



## RESEARCH QUESTIONS IN ROBOETHICS

Kadir Alpaslan DEMİR <sup>1\*</sup>

<sup>1</sup>Department of Software Development, Turkish Naval Research Center Command, 34890, Istanbul, Turkey  
kadiralpaslandemir@gmail.com

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\*Corresponding author

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### Abstract

*Robots are becoming a part of our lives. Unmanned aerial vehicles are occupying our skies for both civilian and military purposes. Robots started to serve customers in stores. Autonomous cars are being tested on streets. Robot toys are entertaining our children and they will become friends with our children. Robotic surgery is expanding. Companies are developing robots to become companions to elderly people. There are many other types of robotic applications. Currently, these applications are limited in number and scale. However, with the current fast pace of the robotic technology research, we can expect a wide-spread use in the near future. All these robotic applications will have significant impacts on our society. While this technology brings great benefits, it will also bring new challenges. We will be subject to questions never asked before. Some of these challenges and questions will be about ethical issues surrounding robotics. Roboethics is an emerging discipline dealing with ethical issues related to robotics. To shape this emerging discipline and guide related studies, we first need to ask good research questions. In this study, the goal is to identify and discuss various roboethics research questions. Some of the questions discussed in this paper are essential questions and the search for answers to these research questions will lead to many other interesting and advanced research questions. This study serves as a starting point for researchers interested in working roboethics.*

**Keywords:** Robotics, Ethics, Roboethics, Robot Ethics, Machine Ethics, Artificial Intelligence, Ethical Robots

## ROBOETİK ALANINDA ARAŞTIRMA SORULARI

### Öz

*Robotlar artık yaşamımızın bir parçası olmaktalar. İnsansız hava araçları çok çeşitli sivil ve askeri amaçlar için gökyüzünü doldurmaktadır. Robotlar mağazalarda müşterilere hizmet vermeye başladılar. Otonom araçlar yollarda test sürüşündeler. Robot oyuncaklar çocuklarımızı eğlendirmekte ve onlara arkadaş olmaktalar. Robotik cerrahi uygulamaları yaygınlaşmakta ve çeşitli teknoloji firmaları yaşlılara yardımcı olacak robotlar geliştirmektedir. Bunların haricinde daha birçok değişik robotik uygulama üzerinde çalışılmaktadır. Bu ve diğer robotik uygulamalar henüz sayı ve kapsam olarak sınırlı olmasına rağmen, robotik teknolojilerin gelişme hızına bakarsak, yakın bir gelecekte robotların yaygın bir şekilde kullanılacağını tahmin edebiliriz. Tüm bu robotik uygulamalar yaşamımızı ve toplumumuzu derinden etkileyecektir. Bu teknoloji birçok fayda sağlamakla birlikte yeni sorunlara ve problemlere yol açacaktır. Daha önce hiç aklımıza gelmeyen sorularla karşı karşıya kalacağız. Bu soruların bazıları robotlarla ilgili etik konularda olacaktır. Robot etiği veya diğer adıyla roboetik, robotik alanındaki etik konuların çalışıldığı yeni gelişen bir bilim alanıdır. Bu yeni gelişen bilim alanını şekillendirmek ve ilgili araştırmaları yönlendirmek için öncelikle iyi araştırma sorularının ortaya konması gerekir. Bu çalışmanın amacı roboetik alanındaki bazı temel önemli araştırma sorularını tespit etmek ve tartışmaktır. Bu temel araştırma sorularının cevaplarını bulmaya çalışmak bizlere daha ilginç ve ileri seviye araştırma sorularına yöneltecektir. Bu çalışma, roboetik alanında çalışmak isteyen araştırmacılara bir başlangıç noktası olmasıyla önemlidir.*

**Anahtar Kelimeler:** Robotik, Etik, Roboetik, Makine Etiği, Yapay Zekâ, Etik Robotlar

### 1. Introduction

Most science fiction has become a reality in due time. To develop a technology, we first have to envision it. Some of the technologies Jules Verne envisioned in his science fiction novels are now a part of our lives. For example, today, we have submarines that can navigate underwater for months. Actually, the nuclear-powered submarines are only restricted to the food supply in the ship. They can distill and process seawater to obtain drinking water. Many examples can be provided from the novels that are a reality today. Robots have found its place in many science fiction novels. Some of this science fiction related to robotics will become reality in the future.

