Autonomous Machines

Emerging Risks Initiative – Position Paper

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CRO FORUM

Foreword

For better or worse, autonomous machines are playing an increasingly important role in all aspects of today's reality.

Autonomous machines encompass self-driving cars, robots and autonomous equipment used for manufacturing, mining, farming, transport, medical care and assistance, lethal autonomous weapons and many other applications. They represent important examples of technological developments that are occurring quickly, affecting almost all sectors of the economy, and leading to important new legal, regulatory, societal and ethical considerations.

In particular, autonomous machines may have profound implications for re/insurance. As human error is the main cause of accidents, a wider use of autonomous machines might lead to a transition from loss frequency to severity, and losses may accumulate in new ways. Autonomous machines also have the potential to significantly improve risk management, prevention and disaster investigation.

In this publication, the Emerging Risks Initiative (ERI) of the Chief Risk Officer (CRO) Forum has aimed at summarising the main issues that the re/insurance industry currently faces as a result of advances in the use of autonomous machine technology. Presented in instructive, simple terms and illustrated with many practical examples, it is a contribution to the CRO Forum's goal of providing best practice in risk management to advance business. In line with earlier papers by the ERI – in particular the Smart Factory issued in 2015 and dedicated to the convergence of innovative technologies in manufactures – this publication is a further demonstration that the re/insurance industry is concerned with, and strives to stay abreast of, key social and technological evolutions.

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Frieder KNÜPLING
Group Chief Risk Officer, SCOR

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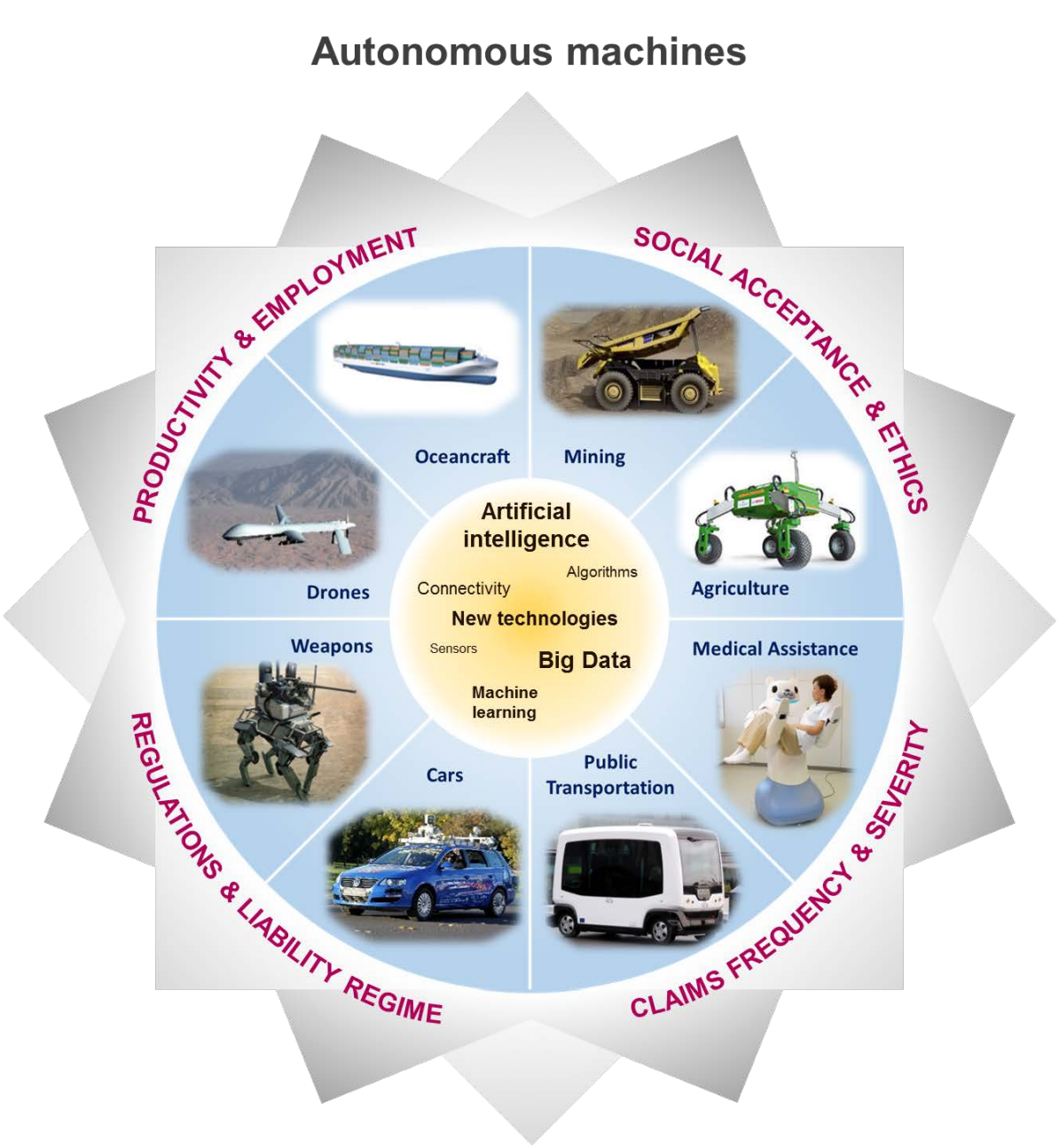


Diagram of contents of this position paper:

- *Inner circle: Enablers of the autonomous machines' technology;*
- *Pie chart: Eight selected examples of autonomous machines;*
- *Outer ring: Outputs for society and impacts for re/insurance of the development of autonomous machines.*
  Top part of the graph: outputs detailed in Chapter 1 – Delegation of Decisions to Machines: Impact on Corporate Landscape and Processes.
  Bottom part: outputs detailed in Chapter 2 – Impacts on Re/Insurance Underwriting Risks.

Executive Summary

Autonomous machines increasingly feature in business's and people's everyday lives. With exponential advances expected in the next few years in artificial intelligence, robotics and data-supporting infrastructure, autonomous machines are set to become prevalent. Almost all economic sectors will be affected, including manufacture, transportation, food industry, agriculture, health, education, finance and insurance. The impact of automation on growth and employment will be major, including raising ethical concerns and societal implications.

The topic of 'Autonomous Machines' is one of the most interesting emerging risks from a re/insurance perspective. Major uncertainties are already arising during a transition period that sees the increasing cohabitation of humans and machines. In the longer term, the impact of machine autonomy could be highly significant for re/insurers, as it is likely to bring fresh uncertainties and transform most types of claims or models of liability. As machine autonomy improves, the changing nature, frequency and impact of risks will inevitably lead to the reframing of several lines of business, new inclusions and exclusions from re/insurance portfolios.

In minimising the human factor, which is usually the main cause of accidents, a shift from loss frequency to loss severity might take place. The same programming error could be replicated on numerous machines or one machine could repeat the same erroneous activity several times leading to an unforeseen accumulation of losses. A systemic malfunction of autonomous machines controlling critical infrastructure systems (e.g. IT-network, power supply) might even significantly affect the highly interconnected global economies and societies.

New behaviours and usages could equally generate new risks and categories of customers requiring different kinds of insurance products. Responding to these new types of demand, re/insurers could find opportunities to develop innovative products. Some lines of business such as Motor Third Party Liability, Cyber, Personal Liability, Injuries and Damages could be strongly impacted.

Disaster response is another important use of autonomous machines such as unmanned vehicles and robots. By operating in environments that could be dangerous or impossible for humans to access, they offer huge potential for the re/insurance industry. Machine autonomy for disaster relief may improve claims handling, loss mitigation, pre-disaster planning, risk evaluation and even fraud prevention. Reducing risks and improving time and cost effectiveness could help enhance the efficiency of insurance services and offer better-quality customer experience.

The topic of machine autonomy covers numerous fields of activity from simple autonomous algorithms to the upcoming human-like machines (see 'What is an autonomous machine?' on page 5). For the purpose of this paper, the Emerging Risks Initiative of the CRO Forum resolves to concentrate specifically on the impact for re/insurance of physical autonomous machines. Pure software, simple bots or smart applications – that are not implemented into a physical device – will not be in focus. Several dedicated examples further illustrate the discussion on the various expected impacts of autonomous machines on: private and public transportation, mining, drones, ocean craft, weapons, agriculture and medical care (see the diagram of contents on page 3).

The full extent of impacts from autonomous machines on the re/insurance industry is still difficult to assess. Whilst some of the vulnerabilities are already apparent, it is clear that the opportunities offered by these new technologies are immense. However, with such a level of uncertainty and the potential for significant impacts, autonomous machines still represent a major emerging risk for the re/insurance industry.

WHAT IS AN AUTONOMOUS MACHINE?

Definition and scope[1]

A machine is made of parts and mechanisms driven by energy to produce power and/or a mechanical motion for an intended purpose. In this paper, a machine is considered "autonomous" as soon as it:

- possesses some ability to treat and react to information about its surroundings that can be unpredictable;
- executes tasks and self-manages over an extended period of time with little or no human intervention or assistance; and
- is able to take decisions, the decision making process being delegated from the human operator to the machine.

Mechanism of autonomy[2]

Perception
- A battery of sensors gives the machine the ability to 'perceive' its environment: positioning of human beings, objects and other constraints.

Context understanding
- The data retrieved from the environment is processed to interpret the situation in a scenario recognisable by the machine.

Decision making
- The more appropriate response behaviour(s) is(are) chosen among options in accordance with the context and purpose of the reaction.

Action
- The chosen behaviour is carried out through actual movements of the machine's parts or activation of its mechanisms.

Intelligent machines

Autonomous machines react based on models. In a deterministic approach, all possible scenarios have been envisaged and the outputs taught to the machine. However, this is hardly possible in complex or unpredictable environments.

Machine learning is a game changer. With a basis of selected inputs, the machine learns from past experience how to react to real situations. Closed and secured locations are ideal for the development process of such autonomous machines.

Human-machine interactions[3]

Autonomous machines have been created for humans, to work with humans and to answer human purposes (e.g. to improve capacities, productivity, safety and reliability). As such, their successes and failures can only be assessed in this ecosystem of human-machine interactions.

The challenge of autonomous machines is more a social one than an engineering one. New habits, ways of living, responsibilities and models of ownership should be expected.

From a re/insurance perspective, this will impact consumer behaviours and expectations.

Risks

Blind spots
- Not everything can be perceived by the standard sensors, therefore the machine decision-making process can be biased. 'Perfect' perception is impossible.

Machine failure
- There will always be scenarios that have not been anticipated. Society might need to accept that machine autonomy will bring new risks. Yet people may have very low tolerance because the error will not be a human one.

Lack of control
- Defining constraints to frame the machine learning mechanism could be complex, depending on who creates the rules, who monitors how and what the machine learns, and the level of detail of this framework.

Lack of transparency
- Machines are not yet able to justify the decisions they take. Even programmers have little control and understanding over outputs of the artificial intelligence they created.
- The vulnerability to hacking and to cyber risks is increased.

Partial autonomy
- The stage of partial autonomy is the most perilous.
- The paradox is that the more a system is autonomous, the harder it is for humans to regain control in case of crisis or machine failure.

Over-confidence
- The target of user interaction is to switch from a feeling of little confidence to reliance on the machine. However, over-confidence could also be the cause of accidents.

Introduction

> *"Robots should inspire hope, not fear. Digital transformation is having an enormous impact on jobs and society. If we act now and invest in developing and shaping the right skills, then the 'digital' workforce will be the real catalyst for sustainable and inclusive growth in the 21st Century."*
>
> **Stephan Howeg (World Economic Forum) – 2017[4]**

The Rise of the Machine

The fourth industrial revolution is here, with technological innovations that have the potential to transform society. The development of machine autonomy and its close companion, artificial intelligence, has picked up speed after a long and slow initiation phase. Advanced developments, innovations and new uses are appearing at an increasingly fast pace. While manufacturing has been an early adopter of advanced robotics and automation, other fields are increasingly making use of autonomous systems.

