



3rd World Conference on Technology, Innovation and Entrepreneurship (WOCTINE)

## Industry 5.0 and Human-Robot Co-working

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### Abstract

According to many, we are at the brink of the fourth industrial revolution. The theme of Industry 4.0 is "Smart Manufacturing for the Future". Now, some futurists even discuss what the fifth industrial revolution's theme will be. There are a few visions for Industry 5.0. One emerging theme is human-robot co-working. In recent years, we have seen significant advancements in robotics and artificial intelligence (AI) research. Today, there are robots for various purposes at affordable prices in the market. It is not long before we closely interact with robots in our lives and workplaces. Testing autonomous cars in traffic is a promising example of this upcoming trend. There are companies having an employee record for robots or AI applications. While there are many studies on human-robot collaboration for low-level tasks with a focus on robot development, we lack studies focusing on organizational issues emerging from human-robot co-working. In this study, we discuss the possible issues related to human-robot co-working from the organizational and human employee's perspective. We believe the issues identified in this study will be the focus of many upcoming organizational robotics research studies.

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Peer-review under responsibility of the scientific committee of the 3rd World Conference on Technology, Innovation and Entrepreneurship

*Keywords:* Industry 4.0; Industry 5.0; Organizational Behaviour; Human-Robot Coordination; Robots in Organizations; Human-Robot Co-working; Organizational Robotics

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### 1. Introduction

Industrial revolutions are mostly targeted on separating man's work with machine's work. Either we call it a "machine" or a "robot", these machines will eventually take responsibility for most of the jobs that are hard, boring, or dangerous for people. For example, cleaning a room or an office can be easily done by cleaning robots. It is only

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a matter of time that all cleaning jobs will be done by robots in the future. Although today, we are at a point where both robots and people can do the cleaning jobs, past experience about the speed of automation shows that in the future people do less cleaning than the robots do. The speed of automation diffusion into our lives is largely dependent on the technology level and the acceptance of robots by people. Due to the possible significant impacts of robots on society, it is important to study the interactions between humans and robots and their effects on society in general.

Since its introduction in 2011, Industry 4.0 generated a lot of interest. There are many research studies and conferences on Industry 4.0. In addition, some scholars and futurists already started the discussion on Industry 5.0 [7, 8]. They put forward various visions for Industry 5.0. One emerging theme for Industry 5.0 is human-robot co-working [7]. At this point, we cannot be sure what the theme of Industry 5.0 will be. But we can be sure that human-robot co-working will be a significant innovation for society and it will significantly affect the way we conduct businesses.

In the next section, we discuss industry 5.0. We further compare Industry 4.0 and two visions for Industry 5.0. In the third section, we focus on the issues related to human-robot co-working. Finally, we conclude the study with a brief discussion of future research opportunities.

## 2. Industry 5.0

We had three industrial revolutions. Now, to most, we are experiencing the fourth one. Figure 1 depicts these revolutions in a timeline. Note the shortening time span between revolutions. There were 100 years between the first three revolutions. It only took around 40 years to reach to the fourth one from the third. It is possible that to reach to the fifth one will take less than 40 years.