Robots will be in our lives in a couple decades [1]. Robotic cars are already on the roads [2]. There are ambitious plans for the use of aerial drones for delivery in the civil airspace [2]. Therapeutic robots will serve as patient-caregivers [3]. Robots help educate our children at homes via home robot-assisted learning [4]. Military robots will change wars and how they are fought [5, 29]. Robots may even be our friends [6]. We are

already experiencing changes in our lives because of robotics. Crawford and Calo claim that artificial intelligence presents a cultural shift as much as a technical one [7].

Unmanned aerial vehicles (UAVs) are in use for some time now [8]. Most of them have a certain level of autonomy. They can take off and land autonomously. They can navigate and even conduct certain missions autonomously [9]. UAVs are used for military and civilians purposes [10]. Some military UAVs are armed with lethal weapons. US made Reaper is an example of a male UAV with missiles. They are actually being used in combat zones. To our knowledge, the decision to fire a missile upon a human target is made by a human pilot operator. However, with today's artificial intelligence technology onboard a UAV, it is possible to identify and fire upon a target autonomously. So, in combat zones, there is the possibility that a machine can kill a human being with today's technology. Therefore, even today, we face the ultimate question: Are we going to allow machines to kill humans?

Autonomous cars – in other words, self-driving cars – are already being tested and getting ready for roads. Google, Uber,

Tesla, and many others are developing prototype vehicles with various levels of autonomy. Moreover, many companies started working on technologies for autonomous cars. Automotive industry giants are buying or collaborating with AI startups and companies. Today, in Silicon Valley, it is not hard to find a venture capitalist willing to fund a good idea contributing to smart transportation. Autonomous cars will be in our lives in the near future. However, this important technology will create many legal and ethical issues. Sullins think that not the technical problems but the social problems related to the use of robotic cars will be the main challenge during the advancement of this technology [2]. For example, who or what will be responsible in case of an accident: The autonomous car or its maker? What are the implications for auto insurance policies?

Movies such as "Bicentennial Man", "A.I. Artificial Intelligence", and "I, Robot" deal with robots having emotions. There are advertisements for robot toys claiming to have emotions. One striking example is Cozmo, developed by a company named Anki [11]. While we can easily argue that this robot toy can only mimic emotional behavior determined by a computer program, the imitation is quite fascinating. For example, Cozmo presents behavior imitating happiness when it wins a game. Cozmo seems to get scared when it is nearly falling from an edge of a table. According to Cozmo designers, the robot is able to present behavior related to tens of emotions. There is a research area called affective robotics that deals with robotics simulating emotions and other human expressions and body language. The goal is to design robots interacting with its users in a natural way [6]. Breazeal offered the term sociable robots: *A sociable robot is able to communicate and interact with us, understand and even relate to us, in a personal way. It is a robot that is socially intelligent in a human-like way. We interact with it as if it were a person, and ultimately as a friend.* [12]. So, when a machine presents behavior that is easily associated with an emotional response and this response is recognized as an emotion by a human, then, what are we going to call this: an emotion or a programmed behavior?

While internet of things is seen as one of the main technologies of Industry 4.0, advanced robotics will also be an important technology enabling the revolution of Industry 4.0. Actually many robots, as part of smart factories, will be a thing in the internet of things. It is possible that at some point, Industry 4.0 will be humanless factories filled with robots manufacturing all sort of things including other robots. Today, even technology forecasters started the discussion for Industry 5.0 [13]. Furthermore, they argue that Industry 5.0 will be co-working of humans and robots. Naturally, there will be many ethical issues in the notion of co-working of humans and robots.

In this paper, various current research questions in roboethics are presented with a brief discussion. The goal is to provide a starting point for productive discussions leading to further research questions. In most research papers, robots without intelligence are separated from artificially-intelligent robots (AIR). In this paper, the term robot refers to an artificially-intelligent robot.