Automation, autonomy and artificial intelligence offer new possibilities in fields as diverse as work, mobility, communication, services, healthcare and life management. 'Self-directing' and supposedly 'independent' machines will have to fully integrate into social and technical networks designed for and by humans. Successes and failures of these machines will be determined from their ability to achieve their intended purpose and from the economic or social impact they will have on societies.

As the topic is vast, this paper takes a selective approach and limits itself to autonomous machines that have a physical manifestation. Consequently, it does not cover pure software, simple bots or smart applications that are not implemented into a physical machine, although these technologies are briefly covered where relevant (see 'Artificial intelligence and re/insurance' on page 7).

Impacts on the Re/Insurance Industry

The potential for autonomous machines to revolutionise the way we live brings major uncertainties for the re/insurance industry. Foreseeing a world where people will have to coexist with machines that are partly or wholly autonomous will pose major challenges to re/insurers.

Because human and machine will be in constant interaction, the re/insurance industry has to anticipate and adapt to new challenges. Taking over or supporting human tasks, autonomous machines will offer new possibilities, but also unfamiliar risks. Consumers may modify their behaviours and have higher expectations in terms of safety and reliability of the machines. The types of accidents could be impacted with new trends in frequency and severity of losses. Emerging models in ownership and usage could also shift the framework of responsibilities between the machine, its owner, the manufacturer or even the programmer.

Such questions will most likely trigger an evolution of global regulations, resulting for instance in the legal recognition of the machine as a responsible stakeholder, thus directly impacting claims and re/insurance portfolios. The ability of some machines to make decisions for themselves will redefine internal processes and transform the re/insurance corporate landscape and underwriting activities, bringing both risks and opportunities.

This publication aims to provide insights into the impact of autonomous machines for the re/insurance industry, focusing on these aspects and further illustrating with practical examples.

ARTIFICIAL INTELLIGENCE AND RE/INSURANCE

Although not the main focus of this paper, artificially intelligent software that does not require a physical form may also have a major impact on the re/insurance industry. The following is a brief summary of the topic.

What is artificial intelligence?[5]

Artificial intelligence (AI) characterises machines, computers or software that simulate the intelligence of humans' behaviour to achieve goals. In computer science, the field of AI research defines itself as the study of "intelligent agents": any device that perceives its environment and takes actions that maximise its chance of success at some goal.

Non-physical machines equipped with AI are rapidly approaching and could replace human workers in many activities. The jobs threatened by these new intelligent technologies include not only workers in manual or "blue collar" roles, but also professional occupations, such as lawyers, consultants, writers and brokers.

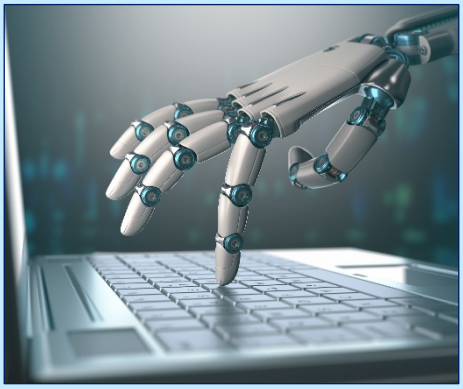
Furthermore, AI is often coupled with machine learning, the ability of the machine to learn from various data and from its own experience[6]. Such a machine is able to perform new or unexpected tasks based on predictions from its past experience (see the different levels of AI in the table below)[7]. Potential fields of application are numerous, for instance in medical diagnosis, smart cities, economics, data treatment and fraud detection.

An even more futuristic view envisions the coming of Strong Artificial General Intelligence (AGI) that would be able to perform any task as well as a human and pass itself off as indistinguishable from a human in cognitive, perceptual, learning, manipulative, planning, communication and creative functions. As for now, such capabilities are still a long way off.

TYPES OF AI: FROM REACTIVE TO SELF-AWARE			
Type I (existing)	**Type II (existing)**	**Type III (in the future)**	**Type IV (in the future)**
Narrow / weak Artificial Intelligence		**Artificial General Intelligence**	
Purely reactive	Limited memory	Theory of mind	Self-aware
Perceives and reacts to its environment in one area of specialisation	Its past experiences are added to pre-programmed situations	Understand human emotions and thoughts, which enables it to interact socially	Can form conscious internal representations of itself and make abstractions

Special development on insurance-related applications

Insurance-related applications using AI already exist. For instance, robo-advisors are software that algorithmically generate investment allocations and pricing advice, while keeping up with market evolutions and shifts in customers' behaviours.



By automating services, underwriting processes and claims management, AI in re/insurance allows for better client tailoring – both in giving advice and in interactions – faster handling of claims and more accurate management of portfolios. Direct benefits are expected in the form of cost savings from increased operational efficiency, quicker customer-service, and better brand reputation[8]. Intelligent automation increases the time that human workers can allocate to tasks not yet manageable by AI.

Main risks for the re/insurance industry

The risks related to the use of artificial intelligence in re/insurance services are similar to most digital innovations, with the well-known concerns over data quality, data protection and adequate IT infrastructure. But some specific risks come on top of these: for example if robo-advisors have the same fiduciary responsibilities as a human, the current legal framework may need to be revised[9].

The regulatory implications are significant. The potential for disruption and destabilisation of the insurance market from fully autonomous and interconnected systems controlling large portions of the market should be monitored. Where intelligent and autonomous systems make underwriting or claims decisions there could be implications for claims costs and unforeseen exposure outside the risk appetite of a re/insurance company. This is especially true where the re/insurer is not able to adequately explain the decisions being made or the decision making process.

1 Delegation of Decisions to Machines: Impact on Corporate Landscape and Processes

Key findings

- Autonomous machines will affect all sectors of the economy; yet, there is a great deal of uncertainty on the timescale and the extent of this trend;
- The impact of automation on growth and employment will be major. New jobs will be created, but between 9% to 50% of the current labour force could be automated;
- Major ethical concerns and societal implications will rise;
- Re/insurance own operations will need to adapt to new demands and competition, but also to massive data management and new regulations on personal data.
- For the re/insurance industry itself, there will be potential consequences on the workforce and competitiveness (enhanced decision making).

1.1 Impact on the Business and Operational Landscapes

1.1.1 Implications for economy and consumers as (potential) insurance customers

After colonising manufacturing productions, autonomous machines are moving into other areas of business and life. Despite the publication of several studies on the subject, the general impact on the economy and on the workforce from automation is still unclear[10]. Areas that should be the most impacted, potentially in the short term are: accommodation and food services, manufacturing, agriculture and farming, transportation and logistics, retail trade, mining, medical and social care, and home assistance (see 'Sectors of activity likely to be most impacted by autonomous machines' on page 9).

Autonomous machines are likely to impact economic growth in two ways. On the one hand, there will be a boost in growth and wealth, due to enhanced efficiency and productivity. For example, in many countries autonomous machines could offset the impact on the workforce of a decline in the working-age population. On the other hand, workplace automation will also eliminate many low or middle skilled roles, leading to stagnating or even declining wealth for more than a third of the population in developed countries.

Adaptation efforts, such as retraining employees or re-educating society, will struggle to keep pace with the fast development of machine intelligence and its vast applications. Even if the creation of many new human jobs is likely, significant net losses in employment are possible. An associated decrease in mass consumption is to be expected, if spending power of households remains closely related to income from human labour. These possible social evolutions raise public concerns.

The replacement of employees by machines will ultimately change the time productivity, cost ratio and organisational structure of a company. For instance, human wages are relatively steady and regular, but rising over time whereas machines historically represent a single-impact burden for purchase with additional maintenance costs later on.

The threat to employment from the rise of robots is now being taken seriously by Central Bankers: this was discussed during their seminar in June 2017 in Sintra (Portugal)[11].

SECTORS OF ACTIVITY LIKELY TO BE MOST IMPACTED BY AUTONOMOUS MACHINES

Sector of activity	Automation potential %
Accommodation and food services	73
Manufacturing	60
Agriculture / farming	58
Transportation and logistics	57
Retail trade	53
Mining	51

The McKinsey Global Institute estimated the automation potential of various sectors of activities[12]. The sectors with automation potential above 50% are illustrated in the table to the left.

Re/insurers may need to flex from traditional physical insurance covers to more liability and business interruption covers to meet the changing needs of manufacturers and clients in these sectors of activity.

Accommodation and food services: There are already high levels of automation in food production and the introduction of robotics will no doubt equally take place. The use of smart sensors to adjust manufacturing to the variation in ingredients may also become a factor in smart food production. The rise of artisan foods indicate there may persist a place for manual manufacturing, however this is likely to remain niche and increasingly expensive as labour costs increase in relation to automated machines. (The CRO Forum ERI Paper has published in 2013 a position paper on Food and its impact on the risk landscape)[13].

Manufacturing: Many tasks are already undertaken by autonomous machines. Connected production is starting a further wave of automation, which may not inevitably lead to a reduction in jobs. Currently, countries with a high share of autonomous machines doing work (e.g. the USA, Germany and the Republic of Korea) have high employment rates[14]. Automation may give rise to more flexible production approaches, with implications where there could be reliance on only a few highly skilled individuals. (The CRO Forum ERI has published in 2015 a position paper on the Smart Factory)[15].

Agriculture / Farming: Robots already milk cows, provide feed, do the cleaning and help in harvesting. Full and intelligent automation is a logical next step. With increasing pressure on food costs and fewer people willing to work in farming, automation has been welcomed and will become increasingly necessary for a farmer to be competitive. (See focus on page 27).

Transportation and logistics: Connected and autonomous vehicles will lead to a sharp reduction in associated employment. Eventually, human drivers of trains, lorries, ocean crafts, taxis, or even planes in a more distant future, will be obsolete. For example, studies show that in ten years every third truck sold in Europe will be steered autonomously[16]. (See focuses on page 17, 21 and 23).

Retail trade: The retail industry is undergoing significant changes due to automation and digitalisation, for instance with the development of online trade platforms. Online shopping is rapidly eroding physical retail, and logistics can be easily handled by autonomous machines. If “live shopping” remains in the future, it could be mostly operated by robots, as demonstrated by pharmacies automating dispensing systems across Europe. This may have few implications for re/insurers as public liability will remain one of the key products required.

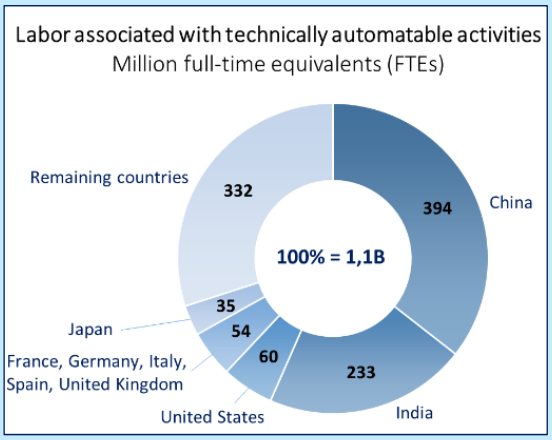
Mining: Mining assets are now instrumented and intelligent, reporting their location, status and other key metrics remotely and automatically. This trend is set to continue: automated fleets typically record a 10 to 20% production increase compared to manned vehicles, together with significant savings in maintenance, tyre life and fuel. (See focus on page 19).

