Regulation for Artificial Intelligence and Robotics in Transportation, Logistics and Supply Chain Management

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Editorial Introduction by the Guest Editor

Under the terms of *Internet of Things, Industry 4.0* and *Physical Internet* as well as several others, many automatization and digitalization trends are on the move for the transportation, logistics and supply chain sector. Many technology aspects are driving these developments, in line with economic aspects. But increasingly also questions of human perception, motivation and safety are entering the discussion, emerging as a crucial topical area for overall economic impact and success.

Regulation for technology developments in artificial intelligence and robotics are commonly seen as one of the important yet structurally neglected fields regarding the human perspective on increasing automatization. This was highlighted in 2017 by the European Parliament report and a public consultation, indicating that a vast majority of citizens in Europe is regarding those developments as positive innovation fields but where further safeguards and regulations are needed, see the EP Resolution on Civil Law Rules on Robotics, 2015/2103(INL).

This issue is connected to an innovation workshop that took place on February 26 2018 at the Florence School of Regulation and directed at discussing the state of the art within the field of transportation, logistics and supply chain management. Furthermore, an evaluation regarding possible actions like regulation, agency- or industry-based approaches for establishing safeguards towards effective but risk-mitigating settings for this sector is aimed for.

Initial contributions collected here are directed at providing an interdisciplinary overview regarding the perspectives of industry and logistics actors, researchers in the economic, computer sciences, law and sociology domains as well as other interested parties from the field of political actors and associations. This shall enable the start of an open discussion what sorts of regulation are necessary in order to secure human trust and motivation in AI and robotics developments without placing too much of a burden to the economic development in the transportation, logistics and supply chain sector.

Guest editor: Matthias Klumpp, Professor for Logistics at FOM University of Applied Sciences Essen and 2018 Visiting Fellow at the European University Institute

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dossier

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Regulation for Artificial Intelligence and Robotics in Transportation, Logistics, and Supply Chain Management: Background and Developments

Matthias Klumpp*, Caroline Ruiner**

Digital solutions and artificial intelligence applications provide innovation potential for transportation, logistics, and supply chain management. However, the question of competencies, motivation, and acceptance of the human workforce is important for the practical success of such initiatives, in firms and in comprehensive transportation systems and networks. This section addresses the background for an inquiry into the framework conditions, recent developments and necessities for regulation of robotics and artificial intelligence in this field.

Background

There are a multitude of digitization and automation developments in the transportation, logistics and supply chain management domain, highlighted by concepts such as *Internet of Things, Industry 4.0*, or *Physical Internet* (Zhong et al., 2017; Fawcett & Waller, 2014). Technological aspects are the main drivers for these developments, and in most cases, they are aligned with economic factors such as cost savings or increasing customer reaction and time to market speed (Masoud & Jayakrishnan, 2017; Wojtusiak, Warden & Herzog, 2012). But besides these technical and economic issues, questions of competencies, motivation, and acceptance with the human workforce are also increasingly entering the discussion and emerging as a crucial topical area for overall economic impact and success (Mavrovouniotis, Li & Yang, 2017; Zijm & Klumpp, 2016). In this context, regulation in robotics and artificial intelligence (AI) is commonly seen as an important yet underrepresented field related to the human perspective on increasing automation. This point was highlighted in 2017 by a European Parliament report and a public consultation (Delvaux, 2017), which indicated that many citizens in Europe regard developments in robotics and AI as positive innovation fields, but require further discussions and regulations (Table 1).

It can be recognized that in an overall perspective, AI as a future development trend is seen more critical than the use of robots – who are in many cases perceived as support and help to humans. In detail, this is connected to a majority of 83% of all respondents agreeing or strongly agreeing to the statement that robots are good for society as they help people – whereas only 34% of respondents agree or strongly agree to the statement that robots steal peoples' jobs. Still, a huge majority of 92% also agrees or strongly agrees that robots are a technology that requires careful management, i.e. regulation and oversight. On the other hand, half of all respondents (52%) agree or strongly agree towards the statement that AI is a threat to privacy. However, favoring AI application is the fact that only 26% of respondents agree or strongly agree to the statement that AI is a threat to fundamental human rights. Altogether, these statements represent the mixed perception of citizens

	Strongly agree	Agree	Neither agree/ disagree	Disagree	Strongly disagree	Don't know
Robotics						
Technology requiring careful management	57 %	35 %	4 %	2 %	2 %	-
Necessary for hard or dangerous jobs	57 %	35 %	5 %	2 %	1 %	-
Efficient way for transport/delivery	37 %	34 %	16 %	9 %	3 %	1 %
Good for society as they help people	34 %	49 %	11 %	3 %	3 %	-
Steal peoples' jobs	9 %	25 %	31 %	25 %	9 %	1 %
Create inequity	5 %	13 %	21 %	32 %	24 %	5 %
Artificial Intelligence (AI)						
Threat to privacy	20 %	32 %	22 %	14 %	8 %	4 %
Threat to humanity	13 %	16 %	23 %	22 %	22 %	4 %
Threat to fundamental human rights	12 %	14 %	25 %	22 %	20 %	7 %

Table 1. Public Perception on Robotics and AI Applications in Europe (Question: Please indicate if you agree or disagree with the following statements).
Source: Evas (2017), p. 11-12 (n=259)

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towards automation (robots) and digitization (AI) trends – hinting at a positive attitude of citizens towards a political regulation role in these fields. Regarding regulation fields, the report outlined the following six key areas of regulatory action in detail regarding robotics and AI application in the European Union, namely (European Parliament 2017, p. 8):

(1) Rules on ethics

(2) Liability rules

(3) Connectivity, intellectual property, and flow of data

(4) Standardization, safety, and security

(5) Education and employment

(6) Institutional coordination and oversight.

In order to discuss such regulatory action further, it can be distinguished between regulatory approaches, arguments for regulation and areas of regulation. Approaches can be divided into law regulation, agency-based regulation or industry-based approaches for establishing safeguards towards effective but risk-mitigating settings. Relevant impacts from the public consultation indicate significant public support for political regulatory action in this field due to the reports of citizen opinions and anxieties (Table 2).

As Table 2 shows, arguments for regulation are headed by the items 'data protection' (85% of respondents are concerned or strongly concerned) and 'values and principles' (81% are concerned or strongly concerned). In addition, liability rules are an important argument in the eyes of citizens with 74% being concerned or strongly concerned about this issue. Smaller shares of the respondent group are listing arguments such as EU competitiveness (66% are concerned or strongly concerned), physical safety (54% are concerned or strongly concerned), or intellectual property (44% are concerned or strongly concerned). Regarding areas of regulation, transportation is present very prominently in the top five areas with autonomous vehicles being number one (87% regard it as important or very important) and drones being number four (73% deeming regulation in this area important or very important). In-between medical and care robots are seen as necessary area of regulative action (with 80% and 73% deeming these areas to be important or very important respectively). In addition to this, the world of work has to be recognized too since this is where robotics and AI applications are implemented and people encounter them actively in cooperation.

	Strongly concerned	Concerned	Neutral	Not concerned at all		Don't know
Arguments for Regulation						
Data protection	51 %	34 %	8 %	6 %		1 %
Values and principles	51 %	30 %	9 %	10 %		-
Liability rules	35 %	39 %	19 %	6 %		1 %
EU competitiveness	29 %	37 %	22 %	8 %		4 %
Physical safety	26 %	38 %	22 %	11 %		3 %
Intellectual property	17 %	27 %	27 %	24 %		5 %
	Very important	Important	Neutral	Somewhat important	Not at all important	Don't know
Areas for EU Regulatory Action						
Autonomous vehicles	55 %	32 %	5 %	4 %	4 %	-
Medical robots	48 %	32 %	12 %	5 %	3 %	-
Care robots	38 %	35 %	15 %	8 %	4 %	-
Drones	42 %	31 %	12 %	6 %	3 %	1 %
Human repair	40 %	32 %	13 %	4 %	2 %	4 %

Table 2. Public Expectations regarding Regulation Motivation and Areas in Europe.

Source: Evas (2017), p. 11-12 (n=259)

Human Work and Digitization

The EU study presented indicates how citizens perceive robotics and AI applications, their anxieties and highlights certain approaches for the regulation of new technologies. The citizen's perceptions are likely to match the perceptions of the workforce. Likewise do the key areas of regulatory action take into account the human factor in automated and digitized work settings which is important with regard to the employer's due diligence obligations. Moreover, the human factor is of crucial relevance since workers' perceptions affect the acceptance and their handling of robotics and AI (Ventakesh & Davis, 2000), and is, thus, central for the economic impact and success of these new forms of work organization. A positive attitude towards work settings usually comes along with intrinsic motivation – defined as behavior coming from within an individual, out of interest for the activity and enjoyment – leading to high job performance and satisfaction, commitment and innovation (Deci & Ryan, 2000). Accordingly, if digitization in the working context is perceived as positive and supportive, it will promote pro-organizational behavior. In this respect, the careful management and design of digitization in the working context plays a key role and is the central leverage to orchestrate the workforce. Measures of Human Resource Management (HRM) therefore need to consider the use of robotics and AI in the work process based on an overall strategy implying specifications and rules, e.g. in terms of ethics, safety and security issues. Moreover, an adequate information of and communication with the workforce will promote liability and trust (Lewicki et al., 1998). For a positive attitude and efficient use of new technologies in work processes, it is crucial that workers perceive the support of the management, that the organization values their contributions and cares about their well-being (Eisenberger et al., 1986). To foster intrinsic motivation in digitalized work contexts, workers attach great importance to experiencing autonomy and their tasks as meaningful (Hackman & Oldham, 1980). This would also mean that the interaction between robots, AI and workers is seen as equally and free, meaning that workers perceive locus of control (Rotter, 1966). Therefore, it is essential that workers obtain the qualifications required for working with new technologies. Consequently, the alignment of the workers' competencies towards changed work requirements is a basic prerequisite for the acceptance of robots and AI in work contexts. The acceptance of new technologies in work settings will also be supported when the process of automation and digitization is not only organized top-down but also bottom-up, i.e. when workers have the opportunity to participate in organizing and designing digitization processes, contributing their ideas and perspectives (Boxall & Purcell, 2003). Finally, the use of new technologies in organizations is not only designed in cooperation with management and workers but also involving actors like employee representatives (e.g. works council), securing the workers interests in data protection as well as general values and principles. This would eventually help to promote the understanding of robots and AI supporting the workforce and establishing a regulatory framework securing workers' positive attitudes.