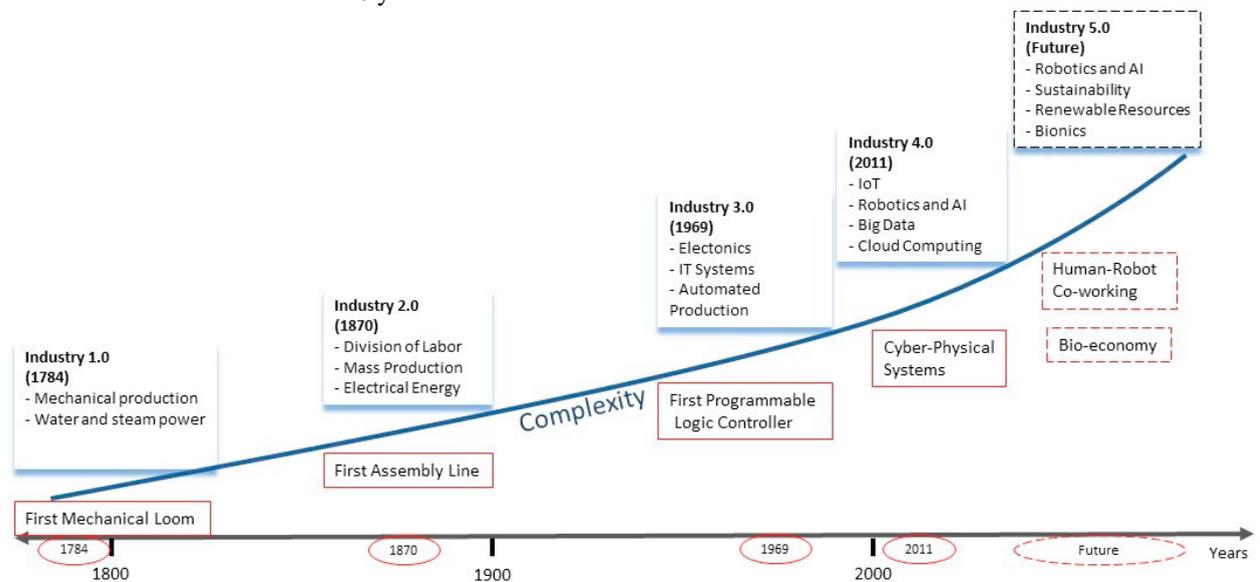


Fig. 1. From Industry 1.0 to Industry 5.0.

Industry 4.0 was an initiative by the German Government. The theme of Industry 4.0 is "Smart Manufacturing for the Future". Its goal is simple and similar to previous revolutions: To increase productivity and achieve mass production using innovative technology. There are a number of trending technologies helping to achieve Industry 4.0. The main trending ones are the internet of things, robotics and artificial intelligence (AI), big data, and cloud computing. There are also other technologies supporting Industry 4.0. 3D printing, virtual and augmented reality, smart factories, smart logistics, ambient intelligence [6] are among these. Note that these technologies are not specifically developed for Industry 4.0. The vision of Industry 4.0 bring these technologies together toward the goal of smart manufacturing. There are also criticisms on Industry 4.0 [12] since it is a top-down government initiative with a predefined notion [7, 13].

Currently, two visions emerge for Industry 5.0. The first one is “human-robot co-working”. In this vision, robot and humans will work together whenever and wherever possible. Humans will focus on tasks requiring creativity and robots will do the rest. Another vision for Industry 5.0 is bioeconomy [7]. Smart use of biological resources for industrial purposes will help to achieve a balance between ecology, industry, and economy. According to the European Commission, bioeconomy is “the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products, and bioenergy. It includes agriculture, forestry, fisheries, food, and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. Its sectors have a strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science, and social sciences), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge.” [14]. Biologization is the guiding principle of the bioeconomy and has the potential to create a fundamental change in industries [15]. Therefore, bioeconomy may be the theme or at least a part of the next industrial revolution. Table 1 provides a comparison of Industry 4.0 and Industry 5.0 visions. See [7] for a detailed discussion of these visions. Note that Industry 5.0 may be about both human-robot co-working and bioeconomy. Moreover, other themes, such as space life, space industries, and space mining, may be the next or a part of the next revolution. Scientists are already cautioning us to be careful in using space resources [16]. Space mining may turn into the next “gold rush”.

Table 1. A Comparison of Industry 4.0 and Industry 5.0 Visions

	<b>Industry 4.0</b>	<b>Industry 5.0 (Vision 1)</b>	<b>Industry 5.0 (Vision 2)</b>
<b>Motto</b>	Smart Manufacturing	Human-Robot Co-working	Bioeconomy
<b>Motivation</b>	Mass Production	Smart Society	Sustainability
<b>Power Source</b>	Electrical power Fossil-based fuels Renewable power sources	Electrical power Renewable power sources	Electrical power Renewable power sources
<b>Involved Technologies</b>	Internet of Things (IoT) Cloud Computing Big Data Robotics and Artificial Intelligence (AI)	Human-Robot Collaboration Renewable Resources	Sustainable Agricultural Production Bionics Renewable Resources
<b>Involved Research Areas</b>	Organizational Research Process Improvement and Innovation Business Administration	Smart Environments Organizational Research Process Improvement and Innovation Business Administration	Agriculture Biology Waste Prevention Process Improvement and Innovation Business Administration Economy

### 3. Issues in Human-Robot Co-working

In a previous study [2], we discussed the issues related to integrating robots into organizations. The issues identified indicate prospects of significant changes in organizations. The issues include evolutions in organizational behavior, structure, workflow, ethics, and work environment. Furthermore, acceptance of robots in workplaces, discrimination against robots or people, privacy and trust in a human-robot co-working environment, redesign of the workplaces for robots, education, and training are among the important issues. Table 2 lists these issues.