Medical and social care: Due to ageing populations, the lack of staff and pressure on costs, autonomous care workers and nurses could be of huge support to the medical and social care industries. Robots are in the process of being introduced in social care in Japan but are yet to become widely used. Today in some modern hospitals, food distribution, pharmaceuticals, laundry handling, diagnosis and assistance in surgery are executed by robots and machines with a steadily rising degree of autonomy. More specialised and remote medical care will become increasingly viable with the use of robotics. The implications for health, life and liability insurance are significant. (See focus on page 25).

Home assistance: Households are already starting to engage robot help in repetitive activities. Autonomous machines capable of doing the window cleaning, lawn mowing or vacuum cleaning is a reality and likely to become more common as capabilities increase and costs decrease. Yet, analysis demonstrates that human helpers will not become obsolete, as some activities still can be done better, quicker and in some cases cheaper by humans. Implications for insurers may be limited with little change in life or P&C insurance products, although claims could increase as households own increasingly sophisticated devices and appliances.

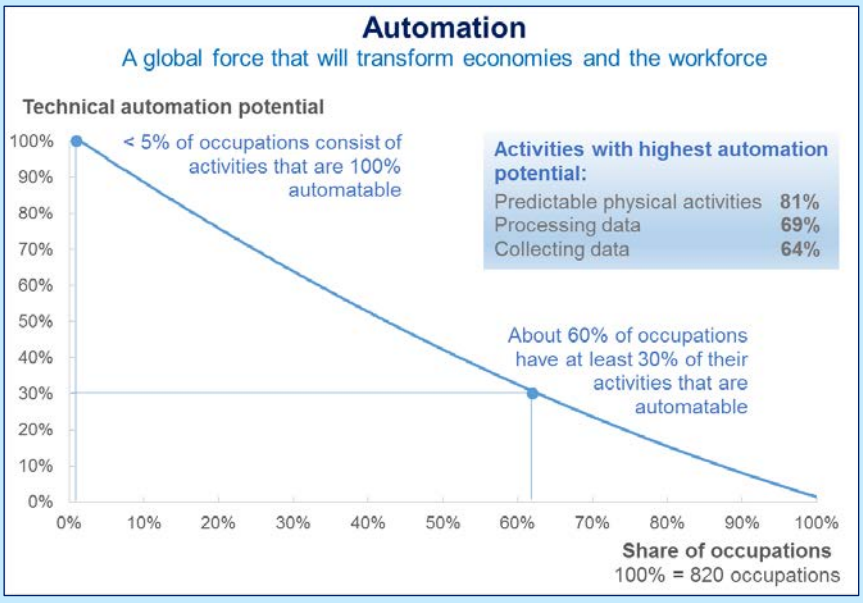
Whilst some studies conclude with substantial potential growth resulting from these trends (see below 'Automation's impact on employment and productivity'), the World Economic Forum sees in 2017 *"Artificial Intelligence and Robotics as the emerging technology with the greatest potential for negative consequences over the coming decade*"[17]. Another study in 2016 of twenty-one member countries of the Organisation for Economic Co-operation and Development (OECD), using a different methodology, concluded that only 9% of tasks are automatable[18].

AUTOMATION'S IMPACT ON EMPLOYMENT AND PRODUCTIVITY



The McKinsey Global Institute released in January 2017 a thorough study[19] on the impact of 'automation' on employment and productivity. Even if basic 'automation' and 'machine autonomy' should be distinguished, this study provides good insights into the potential disrupting effect of these trends.

One of their conclusions is: "*Almost half the activities people are paid almost $16 trillion in wages to do in the global economy have the potential to be automated by adapting currently demonstrated technology, according to our analysis of more than 2,000 work activities across 800 occupations. While less than 5 percent of all occupations can be automated entirely using demonstrated technologies, about 60 percent of all occupations have at least 30 percent of constituent activities that could be automated. More occupations will change than will be automated away*."



Adapted from: McKinsey (2017). "A future that works: automation, employment, and productivity. Executive Summary".

Another factor to consider is the location of a business. If most activities can be undertaken by autonomous machines and if logistical costs decrease, factories and other businesses may no longer need to be located near skilled workers, customers or raw materials. Sources of cheap and environmentally friendly power sources may become an even greater driver of location. Any significant shifts in the location of businesses could have an amplifying effect on any other employment factors.

Increased structural unemployment will lead to reduced taxes and higher benefits, potentially placing pressure on government finances, unless there is a substitute. Alternative taxation systems such as negative income taxes and robot taxes are only partial solutions to limit seemingly inescapable job losses[20]. This will have further implications if concepts like the 'Universal Basic Income' become commonplace.

1.1.2 Implications for operational activities of re/insurance companies

Physical autonomous machines are set to transform labour intensive industries with physically demanding or repetitive roles. Insurance does not normally fit into this bracket, yet important impacts on the operational activities of re/insurance companies might be triggered by various sources:

- **Massive data integration and management**

  Autonomous machines will generate massive amounts of data available to their manufacturers and to their clients. Access, appropriation and treatment of such data for risk selection and pricing might become a decisive competitive advantage.

- **New regulations on personal data & data portability**

  For a significant part, data generated by autonomous machines will be personal data, because they directly or indirectly give information about identifiable individuals (e.g. autonomous car). Thus, the data economy expansion is only possible with appropriate policies and regulations. The European General Data Protection Regulation (GDPR) that comes into force in May 2018 aims to help the data economy development while guaranteeing a certain level of protection for individuals.

  In order to boost data economy development, the GDPR aims to increase the confidence of individuals in the processing of their data, by introducing the concept of data processor responsibility or by empowering the individual to manage their own personal data, with a reinforced information obligation and a growing need for the collection of consent.

  A right to data portability is also provided by the Regulation: on request, the data controller must transfer the data collected on that person, in a reusable format, to the other data controller chosen by the data owner. This measure aims to boost competition in certain sectors and to allow greater data mobility.

- **Enhanced decision making**

  Autonomous wearables controlling health or conducting genetic testing of insureds with life or critical illness policies may lead to disease prevention or conversely anti-selection behaviours.

  Autonomous machines such as drones (or small submarines) may be used for pricing purposes, such as to assess and provide a quote for objects to be insured (e.g. buildings or ships), and for claims assessment.

1.2 Consequences for Corporate, Regulation and Society on Ethical and Moral Issues

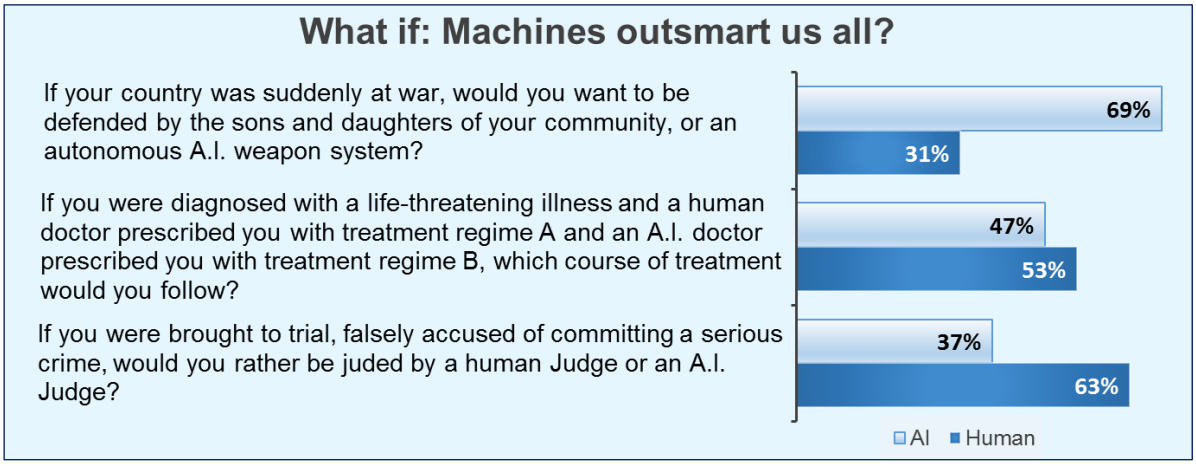
1.2.1 Ethical concerns are rising

The idea of machines being equipped with response and decision making abilities comparable to those of humans has been a source of fascination even before Alan Turing coined the "Turing test" in 1950 to assess a machine's ability to exhibit intelligent behaviour indistinguishable from that of a human.

As machines have gained in intelligence and autonomy, so ethical considerations have emerged as important considerations for product development. For example, the roll-out of autonomous vehicles could dramatically increase traffic safety by removing instinctive and sometimes irrational human behaviour, which is by far the main cause of road accidents. On the other hand, the absence of any innate capacity to make moral judgements on the part of the controlling software could cause it to take decisions which, while technically rational, would nevertheless result in serious harm either to the vehicle occupants or other road users (see 'Autonomous vehicles ethics' on page 13).

As machine decisions are based on preprogramed rules and observations from the world, any cognitive biases in the observation data could be amplified by the machine. This could result in a situation in which the machine unintentionally deceives or even acts against the interest of human users[21].

Wider ethical concerns cover the degree to which machines should substitute humans in critical activities such as defence, surgery, medical treatment and law enforcement[22] (see below 'What if: Machines outsmart us all?'). If machines prove to be more effective at certain tasks than humans, there may be fewer human practitioners and society may lack human knowledge on performing critical activities.



Adapted from: World Economic Forum (2017) "Why robots should inspire hope, not fear" & Poll conducted by the World Economic Forum at the Annual Meeting of the New Champions in Dalian, China (2015)[23]

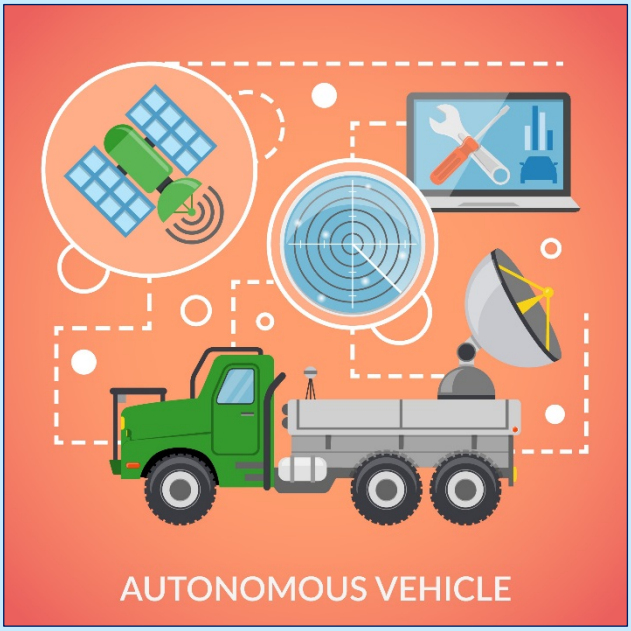
All in all, minimum industrial standards and codes of conduct are gradually being produced in order to help manufacturers, engineers, designers and managers to understand limitations of machine-based decision making and to follow ethical principles when developing intelligent machines[24].

AUTONOMOUS VEHICLES ETHICS

Imagine driving on a mountain road and after a blind bend you see, all of a sudden, five workmen in the road just a few metres from you. You immediately recognise that there is no time to brake and save their lives. Your only alternative is to abruptly change lane. However, it is not your luckiest day because on the opposite lane there is a child running after a ball. So, do you keep driving and let five people die or do you intentionally change lane and kill one child?

Although the probability of coming across this scenario is unlikely on a daily commute, it illustrates the so-called "trolley dilemma"[25], a thought experiment in ethics showing that human judgements may follow different ethical principles, typically utilitarian (i.e. one person dying is better than five people dying) versus relativism (i.e. killing is incommensurably worse than letting someone die).

In such a rushed situation, a human driver would need to decide in a split second, therefore any consequence may still be ethically understandable. But for an autonomous driving vehicle, with wider observation capabilities and faster decision making, a deterministic and predefined outcome would be expected.