Connected to these general HR concepts, one central motivation for regulatory action is to promote the worker's acceptance and to mitigate possible human resistance towards robots and AI applications in transportation, logistics and supply chain management. Therefore, it is helpful to understand the structure of typical workers' resistance towards automation within the field of transportation, logistics and supply chain management – this is depicted in the following Figure 1.

In many business application contexts three major resistance hurdles can be identified before a full human cooperation mode can be reached. First, workers have to accept single automation steps as AI competence, e.g. the competence of an automated steering system to handle truck cruise control orders. Second, it is even harder and usually met by a higher level or hurdle of human resistance to accept independent AI decisions, e.g. suggestions by a navigation system in driving trucks. There might for example be higher rates of neglect, meaning navigation

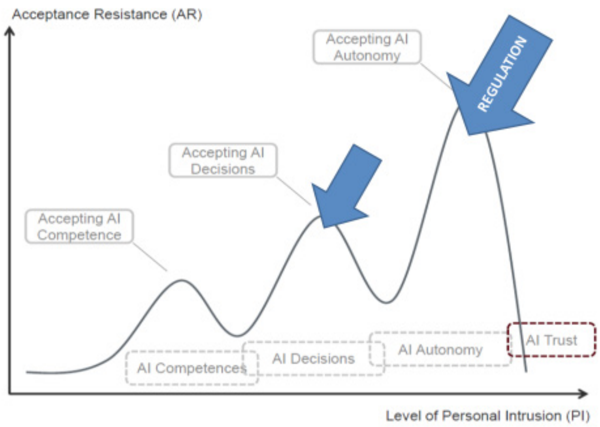

Figure 1. Motivation for Regulation in Robotics and AI Applications in Logistics.

Source: Adapted from Klumpp (2018), p. 234

suggestions are overturned in practice. Third, human actors have to accept AI autonomy, for example an autonomous steering system for trucks. In this case, the resistance might be highest as autonomous behaviour of automated systems brings about the highest level of fear and insecurity among human coworkers. In this area, regulation might therefore be needed the most and provide the most benefit: Regulation may help to reduce the volume and impact of these human resistance hurdles for an efficient human-computer interaction (HCI). This can be achieved as human workers may be able and motivated to start HCI settings with a lowered resistance of they know that regulations are in place safeguarding their physical safety and their personal data protection and employment rights.

Areas of Regulation in Transportation, Logistics and Supply Chain Management

Applying the six defined key areas of regulation as outlined in the EU study specifically towards the transportation, logistics and supply chain sector, the following observations can be derived:

(1) *Rules on ethics*: Especially in transportation – as public traffic is concerned – ethical rules of engagement are important, e.g. if accidents occur and split-second decisions have to be taken by automated systems like which deviation route to take with specific casualty impacts. The major problem in this area is, that such decisions have to be implemented beforehand within the automated and AI transportation systems, as in many cases reaction times will be too short for any human driver to contemplate and interfere with the autonomous steering e.g. of trucks and

cars.

(2) *Liability rules*: Again, transportation as far as public transportation is affected will be a major development field for liability rules and within their wake insurance markets and products for automation and digitization. But also in the production logistics environment many important liability questions will arise, e.g. who might be liable for incorrect order volumes (order volume too high with subsequent warehousing costs or order volume too high with resulting production interruptions and market costs from customer contracts).

(3) *Connectivity, intellectual property, and flow of data*: Connectivity is a major concern for the transportation, logistics and supply chain management field as a global sector. Therefore, many research endeavors already explore the use of standardized industrial data spaces also for transportation. This will be increasingly important as many applications (like with smartphones) will arise for transportation and logistics settings, requiring a unified communication and interaction framework.

(4) *Standardization, safety, and security*: As transportation always includes a physical component, safety and security issues are highly important, affecting many public hubs (ports, stations and airports) as well as main lines throughout the countries and around the globe. Security issues might easily clog up passenger and cargo traffic, resulting in large economic losses as well as private burdens in terms of lost time and increased stress. Therefore, automation and digitization developments are urged to enhance the overall safety and security level in transportation, as well as providing this increase at lower economic and societal cost.

(5) *Education and employment*: Work and qualification issues are very relevant in the logistics sector as it represents a personal-intensive service industry. Digitization is seen as an ambivalent trend regarding this as there are at the same time effects of eased work burden and facilitated training and education by electronic means as well as increased work burden and stress by the way of increased transparency and oversight or even job losses in specific areas – though it has to be emphasized that the total number of jobs is not expected to be reduced in the transportation sector for a long time to come. But it cannot be neglected that qualification requirements will change and therefore the importance of education and training, requiring also structuring and evaluation regulatory action from the authorities in this field.

(6) *Institutional coordination and oversight*: The interaction of different institutions in supply chains and global transportation will change, as on the one hand digitization and the use of AI will facilitate many processes and services along the transport ways. For example, document translation can be automated in the near future, lower cost and time requirements in customs, transportation and logistics. This will on the other hand also require coordination among supply chain partners, as they have to agree on standards and cost sharing regimes for automated services.

An interdisciplinary perspective from different science disciplines is helpful in implementing such regulatory areas. This includes the perspectives of industry and logistics actors, researchers in the economic, computer sciences, law, and sociology domains, as well as other relevant parties from the field of political actors and associations. This could be an invitation to start an open discussion about what sorts of regulation are necessary in order to secure human trust and motivation in robotics and AI developments without placing too much of a burden on the economic development in the transportation, logistics, and supply chain management sector (Klumpp, 2018; Petit, 2017; Fors, Kircher & Ahlström, 2015).

Contributions and Outlook

The contributions of this issue are aligned with a multi-perspective analysis regarding the question of regulation for robotics and AI applications in transport, logistics, and supply chain management, intending to provide a sort of mapping of future research topics in this (Wieland, Handfield & Durach, 2016). At the same time, they are addressing different aspects from the described six key areas of regulation of robots and AI: The first two contributions start with a business practice perspective. *Julian Sanders* emphasizes the dynamic innovation requirements for logistics service providers on a global scale, hinting at the necessity of regulation in the area of 'institutional coordination and oversight'. While following that, *Dominic Loske* outlines the challenges of a day-to-day transportation and logistics situation in urban food retailing, focusing on the question of human training for truck drivers facing ever-faster digital innovation steps; this is discussing the 'education and employment' area of regulative action as outlined above. From a production logistics research perspective, *Francesco Pilati* and *Alberto Regattieri* provide an outlook on what big data analysis can do for an improved ergonomics situation in production. This again is addressing the regulation areas 'standardization, safety and security' as well as 'institutional coordination and oversight', including the role of unions and other work safety institutions in the production logistics context. *Giuseppe Contissa, Francesca Lagioia* and *Giovanni Sartor* analyse the impact of automation in the allocation of liability within autonomous cars. They discuss the tasks allocation between human and automation, and the resulting responsibilities.

Altogether, the issue is aimed at sparking a discussion regarding future questions for regulation towards the application of robotics and AI in the transportation, logistics and supply chain sector in order to allow for a smooth and efficient changeover with digitization trends. As can be recognized from this issue, there are manifold open gaps and research items to be applied in this context in the upcoming years.

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Regulation for Artificial Intelligence and Robotics in Transportation, Supply Chain Management, and Logistics

Julian Sanders*

Previous production-oriented developments in technical infrastructure and IT form the basis for recent trends of automatization and digitalization in the transportation, supply chain, and logistics sector. Along with economic aspects, areas such as human perception, motivation, and safety are gaining in significance against the background of artificial intelligence and robotics. Long seen as contradiction, these factors are now understood as a crucial enabler for overall economic impact and success. In particular, for the people-oriented logistics business, but also for many other industry branches, the question of regulation becomes increasingly important in order to secure human trust and motivation in artificial intelligence and robotics without raising the burden to economic development.

Introduction

Through terms such as the *Internet of Things, Industry 4.0, and Physical Internet,* many automatization and digitalization trends are developing for the transportation, supply chain, and logistics sector. Both trends result largely from production-based developments over the last years that have changed the role of data comprehensively (Figure1). Starting with the implementation and operation of LVS systems in the 1970s, data became rapidly enabler for processes in the 1990s and also for products until the 2000s, and are today products themselves. The different data development stages should not be understood as disjunct, rather as parallel developments in companies. For one thing, data are the result of digitalization and automatization, but also a resource for service creation or even products, which leads to the 'data paradox'.

Considering that the number of connected devices has increased by a factor of almost 35,000 since the first connected devices were launched in 1992, the development of the *Internet of Things* has increased the number of connected devices almost exponentially. By 2020 the total amount of connected devices will double to 50 billion due to further development of the *Internet of Things* (Figure 2).

In summary, past and present trends of the *Internet of Things, Industry 4.0*, and *Physical Internet* are results of the development and understanding of data and its importance. Therefore, the topical framework of automatization and robotics, enabled and driven by these developments, became one of the most important action points for a wide range of industries in the future. The application of automatization and robotics, combined with artificial intelligence will be a major innovation in transportation and supply chain management, but also growth and efficiency driver in the next 15 years. Focusing on challenges and opportunities for the logistics sector, the recent trends can even be described as a 'game-changer' for many different areas.

