countries. *STPEI Insight* 2014;134(0):1–16 [Internet], <http://kiss.kstudy.com/public/public2-article.asp?key=50264670> [In Korean]. Available from:..
- [42] Simchi-Levi D. US re-shoring: a turning point, *Annual Re-shoring Report*; 2012.
- [43] International Labour Office. Rules of the game: a brief introduction to International Labour Standards. *Int Labour Off* 2014;1–130.
- [44] Chen YK. Challenges and opportunities of internet of things. In: 17th asia South pacific des autom conf IEEE 2012. p. 383–8.
- [45] Goodman PS. The robots are coming, and Sweden is fine. *The NewYork Times*. 2017 [Internet], <https://www.nytimes.com/2017/12/27/business/the-robots-are-coming-and-sweden-is-fine.html>. Available from:..
- [46] Sunwook K, Manury AN, Joseph LG. Augmented reality “smart glasses” in the workplace: industry perspectives and challenges for worker safety and health. *IIE Trans Occup Ergon Hum Factor*. 2016;1:253–8. Institute of Industrial Engineers.
- [47] Le QT, Pedro A, Park CS. A social virtual reality based construction safety education system for experiential learning. *J Intell Robot Syst Theory Appl* 2015;79(3–4):487–506.
- [48] Ciullo A, Catalano M G, Bicchì A, Ajoudani A. A supernumerary soft robotic hand-arm system for improving worker ergonomics. *Int Symp Wearable Robotics* 2018:520–4.
- [49] Friedman TL. The world is flat: a brief history of the twenty-first century. New York: Macmillan; 2005.

- [51] Schwab Klaus. Globalization 4.0: a new architecture for the fourth industrial revolution. Foreign Affairs. 2019. Available from: <https://www.foreignaffairs.com/articles/world/2019-01-16/globalization-40>.
- [52] Birth K. Time and the biological consequences of globalization. *Curr Anthropol* 2007;48(2):215–36.
- [53] Wehr TA. Photoperiodism in humans and other primates: evidence and implications. *J Biol Rhythms* 2001;16(4):348–64.
- [54] KOSHA. Korean Working conditions Survey. KOSHA. p. [In Korean]. Available from: http://kosis.kr/statHtml/statHtml.do?orgId=380&tblId=DT_380002_E006&conn_path=13.
- [55] Kim YS, Cho HH. First and second Korean working conditions survey: a comparison between South Korea and EU countries. *Korean J Occup Heal Nurs* 2015;23(4):277–86 [In Korean].
- [56] Yvan T, Alain R, David T. Association between light at night, melatonin secretion, sleep deprivation, and the internal clock: health impacts and mechanisms of circadian disruption. *Life Sci* 2017;173:94–5.
- [57] Eva SS, Francine L, Frank ES, Walter CW, David JH, Ichiro K, et al. Rotating night shifts and risk of breast cancer in women participating in the nurses' health study. *J Natl Cancer Inst* 2001;93(20):1563–4.
- [58] Schernhammer ES, Kroenke CH, Laden F, Hankinson SE, Kroenke H. Night work and risk of breast cancer. *Epidemiology* 2014;17(1):108–11. * Volume Number.
- [59] Jia Y, Lu Y, Wu K, Lin Q, Shen W, Zhu M, et al. Does night work increase the risk of breast cancer? A systematic review and meta-analysis of epidemiological studies. *Cancer Epidemiol* 2013;37(3):197–206. <https://doi.org/10.1016/j.canep.2013.01.005> [Internet] Available from:..
- [60] Eva SS, Francine L, Frank ES, Walter CW, David JH, Ichiro K, et al. Night-shift work and risk of colorectal cancer in the nurses' health study. *J Natl Cancer Inst* 2003;95(11):825–6.
- [61] Conlon M, Lightfoot N, Kreiger N. Rotating shift work and risk of prostate cancer [1]. *Epidemiology* 2007;18:182–3.
- [62] Vyas MV, Garg AX, Iansavichus AV, Costella J, Donner A, Laugsand LE, et al. Shift work and vascular events: systematic review and meta-analysis. *BMJ* 2012;345 [Internet]. <http://www.bmj.com/cgi/doi/10.1136/bmj.e4800>. e4800–e4800. Available from:..
- [63] Knutsson A, Kempe A. Shift work and diabetes - a systematic review. *Chronobiol Int* 2014;31(10):1146–51.