## 2. Robotics

The term robot comes from the Czech word *robota* meaning *forced labor*. The term was first coined by Karel Čapek's. He used the word in a science fiction play titled R.U.R. '*Rossum's Universal Robots*' (1920). Note that even the origin of the word is quite striking and may lead to interesting discussions for roboethics in the future.

Robotics is an area dealing with the design, manufacturing, operation, and use of robots. The people involved with robotics are called roboticist. Universities started offering courses and programs in robotics. Robotics engineering is becoming a profession. Robotics requires the study of many disciplines such as Mechanics, Applied Physics, Mathematics, Automation and Control, Electrical and Electronics Engineering, Computer Science, Cybernetics, and Artificial Intelligence [14]. Furthermore, it is also related to Logic, Linguistics, Neuroscience, Psychology, Biology, Physiology, Philosophy, Literature, Natural History, Anthropology, Art, and Design [15]. In this aspect, robotics requires the unification of two important scientific cultures: Science and Humanities [14]. Robotics requires a multidisciplinary approach and thinking [2]. As a result, robots are developed by a team of engineers and scientists.

## 3. Roboethics

As the number of robots and their use increase in our daily life, there will be many unprecedented impacts on our society. Most of these impacts will be the subject of roboethics research. The name roboethics was proposed by Gianmarco Veruggio during the *First International Symposium of Roboethics* held at Sanremo, Italy in 2004. The disciplines or fields related to Roboethics are presented in Figure 1 [15]. While other fields may also contribute to Roboethics, these are the main ones to be involved with Roboethics.

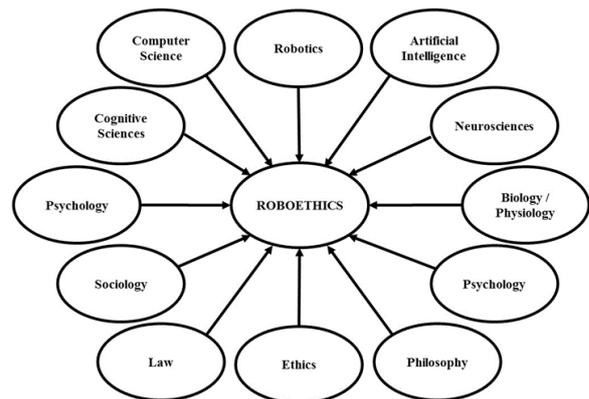


Figure 1. Disciplines Related to Roboethics [15].

Isaac Asimov, a science fictions novelist, envisioned an ideal set of rules for robots to follow. They are commonly known as *Asimov's Three Laws of Robotics* [16]:

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Later, Asimov added an additional law that is called a zeroth law. This law preceded the previous ones in terms of priority:

0. A robot may not harm humanity, or, by inaction, allow humanity to come to harm.

Many researchers, such as Anderson [16] and Arkin [17], emphasize that Asimov's Laws of Robotics falls short for establishing a basis for robot or machine ethics. However, these laws are important as they started an early discussion even among scientists and philosophers. Arkin states that a discussion related to the ethical behavior of robots would be incomplete without a reference to these laws [17]. Currently, Asimov's laws of robotics are too vague to implement in a robot. For example, how can we determine the situations in

which a robot, through inaction, allow a human being to come to harm? Protecting its own existence require a self-awareness. How are we going to achieve self-awareness in robots? On the other hand, Asimov's laws of robotics also provide various interesting questions. What is a robot? What is "harm" to humans: Physical and Psychological? What kind of orders will robots obey? Whose orders will be obeyed by robots? What is humanity in the context of robotics? There may be many other questions.

#### 4. Roboethics Research Questions

There are many interesting open research questions related to roboethics [18]. Research papers including this one are only scratching the surface of roboethics by asking and framing these interesting research questions. Sullins briefly discussed various interesting open questions and subfields of roboethics [18]. Table 1 lists these subfields. While Sullins mostly focused on subfields in his article [18], I focus on specific research questions related to roboethics. Naturally, as Sullins also pointed out that his and this study are not and could not be exhaustive at this stage.

Table 1. Roboethics Subfields of Study [18].