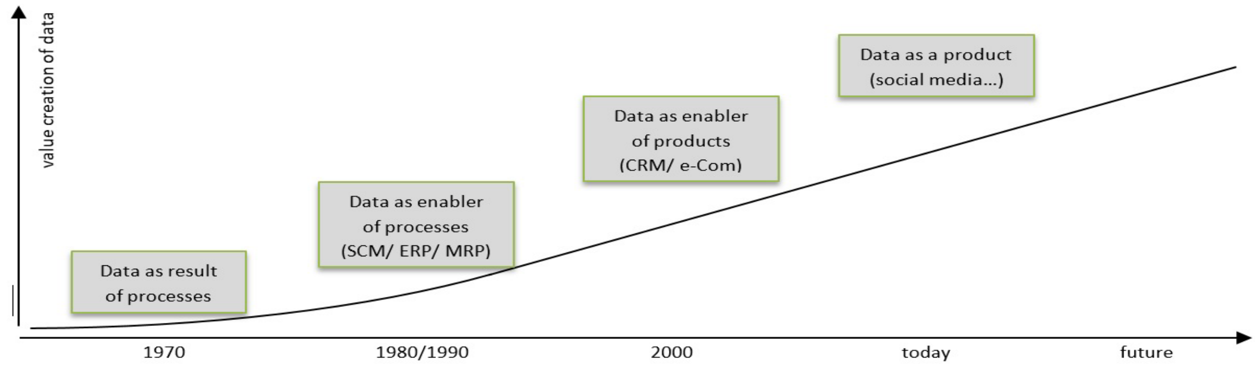

Figure 1. Role of data in the course of digitalization and automatization

Source: Otto, B. (2016)

Risks and opportunities

The main exogenous drivers for the recent developments in digitalization and automatization are cost pressure (46 percent), staff shortage (64 percent), complexity (39 percent) and dynamically changing buying behavior (57

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percent), combined with endogenous factors stated as the need for transparency in supply chains (55 percent), business analytics (62 percent) and collaboration (55 percent).

Next to the challenges, logistics companies consider opportunities in terms of additional revenues (34 percent) and cost reduction (34 percent), (Kersten et al. 2017, p. 19). Many developments are driving these aspects with enabling technologies, also in line with economic success. In direct comparison, the opportunities of digitalization and automatization outweigh the counteracting risks of digital transformation (Figure 3).

Against this background, it can be noted that the vast majority of companies in transportation, supply chain management, and logistics expect fewer risks than opportunities from digital transformation driven by digitalization and automatization. Nevertheless, the logistics sector attaches high importance (59 percent) to the burden resulting from regulation and compliance related to digital transformation, making this a crucial topical area for overall economic impact and success.

Regulation conclusions

Regulation for technology developments in artificial intelligence and robotics can be seen as an important yet structurally neglected field regarding the human perspective on increasing automatization. This point was underlined in 2017 by a European Parliament report and a public consultation for the European Union, which indicated that a majority of citizens in Europe regard those developments as positive innovation fields, but with the need for further safeguards and regulations (see the European Parliament Resolution on Civil Law Rules on Robotics, 2015/2103 (INL)). Therefore, questions of human perception, motivation, and safety are increasingly entering the discussion (Ruiner & Klumpp, 2018a).

It has been found that human-AI collaboration decisively depends on its design requiring opportunities for autonomous decisions, feedback, and participation, as well as individualized and respectful communication of support and care. For acceptance and human-AI team-building, as well as proactive use of AI, digital devices and automatized robots must be designed to support humans, not to control or direct them. Thus, the preparation and participation of the human workforce in combination with such applications as human-computer interaction (HCI) is an important issue for individuals regarding the acceptance and use of AI, for unions, politics, and regulation, as well as businesses, in order to retain competitiveness and design positive impacts. Furthermore, regulation issues require local, regional, national, and European actors to address standardization, safety, and trust issues for the public, as well as the European workforce in transportation and logistics. All societal groups and representatives are called on to help with this major task, as the world of work as well as general mobility will change significantly and will require structured guidance (Ruiner & Klumpp, 2018b).

As the aim of this article was to describe past, recent and future trends in digitalization and automatization against the background of regulation focusing on risks and opportunities of the digital transformation, it should be noted

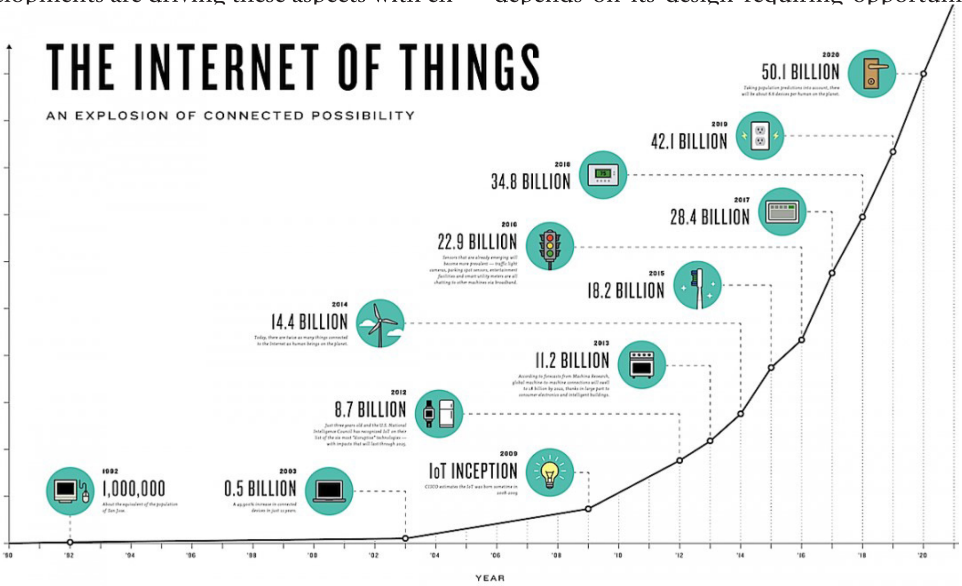

Figure 2. Development of connected devices

Source: Mesh-Net Limited (2017)

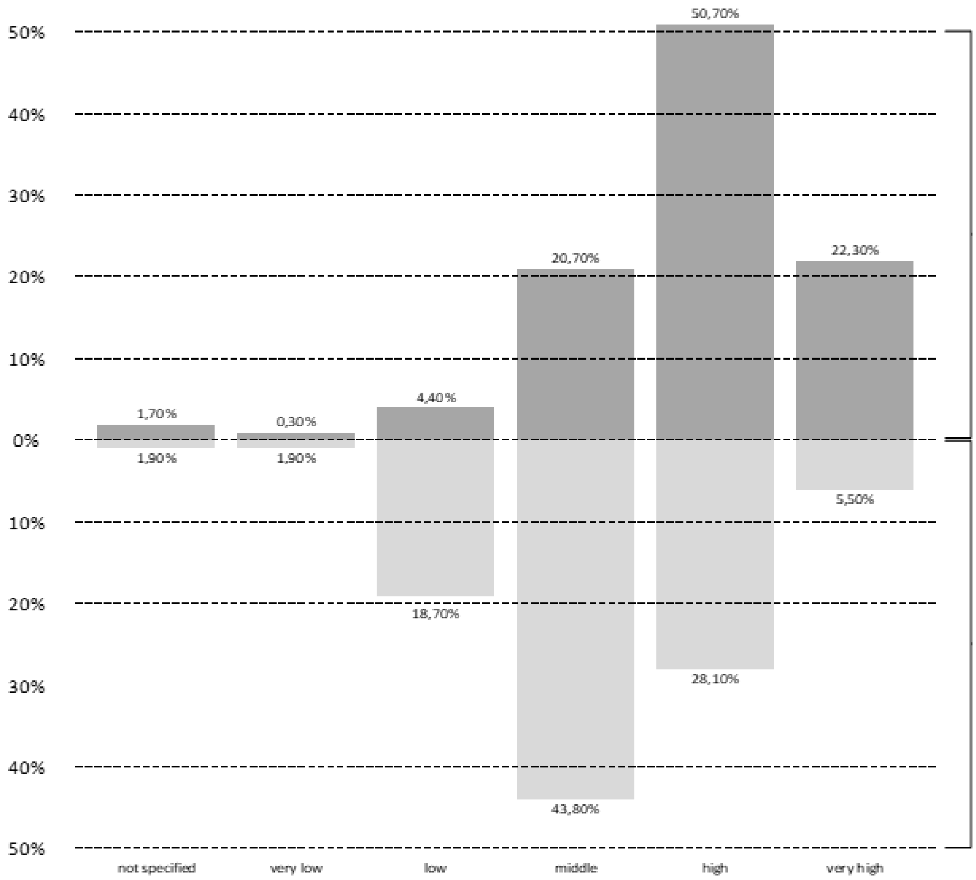

Figure 3. Comparison of risks and opportunities of digitalization
Source: Kersten, W.; Seiter, M.; von See, B.; Hackius, N.; Maurer, T. (2017)

that all related topics warrant further investigation. Moreover, sufficient attention and support must be given to exploring a detailed and sensible framework as well as operational solutions to process, collaboration, and regulation questions. Only if all factors, perspectives and dependencies have been thought through, planned, and taken into account by all relevant stakeholders will digitalization and automatization be able to help the transportation, supply chain management and logistics sector achieve higher efficiency built on trustful, secure, and motivated human perception.

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How to prepare workers for logistics innovations today and tomorrow

Dominic Loske*

Artificial intelligence and the Internet of Things enable new and non-foreseeable potentials in various development and application scenarios. This disruptive and exponential development in informational technology has triggered a rapidly falling half-life of knowledge that underlines the importance of lifelong learning and the fast adaptation to new situations in logistics.

Introduction

The term *logistics* is ambiguous and has been examined from different perspectives in scientific literature. As an application-oriented scientific discipline, logistics analyzes the flow of goods in collaborative economic systems and provides recommendations for their design and implementation. Furthermore, logistics can be discussed as a branch that connects value chains of various dimensions (Pfeiffer, 2016). As an activity, logistics includes the spatial-temporal transformation of goods, handling, packaging, order-picking, and sorting (Baumgarten et al., 2004).

The aim of the present paper is to provide practice-oriented examples of applied procedures when preparing workers for logistics innovations today and to discuss possible ways for preparation, applied in the near future. Accordingly, the paper concentrates on logistics as an activity and provides insights to the working fields of truck driving and transport planning.

Methodology

Practice-oriented examples are related to distribution logistics and provided by the expertise of a senior transport manager employed at one of the largest food retailing companies in Germany. After a brief introduction of a working system model, two cases are discussed. These cases concentrate on a short work task description and an explanation of how workers are prepared for logistics innovations, both in the past and today.