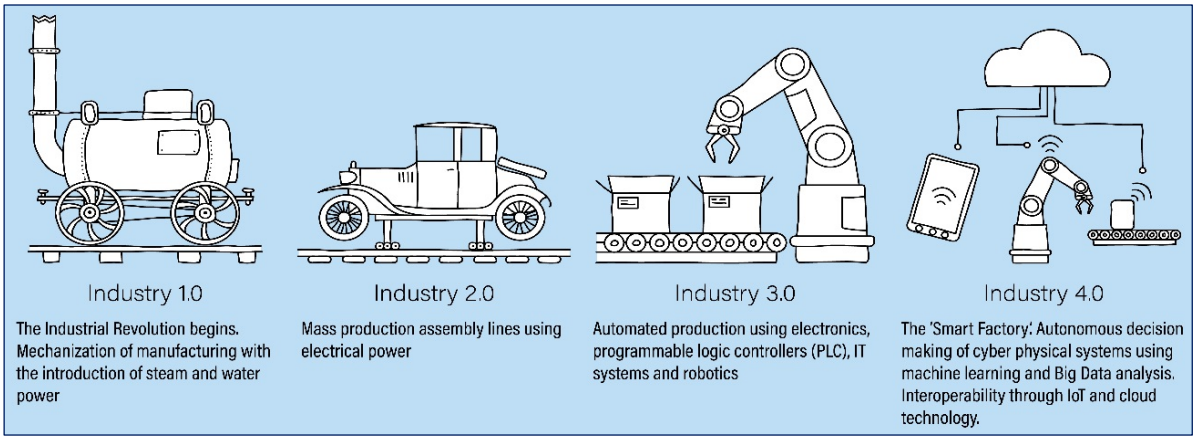
Another relevant aspect is the concept of ownership. To what degree should an autonomous vehicle preserve the life of the owner even against widely accepted ethical principles? In the aforementioned example, a widely accepted utilitarian view of saving the life of the five workers may not hold anymore if instead of the child there was a huge truck on the opposite lane that would certainly take the car owner's life. This may introduce paradoxes where people have different judgments depending on whether they are directly involved in an accident or not[26]. A recent MIT "AgeLab" study shows that 48% of sampled people would not buy a fully autonomous car[27].

As ethics is different from law, many stakeholders such as regulators, vehicle manufacturers and motor insurers are interested in defining the most ethically acceptable outcomes in relation to the different scenarios involving autonomous vehicles. A platform for gathering the different human perspectives on such complex moral judgements has been successfully built by the MIT Media Lab[28]. The Lab's team believes that millions of autonomous vehicles will soon be on the road, therefore taking algorithmic morality seriously is urgent.

1.2.2 Societal and regulatory implications

For governments, the introduction of autonomous machines exacerbates the challenge of finding the optimal balance between efficiency and equity. The crucial point is that jobs do not only bring wealth, but also provide a sense of purpose, self-esteem and identity[29]. Therefore, solutions that facilitate human-machine interaction in the workplace without making human labour obsolete may be preferable. For example, letting machines perform only the repetitive and dehumanising aspects of human jobs could allow employees to focus on aspects that require social intelligence, creativity and perception[30].

Previous industrial revolutions have resulted in social change as well as economic. Socialism arose during the first industrial revolution, the green movement arose during the second industrial revolution and the third revolution brought people together from around the world[31] (see illustration below). Each industrial revolution has changed the way of working along with where the work is done, adding to and amplifying the social effects at each stage of industrial development.



The intelligence of today's autonomous machines depends on the quantity and quality of available data. This gives rise to new challenges in data protection and repurposing[32]. Governments can be seen as sources of data, where collected for regulatory and governmental purposes and as primary actors in protecting personal data, as the technology develops.

The other aspect that these new technologies present is the potential for their misuse by segments of society with malicious intent. Whether these be criminal or rogue states/organisations, the development of autonomous machines will likely create new opportunities for theft, extortion, repression or misrepresentation. Potential examples of such malicious developments, are cyber-attacks by mafia organisations or the use of Lethal Autonomous Weapons (LAWs) (see 'Lethal autonomous weapons' on page 15) by terrorist groups. Society, including re/insurers, should remain alert to this potential and work to counteract these threats as they arise.

New paradigms of responsible innovation[33] and proper legislative frameworks[34] are needed to govern ethical and social consequences of autonomous machines, which present new business and societal risks. Indeed, the increasing interdependence of autonomous machines and society poses direct risks (e.g. cyber security) and indirect risks (e.g. company reputation and terrorism). Use of personal data could, if not properly regulated, turn into invasion of personal privacy. The new European regulation GDPR and in particular the 'right to be forgotten' is an important step to prevent moving in this direction.

Even though such risks are situated in the longer term, their impact could be large and prevention measures need to be taken now.

LETHAL AUTONOMOUS WEAPONS

Lethal Autonomous Weapons (LAWs) are robots designed to automatically identify and attack targets. Infrared detectors, cameras and motion sensors, computer and energy supply are part of the machine and allow the LAW to move and act autonomously.

LAWs can operate on land, in the air, on water, under water or in space. As of 2017, the autonomy of current systems remains under close human supervision – with some exceptions possible for certain defence systems.

Initially, the idea behind using Lethal Autonomous Weapons was to prevent blood toll during military operations that would have normally involved human soldiers. In the past, the development of autonomous weaponry was hindered by problems with efficiency, energy and acceptable control systems. With improvements in computer efficiency and energy storage systems, the use of LAW is now becoming more widespread.

The major concerns of this kind of technology for mankind would be if such autonomous weapons were to become able to make life and death decisions independently of human control. Artificial intelligence has the potential to evolve faster than the human race, which generates a tremendous raft of ethical and legal issues on who should be held responsible for the use of LAWs.

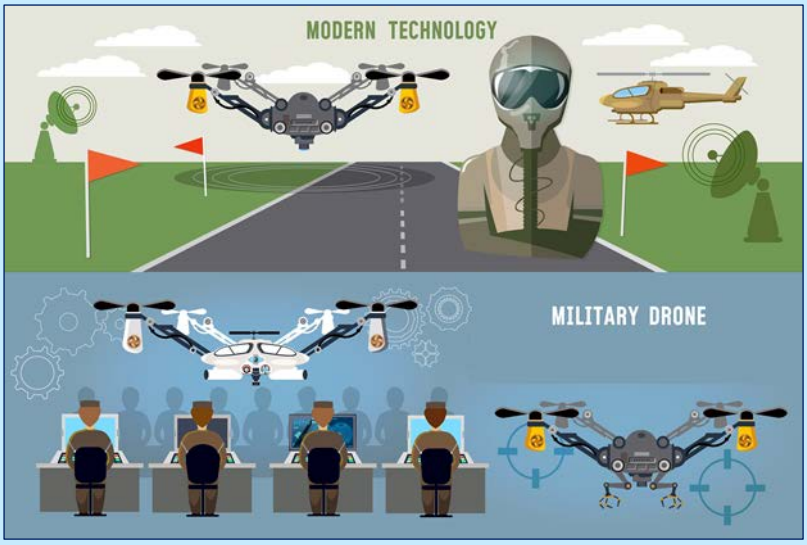
Potential negative consequences of LAW technology are:

- Misuse of LAWs: the use of autonomous weapons could be redirected towards criminal activities such as homicide activities, armed bank robbery, kidnapping, blackmail and rising number of shooting rampages;
- Geopolitical conflicts: military operations using LAWs could intensify the known political “hot spots”;
- Possible new world order: LAWs could act as amplifiers for populism, social disparity and all other geopolitical conflicts;
- Genocides: LAWs could be used on a large scale as a means of suppression and killing of ethnic and religious minorities in exposed countries;
- Rise of terrorism attacks: new kinds of attacks that would divert autonomous weapons from their intended use could emerge;
- Political demonstration / maintenance of autocratic systems with LAW technology;
- Rising number of riots and revolutions.

Several prominent specialists in robotics artificial intelligence are already trying to alert to the dangers of LAWs. In 2015, over 1,000 subject experts signed an open letter from the Future of Life Institute, to call on the United Nations to ban the development of autonomous weapons[35]. Again in 2017, 116 industry leaders and prominent scientists published a petition to ask for “Killer Robots” to be regulated[36].

Military drones

Autonomous armed drones, easy to mass produce, give the army the ability to strike and conduct warfare from a distance. From an ethical point of view, this removes the element of human compassion and reasoning process that comes with the soldier’s physical presence in the field[37]. In addition, cheap drones would be broadly exposed to security concerns such as data hijacking or cyber vulnerabilities, with the potential to leak sensitive information on military operations (location, audio, visual data, etc.) or even to be returned against the drones’ owning army.



2 Impacts on Re/Insurance Underwriting Risks

Key findings

- The assignment and coverage of liability will be more challenging;
- The transition period, where humans and autonomous machines coexist, will likely be a period of intensified risk;
- Overall a shift from loss frequency to severity might take place;
- New forms of accumulations will emerge and the vulnerability of the various systems to cyberattacks and to malicious acts will increase even further;
- Whilst traditional insurance covers will be substantially revisited (changes in insurance premium income, corresponding breakdown by lines of business), new liability insurance products will emerge to match the demand from manufacturers, programmers and clients;
- Opportunities will arise also for the re/insurance industry from a Life and Health perspective;
- Claims management processes will be revolutionised;
- Autonomous machines will significantly improve risk management, prevention and disaster investigation.

2.1 Threats

2.1.1 Establishing liability could become more challenging

Autonomous machines are designed to interact with their environment, making decisions that affect the objects and people surrounding them. As these interactions may lead to personal injury or property damage, they will need to be taken into account in various liability covers.

However, the process of assigning liability may be less straightforward than currently practiced. Autonomous machines are complex products, composed of advanced hardware (i.e. sensors) and often state-of-the-art software (i.e. AI-based technology) and developed by a number of different entities[38]. Coupled with self-learning capacities, the intertwined value chain of autonomous machines will make it difficult to distinguish where the liability rests[39]:

- It may arise from a product defect, in which case the producer will be held liable;
- It may be traced back to user error, in which case the user will be held liable. There will always be a possible responsibility of the customer for misuse and/or poor maintenance, triggering a malfunctioning of the machine itself that would ultimately cause damages incurred to a third party or to the owner of the machine (in the case that it is not the customer himself, for example in a shared economy model); or
- It could even result from communicating errors of all sorts, e.g. between two machines, between machine and sensors or between machine and infrastructure.

Given the number of potential parties involved in an incident including an autonomous machine (manufacturers, telecommunications, global positioning, software vendors, hardware vendors, owners, repairers, ‘operatives’, etc.) it may be difficult to assign liability and thus determine which insurance provider should pay the claim (see ‘Driverless cars’ on page 17). In the UK, as elsewhere, legislation is in preparation to enable autonomous cars to operate on public roads. This may address the liability question for cars and is likely to maintain the obligation for insurance cover to be held by the owner, although the insurer may be able to pursue other parties to recover claims. However in some areas, especially commercial, the apportionment of liability may not be so straightforward and may require further regulatory and legislative work.

DRIVERLESS CARS

Driverless cars are individual cars and motor fleets that drive without human intervention. They should still be distinguished from automated vehicles – those in which at least some aspects of a safety-critical control function (e.g. steering, throttle, or braking) occur without any direct driver input[40]. Autonomous car technology is already selectively deployed in some driver assistance systems in cars today. By 2030, all new vehicles should be equipped with at least partial automation, the expectancy of the market share for full autonomy being still very uncertain. One thing is sure, the world's vehicle fleet is evolving and new actors are stepping up.