Bagdasarov and her colleagues investigated the organizational considerations of working with robots [11]. They discussed the issue under three sets of factors: Individual, organizational, and robotic agent. Under each set, the authors suggest considering various factors. Employee’s age, gender, level of education, experience with technology/technical background, expectations, and social perceptiveness/interpersonal sensitivity are the individual factors. The organization’s workflow, physical environment, social/emotional context, training, and employee-robot goal alignment are the organizational factors. The robot’s appearance, behavior, capabilities for interaction, and safety are the robotic agent factors.

In the rest of the section, we focus on human-robot co-working issues not discussed in [2]. Note that some of the issues have both organizational and personal implications. It is not easy to draw a line between an organizational and personal issue.

Table 2. Issues Related to Integrating Robots into Organizations. [2]

Evolution in Organizational Behaviour
Acceptance of Robots in the Workplace
Evolution in Organizational Structures and Workflows
Evolution in Work Ethics
Discrimination against Robots or People
Privacy and Trust in a Human-Robot Collaborative Work Environment
Education and Training
Redesign of Workplaces for Robots

### 3.1. Legal and Regulatory Issues

According to one definition, a robot is *a machine that senses, thinks, and acts* [5]. This is a simple but problematic definition. What do the thinking and acting mean for a robot? Oxford dictionary defines a robot as *a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer*. Merriam Webster dictionary defines a robot as *a machine that looks like a human being and performs various complex acts (such as walking or talking) of a human being*. These definitions are problematic as well. One resorts to a vague concept such as a carrying out a complex series of actions automatically. The other one assumes that a robot looks like a human being. These vague definitions indicate that we have yet to find a satisfactory definition.

Without the necessary regulations, human-robot co-working will create many problems. First of all, we need to legally define what a robot is. While there are scientific definitions for the robot, only a legal definition of a robot is binding for businesses and organizations. There are many types of automated machines. A robot is an automated machine as well. There are automation levels defined for machines [4]. The distinction between an automated machine and a robot should be clear in a law regulating the human-robot co-working. There are also closely related entities such as drones and cyborgs. The regulations should also include the distinctions of robots from drones and cyborgs. In addition to a clear definition, the law and other relevant regulations should at least include the types of robots that can be used in workplaces, the roles and responsibilities of robots, the types of decisions robots are allowed to make regarding humans, the types of robot malfunctions and who is responsible in a robot malfunction, the division of responsibilities in robot malfunctions, whether the robot software follows certain hard-coded rules or is allowed to learn and evolve, the certifications robots require, the certification authorities and their responsibilities.

There will be many discussions regarding the regulations for robot development, manufacturing, and certifications. Are going to allow anybody, any company, or any organization to develop a robot and put the robot into our homes, our workplaces, and our lives? Currently, many countries are unsuccessful in regulating the air space for drone use. We need to be ahead of such rapid deployment of autonomous machines. The legal and regulatory issues surrounding the use of artificial intelligence, robots, drones, and cyborgs will be the focus of many research studies.

### 3.2. Personal Preference toward Working with Robots

The personal preference of using or not using a particular technology varies from human to human. There will be people who will be eager to work with robots and who will strongly oppose to the idea of working with robots. Organizations willing to benefit from human-robot co-working in their workplaces should be aware of these personal preferences. If organizations mostly consist of employees with a negative attitude toward robots, then their transition to human-robot co-working environments will not be easy or even possible. Since, human-robot co-working is not a reality yet, the personal preference toward working with robots is mostly shaped by the media rather than first-hand experiences. There are many famous movies or TV shows depicting the fantasy of robots taking over the world or fighting the human race. This negative media has an effect on personal preference toward working with robots.

### 3.3. Psychological Issues Resulting from Human-Robot Co-working

Advanced technology has a certain psychological effect on humans. Addiction to video games is considered a psychological disorder that is gaining attention. There are people with strong attachments to their smartphones. There is even a phobia called “nomophobia” meaning no mobile phobia. According to the Collins dictionary, nomophobia is defined as *a state of stress caused by having no access to being unable to use one's mobile phone*. We do not currently know whether there will be a “robophobia” or “norobophobia”. However, it is quite likely that an advanced technology such as a robot will have various unprecedented psychological effects on many employees. Psychological issues related to working with robots and their effect on organizational climates will be a research topic for organizational robotics.