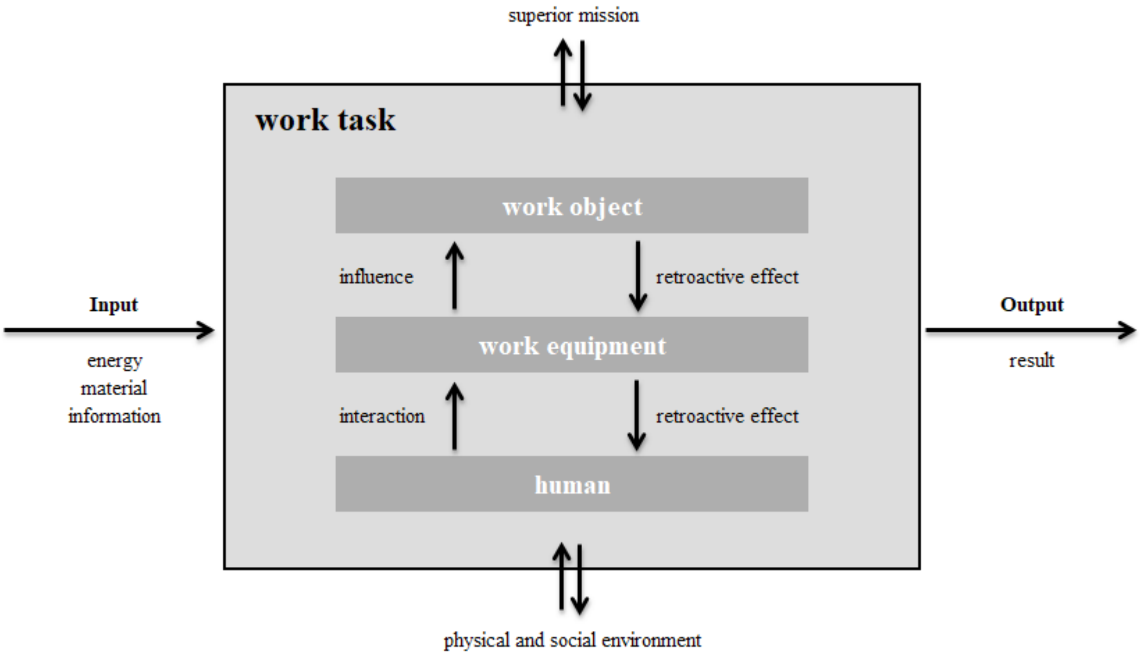

Figure 1. Working system

Source: Authors' own illustration based on Hardenacke et al. (1985), in Luczak (1997)

To be able to estimate how human workforce will be prepared in the future, it is necessary to include possible

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developments in digital technologies. Therefore, a scenario technique used in scientific literature in order to estimate future development has been applied. The advantage of this method over other instruments is that the future is understood as a possibility space with many different directions of development and not as a fixed track (Gausemeier et al., 2009). The primary influencing factors are digitalization as a development boost causing disruptive changes and a shortage of specialists caused by the demographic change and an aging workforce (Eisenmann, Ittermann, 2017).

The working system as a frame of reference for practice-oriented insights

In order to explain the way how workers are prepared for logistics innovations today, the model of a working system is used. The focus of the model is the work task, which is derived by a superior mission of the organization (Figure 1).

To accomplish the working task, the human resource impinges on the work object by using work equipment (Luczak, 1997). Successful interaction between humans and the work equipment is necessary and requires a certain level of qualification. In addition to the input and output factors, exogenous factors such as the physical and social environment influence the working system and subsystems (Schultetus, 2006).

Case 1 – Preparing truck drivers for logistics innovations today and tomorrow

Truck drivers working in distribution logistics of food retail companies have to face changes in digital innovations related to track-and-trace systems. Mobile devices or handheld scanners are currently used to display work tasks for the truck driver; for example, to load a certain amount of containers for a grocery store and deliver them within a given time window.

In order to fulfil such tasks, the truck driver must scan all relevant 1D barcodes, which are attached to the containers, load them into his or her truck, and record differences between the data provided by the mobile device and the determined condition of transported goods. Furthermore, the mobile device is used to record the activities in reverse logistics. Figure 2 describes the working system of a truck driver in distribution logistics of food retail companies.

Currently, all truck drivers at a depot are trained intensively whenever disruptive innovations in track and trace systems take place. At the food retailing company examined in this case, an intensive seminar-based training was held for all truck drivers when the first track and trace system was integrated in 2007.

A second wave took place in 2014 with intensive seminar-based training supported by a digital mock-up with a demo tour. The need for this preparation was, on one hand, derived by a new design; on the other hand, a different operating principle significantly extends the processes covered in the whole working system.

In 2018, a third wave will take place in which design and hardware will change fundamentally. The truck drivers will be prepared to face these changes by conducting a self-study with a digital mock-up-based demo tour, an

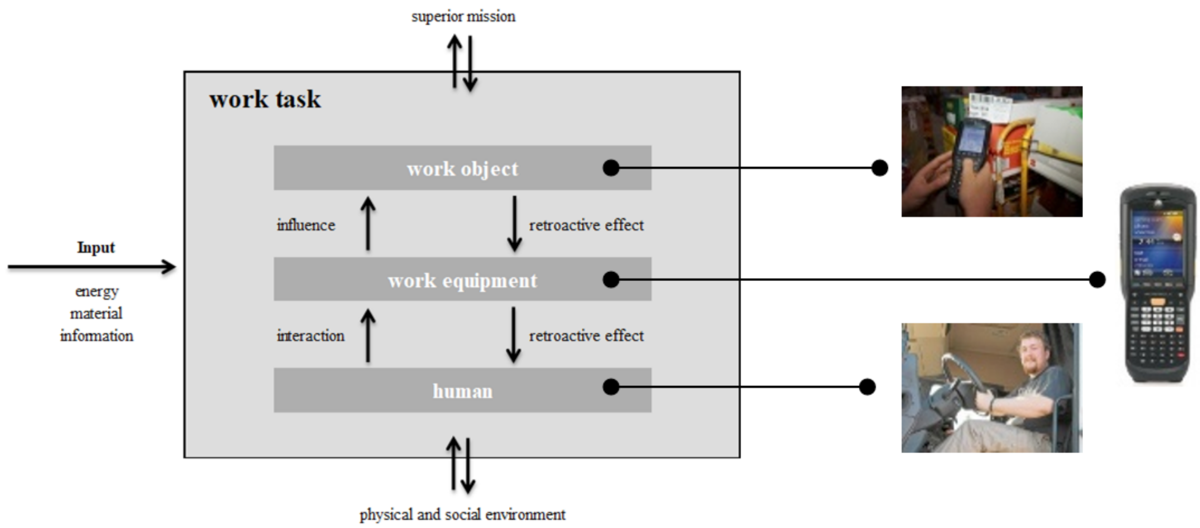

Figure 2. Working system of a truck driver in distribution logistics

Source: Authors' own illustration based on Hardenacke et al. (1985), in Luczak (1997)

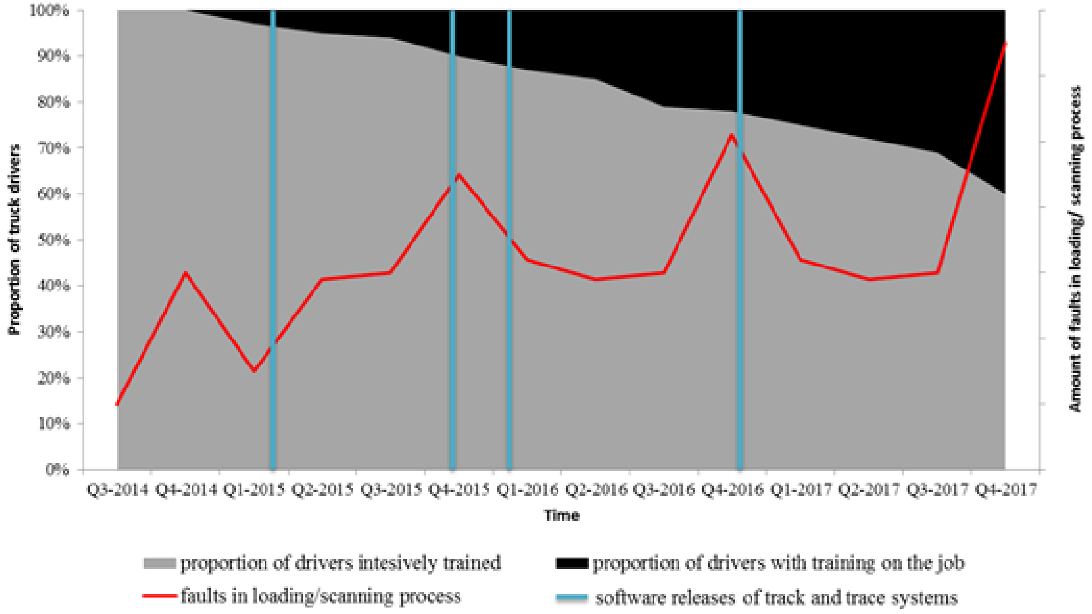

Figure 3. Relation of estimated training level and faults in loading/ scanning process for 2014 to 2017

Source: Authors' own illustration

online video playable on a smartphone to explain the functions and features of the mobile device, and two weeks of support from experts placed in the area of the warehouse where the truck drivers are loading their trucks.

New truck drivers who begin work after these waves of disruptive innovations occur due to an increase of transportation capacity in a depot or due to fluctuation effects are not prepared by intensive seminars but by on-the-job training from existing drivers. In this context, a loss of knowledge is expected and can also be traced back to the fact that new releases cause slight changes.

The expectation can be conditionally proven by faults occurring in the loading and scanning process, which are measured in the amount of containers that not scanned properly and were therefore left back in the warehouse. All contents described are summarized in Figure 3.