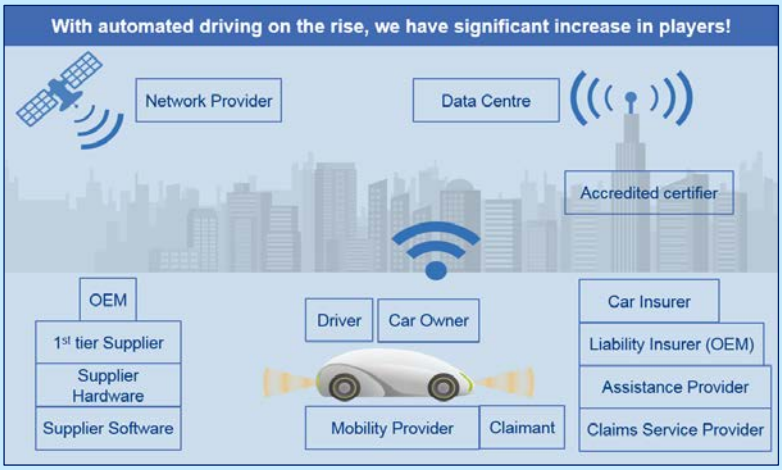
The emergence of driverless cars could be facilitated both by technological and social evolutions. Quick electronics and IT advances will make technology affordable. The rapid development of connectivity, machine-to-machine communication and remote sensing tools will also serve as a catalyst. Smart cities may bring appropriate infrastructures such as smart highways. Digital natives' acceptance of new technologies will make them early adopters of autonomous vehicles. The rise of the 'Sharing Economy' will also contribute to a smooth adoption by developing the concept of cars as a service, with an expectable shift from "just in case" ownership to "just in time" rental.

In 2015, European insurers paid the amount of €102 billion of motor claims[41]. The current regulatory system protects vulnerable road users – pedestrian, bikers, and passengers. Besides this, the procedures in case of an accident have already been tested for decades and have been demonstrated to work well in protecting the final user.

Procedures in the event of accidents involving driverless cars should allow timely management, access to justice and cross border protection, giving a consistent framework across Europe for all involved parties. A way to ensure coexistence between conventional vehicles, semi-automated vehicles, motorbikes, pedestrians and fully autonomous cars will be necessary in coming years. This transition period might be the most uncertain one, with the possibility of heightened severity and frequency of claims.

One very concrete foreseeable consequence is the improvement of road safety. Since human error accounts for 93% of accidents[42], the advent of driverless cars is regarded as an opportunity to drastically reduce the number of car crashes. While this is a bright perspective for society, it may also imply a redefinition of motor insurance.

The deployment of driverless cars will likely expand liability coverage and risks insured due to questions around who or what is in control, and where the fault originated (e.g. driver, manufacturer, software provider, telco, government, etc.). In terms of responsibility, a new scheme could emerge where:



- Car manufacturers' responsibility would be engaged in case of car malfunction or lack of solution robustness;
- Fleet managers' responsibility would be engaged in case of lack of maintenance;
- Users' responsibility will be engaged in case of damage inside the car or related to their interaction with the parked car;
- A no-fault liability scheme could emerge, in which the insured is covered whoever is at the origin of the claim.

In this framework, the "Gear 2030" working group was launched by the European Commission in 2016 with the objective of informing a future regulatory framework for autonomous cars[43]. This group is establishing a consensus view of all the automotive industry stakeholders with the aim of paving the way for the wider roll-out of autonomous vehicles. In the meantime, risk will gradually shift from human to cyber. Numerous security threats will arise with the growing connectivity of cars, which could become the target for cyber criminals or even cyber terrorists.

Hacking threats will hence become a major issue that could radically change the pricing model of motor insurance, leading motor insurance to move from an attritional model to a serial or an extreme event pricing model.

2.1.2 Human-machine collaboration also poses potential risks.

As autonomous machines are supposedly safer, the risk of accidents in situations of human-machine interactions should be limited. However, robots and humans will increasingly share the same work environment, performing tasks in a collaborative manner. Accidents may still happen, due to sensor failure leading to erroneous decision making from the robot's side or, more likely, due to inappropriate and unsafe human behaviour that would not have been envisioned by the machine.

A recent example is the Air France 447 disaster where the combination of automated systems and human actions was a factor for the crash. Airspeed sensors failed, causing the autopilot to disconnect and the automated control systems to change settings. The actions of the pilots following the incident indicated a lack of understanding of the real state of the aircraft, presumably due to erroneous airspeed indications – the ergonomic design of warnings impacting correct interpretation – and potentially by a lack of trust in some of the warnings. As a consequence, the pilots were wrongly concerned about over-speed when the plane was in fact stalling.

In the past, there have been cases of fatal accidents involving non-autonomous – and later, partially autonomous – robots in well-defined and controlled environments, mostly in factories[44]. The immense challenge is to anticipate the risks of fatal accidents in uncontrolled environments, such as public roads and crowded public spaces, where humans and autonomous machines will interact.

The degree of risk relating to the growth of machine autonomy will vary across sectors. The key inhibitor to the speed and magnitude of the shift to automation is likely to be, at first, the little confidence people will have in completely automated devices and infrastructure, leading to a very low tolerance for any accident related to or involving autonomous machines.

The re/insurance industry will have to anticipate these risks from the human-machine collaboration. By anticipating and adapting to technological advances, re/insurers will be able to keep playing a major role as enablers of development and to offer appropriate cover in case of unforeseen events.

2.1.3 New form of accumulation

Growing use and better machine autonomy will also affect the supply chain and distribution chain management[45].

An identical dysfunction, e.g. from a programming error or an inadequate software update, could be reproduced in a large number of machines, generating a significant concentration risk. Alternatively, one deficient machine could autonomously repeat the same erroneous activity several times.

Automation offers several opportunities for optimisation, efficiency, continuity of production and reduction of day-to-day losses (see 'Autonomous vehicles in mining' on page 19). However, autonomous plants also bring new risks. For instance, a product defect can be created due to a defective algorithm or by how the manufacturer handles/uses the AI. Large volumes of faulty products could be created and go undetected, which would ultimately lead to massive accumulation risks.

AUTONOMOUS VEHICLES IN MINING

Mining has always been a source of innovation, and autonomous machines can help further improve economic benefits, efficiency, safety, environmental care, social integration and greater confidence in analysis and throughput[46].

Autonomous systems and vehicles in mining have been developed and trialled since the early 1990s. Since 2010, autonomous vehicles are fully integrated into operational mines and can manage the whole production of some predictable and repetitive operations. In September 2015, the Western Australian government released the world's first code of practice for autonomous mining, the purpose of which is to provide guidance in the safe implementation of these technologies.

Both heavy equipment manufacturers and large mining companies have driven the advent of autonomous systems. Unsurprisingly, these systems have developed mainly in large and sparsely populated countries that cultivate a strong mining tradition with remote mine locations. Moreover, this technology is most appropriate where large volumes of material are handled, i.e. in the segment of bulk commodities (iron ore and coal for instance).

So far, mainly the hauling (driverless trucks & heavy-haul trains) and drilling systems have benefited from automation, but there is potential for other areas in the future. The technologies used are usually based on existing ones, such as wireless networking, satellite navigation (GPS), collision avoidance systems (laser, radar, cameras) and autonomous vehicle controllers.

Risks and drawbacks:

New risks emerge with the rise of autonomous systems in mining:

- High dependency on technology and reliance on human-machine interfaces poses new risks on mining operations. Fleets of autonomous trucks or drill rigs may not be easily taken over by operators: workers not on site anymore or equipment not designed with the option of being operated conventionally by a human. Moreover, the driver as a situation-identifier is lost, e.g. to spot cracks on haul roads or material slippage on pit walls.
- System malfunctions and cyber-attacks could bring a whole operation to a halt (hacking of industrial plants for extortion or cyber-espionage campaigns) through dependence on digital service providers.
- Some "single point of failures" through suppliers of digital services are becoming increasingly critical (global positioning systems, data providers, specialised software editors, etc.) and business continuity plans in case of service disruptions must be carefully designed and tested. Autonomous systems malfunctions could potentially impact a very large number of trucks, which brings an accumulation of risks that need to be understood by insurers.

The elimination of certain jobs brings reputational risk, even though there is additional need for qualified jobs to install and maintain autonomous systems.

Opportunities and benefits:

Overall, automation can offer many benefits in the area of mining:

- Safety of personnel is improved by removing people from hazardous workplaces. Automation reduces the risk of driver fatigue;
- Cost for commuting personnel to mine site (fly-in / fly-out) and providing accommodation is reduced;
- Productivity and operating costs are optimised by reduction in cycle times, better vehicle and fuel utilisation, decreased process variability, and reduced unscheduled maintenance;
- New and changed risk exposure will provide opportunities for new products and therefore new business for re/insurers. Increased exposure to system failures and cyber-attacks raises the need for Cyber Risk solutions and Business Interruption protection. Unmanned vehicles also require Third Party Liability insurance protection.

2.1.4 Higher sensitivity to cyber risks

Industries will be more susceptible to larger tail risks from system failure and hacking. In the event of machine failure, the risk of global system failure will be high, as the same algorithms and sensors will be embedded in all machines. Reliance on autonomous systems may therefore increase the vulnerability to cyber-attacks of smart factories, critical infrastructure and freight companies (see 'Autonomous ocean craft' on page 21).

Cyber risk arising from systems hacking will become even more serious and insidious. The widespread use of autonomous machines in all areas of our lives will attract a large number of expert hackers or ill-intentioned parties, with potentially very serious consequences. A systemic malfunction of autonomous machines controlling critical infrastructure systems (e.g. IT-network, power supply) might even significantly affect our interconnected global economy and society.

These new cyber threats linked to machine autonomy will need to be considered in Business Interruption and Contingent Business Interruption insurance covers.

2.1.5 Enhanced criminal activities

The development of machine autonomy also has implications for financial crime and theft. Cyber technologies provide real opportunities for criminals who have the knowledge to hack autonomous machines. As well as theft of equipment, this could be used for criminal damage or extortion.

In addition, autonomous machines can be used by criminals to commit crimes. Throughout history criminals have often been skilful in recognising opportunities created by technological advances, in several cases being one step ahead of the authorities. A case in point would be the use of drones to smuggle drugs, mobile phones or guns by dropping them into federal prisons[47].

Financial and insurance industries can equally be victims of such events. For instance, autonomous machines were recently used to break into a safe[48]. Such criminal activities will have implications for the cost of claims, customer service and product design.

Alternatively, there could also be a rise in terrorism and planned attacks directed towards autonomous systems, from people having reactionary attitudes or fear towards technological changes.

AUTONOMOUS OCEAN CRAFT

While the advance of the autonomous car stirred up a lot of public debate, rapid developments are also underway in a less prominent, but arguably equally significant mode of transportation: autonomous marine shipping.

Forecasts from the Rolls-Royce led initiative Advanced Autonomous Waterborne Applications (AAWA) consider the first stage of a remotely operated local vessel to be in operation by 2020. Autonomous boats should arrive in international waters by 2025 and be a common sight on the world's oceans by 2030[49]. At the beginning, it seems likely that the first autonomous vessels will be harbour tugs or ferry vessels, for example applied close to the coast or to carry equipment on short distances across the mouth of a river or a fjord[50]. As technological development advances and international maritime law adapts, the world might be ready for fully autonomous oceangoing cargo ships over the next ten to fifteen years.