### 3.4. Social Implications of Human-Robot Co-working

Humans are social creatures. They interact with their kind in various aspects of their lives including work. Having social events at work to increase work performance is a common practice in many organizations. When the number of robots in human workplaces increase, the number of humans may likely decrease. This may limit the social interactions between humans. Even if the number of human employees stays the same, the introduction of robots into workplaces may have unprecedented effects on social interactions in the workplace. Some humans may prefer robots that show social behavior. Some will think social behavior shown by robots is unreal and this kind of social robot behavior is just computer programming that is actually fake. Employees will have different views on how to interact with robots socially. The issue gets complicated when there are robots in management or superior position. Employees tend to show respect for their superiors or managers. Respect is a social behavior. Humans may get confused about whether they should respect a robot manager or not. Since, in fact, respect will mean nothing to a robot. These kinds of issues will be new, confusing, and even frustrating to many. There are studies showing that children treat robots as they treat their living pets [18]. Just like today's new generation having inevitably more interaction with smartphones and they see the smartphone as a part of their life, the future of robot-human interaction may be similar to this human-smartphone interaction. It seems social studies will be an integral part of human-robot co-working research.

### 3.5. The Changing Role of Human Resources Departments

Conducting work analyses, developing job descriptions, and filling the jobs with the people having the right qualifications are among the important responsibilities of human resources departments. Except for industries utilizing industrial robots, a vast majority of organization currently employ humans for work. As robots become a part of organizations, human resources departments will face new challenges. In addition to their current responsibilities, they will also need to identify the jobs to be handled by robots. They will basically decide the jobs to give to robots. The importance and responsibilities of human resources departments will increase. Eventually, human resources departments will evolve and they may even be named differently in the future.

Today, there are companies and businesses advertising themselves as “green”. They claim to be sensitive to the environment. The “green” businesses and organizations try to act responsibly toward the environment even though these initiatives drive up costs. In the future, there may be even businesses claiming to be “human”. These organizations will only employ humans even though being a “human” organization drives up costs assuming employing robots is a cheaper alternative. These “human” organizations will claim that they act socially responsible toward humans and they create jobs for humans.

Conducting work analyses, creating job descriptions, and identifying business processes are among the most important responsibilities of the human resource management departments. Human resource management departments will need to redo most of their work considering robots before integrating robots into their organizations.

### 3.6. The Changing Role of Information Technology Departments and Emerging of Robotics Departments

As the use of technology is becoming inevitable for organizations, the importance of information technology (IT) departments increases. To realize the vision of human-robot co-working, organizations will need to find a way to

acquire and maintain the robots. At first, this task will be likely assigned to IT departments. Later on, organizations may create robotics departments responsible for acquiring and maintaining the robots in the organization.

As robots take important responsibilities, robot maintenances and upgrades should be done in a safe and secure manner. Information assurance of robots will be important. Securing information acquired by robots will be a challenge and even complicated than securing current organizational IT infrastructures. Human-robot co-working will likely complicate assuring information and ensuring privacy at work. This will likely be an important research topic for information security researchers.

### *3.7. Ethical Issues Resulting from Human-Robot Co-working – Ethical Status of Robots*

Being honest, hard-working, and helpful are among the expected ethical behavior from human employees. Robots that are selfless, have no ambition, does not know laziness, and cannot lie will certainly have an effect on how we perceive current work ethic values. Humans may not be able to compete with robots in achieving a good ethical norm in this aspect. It is hard to predict how work ethics will evolve in a human-robot co-working environment. Furthermore, there will likely be an ethical norm defining the interactions between humans and robots. In a study, it is reported that humans may feel sorry even to events such as one robot behaving badly toward another [17]. We will have to determine the ethical status of robots in workplaces.

### *3.8. Preference toward Types of Robots to Work with (Learning or Rule-based Robots)*

A great deal of research goes into machine learning and developing robots that can learn. However, machine learning may have consequences. Robots with machine learning capabilities may show unpredictable behavior. If this unpredictable behavior is frequent, then humans will be reluctant to assign important tasks to robots. Depending on the behavior, some people may even refuse to work with robots. On the other hand, rule-based robots are predictable. However, they will be limited in their learning capabilities. As a result, we will probably face a tradeoff in the types of robots that will be used in human-robot co-working environments. We may need to choose between a learning robot with the possibility of unpredictable behaviors and a predictable rule-based robot that is incapable of or limited in learning.

### *3.9. Learning to Work with Robots*

Humans know robots as a concept from books and movies. However, human-robot co-working will be new to almost all employees in offices. While interacting with robots is expected to be easy, the actual experience may be different from the expectancy. We may have to learn how to behave toward the robot to get what we really want. Non-verbal communication is an important part of human interaction. Robots may or may not understand these non-verbal communications. Humans will need time to learn and get used to working with robots.