In the future we expect increased fluctuation of truck drivers, as well as more frequent and extensive changes in digital technologies. Without proper preparation, modifications in the technosphere and infosphere will reinforce the truck driver's potential for faults while fulfilling working tasks. Consequently, the future approach is a constant refresh and training of knowledge for all truck drivers without waiting for disruptive changes in hardware or software.

Case 2 – Preparing dispatchers for logistics innovations today and tomorrow

Dispatchers working in distribution logistics of food retail companies have to face changes in digital innovations related to transport planning systems. The working system is used to plan tours with the aim of ensuring a punctual, complete and cost-efficient delivery of grocery shops. The bases for their work are orders placed by the shops and available resources as trucks ready for transportation. Figure 4 describes the working system of a dispatcher in distribution logistics of food retail companies.

The increasing amount of available information (1) caused by the technical development of logistic systems in the last years triggered a performance enhancement of transport planning systems (2). As a result, a constant improvement in the level of competences for dispatchers is required (3).

Today dispatchers are schooled in a manner similar to truck drivers in a seminar concept that is held whenever disruptive changes for the working equipment take place. New employees are prepared by an intensive training on the job that lasts at least half a year. There is currently no preparation when add-ons for the planning software are introduced, except when release descriptions are provided. These documents contain all new features without filtering relevance or importance and are written from a technical point of view because they are provided by the IT business unit.

The result is an increasing amount of features that are not used despite being available. Figure 5 illustrates this by contrasting available and used features. The development of available functions is based on software releases and updates. The increasing usage of the software in Q1-

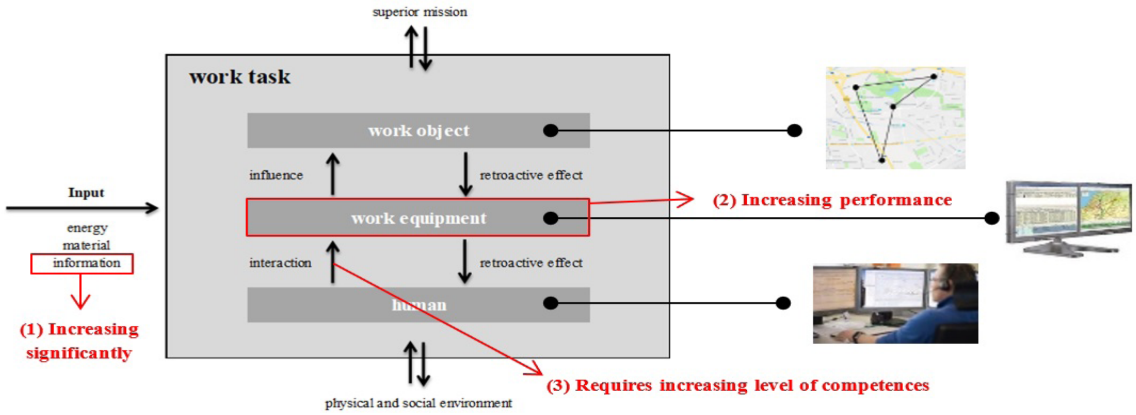

Figure 4. Working system of a dispatcher in distribution logistics

Source: Authors' own illustration based on Hardenacke et al. (1985), in Luczak (1997)

2016 and Q4-2016 is not attributable to the preparation of employees but to a change of the work task.

The scientific literature predicts an exchange of roles in logistic systems with a transfer of executive human work to computer systems. Therefore, employers have to search for possibilities to transmit new available features to employees and to lower possible acceptance and resistance hurdles when increasing automation or implementing artificial intelligence (Klumpp, 2017). This will be increasingly important due to the fast, disruptive, and exponential development in informational technology and due to technological advances. A rapidly falling half-life of knowledge underlines the importance of lifelong learning and the fast adoption to new situations in logistics (Wróbel-Lachowska, 2018).

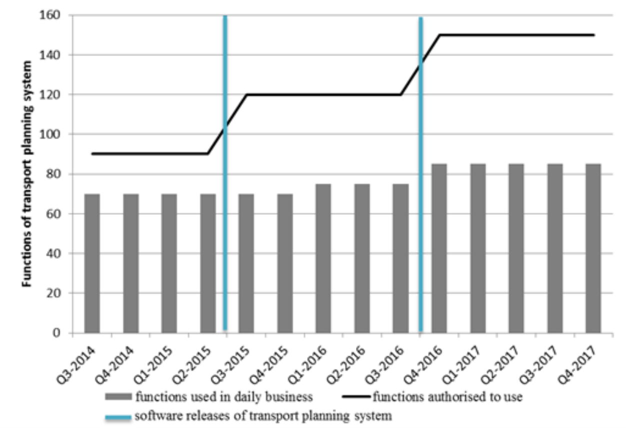

Figure 5. Relation of available und used functions of transport planning system for 2014 to 2017

Source: Authors' own illustration

Conclusion

This paper has presented practice-oriented examples related to distribution logistics provided by the expertise of a senior transport manager employed at one of the largest food retailing companies in Germany in order to gain insights into how workers are prepared for logistics innovations today. As a frame of reference, the working system introduced by Hardenacke et al. was applied to the cases of how truck drivers and how dispatchers are prepared for logistics innovations today. Similarities of the two cases are the emergence of an aging workforce and a lack of specialists, the preparation whenever disruptive innovations take place, and the type of training that is carried out by seminar-based training methods and recently with digital mock-ups.

To prepare truck drivers and dispatchers for logistics innovations, a rapidly falling half-life of knowledge can be observed that underlines the importance of lifelong learning and fast adaptation to new situations in logistics. Employers have to turn away from inflexible training rhythms and start to adapt permanent methods for qualifying workforce. Schooling truck drivers through gamification, such as the MARTINA application provided by FOM University of Applied Science, while they are waiting for new working tasks can be understood as a role model of efficient, effective, and constant improvement of the qualification of workforce.

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The impact of digital technologies and artificial intelligence on production systems in today Industry 4.0 environment

Francesco Pilati and Alberto Regattieri*

The industrial environment is currently experiencing its fourth industrial revolution, distinguished by the ubiquitous use of sensors that are able to capture large volumes of data regarding production processes. This vast quantity of digital information represents the raw material of the 21st century, which is able to fuel the decision processes of the factories of the future. The development and exploitation of novel algorithms and methods derived from cognitive processes of human beings represents the latest trend, both for research and application in the industrial sector. The adoption of artificial intelligence tools and techniques to design and manage smart assembly and manufacturing systems is the core of this manuscript. Two real industrial applications are presented to test and validate the afore-described approach, analysing both the advantages and the drawbacks of such solutions. In particular, a hardware/software architecture based on depth cameras is developed to digitalize the operator motions within assembly or manufacturing systems, whereas a set of neural algorithms defines the maintenance policies for continuously condition-monitored production systems.

Introduction

The industrial environment is currently experiencing what has been described as the fourth industrial revolution, namely Industry 4.0 (I40). The ubiquitous usage of sensors, which communicate through a world-wide network, make it possible to connect, in real-time, several entities of production systems, such as machinery, equipment, final products, components, workers, suppliers, customers, etc. Together, these elements comprise the Internet of things (IoT) (Stankovic, 2014). The huge volume of data produced by these connect objects is the raw material of the 21st century (Bortolini et al., 2017). These technologies facilitate the development of a new production paradigm, which has been termed personalized production. This paradigm satisfies the customer's contemporary need to participate in the production process since the product design phase (Hu et al., 2011).

Furthermore, today's industrial environment is distinguished by three trends of extreme importance. First, the workforce is aging alarmingly. In the last three lustrums, the percentage of European employees older than 50 years increased by 10 percent; that is, from 20 percent to 30 percent of the total working population (OECD, 2015). Currently, 5.8 million European workers are 60 years or older (7.4 percent of the entire workforce). Second, Western countries, Europe in particular, are experiencing the re-shoring of production plants that were previously off-shored to emerging countries (Ellram et al., 2013). This important trend is driven by growing labour costs in emerging countries that are almost equal to those in Western countries; the higher soft and digital skills of Western workers compared to those of emerging country competitors; the remarkable savings in transportation costs, which benefits local supply chains; as well as the flexibility and responsiveness needed to meet customer expectations (Davies, 2015).

Such a digital industrial environment generates a huge volume of date at high pace. Therefore, the development

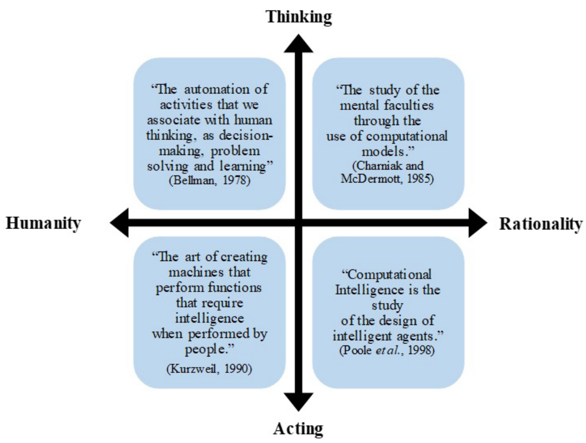

Figure 1. Artificial intelligence definitions proposed in the literature considering the thinking-acting and humanity-rationality dimensions

Source: Russel and Norvig, 2003

and adoption of appropriate models and methods, as well as algorithms and techniques, is of major importance to obtain meaningful information from these data sets. One of the latest trends is represented by the adoption of biology-inspired algorithm, as artificial intelligence (AI). The definition of AI can be provided considering two relevant

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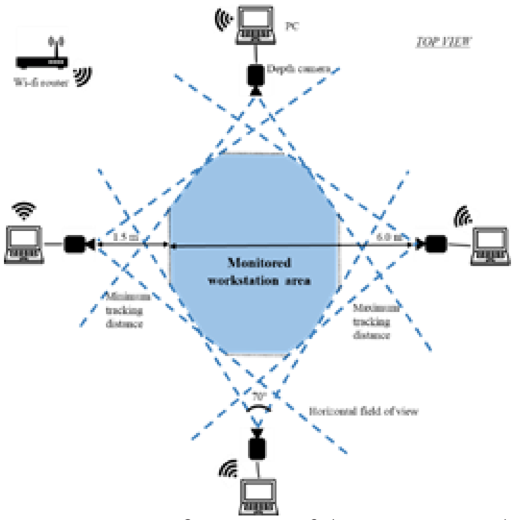