Remotely operated local vessels		Remotely operated ocean-going vessels	
2020	**2025**	**2030**	**2035**
Reduced crew with remote support and operation of certain functions	**Remote controlled unmanned coastal vessel**	**Remote controlled unmanned ocean-going ship**	**Autonomous unmanned ocean-going ship**
Unmanned ships will most likely start with local applications			

Adapted from: Rolls-Royce Marine (2016). "Autonomous ships: The next step", p.9

The technologies to create remote and autonomous shipping are already there and the challenge is to find the optimum way to combine them in a reliable and cost effective manner[51]. Sensor technologies provide the vessel with an accurate perspective on the vessel's surroundings at all times and through all conditions. Inputs from radars, high definition visual cameras, thermal imaging and LiDAR (Light Detection and Ranging) sensors are combined together, while central control algorithms use these sensory inputs for decision making in order to navigate the vessel safely. Next to the interaction between external sensors and central control algorithms, are communication devices that still permit human input from the land, if needs be.

The usage of autonomous vessels provides several advantages, for one it would likely enhance the safety of the staff that would not be present on-board, and reduce the number of human errors. According to Allianz, between 75% and 96% of marine accidents are the result of human error[52]. Autonomous boats would thus have the potential to prevent severe events and significant losses for re/insurers in the marine sector.

The threat of piracy would be significantly reduced, as crewless ships could be built so that they would be difficult to board on high seas. Furthermore, such ships could be designed with higher cargo capacity and lower wind resistance, as no crew would need to be accommodated. Features, such as deck house, crew quarters and ventilation, heating and sewage systems could be eliminated. This would make the ships lighter and leaner, lowering fuel consumption and reducing operating costs. Conversely, this additional space could be used to transport more cargo, which would mean more profitability for the freight company[53].

Yet, ship autonomy also brings risks. The absence of a crew removes the ability to contain fires or on-board explosions, which are the highest factors of ship losses, and the higher cargo capacity significantly increases the loss potential. Autonomous vessels also increase the risk of hijacking and loss of communication. For re/insurers, this means an opportunity to develop enhanced marine cyber and liability coverage[54].

Just as challenging as the technological developments required for autonomous shipping would be the regulatory changes required to allow such ships to become fully operational. Currently, international sea voyage is governed by a range of national, international and private legal frameworks. Linked to these challenges is the question of legal liability in the event of an accident and what types of new insurance coverages could apply. Several initiatives are underway to provide for greater standardisation of international maritime rules, to create a solid legal footing for autonomous maritime transport.

2.2 Opportunities for Re/Insurance Underwriting Risks

While undoubtedly posing a number of threats, the rise of autonomous machines could also yield valuable opportunities for the sector.

2.2.1 Product Liability for machine manufacturers

Product Liability will be the first area of focus for new insurance products. The possible shift of responsibility from human to machine, and therefore to the manufacturer, could cause an increased turnover of portfolios deriving from Personal Liability to Product Liability. This coverage could be provided by very specific products that would cover the product liability of the companies that build or manage autonomous machines (cars, planes, drones, public transportation, agriculture, factories, child minding, cooking, etc.).

Another aspect linked to Product Liability is the protection from damages due to infrastructure failure. For instance, a computer crash or a cyber-attack involving one or more cloud servers could disable or even hijack a complete fleet of autonomous machines, with more severe consequences.

In the longer term, a new policy specifically designed for a world of coexistence with autonomous machines could cover "*injuries and damages from malfunctioning machines*".

2.2.2 Personal Liability for machine owners or users

Product Liability will not cover all the needs of the customer: there will always be a general responsibility for misuse or poor maintenance of the machines. Third Party Liability will most likely continue to exist and dedicated extensions or new products could be developed to cover these risks.

There could be a dedicated area for retail personal insurance extended to new risks emerging from autonomous machines. "No-fault" own damages of the customer are almost the same as the risks covered by Product Liability, but in this situation the insurer would pay regardless of the offender, with following recourse against the manufacturer. In fact, for a retail customer it would be easier to manage a critical situation with his own insurer rather than to act against a multinational firm.

The owner of an autonomous machine could also need his own coverage to protect from material and physical damages that may arise from its usage.

2.2.3 Professional Liability for programmers

Error and Omission products could be designed specifically for the programmer of an algorithm used in an autonomous machine. Professional Liability insurance could be necessary for programmers in case of mistakes on the program (that would then fail to perform properly), misrepresentation of the machine capability or alleged negligence on implementing securities against hacking.

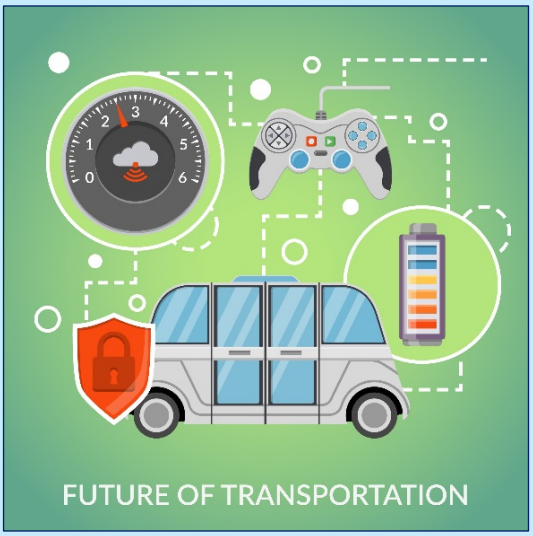
2.2.4 Some "brand new" coverage to cope with new models from machine autonomy

Mobility will become more complex and will involve multiple modes of transportation, between owned or shared vehicles, public transports, etc. The need for complex mobility coverage could emerge, to accompany customers along their multi-modal journeys (see 'Autonomous public transportation' on page 23).

Insuring new technologies will create opportunities under Property and Casualty lines for insurers. Workers' Compensation insurance may also be impacted positively, as safety of the workplace is expected to be improved thanks to machines taking over heavy or dangerous work.

AUTONOMOUS PUBLIC TRANSPORTATION

The automotive industry is developing autonomous vehicles at a rapid pace. Ultimately the public transport sector will be heavily influenced by these developments, with disruptive effects upon the existing system.



Autonomous vehicles and public transport

Given that, on average, private vehicles are currently in use less than 4% of the time, it is likely that the introduction of automated vehicles will change the concept of car ownership, with a move towards a short term rental model and automated taxis. Some experts believe that a large number of shared or rented autonomous vehicles could impact the traditional public transport model, due to the large availability of vehicles that automatically transport people door-to-door. Other experts, on the other hand, believe that public transport will continue to grow, given the higher space/people ratio.

Autonomous buses may follow strictly planned routes or develop more flexibility and adapt to customer needs, through the use of real time connections.

Automatic subways

There are currently fifty-three automatic subways worldwide and roll-outs in other locations are expected. Subways are well-suited to automation since the course is fixed. Automation reduces delays and increases the number of trains on the line, ultimately offering more comfort to passengers. These advantages could lead the way for other modes of public transportation.

Airplanes

For air transport, the main barriers are regulatory and emotive. It remains to be seen how long it will take for passengers to accept travelling in a fully automated aircraft, even if the majority of current accidents are due to human error. A UBS report published in 2017 warns that only 17% of travellers would be willing to fly without a pilot[55].

Impact upon the re/insurance business

The key development for re/insurance is expected to be the need for a new kind of insurance that would cover the responsibility of the manufacturer and the significantly increased level of cyber risk.

The introduction of autonomous vehicles will ultimately result in fewer accidents, as human error will be removed. In addition, although ultimately accidents will reduce in frequency, there is likely to be an increased complexity in establishing liability when things do go wrong, an increased risk of systemic issues due to reliance on software and an increased vulnerability to cyber-attack.

2.2.5 Specific opportunities from a Life and Health perspective

Machine autonomy in the field of healthcare and social care could have negative financial aspects for public and private health spending. The development of medical autonomous machines or the adoption of assistance robots caring for elderly or ill people, could lead both to higher costs of specific interventions as well as higher life expectancy for people in need of care, with the latter influencing the cost of pensions, annuities and long-term care covers.

Nonetheless, human-machine collaboration in the medical sector could also have a positive financial impact on insurance lines related to mortality and disability by improving prevention, treatment and patient care (see 'Medical assistance robots' on page 25). Shifting the heavy parts of the care work from humans to machines will allow the scarce resource of the workforce to be employed in areas that create more value. At the same time, the cost of care will be reduced – after the initial capital outlay for the equipment of hospitals and medical centre with these costly technologies – as more efficient machines replace expensive human workers. This will benefit not only physical health, mental health and wellbeing of the people taken care of, but also of people relieved of the burden of care giving, therefore reducing disability claims.

From a societal aspect, autonomous machines should enable humans to work fewer hours, in less harsh environments doing less manual work with lower likelihood of major industrial incidents. Therefore, life expectancy, general health into old age and human wellbeing could significantly change, which could have implications on mortality and potentially morbidity.

2.2.6 New forms of insurance models and players

Nowadays, massive availability of data, exponential rise of computing power at low cost and acceleration of powerful algorithms that mimic the human brain have triggered significant industrial investments towards the development of machines capable of taking over human tasks[56].

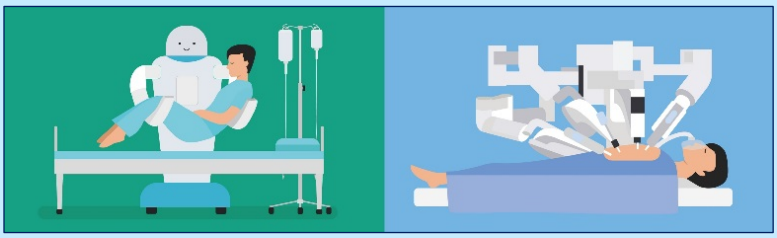
As a result, traditional industries are being disrupted while new players, such as FinTech and HealthTech companies, are being created in growing numbers. Furthermore, the software supporting autonomous machines is likely to be held by a small number of major companies that succeed in associating competitiveness and employment implications. This is likely to create new competition for traditional re/insurers.

> *"If we find that insurance providers are not matching the insurance proportionate to the risk of the car, then, if we need to, we will in-source it."*
> **Elon Musk (Tesla) – 2017[57]**
>
> *"Self-insurance could be a good stop-gap measure while insurers sort out their business. But we also need independent insurers to be engaged as a neutral arbiter of risk, letting technology developers focus on what they do best".*
> **Patrick Lin (Forbes) – 2016[58]**

On the other hand, opportunities already arise today for new kinds of partnerships between re/insurers and these new Tech companies, such as InsurTech.

MEDICAL ASSISTANCE ROBOTS

In a context of rising healthcare costs and ageing population, autonomous equipment is expected to offer great opportunities for healthcare as useful tools to enhance quality, availability and to mitigate the burden.



The demand for personalised healthcare will be a driver on the road to adoption. Robots in healthcare should have the ability to perform tasks that human beings do not wish to or cannot do as efficiently. Since autonomous caregivers provide homecare, which is often preferred by patients and less expensive, cost reduction is expected from delaying or avoiding admission of individuals to care homes or hospitals.