Furthermore, there will be robots with different capabilities. Some will be advanced and some will not. It will be hard and confusing for humans to distinguish robots with different capabilities. Robot manufacturers will need to find a way to develop robots that can inform about their capability without confusion. Humans will need to learn how to work with different kinds of robots.

### *3.10. Negative Attitude Toward Robots due to Shrinking Human Workforce*

According to a study, what humans most fear about robots at both personal and societal level is the loss of jobs [9]. As robots start taking over jobs from humans, there will likely be a negative attitude toward robots. Some will argue that the use of robots will increase unemployment. The counter-argument to this view is that new jobs will be created. History shows that this counter-argument has validity. While robots take over mundane jobs, humans will focus on jobs requiring creativity, artistry, research, and development. However, there is a dilemma in this view. The people losing jobs will unlikely to possess the education, training, and skills to assume the responsibility of jobs requiring creativity. Consider a middle age female housekeeper at a hotel. When she loses her job to a robot, it is unlikely that she will possess the necessary qualifications for a position as a marketing campaign manager that will likely be a job

for humans in the robotic age. The worker unions will strongly oppose to robots if they cause unemployment. The constituents having this negative attitude will reach out to their politicians making robotic laws and regulations or voting for them. As a result, at least in the early years of the robotic age, people may have a negative attitude toward robots as they cause unemployment.

### 3.11. Humans Competing with Robots or Robots Complementing Humans

The positions and roles robots assume will be a source of discussion among scientists and practitioners. Placing robots in roles complementing what humans do will be an easier solution. Humans will not lose jobs and consequently, they will not feel threatened by robots. Most humans may even prefer obedient robot assistants. The robots in these positions will help humans complete tasks without the burden of managing a human assistant. Furthermore, as robots take over mundane and cumbersome tasks, humans will have more time for tasks requiring creativity and higher intelligence. Robots complementing humans is an easier, straightforward, and less problematic solution for creating human-robot co-working environments. On the other hand, some people may advocate that robots may or even shall take positions that humans compete for. They will argue that this will improve the performance of human employees. Naturally, humans compete with each other for positions in organizations. Adding robots into this competition will complicate management and organizational behavior. There are even studies investigating the reactions of humans to a commanding robot [10].

Table 3. Human-Robot Co-working related Issues.

Legal and Regulatory Issues
Personal Preference toward Working with Robots
Psychological Issues Resulting from Human-Robot Co-working
Social Implications of Human-Robot Co-working
The Changing Role of Human Resources Departments
The Changing Role of Information Technology Departments and Emerging of Robotics Departments
Ethical Issues Resulting from Human-Robot Co-working – Ethical Status of Robots
Preference toward Types of Robots to Work with (Learning or Rule-based Robots)
Learning to Work with Robots
Negative Attitude Toward Robots due to Shrinking Human Workforce
Humans Competing with Robots or Robots Complementing Humans

## 4. Conclusions

Whether Industry 5.0 will be about human-robot co-working or not, human-robot co-working will still be a big change for organizations. In fact, robots in our lives will likely to be a significant change for mankind. We are trying to build a technology that resembles humans in many aspects. Some will find this innovative and exciting. Some will find it outrageous, frustrating, even a threat to mankind. This negative attitude toward robots is boosted by the media. Our survey studies regarding robots in society will be biased by this negative attitude. One of the first scales developed for measuring attitude toward robots has a negative perspective. Until humans actually live and work with robots, we cannot be sure how humans will react to robots. The attitude toward robots will likely to evolve as humans experience with robots. Today's children may react differently from how our generation reacts. Since they will grow with this or similar technologies. Their children will be in a society with robots. We should be aware of this generation differences and start building a robotic society in which humans benefit from this technology to its maximum extent and try to minimize the consequences. In this study, we discussed the possible issues that may arise from human-robot co-working. Legal, regulatory, psychological, social, ethical issues are among the main issues. While changing the role of human resources and information technology departments, different personal preferences toward working with robots, types of robots preferred to work with, learning to work with robots, competing or cooperating with robots, and possible negative attitudes are also among the important issues. All the issues discussed are subjects for further discussion, investigation, experimentation, in short for a wide range of research. We need to collect data as they are

available for collection. At this point, we can only survey the expectancy and vision. Even the experimentation we conduct may not be definitive until human-robot co-working environments actually exist.

## Acknowledgments and Disclaimer

The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of any affiliated organization or government.

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