Figure 2a. Configuration of the MAS network of depth cameras

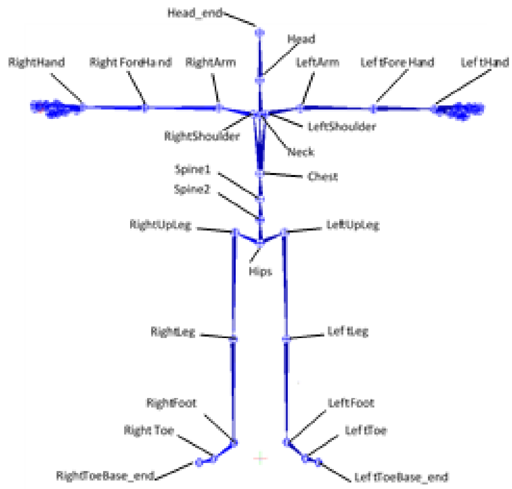

Figure 2b. Skeleton joints of the acquired human body

Source: Author's own compilation

dimensions: thinking vs. acting and humanity vs. rationality (Russel and Norvig, 2003). The former measures the degree of reasoning against behaviour in a decision process, whereas the latter compares the decision process with human versus purely rational approaches. Considering these dimensions, Figure 1 proposes four relevant but different definitions of AI that have been suggested in the literature.

This technology ensures a precise measurement of the operator absolute positons in the industrial 3D environment in relation to the difference pieces of equipment, products, and furniture displaced in the shop floor area. The MAS automatically, quantitatively, and dynamically evaluates a set of key performance indicators (KPIs) that deal with the monitored production process both from an ergonomic and a logistic perspective.

The large volume of data acquired by the MOCAP system represents the absolute geometric coordinates of each joint of the operator's body on the shop floor, and therefore his skeleton posture. The developed MAS leverages this information from an ergonomic perspective to dynamically evaluate the angle of every human body articulation and the related movement over the monitored time (Figure 3a). These data are further processed by the MAS to dynamically and automatically assess several ergonomic indices that evaluate the postures and movements of operators during working activities. For instance, the OWAS, REBA, NIOSH and EAWS can be easily evaluated by leveraging the distinctive features of the MAS. A useful tool provided by the MAS is the automatic analysis of index trends in relation to the risk categories and specific body parts,

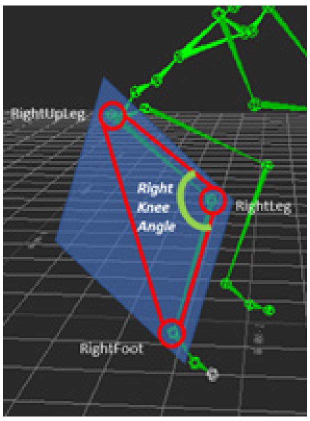

Figure 3a. Body articulation angles, knee exemplification.

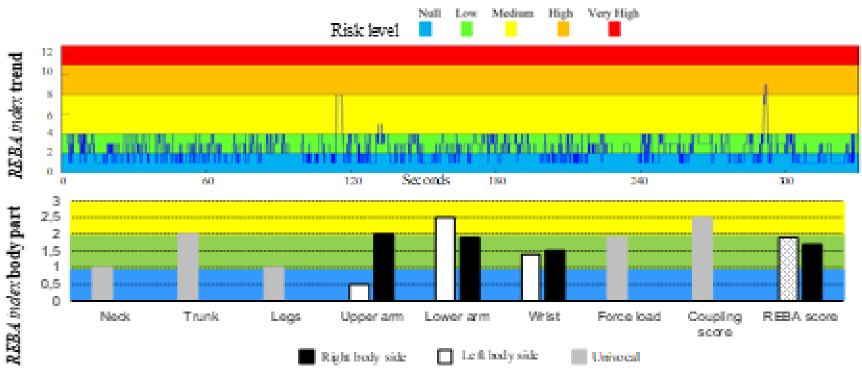

Figure 3b. Ergonomic index trend over time and per body part.

Source: Author's own compilation

which makes it possible to identify those tasks or manual activities that require corrective actions (Figure 3b).

Concerning the productive performances of the monitored operator within the shop floor, the MAS automatically and quantitatively evaluates the following set of KPIs: travelled distance and velocity of the operator and his different body parts; vertical movements due to lifting and lowering activities; worker's travelled paths and trajectories of his hands (Figure 4a); picking activity in-depth assessment (visited locations, duration, frequency, etc.) (Figure 4b); and working time partitioning, such as the distinction between added-value (task execution) and no added-value (walking, picking, etc.) activities.

an immediate maintenance intervention. A real industrial application of the proposed approach is represented by a fresh pasta production system. A particular system component determined several severe breakdowns in the entire production process. A customized AI algorithm has been developed to determine which operating parameter to monitor, along with its value, which distinguishes between a safe, warning and breakdown working zone. The following Figure 5 presents this exemplification.

The approach describe above is distinguished by several opportunities that positively affect the technical and economic performances of the analyzed production system during its entire lifetime. In particular, the most relevant

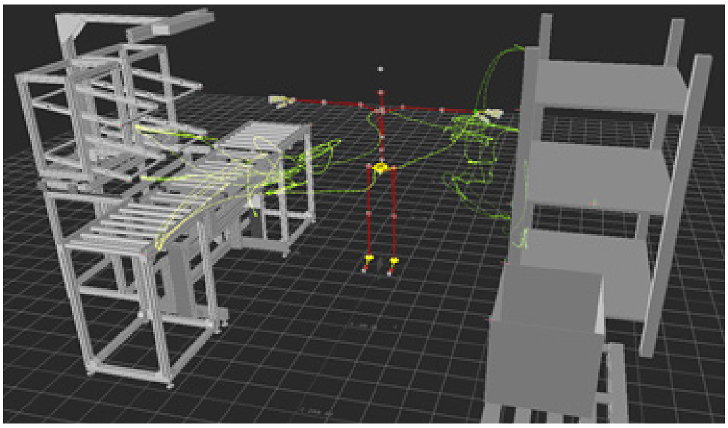

Figure 4a. Travelled paths and trajectories of operator and his hands.

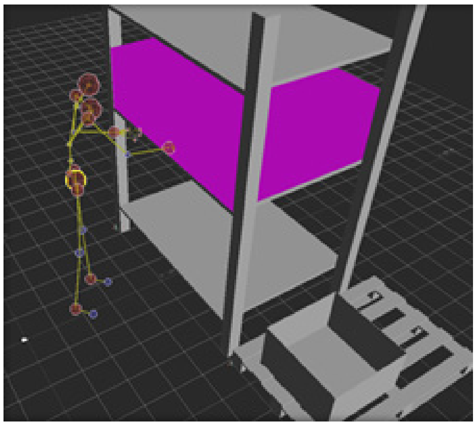

Figure 4b. Assessment of component picking from shelves.

Source: Author's own compilation

advantages of maintenance policies based on the continuous condition monitoring of an operating parameter are listed below (Alsina et al., 2018):

- Enhanced plant, production system, or machine availability
- Lower total cost of ownership of the considered production system
- Improvement in the design of complex production systems
- Potential revenue source for the maintenance department due to the sale of added-value services such as RAM analysis, maintenance strategy optimization, and forecasting of spare-part consumption.

Beside these positive aspects, the adoption of AI algorithm for the definition of maintenance policies, in particular the exploiting of continuous condition monitoring, is distinguished by some possible but severe threats.

Data analytics for condition based maintenance

A remarkable opportunity in the field of production system maintenance is represented by the adoption of data analytics tools and techniques that exploit AI algorithms, in particular for continuous condition monitoring. The aim of the maintenance policies is to define the optimal instant to perform a maintenance intervention, whether a component repair or replacement, in order to minimize the production system total breakdowns and maximize its techno-economic performance. A recent trend in this field of research is represented by the definition of the maintenance policies through the continuous monitoring of one or more relevant operating parameters of the considered production system. Thus, the maintenance interventions are defined considering the real-time conditions of one or more continuously measured parameters. Appropriate AI algorithms have to be developed and trained to define which alert threshold of the monitored parameter requests

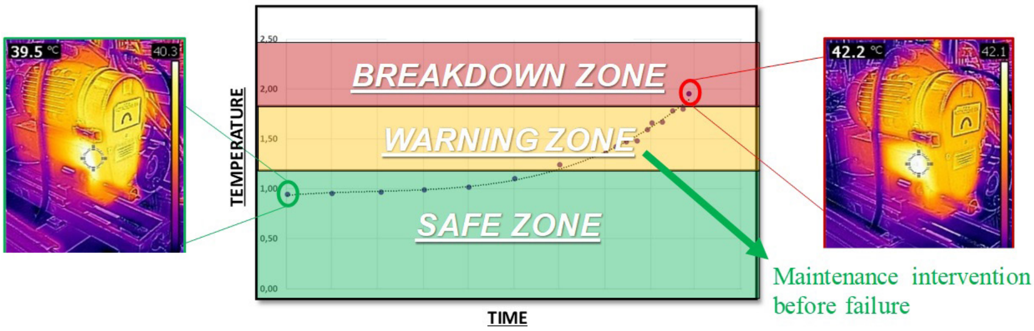

Figure 5. Maintenance policy based on the continuous condition monitoring of an operating parameter.

Source: Author's own compilation

First, the determination of the link between a weak monitored signal and the component or system reliability is significantly challenging. The most relevant decisions deal with the definition of which parameter to monitor, which is the link between the parameter value and the time before failure and whether or not to link the condition information with a known failure state of the monitored component. Furthermore, a major challenge is represented by the definition of a proper measurement chain and the storage of the collected data. The relevant decisions deal with the identification of which sensor is appropriate for the monitored process, where to place the sensor considering the appropriate necessary space, the storage capacity of the collected data with a demanding amount of data to be managed, and customer unwillingness to provide the data about their production processes. Finally, the first signals to be used, at low cost, are those typically needed to control the technological process of machines; these are often available but neglected, such as positions, speed, currents, and temperatures.