Going beyond existing automated medical systems, specialised machines with higher level of autonomy are under development. Such technologies will enter hospital surgical suites, patient rooms, healthcare facilities' hallways, in-home patient care and eventually all of our daily lives:

- **Routine tasks:** In 2015, a San Francisco hospital deployed a set of robots that transport food, medicines, lab specimens, linens and trash: several other hospitals followed suit[59]. Researchers have developed prototypes of robotic scrub, nurses that handle and pass surgical instruments, using voice recognition[60] or real-time tracking of hand gestures through computer vision and pattern recognition[61].
- **Emotional impacts:** Socially interactive robots can alleviate loneliness and have therapeutic benefits. Paro[62] is a stuffed animal robot that, through playful interactions, can stimulate patients with dementia, Alzheimer's and other cognition disorders. Jibo[63], Pepper[64], and Buddy[65] are companion robots that can become part of the household. In the coming years, these devices may offer healthcare-specific solutions, such as providing personalised advice, suggesting preventive measures, monitoring individuals' health status, etc.
- **Nursing and rehabilitation care:** Some of their functions include providing medication assistance or personal care, helping to move patients and communicating with doctors, both in hospital and in home-care settings. Many nursing staff experience back pain and other disorders over their careers and these injuries lead to expensive disability claims. Using a robot for patient handling could make a difference.
- **Medical exoskeletons:** Wearable robots designed to move or strengthen limbs are already being used to help paralysis patients in recovery. They could also provide an alternative to wheelchairs for people with mobility disorders and prevent falls, which are a leading cause of fatal injuries among the elderly[66].
- **Surgical tasks:** For the time being, so-called "surgical robots" are not yet autonomous since they are directly tele-operated by human surgeons (e.g. daVinci Surgical System). However, researchers are working on developing robots that will autonomously perform routine or tedious parts of an operation, albeit still under the supervision of human surgeons[67].
- **Medical treatment:** With increasing access to data stored in the cloud and progress in artificial intelligence, autonomous machines will be able to offer personalised medical advice and make real-time medical decisions. Ultimately, they might take over tasks currently carried out by nurses or medical doctors. However, artificial intelligence without human control is not yet a reality, and might not be for a long time.
- **Nanorobotics:** The emerging field of nanorobotics may offer game-changing possibilities to treat and cure previously untreatable and incurable diseases. A nanorobot is an atomic machine tasked with missions of diagnosis and designed to continuously run a specific operation, such as delivering drugs, with accuracy at nanoscale dimensions. These nanorobots are bacterium-scale mechanical devices with on-board sensors, manipulators, pumps, motility mechanisms, communication facilities, programmable computers, and biocompatible external hulls. This development may reduce morbidity and mortality, impacting claims experience of insurers in the long-term.
- **Life risks associated with medical expenses, disability and mortality** may be impacted by the rising use of medical autonomous robots. Long-term care covers will be impacted due to the initially high cost of new technologies and the fact that treatments could sustain life for a longer period whilst still needing expensive care. Product and Professional Liability covers will also be affected.

Access to personal medical data and sharing of the location of medication, objects and people will be needed. Data privacy and security will thus be of great importance[68]. Cyber risk will also be an issue to consider, as autonomous medical robots will be prone to cyber-attacks and hacking.

2.3 Claims Handling and Incidence Response

2.3.1 A new world in claims

Claims frequency is likely to be lower in the future compared to current levels, the extent of which currently remains unknown. At the same time, the consequences of a single incident could be of greater impact, because of the repetitiveness of an automated activity. For example a single programming error could generate a great number of damages, such as a bug in autonomous farming that would stop irrigation too soon, ruining harvests in many countries (see 'Autonomous machines in agriculture' on page 27). Damages to high-tech autonomous vehicles will also certainly be more expensive, due to higher repair costs of machines with advanced technologies embedded.

Consequently, the estimation of future claims is quite complicated: it is likely that the overall cost of claims will be lower but the ultimate outcome and the length of time needed to reach this stage are uncertain.

In addition, material damage, bodily injury or death caused by a machine could be judged with greater severity than the same damage caused by a human being.

2.3.2 Autonomous machines in the claims handling process

Another important application of autonomous machines would be in the claims handling process itself.

For instance, in order to assess the severity of damages following a catastrophe, such as an earthquake or hurricane, insurance companies could swiftly deploy drones or similar autonomous vehicles. Such vehicles would even possess the technical capabilities to conduct claims inspections, obtain photographic evidence or sample materials for further lab testing. So instead of claims adjusters having to drive to remote locations, autonomous machines could be used to determine which areas have sustained the most severe damage and where it would make sense to deploy additional claims adjusters[69].

Likewise, autonomous machines allow access to structures difficult or dangerous to reach, in order to inspect the occurred damages. For instance sites located under water, in danger of collapse and contaminated by radioactive waste, hazardous materials, biological or chemical contaminants would be too risky to be surveyed with a manned vehicle or in person[70].

Autonomous machines would also increase the efficiency and potential quality of the claims handling approach, by providing speedy and cost effective estimates of the losses sustained in a stricken area. As certain areas at a damaged site might be inaccessible for a human claims adjuster, infrared cameras could be used to detect potential water or air leaks and significantly reduce the time for claim settlements, thereby improving the customer experience. Furthermore, autonomous vehicles can cover large areas of property in a much shorter time span.

Nonetheless, where robots support claims determination, there is the potential for claims costs to be impacted through poor handling or incorrect evaluation of the claim.

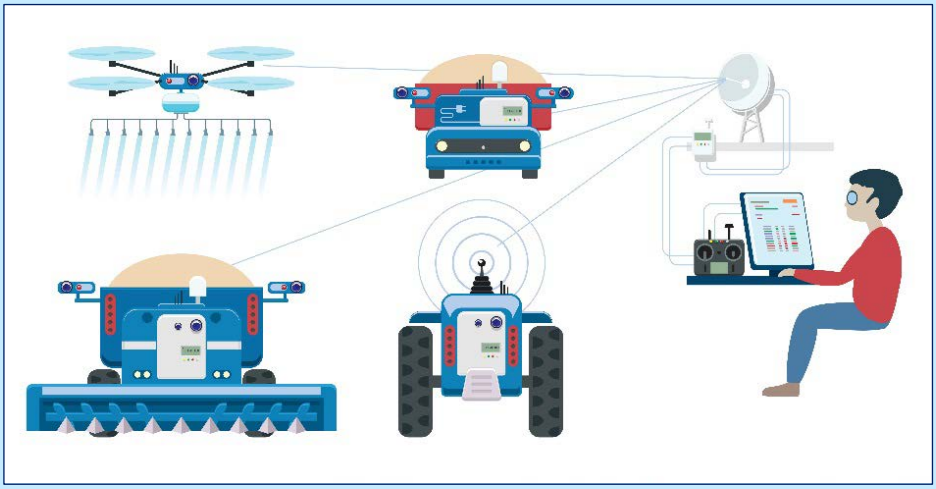
In addition, claims fulfilment could be made cheaper, quicker and more efficient through the deployment of autonomous machines, for distribution of replacement goods and/or autonomous repairs. Coupled with other advanced technologies such as 3D printing, this could significantly enhance claims handling.

AUTONOMOUS MACHINES IN AGRICULTURE

Autonomous machines are increasingly being adopted in large and small farms. They help optimise production, support efficient use of resources (precision farming), and free human labour from strenuous manual work.

Two paradigms for implementation of autonomous systems in agriculture can be distinguished, even though they are complementary rather than mutually exclusive:

- Single autonomous machines – for example autonomous tractors – are integrated into a traditional farm's existing machine park and add specific possibilities to conventional farming. An autonomous tractor allows for ploughing, seeding and other fieldwork independently of a human driver. Farming on private land fosters early adoption of autonomous vehicles that remain under supervision of the owner / user, while enabling the latter to do other things in parallel. Such autonomous vehicles in farming will be assisted by a variety of guidance systems, from differential GPS to sensors. Apart from tractors and related machinery, single autonomous machines may include drones and robots, which have been most successfully advanced and adopted lately. Equipped with cameras and sensors, drones can autonomously map a field, measure irrigation needs, plant growth, pests, etc. and broadcast the data in real-time to the farmer's smart phone or a central computer.
- Apart from single and independent autonomous vehicle use, another autonomous machine approach appears promising for farming. It integrates various interdependent functionalities into one (more or less) closed autonomous system. The fully automated closed greenhouse is a case in point, where all the farming processes are taken care of by a central system, from seeding, watering and weeding, up to the harvesting of vegetables and fruits. In animal farming, such integrated autonomous systems will gain in importance, and even cyclic combinations of plant and animal systems are conceivable, where the management of the cycle would be delegated to a machine.



Some describe the role of the future farmer as a General, commanding mechanical troops from the headquarters. A less prestigious vision depicts the future farmer more as a janitor, or a facility manager. The farmer will be needed to resolve issues encountered by autonomous systems, for instance how to handle an obstacle or a task, to set priorities and to oversee the smooth operating of the autonomous machinery. He will manage the supply chain and will bridge the autonomous or partially autonomous farm system with the outer world. Undoubtedly the future farm equipped with autonomous machines will require less human labour.

The introduction of autonomous machines into farming also brings new risk, of which cyber vulnerability is a most obvious one. As the autonomous systems rely on electronics, electric power, satellite or internet transmission or alternative communication channels, other systematic dependencies and interconnectivity risks could increase in parallel. To re/insurance, the implementation of integrated autonomous systems may tighten customer relations. Shared monitoring data from the farm's system can support claims handling and claims adjustment. It may also facilitate differentiated parametric solutions, e.g. for weather or drought, but the farm becoming a big data centre may also invite data technology companies as new players into Agro insurance.

2.3.3 Autonomous machines disaster relief

The use of unmanned vehicles and robotics for disaster relief has witnessed a sharp increase since the beginning of the twenty-first century (see 'Emerging use of unmanned aircraft systems' on page 29). The Centre for Robot-Assisted Search and Rescue estimates that they have been involved in over fifty disaster responses involving unmanned autonomous vehicles, spanning events such as the destruction of the World Trade Centre in 2001, the Haiti Earthquake in 2010 and the Tohoku Tsunami in Japan in 2011[71].

Smart software allowing for partial or fully autonomous operations of machines could further enhance their effectiveness for incident response. While the application of such technologies is not yet widespread in the insurance industry, government sponsored projects are underway to test how smart software in combination with unmanned vehicles could improve incident response in emergency situations. By gathering data from an affected area, software agents – algorithms that can work with a degree of autonomy – will draw a picture of the situation, supporting the response team in allocating their resources for effective damage mitigation or even to save lives[72].

The UK government-sponsored project 'Orchid' employs various software agents that can sift through data coming from disaster areas, such as pictures, tweets or sensor readings. Collection of the data could come through unmanned vehicles located in this area.

2.3.4 Autonomous drone in risk evaluation

Next to incident response and claims adjustment, the use of autonomous drones also provides opportunities for pre-disaster planning, risk evaluation, or even fraud prevention. For example, it would allow identification of risk areas before a disaster strikes, permitting the insurance company to formulate a disaster response and pre-emergency plan. People in potentially affected areas could be warned to secure their properties, prepare their homes and evacuate the affected area.

Likewise drones could enable a more effective risk assessment, as they permit exposure investigations in areas that are otherwise difficult to access. Use of drones would also enable more efficient risk engineering surveys, allowing numerous specialists to participate virtually in a site visit, for example steering a drone using remote controls, obtaining real time camera views and communicating with other specialists through virtual conferencing without the requirement of having a specialist on site.

EMERGING USE OF UNMANNED AIRCRAFT SYSTEMS

Use of drones or unmanned aircraft systems (UAS) in public airspace is increasing dramatically. In the USA the Federal Aviation Administration (FAA) projects that commercial UAS sales will grow from 600,000 in 2016 to 2.7 million by 2020. In addition, the number of 1.9 million UAS for recreational use is set to reach 4.3 million over the same period[73]. Such projections are driven by UAS becoming cheaper, smaller and easier to use, as well as regulatory progress.

Commercial drone usage continues to increase and evolve[74]. The freight company DHL piloted a test case in Germany to deliver emergency supplies and medicine by "parcelcopter" from the mainland to the island of Juist in the East Frisian Islands. The first successful US pilot program of a "ship to shore" UAS delivery of medical supplies was recently carried out on the New Jersey coastline. In Africa there are plans to use them to deliver blood and vaccines to remote areas, potentially saving thousands of lives a year. In Brazil UAS are used as monitoring tools to prevent the exploitation of slave labour in agricultural areas.