- [64] Koo YS, Song J-Y, Joo E-Y, Lee H-J, Lee E, Lee S-K, et al. Outdoor artificial light at night, obesity, and sleep health: cross-sectional analysis in the KoGES study. *Chronobiol Int* 2016;33(3):301.
- [65] Bara A-C, Arber S. Working shifts and mental health – findings from the British Household Panel Survey (1995–2005). *Scand J Work Environ Health* 2009;35(5):361.
- [66] Lee HY, Kim MS, Kim O, Lee I-H, Kim H-K. Association between shift work and severity of depressive symptoms among female nurses: the Korea Nurses' Health Study. *J Nurs Manag* 2016;24(2):192–200.
- [67] Costa G. Shift work and health: current problems and preventive actions. *Saf Health Work* 2010;1(2):112–23.
- [68] Crowley SJ, Eastman CI. Phase advancing human circadian rhythms with morning bright light, afternoon melatonin, and gradually shifted sleep: can we reduce morning bright-light duration? *Sleep Med* 2015;16(2):288–97.
- [69] Lee C, Smith M, Eastman C. A compromise phase position for permanent night shift workers: circadian phase after two night shifts with scheduled sleep and light/dark exposure. *Chronobiol Int* 2006;23(4):859.
- [70] Pallesen S, Bjorvatn B, Magerøy N, Saksvik IB, Waage S, Moen BE. Measures to counteract the negative effects of night work. *Scand J Work Environ Health* 2010;36(2):109.
- [71] Jae Ryang N. Research on the employment instability and its causes. *J Labor Econ* 2005;28(3):111–39 [Internet]. <http://kiss.kstudy.com/thesis/thesis-view.asp?key=2526319>. Available from:..
- [72] Patel PC, Devaraj S, Hicks MJ, Wornell EJ. County-level job automation risk and health: evidence from the United States. *Soc Sci Med* 2018;202:54–60.
- [73] De Witte H, Pienaar J, De Cuyper N. Review of 30 years of longitudinal studies on the association between job insecurity and health and well-being: is there causal evidence? *Aust Psychol* 2016;51(1):18–31.
- [74] Rojas-Rueda D. Autonomous vehicles and mental health. *J Urban Des Ment Heal* 2017;3(2).
- [75] Hyun-Sung L. A research on labor of on-demand economy; 2017.
- [76] Industrial Safety and Health Act. Act No.15588 Republic of Korea. Available from: http://elaw.klri.re.kr/kor_service/lawView.do?hseq=43289&lang=ENG.
- [77] JuHwan K. Major issues and needs for driving union. The spread of platform labor establishment of "mobility Support Project team". Seoul Labor Rights Center; 2018.
- [78] Sun Hee C, Woo Seok J, JaHae L. The effect of employment stability on the health status of wage workers. *Korean Soc Sociol* 2007 [Korean Society of Sociology].
- [79] Cavanaugh E. Why is job insecurity so prevalent in Australia?. The Mckell Institute. 2019 [Internet]. <https://mckellinstitute.org.au/research/articles/explainer-why-is-job-insecurity-so-prevalent-in-australia/>. Available from:..
- [80] Soo-Keun K. Understand platform work. Korean industrial Hygiene Association. 2019. p. 20–37 [Internet]. https://kiha21.or.kr/monthly/2019/01/2019_01_09_s369.pdf. Available from:..
- [81] Kim SH. The 21st century proletarian "platform labor. Minplus. 2018 [Internet]. <http://www.minplus.or.kr/news/articleView.html?idxno=4428>. Available from:..
- [82] Korea. Occupational safety and health act. Act No.15588. Korea; 2018. Available from: http://elaw.klri.re.kr/kor_service/lawView.do?hseq=43289&lang=ENG.
- [83] Industrial safety and health Act. Republic of Korea;.
- [84] Uma Rani A, Anita A, Urvashi A, Bjorn Serritzlev B, Janine Marie B. A reflection on the future of work and society. Geneva: International Labour Office. 2017. Available from: https://www.ilo.org/wcmsp5/groups/public/-dgreports/-cabinet/documents/newsitem/wcms_617754.pdf.
- [85] International Labour Office. ILO declaration on social justice for a fair globalization; 2008.
- [86] WHO global plan of action on workers' health baseline for implementation. WHO Doc Prod Serv; 2017.
- [87] OECD Publishing. OECD employment outlook 2015; 2015. Available from: http://www.oecd-ilibrary.org/employment/oecd-employment-outlook-2015_empl_outlook-2015-en.