The application of different AI algorithms to several real industrial production processes to define the optimal maintenance policy confirms this conflicting trend. Some of the approaches that have been tested in various case studies, with mixed results, are listed below:

- An artificial neural network was developed and adopted to forecast the spare-part consumption of packaging machinery, with very positive results.
- A support vector machine was adopted to forecast the reliability of mechanical and electric components in a refrigerating plant, with positive results along with some potential threats.
- A random forest algorithm was implemented to remote monitor a cutting machine reliability assessing the different occurring alarms. The difficulty of assessing and subsequently exploiting the different clusters of alarms led to negative results.

Conclusion and further research

This paper proposes the adoption of AI tools and techniques to design and manage production systems in the *Industry 4.0* environment. Two real industrial applications have been presented to test and validate the approach described above, analysing both the advantages and also the drawbacks that distinguish such solutions. In particular, a hardware/software architecture based on depth cameras was developed to digitalize the operator motions within assembly or manufacturing systems, whereas a set of neural algorithms defines the maintenance policies for continuously condition monitored production systems.

The main outcomes of this research suggest that current and future technological resources offer interesting opportunities to exploit AI tools and algorithms for production systems. AI can accelerate the development of strategies to monitor these systems, with a particular focus on human performances and to define proper and efficient maintenance approaches. A relevant risk is represented by the fact that this new paradigm could eventually emphasize the current problems related to data collection and interpretation. Unfortunately, from an engineering perspective, it is not foreseeable to significantly reduce the difficulty determined by the monitored data interpretation. Thus, further research should focus the effort to reinforce the process to analyze the huge quantity of collected data, along with providing meaningful information that has strong relations and backgrounds to real industrial applications.

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Liability and automation: legal issues in autonomous cars

Giuseppe Contissa[a], Francesca Lagioia[a,b], Giovanni Sartor[a,b]

The deployment of highly automated systems, such as autonomous cars, is going through an accelerated expansion: as usual for emerging disruptive technologies a slow start is followed by a more and more rapid surge. One of the most important legal issues concerning these systems is related to liability for accidents. In particular, highly automated systems will make choices and engage in actions – usually with some level of human supervision, or even without any such supervision. In this context, there is the need to analyse how the decision-making process is split between humans and machines, and critically revise the way tasks, roles, and liabilities are allocated. In this contribution we analyse the impact of automation in the allocation of liability within autonomous cars. We first discuss the tasks allocation between human and automation, and the resulting responsibilities. Then, we analyse how the introduction of different levels automation gives rise to a redistribution of tasks between human and automation and, therefore, a reallocation of the liability burden between the user and the manufacturer.

Task-responsibilities and the impact of automation

In order to introduce the analysis of liability issues, we need to refer to the concept of task-responsibility, i.e. the duty pertaining to the correct performance of a certain task or role.

First of all, we need to identify task-responsibilities of the user, since their violation may result in personal liability. In fact, whenever there is a failure in a complex system, we try to connect the failure with the missing or inadequate execution of a task, and so with the (natural or legal) persons who were responsible for that task. As a consequence of the failure to comply with their task-responsibilities, these persons are subject to blame, penalties, and/or the payment of damages.

Secondly, we need to identify task-responsibilities of the automated system, namely, the requirements the system should comply with. These are also relevant, since a failure to meet them may make the system's producers or maintainers liable. With the introduction of higher levels automation, as task-responsibilities are progressively delegated to technology, liability for damages shifts from human operators to the organisations that designed and developed the technology, defined its context and uses, and are responsible for its deployment, integration, and maintenance.

In this context, it is necessary to adopt a systematic approach to match the degree of automation to different responsibilities of users of automated systems at different levels as well as to the responsibilities of other actors involved (managers, producers, and maintainers)(Contissa et al. 2013).

To this end, we consider the Level Of Automation Taxonomy (LOAT), developed by SESAR 16.5.1 (Save and Feuerberg, 2014) used to assess the levels of automation introduced by a new technology and to determine the corresponding impacts on the division of tasks between humans and machines.

The LOAT table provides criteria for assigning a level of automation to a technology with regard to four different cognitive functions: information acquisition (A), information analysis (B), decision-making (C), and action implementation (D). Figure 1 shows a simplified version of the LOAT: all columns start with level 0, corresponding to a fully manual accomplishment of the task, without any technical support. At Level 1 the task is accomplished with "primitive" technical tools, i.e., low-tech non-digital artefacts. From level 2 on upwards, "real" automation is involved, and the role of the machine becomes increasingly significant up to the level where the task is fully automated.

A certain technology may have different levels of automation, according to whether the actors are dealing with the four cognitive functions mentioned above.

The LOAT expresses varying levels of interaction between humans and the technology in question. In the first instance, it is used to better understand technology. It provides an accurate account of human-machine interaction and serves as a tool for refining the concept of automation. By conceptualizing automation on the basis of the human factor, it generates awareness of human-machine interaction.

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A INFORMATION ACQUISITION	B INFORMATION ANALYSIS	C DECISION AND ACTION SELECTION	D DECISION AND ACTION SELECTION
A0 Manual Information Acquisition	B0 Working-memory based Information Analysis	C0 Human Decision Making	D0 Manual Action and Control
A1 Artefact Supported Information Acquisition	B1 Artefact Supported Information Analysis	C1 Artefact Supported Decision Making	D1 Artefact Supported Action Implementation
A2 Low Level Automation Support of Info Acquisition	B2 Low Level Automation Support of Info Analysis	C2 Automated Decision Support	D2 Step by step Action Support
A3 Med. Level Automation Support of Info Acquisition	B3 Med. Level Automation Support of Info Analysis	C3 Rigid Automated Decision Support	D3 Low Level Support of Action Sequence Execut.
A4 High Level Automation Support of Info Acquisition	B4 High Level Automation Support of Info Analysis	C4 Low Level Automatic Decision Making	D4 High Level Support of Action Sequence Execut.
A5 Full Automation Support of Info Acquisition	B5 Full Automation Support of Info Analysis	C5 High Level Automatic Decision Making	D5 Low Level Automation of Action Sequence Exec
		C6 Full Automatic Decision Making	D6 Medium Level Automat. of Action Seq. Execut.
			D7 High Level Automation of Action Seq. Execut.
			D8 Full Automation of Action Sequence Exec

Figure 1. The Level Of Automation Taxonomy (LOAT)

Source: readapted from Save, L., Feuerberg, B.(2012), pp. 48-50.

Assessing the liability impact of autonomous cars

Road transportation is a domain, where the technological development is introducing high levels of automation. In order to analyse the issues related to the introduction of driving automation, the industry has adopted the SAE international standard J3016, a taxonomy describing the full range of levels of driving automation in on-road motor vehicles (SAE International 2016). The classification system is based on the levels of driver intervention and attentiveness required, resulting in a scale of six levels of automation, ranging from level 0 (no driving automation) to level 5 (full driving automation).

The levels of driving automation are defined by reference to the specific role played by each of the three primary actors (the human driver, the driving automation system, other vehicle systems and components) in performing dynamic driving tasks (DDT). Dynamic driving tasks include all real-time operational and tactical functions required to operate a vehicle in on-road traffic (e.g. lateral/longitudinal motion, monitoring the driving environment, etc.), excluding the strategic functions such as trip scheduling and selection of destinations and waypoints.

Functions 3 and 4 are collectively referred to as “object and event detection and response” (OEDR).

In levels from 0 to 2, the driver performs part of all of the DDT, whereas form level 3 to 5 the Automated Driving System (ADS)[1] performs the entire DDT, while engaged.

In this section, we map the driving automation levels described in the SAE standard to the four cognitive functions of the LOAT. We identify, for each driving automation level and for each cognitive function involved, the responsibilities among user and manufacturer, and the resulting legal liabilities. In analysing the different levels, we focus on the driving tasks affected by automation. We do not consider the cases in which the automated driving system is disengaged, since in these cases all dynamic driving tasks

[1] Automated Driving System (ADS) is “the hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD).” (SAE J3016, pag. 3)

are performed by users. Moreover, we do not consider liabilities not directly related to driving tasks, for example liabilities related to the maintenance of the vehicle and of the ADS systems, which can be apportioned across different actors (the driver, the owner, the manufacturer, etc.).

Level 0

In SAE J3016 standard, level 0 (no driving automation) the driver performs the entire DDT, while the driving automation system (if any), does not perform any part of the DDT on a sustained basis, although the systems in the vehicle may provide warnings or support (e.g. anti-lock brake systems, conventional cruise control, or electronic stability control).

The user is entirely responsible for the following tasks: the acquisition and filtering of information; its analysis; the generation of decision options and the selection of the appropriate ones; the execution and control of actions.

According to the LOAT, the tasks involved in driving at level-0 automation are correspondingly classified as A1 (Artefact-Supported information Acquisition); B1 (Artefact-Supported Information Analysis); C1 (Artefact-Supported Decision Making); and D1 (Artefact-Supported Action Implementation).

In case of accident caused by a failure in executing one of these tasks, the manufacturer is liable only when he provided a defective or non-standard compliant tool, that had a role in the causation of the accident (for example, defective brakes preventing the car to avoid the collision). In all the other cases, user's liability is to be considered.

Levels 1 and 2

Level 1 (Driver Assistance) is defined as "the sustained and ODD[2]-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT." The driver must supervise the driving system performance by completing the OEDR subtask of the DDT as well as performing the other dimension of vehicle motion control.

Level 2 (Partial driving automation) differs from Level 1 because the driving system is expected to execute both the lateral and the longitudinal vehicle motion control simultaneously. Thus, the difference between Level 1 and 2 is merely quantitative, in the sense that it concerns the extent of the automated motions of the vehicle, under human control.

Regarding information acquisition, the system uses predefined criteria to integrate, filter and highlight information; supports the user in integrating data, filters information items and highlights the most relevant. The user, after being instructed on the information acquisition functions, monitors their performance.