Military Applications
Privacy
Robotic Ethical Awareness
Affective Robotics
Sex Robots
Carebots
Medibots
Autonomous Vehicles
Attribution of Moral Blame
Environmental Robotics

#### 4.1 The Definition of a Robot

A robot is defined as *a machine that senses, thinks, and acts* [19]. This is a simple definition with many problems. What do we mean by a machine thinking? What does acting involve? The Oxford definition of a robot is *a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer*. The Merriam-Webster definition of a robot is *a machine that looks like a human being and performs various complex acts (such as walking or talking) of a human being*. Both dictionary definitions have problems as well. What is meant by a complex series of actions automatically? There are also robots that do not look like human beings. It seems we have yet to find a satisfactory definition for a robot. There are also more subtle problems related to the definition. While the scientific definition of a robot is important, what is actually more important is a legal definition of a robot. We have to come up with a definition that can be written into a robot law. As robot-human interaction increases in our daily lives, we will face with moral, ethical, and legal questions. While moral and ethical questions will create many discussions, legal questions have to be answered as soon as possible.

#### 4.2 The Definition of a Cyborg

The word cyborg is the combination of two words: Cyber and Organism. It refers to organisms enhanced with artificial cyber abilities. There are interesting questions about cyborgs as well. Where do the organism end and cyber begin? Who will be responsible when a prosthetic part of a human malfunctions and that human causes harm to another human? As a result, the legal definition of a cyborg will be a discussion for the future as well. Furthermore, how much artificial enhancement are we going to allow beyond normal

prosthetics? In addition, what will be considered as normal prosthetics? There are many questions related to cyborgs as well.

#### 4.3 Designing Ethical Behavior in Robots

While what should be the ethical rules surrounding robotics is a crucial question, another crucial question is transforming these rules into ethical robot behavior. Finding the right ethical rules is the first step. Then, we need to satisfactorily engineer these rules into robots. Anderson argues that before building an ethical robot, we need to be able to develop a program that acts as an ethical advisor to human beings [16]. She focuses on machine metaethics that deals with the field of machine ethics. Machine metaethics talks about the field, rather than do actual work for machine ethics. The ultimate goal of the machine ethics is the development of ethical autonomous machines [16]. Arkin discusses how to embed ethics in a hybrid deliberative/reactive robot architecture [17]. To sum up, to design ethical behavior in robots, we need advancements in robotics, metaethics, and ethics of robotics.

#### 4.4 Integrating Robots into Society

In the future, while some robots will work in factories away from most people, some robots will be providing services directly to people. The interactions between humans and robots will create many discussions and probably evolve over time. The feelings and treatment towards robots may be different in different cultures. Even roboethics may vary from culture to culture. Therefore, roboticists are faced with challenges such as designing robots that are culture-aware and easy to integrate into society. Integrating robots into the society will be a big challenge for the robotics field [28]. More research into the subject will be required.

#### 4.5 Integrating Robots into Organizations and Workplaces

According to the website [30], the robot *Pepper* owned by Softbank Robotics from Japan, is used to welcome, inform, and amuse the customers in more than 140 Softbank Mobile stores. The robot *Pepper* is a humanoid – a human-shaped robot. *Pepper* is able to recognize human emotions and react to these emotions accordingly. Moreover, *Pepper* is able to evolve based on the interactions with its users. *Pepper* is commercially available for businesses at affordable prices. When a technology becomes available to the public at affordable prices, its diffusion is fast. This promises a future with robots in organizations and workplaces.

There are a number of subfields in Robotics that will particularly help us in integrating robots into organizations and workplaces [28]. These are artificial intelligence (AI), Human-Robot Interaction (HRI), Social Robotics, Roboethics, Humanoid Robots. Table 2 lists the issues related to integrating robots into organizations [28].

Table 2. Issues Related to Integrating Robots into Organizations [28].

Evolution of Organizational Behavior
Acceptance of Robots in the Workplace
Evolution of 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

#### 4.6 Moral Responsibility

Who will take the moral responsibility when a robot intentionally or unintentionally harm a human being, an animal, or the environment? What is the responsibility of the designer or the manufacturer of the robot? Will the robots be accountable for their actions? If the actions of a robot are completely deterministic, then we can easily attribute the responsibility to the designer. However, when the robot software has machine learning capabilities and the actions of the robot are nondeterministic, then the issue becomes problematic. We can still hold the designers accountable. Then, the designers will be reluctant to incorporate enhanced machine learning capabilities into robotics.

Unfortunately, the military is one of the first customers of robot technology. We are already expanding the use of robots for military purposes including killing enemies. Proponents of using robots to kill enemies argue that they save allied warriors by doing so. While the word *enemy* is the central point for the proponents, from a humanistic viewpoint, an enemy is still a human. Therefore, the crucial question still remains under debate. Are we going to allow robots to kill humans?

#### 4.7 Roboethics Taxonomy

Taxonomies help a lot in framing a research area. We will eventually develop taxonomies and frameworks for robotics and roboethics. A roboethics taxonomy [20] proposed by Veruggio and Operto is presented in Table 3. Each type of robot in the taxonomy raises interesting ethical concerns. While we need to address these concerns, we also need to identify common concerns. This taxonomy is based on the use of robots for a particular purpose. We also need other taxonomies such as based on robot decision-making capabilities.

Table 3. Taxonomy for Roboethics [20].

Humanoids
Artificial Body
Industrial Robotics
Adaptive Robot Servants
Distributed Robotic Systems
Outdoor Robotics
Surgical Robotics
Biorobotics
Biomechatronics
Health Care & Quality of Life
Military Robotics
Educational Robot Kits
Robot Toys
Entertainment Robotics
Robotic Art

#### 4.8 Ensuring Privacy

Importance and awareness of privacy are already on the rise as information technology develops. Robots will have a lot of information technology in them. Privacy concerns intermingled with a range of ethical concerns will create a lot of discussion among the public. Robots will collect intentional or unintentional private data while living among us. We will inevitably need to regulate the collection and dissemination of private data by robots.

#### 4.9 Automation Levels to be used in Robotics and Roboethics

A widely accepted automation levels for robotics is important for the advancement of the field. Such levels provide a common language among robotics researchers. Furthermore,

they will be used for legal classification of robots. Table 4 provides automation levels for machines [21]. However, we need to extend this and other proposals for automation levels to incorporate ethical capabilities. Only after a universally accepted automation classification incorporated with ethical consideration, we will be able to integrate robots into our society.

Table 4. Automation Levels [21].

Automation Level	Automation Description
1	No computer assistance: the human must make all decisions and take actions.
2	The computer offers a complete set of decision/action alternatives.
3	The computer narrows the selection down to a few.
4	The computer suggests one alternative.
5	The computer executes a suggestion if the human approves.
6	The computer allows the human a restricted time to veto before the automatic execution.
7	The computer executes automatically, then informs humans when necessary.
8	The computer informs the human only if asked.
9	The computer informs the human only if it decides to.
10	The computer decides everything and acts autonomously, ignoring the human.

#### 4.10 Code of Ethics for Robotics Engineers

A number of code of ethics have been proposed for human-robot interaction [22, 25]. Ingram and his friends developed the following code of ethics – also known as WPI (Worcester Polytechnic Institute) Code of Ethics – for robotic engineers [22, 23]. They were inspired by various codes of ethics such as IEEE, ACM, etc [22, 23]. This code of ethics was even accepted by various academic institutions such as Illinois Institute of Technology [24].

<p><b>Preamble</b></p> <p><i>As an ethical robotics engineer, I understand that I have the responsibility to keep in mind at all times the well-being of the following communities:</i></p> <p><i>Global - the good of people and the environment</i></p> <p><i>National - the good of the people and government of my nation and its allies</i></p> <p><i>Local - the good of the people and environment of affected communities</i></p> <p><i>Robotics Engineers - the reputation of the profession and colleagues</i></p> <p><i>Customers and End-Users - the expectations of the customer and end-users</i></p> <p><i>Employers - the financial and reputational well-being of the company</i></p> <p><b>Principles</b></p> <p><i>1. Act in such a manner that I would be willing to accept responsibility for the actions and uses of anything in which I have a part in creating.</i></p> <p><i>2. Consider and respect peoples' physical well-being and rights.</i></p>
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3. Not knowingly misinform, and if misinformation is spread do my best to correct it.
4. Respect and follow local, national and international laws wherever applicable.
5. Recognize and disclose any conflicts of interest.
6. Accept and offer constructive criticism.
7. Help and assist colleagues in their professional development and in following this code.