Regarding information analysis, the system supports the user in comparing, combining and analysing information items concerning the status of the system's processes, based on parameters pre-defined by the user, and alerts him if the results of analysis require his/her attention. The user defines the parameters of the process, takes duly into account the system's outcomes and reacts to its alerts.

Regarding decision making, the system proposes decision alternatives and informs the user about its determinations. The user is monitors the determinations of the system.

Regarding action implementation, the system performs automatically a sequence of actions after activation by the user. The user monitors the sequence and interrupts its execution when needed.

According to the LOAT, the tasks involved in driving at Levels 1 and 2 would be classified as A5 (Full Automation Support of Information Acquisition), B4 (High-Level Automation Support of Information Analysis), C4 (Low-Level Automatic Decision Making), and D4 (High-Level Support of Action Sequence Execution) at maximum.

In case of accident caused by a failure in executing one of the functions, the manufacturer is liable only when providing a defective or non-standard compliant tool that had a role in the causation of the accident (for example, a production defect concerning brakes that cannot prevent the car to avoid the collision, or a design defect concerning the user interface being unable to provide correct information, or a warning defect concerning the lack or insufficient information on the functioning of the automation provided to the user). In all other cases, user's liability is considered, since most of the dynamic driving tasks fall under the user's control and responsibility. In particular, the user might be found liable when acting without reasonable care, including when s/he failed in monitoring the performance of the system, taking duly into account the system's outcomes and reacting timely to its alerts or any other risky situation.

Level 3

In Level 3 (Conditional Driving Automation), the driver (while the ADS is not engaged) is expected to (1) verify the operational readiness of the ADS-equipped vehicle; (2) determine when engagement of ADS is appropriate. When the ADS is engaged, the driver shall be ready to in-

[2]The Operational Design Domain (ODD), is the set of the specific conditions under which a given driving automation system or feature thereof is designed to function, including, but not limited to, driving modes.

tervene and to take back the control when requested. The ADS, while engaged, is expected to (1) perform the entire DDT; (2) determine whether ODD limits are about to be exceeded and, if so, issue a timely request to intervene to the driver; (3) determine whether there is a DDT performance-relevant system failure of the ADS and, if so, issues a timely request to intervene to the driver; (4) disengage an appropriate time after issuing a request to intervene, or immediately upon driver request.

Regarding the acquisition of information, the system supports the information acquisition; has predefined criteria for integrating, filtering and highlighting information; supports the user in integrating data, filtering information items and highlighting the most relevant. The user, after being instructed on how to use the system, monitors its performance.

Regarding information analysis, the system performs comparisons and analyses of data available on the status of the process being followed, based on parameters defined at design level. The system triggers visual and/or aural alerts if the analysis produces results requiring attention by the user. The user takes duly into account the system's outcomes and reacts to its alerts.

Regarding the decision and action selection, the system generates decision options, selects the appropriate ones and decides all actions to be performed. The user can safely turn his/her attention away from the dynamic driving task, but must still be prepared to intervene when called upon by the vehicle to do so, or whenever the ODD limits are about to be exceeded.

Regarding action implementation, the system initiates and executes automatically a sequence of actions, while the user monitors all the sequence and interrupts it during its execution, when requested by the system or whenever the ODD limits are about to be exceeded.

According to the LOAT, the tasks involved in driving at level 3 would be classified as A5 (Full Automation Support of Information Acquisition); B5 (Full Automation Support of Information Analysis); C6 (Full Automatic Decision Making) and D6 (Medium-Level Automation of Action Sequence Execution).

In case of accident caused by a failure in executing one of the functions, since most of the dynamic driving tasks fall under the system's control, the manufacturer is liable (1) when providing a defective or non-standard compliant tool that had a role in the causation of the accident; (2) whenever the system fails to carry out the assigned task with a level of performance that is (at least) comparable to that reached by a human adopting due care under the same conditions.

User's liability is to be considered when (1) the user does not respond appropriately to a request to intervene; (2) whenever the ODD limits are exceeded, since s/he is expected to monitor the system's performance, take duly into account its outcomes and react to its alerts.

Level 4 and 5

Level 4 (High driving automation) is the level where the driver, while the ADS is not engaged, shall (1) Verify the operational readiness of the vehicle; (2) Determine whether to engage the ADS.

While the ADS is engaged, the driver becomes a passenger (if physically present in the vehicle) or a dispatcher. The passenger/dispatcher is not expected to perform the DDT or DDT fallback and to determine whether and how to achieve a minimal risk condition. Thus, the automated DDT fallback and minimal risk condition achievement capability of the system is the primary difference between level 3 and level 4 ADS features. However, the passenger will become a driver after a request of disengagement.

The ADS, while not engaged, is expected to allow engagement only within its ODD. While the ADS is engaged, it is expected to (1) perform the entire DDT; (2) eventually issue a timely request to intervene; (3) perform the DDT fallback, automatically transiting to a minimal risk condition when (a) a relevant DDT failure occurs; or (b) the user does not respond to a request to intervene; or (c) a user requests that the system achieve a minimal risk condition; (4) disengage if appropriate only after (a) it achieves a minimal risk condition or (b) the driver is performing a DDT; (5) delay eventually user-requested disengagement.

Level 5 (full driving automation) differs from Level 4 only for the unconditional/not-ODD specific performance by the ADS. This means that the system can operate the vehicle under all driver manageable all-road conditions, i.e. there are no geographical, weather or time-based restrictions.

Therefore, with regard to the acquisition of information, the system supports the information acquisition; has predefined criteria for integrating, filtering and highlighting information; integrate data, filter information items and highlight the most relevant for the user.

With regard to the information analysis, the system shall perform comparisons and analyses of data available on the status of the process being followed based on parameters defined at design level. The system triggers visual and/or aural alerts if the analysis produces results requiring attention by the user. The user may take into account the system's outcomes and react to its alerts.

With regard to the decision and action selection, the system shall generate decision options, select the appropriate ones and decide all actions to be performed. The user can safely turn his/her attention away from the dynamic driving task but may intervene when called upon by the vehicle to do so, or, in level 4, whenever the ODD limits are about to be exceeded.

With regard to the action implementation, the system initiates and executes a sequence of actions. The user can only monitor part of it and has limited opportunities to interrupt it, for example, in case of user-requested disengagement under appropriate conditions.

According to the LOAT, the tasks involved in driving at levels 4 and 5 would be classified as A5 (Full Automation Support of Information Acquisition); B5 (Full Automation Support of Information Analysis); C6 (Full Automatic Decision Making) and D7 (High-Level Automation of Action Sequence Execution).

In case of accident caused by a failure in executing one of the functions, since all dynamic driving tasks (in level 4, within the ODD limits) fall under the system's control, the manufacturer is liable (1) when providing a defective or non-standard compliant tool that had a role in the causation of the accident; (2) whenever the system fails to carry out the assigned task with a level of performance that is (at least) comparable to that reached by a human adopting due care under the same conditions. Since at this level of automation the user is not expected to respond to any request to intervene when the ADS is engaged, user's liability is to be considered only when the ODD limits are exceeded, or when, following a user's request, the system permits the ADS disengagement.

It should be noted that vehicles under Level 4 or 5 may be designed to be exclusively operated by ADS for all trips. In this case, they may be designed without user interfaces, such as braking, accelerating, steering, etc. These categories of vehicles do not necessarily involve a driver. Whenever user interfaces are missing, the user will not be able to intervene in any of the Dynamic Driving Tasks, and therefore cannot be subject to the related liabilities.

Conclusions

When automated systems are increasingly introduced into a complex system, the main effect is that liability for damage or harm is gradually transferred from humans to enterprises using the automated technology, that replaced the human operator and /or to the technology developer (programmer, manufacturer) that created the technology.

While the trend of transferring liability from the individual to the enterprise has been observed for quite a long time (Brüggemeier 2006), new AI technologies accelerate this trend, since they deeply impact on the tasks of human operators, not only quantitatively but also qualitatively, replacing human operators in their higher cognitive functions, ranging from the analysis of information to the selection of a decision or an action, to the fully automated implementation of the chosen action.

Of course, not all advanced technological systems possess these cognitive functions to the same extent. For example, many currently employed automated systems are not designed to automatically implement the chosen actions, but only to suggest actions to be executed by the human operator.

In order to evaluate the final liability allocation between different actors, it is necessary to assess each technology's different levels of automation in performing different cognitive functions (acquiring information, analysing information, making decisions, and acting on them).

It should be noted that intermediate levels of automation are sometimes those that create higher levels of legal risk for certain actors. It happens because of a high fragmentation of task-responsibilities between the automated technology and the operator in these levels, possibly leading in some circumstances to uncertainty in the assignment of tasks. In addition, intermediate levels of automation usually imply also a greater complexity in the human-machine interface, since fragmented tasks require more interaction between a technology and its operator.

In legal terms, this may translate to an increased duty of care, resulting in a higher liability risk for (a) the operator; (b) the organisation employing the operator, both for vicarious liability and for organisational liability; and, finally, (c) the producer of the technology, since higher complexity in the human-machine interface would increase the risk of technological failure (Schebesta et al. 2015).

Moreover, from a safety perspective, in intermediate levels characterised by higher levels of automation in acquisition and analysis of information, and lower levels in the action selection and implementation, it is questionable, whether the user has concrete possibilities to intervene in the decision-making process, since s/he will not be in the position to critically revise and evaluate (in due time) all the environmental information required to take a decision. In time-sensitive situations, the action by the user will be mostly instinctive, rather than based on a rational process. These may result in worse outcomes. For example, the choice of braking may be taken and executed faster by automation, rather than analysed and proposed to the user, that will subsequently assess, select and implement the proposed action, or even disregard it. Besides, even in non-time-sensitive situations, it is possible to argue that an autonomous car is able to collect the relevant information and evaluate all the possible outcomes of alternative actions more precisely and faster than any human should, for example, considering the car speed and its distance from an obstacle (e.g. a pedestrian or another car) to evaluate the more appropriate manoeuvre (e.g. swerve or stay on course and break). For these reasons, we believe that in many domains, full automation is preferable to intermediate levels of automation, both from the legal and the safety perspective.

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