Riek and Howard developed a set of guiding principles for a human-robot interaction profession code of ethics [25]. There are four main considerations: Human dignity considerations, design considerations, legal considerations, and social considerations. Their code of ethics is clear and concrete compared to Ingram and his friends'. While these code of ethics are in the right direction, we still need work to do in this area.

#### 4.11 Killer Robots

Are we going to allow robots to kill humans? This question raises one of the current hottest debates among AI and robotic researchers [29]. Currently, there are many unmanned aerial vehicles (UAVs) equipped with weapons [8]. These UAVs are used for military missions. There are also other lethal autonomous weapon systems (LAWS). The increasing use of these systems raises concern among scientists and researchers [5, 29, 35-38]. Furthermore, there are attempts to attract public attention on the issue [29]. Recently, in 2013, a campaign to stop killer robots (The Campaign to Stop Killer Robots -<https://www.stopkillerrobots.org/>) was started by a group of scientists and owners of AI companies. The campaign is attracting quite an attention. In 2015, an open letter [32], titled "Autonomous Weapons: An Open Letter from AI & Robotics Researchers", was presented at the opening of the International Joint Conferences on Artificial Intelligence 2015 conference (IJCAI 2015). This letter was signed by more than twenty thousand people including AI and robotics researchers. The letter calls for a *ban on offensive autonomous weapons beyond meaningful human control*. In 2017, at the opening of the same annual major AI conference (IJCAI 2017), another open letter signed by founders and directors of more than one hundred AI and robotic companies was announced. This open letter [33], *An Open Letter to the United Nations Convention on Certain Conventional Weapons*, was part of The Campaign to Stop Killer Robots. In the letter, the use of autonomous weapon systems is called a Pandora's Box. Once opened, it will be hard to close. The use of Lethal Autonomous Weapons Systems (LAWS) is also becoming a concern within the United Nations [34]. Since 2013 United Nations Convention on Certain Conventional Weapons (CCW) Meeting of States Parties, the increasing use of LAWS is being discussed among experts in CCW Review conferences [29].

The use of killer robots will be an important debate in many international conferences and meetings. We may ban the use of LAWS as the campaign to stop killer robots calls or we may regulate the use of LAWS. At this point, it is hard to tell which argument will win.

#### 5. Summary of Research Questions

In this section, we list some of the questions discussed in the previous sections. There may be many other interesting research questions for the field of roboethics. However, the questions raised here are the essential ones for the future.

1. What is the definition of a robot?
2. What is the definition of a cyborg?

3. What should the robot law include?
4. What are the rights of robots?
5. What are the ethical rules of human-robot interaction?
6. How do we classify robots based on an automation level incorporating ethical considerations?
7. How do we integrate robots into the society?
8. How do we integrate robots into the organizations and workplaces?
9. What is the code of ethics for the robotics engineering?
10. Are we going to allow robots to kill humans?

#### 6. Conclusion

There are many open questions in roboethics [18]. In addition, there is much to be done to identify and define what the robot laws should be [26, 27]. Even certain researchers claim that a new branch of the law will be required for robotics [27]. Robots will be crucial for mankind just as the environment is. Therefore, we will need a robotic law just like we need environmental law [27].

Currently, in some areas, not the technological but the ethical and regulatory issues slowing the adoption of various technologies. For example, Amazon had a project for the delivery of products using aerial drones [2]. US Federal Aerospace Administration (FAA) has not approved the use of these drones in the civilian airspace yet. We have yet to regulate the use of robotic cars on the roads. As a result, with the current pace of robotics research in many areas, we clearly need to put more focus on roboethics and robot law.

Sullins argue that roboticists eventually have to deal with ethical issues in their projects [2]. Therefore, learning about roboethics will be a necessity for roboticists. Consequently, roboethics will be a part of many undergraduate and graduate curriculums dealing with robotics in the future sooner than many expected.

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The views and conclusions contained herein are those of the author and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of any affiliated organization or government. This article is a modified and extended version of the study [39] presented in 4th International Management Information Systems Conference, Istanbul, Turkey, 17-20 October 2017.

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