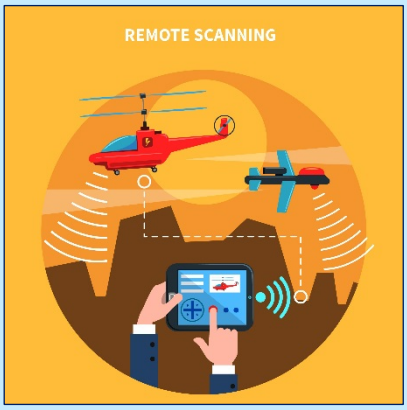
Drones' autonomy is rapidly evolving. In Singapore, Airbus Helicopters and the Civil Aviation Authority are working to perfect a package delivery system in urban areas, while Amazon will conduct similar trials in partnership with the government in the UK. Even the pizza maker Dominos is piloting a pizza delivery scheme in Germany, while the convenience store 7-Eleven recently delivered coffee and a chicken sandwich to a family in Reno in the US. The drone finds the customer's address and landing space all by itself, adjusting the route if a collision needs to be avoided or in case bad weather makes a detour advisable.

The numerous other possible uses of UAS, in various fields enabled their large spread in the commercial, personal goods and service markets. A 2016 PwC study on the commercial applications of drone technology valued the emerging global market for business services using drones at over US$127bn (see below 'How will drones impact business?').

How will drones impact business? Predicted commercial applications and market value by industry		
Infrastructure	Investment, monitoring, maintenance, asset inventory	US$45bn
Agriculture	Analysis of soils and drainage, crop benefit, health assessment	US$32bn
Transport	Delivery of goods, medical logistics	US$13bn
Security	Monitoring lines and sites, proactive response	US$11bn
Entertainment & Media	Advertising, entertainment, aerial photography, shows, special effects	US$9bn
Insurance	Support in claims, settlement process, fraud detection	US$7bn
Telecommunication	Tower maintenance, signal broadcasting	US$6bn
Mining	Planning, exploration, environmental impact assessment	US$4bn

Source: PwC (2016) Clarity from above: PwC global report on the commercial applications of drone technology[75]

Insurance-related use of UAS



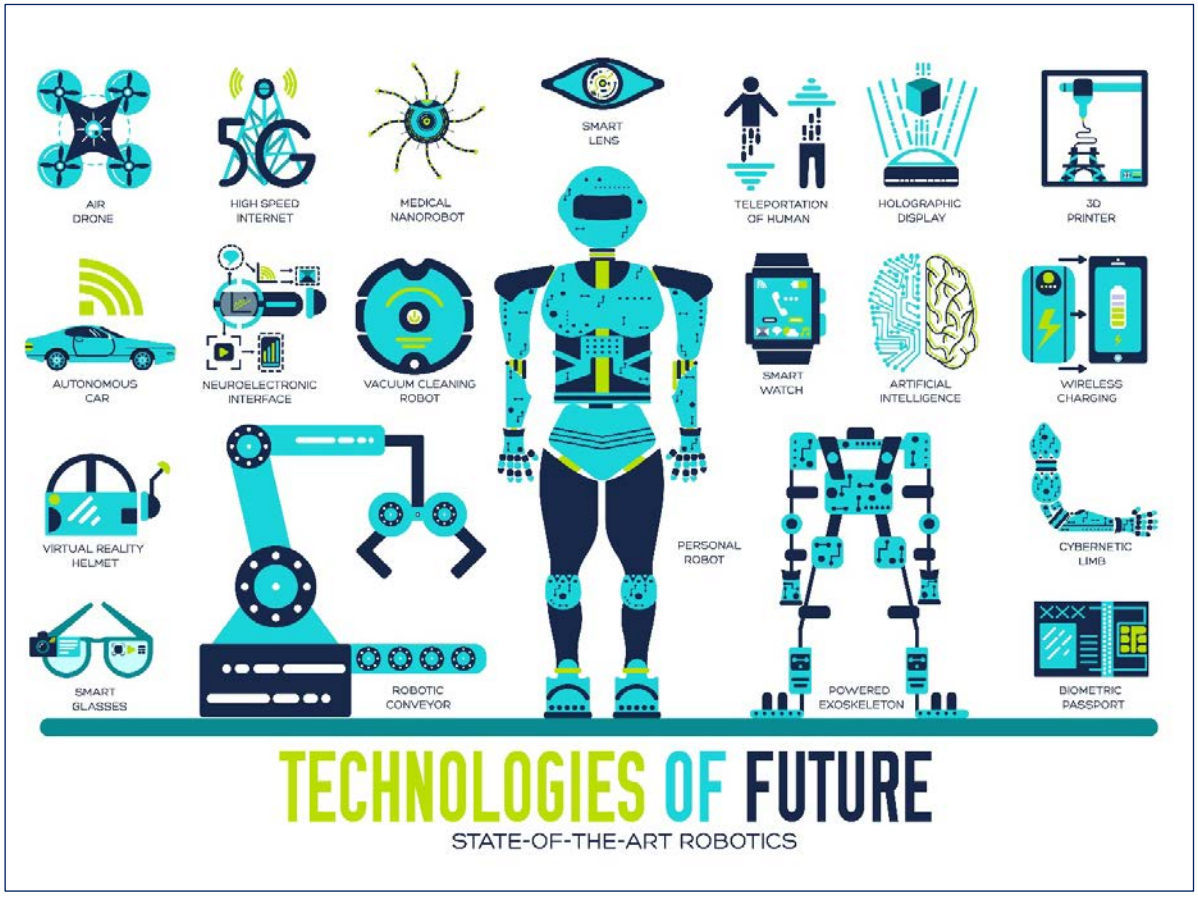
In the shorter term, insurers are using UAS. Both underwriting and claims management can be made quicker and more effective by using such systems to assess risk and survey loss damage. For example, when parts of Tianjin, China were rendered inaccessible after major explosions in 2015, high resolution images taken by UAS after the blasts were compared with previous photographs to determine how many vehicles had been destroyed. Similarly, in the event of a flood, UAS can provide the insurer with a visual overview, helping it to quickly alleviate damage and distress to victims and property.

Looking ahead, as the insurance industry follows the path to increased digitalisation and higher efficiency, the usage of autonomous or semi-autonomous vehicles for core insurance activities such as claims handling, pre-disaster planning, or risk engineering is likely to become more common practice.

Conclusion

The use of autonomous machines in industrial processes is not a new phenomenon – as formerly mentioned in the CRO Forum Emerging Risks Initiative position paper on the Smart Factory – but technological improvement and Big Data allow an exponential development of autonomous machines in almost every aspect of life: transportation, health, domestic, farming, aviation, marine and the way warfare is conducted.

Whilst the development of autonomous machines in daily lives can already be seen, many uncertainties remain, both in terms of timescale and magnitude of impact in the areas of technological evolutions, economic and societal impacts – such as on the labour force – and social acceptance of a human-machine coexistence.



The transition period, where humans and autonomous machines coexist, will likely be a period of exacerbated risk. This period could last several decades with various stages in the level of maturity of technologies and regulations. It will generate increased uncertainty and riskiness until the final stage of automation – with less risk expected – has been reached, if it can ever be reached.

Legal and regulatory uncertainties are emerging in several areas: intellectual property, liability, international tax environment, personal data management and data portability. Serious ethical and moral issues are also implied by the delegation of decision making from humans to machines.

Impacts on re/insurance

Risks for the re/insurance industry are coming from the uncertainty about the place that autonomous machines will take in society in the future and the interactions they will have with humans, on a global scale. From the insurer's point of view, an activity performed by a machine is certainly much safer than an activity based on human decisions: in fact, the majority of claims are due to human error.

Overall a shift from high frequency / low severity claims to high severity / low frequency claims might take place. While it will be the case that automation reduces frequent "standard" accidents, scale in terms of severity will be a driving factor on the risk side. In case of a systematic malfunction a large number of risks are affected and any additional breakdown of a critical infrastructure systems (e.g. IT-network or power supply) will affect our interconnected global economy and society significantly.

If correctly assessed and sufficiently prepared, this transition towards machine autonomy can bring many opportunities for the re/insurance industry, such as new protection needs from manufacturers, programmers and clients, as well as more efficient claims management. As such impacts are envisioned, re/insurers must stay alert to current and future evolutions, remain flexible and be ready to adapt to new situations involving physical autonomous machines.

In general, re/insurance encourages innovation by creating confidence, reducing uncertainty and by understanding and developing resilience against a new dimension of interconnected risks. It is also an enabler of human and technical endeavours, in particular by protecting innovators and their wealth from external shocks.

In the sector of machine autonomy, insurance business may have additional roles to play and an opportunity to drive greater transparency in safety and reliability of new technologies.

In the past, insurance enabled exploration. In the same way, re/insurance can today be an enabler for development with risk-based services driving control development over new risks, or even eliminating new risks as they arise. As soon as the insurance industry, regulators and society agree to collectively cover a new risk, the scaling up of a technology beyond the initial circles of pioneers and entrepreneurs could occur very rapidly.

> *"The role of modern insurance is multifaceted. By managing risks, insurance allows individuals and companies to take risks and innovate. […] It is impossible to predict how the macroeconomic role of insurance will evolve given the major changes in risks created by technology and social evolutions as well as in society's acceptance of risk itself. However, since human societies have always created frameworks to reduce uncertainty by collectively managing risks, insurance mechanisms will undoubtedly continue to exist in one form or another."*
>
> **Denis Kessler (SCOR), Amélie de Montchalin (AXA) and Christian Thimann (AXA) – 2016[76]**

References

Executive Summary

[1] Wikipedia. 31 Jul. 2017. “Autonomous robot”. URL: https://en.wikipedia.org/wiki/Autonomous_robot

[2] Thibault Hervier, Spoon: Artificial creatures, Co-founder & CTO. 30 Mar. 2017. *Autonomous Robots.* Paris: Presentation to CRO Forum Emerging Risks Initiative in-person meeting in Paris on ‘Autonomous Machines’, 30-31 Mar. 2017.

[3] David A. Mindell. 2015. Our Robots, Ourselves: Robotics and the myths of autonomy. New York: Viking, 260p.

Introduction

[4] Stephan Howeq, The Adecco Group, Chief Marketing and Communications Officer. 21 Jun. 2017. “Why robots should inspire hope, not fear”. *World Economic Forum*. URL: https://www.weforum.org/agenda/2017/06/why-robots-should-inspire-hope-not-fear

[5] Wikipedia. 31 Jul. 2017. “Artificial intelligence”. URL: https://en.wikipedia.org/wiki/Artificial_intelligence

[6] Todd Jaquith & The Futurism Team. 2016. ‘Understanding Machine Learning”. *Futurism [Infographics].* URL: https://futurism.com/images/understanding-machine-learning-infographic/

[7] Jun Añover & Red Van Cliff Estocado. 2017. “Types of AI: from reactive to self-aware”. *Futurism [Infographics].* URL: https://futurism.com/images/types-of-ai-from-reactive-to-self-aware-infographic/

[8] The Actuary. 21 Apr. 2017. “Artificial intelligence to ‘completely transform’ insurance industry in the next three years”. URL: http://predictions.theactuary.com/2017/04/21/artificial-intelligence-to-completely-transform-insurance-industry-in-next-three-years/

[9] Kailash Nadh. 30 Mar. 2017. “The Tussle Between Robo Advisers and Human Financial Firms”. *Entrepeneur India.* URL: https://www.entrepreneur.com/article/292176

Delegation of Decisions to Machines: Impact on The Corporate Landscapes and Processes

Impact on the Business and Operational Landscapes

[10] Carl Benedikt Frey & Michael A. Osborne. 17 Sep. 2013. *The Future of Employment: How Susceptible are Jobs to Computerisation?*
URL: http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

[11] David Autor & Anna Salomons. 19 Jun. 2017. *Does Productivity Growth Threaten Employment?* URL: https://www.ecbforum.eu/uploads/originals/2017/speakers/papers/D_Autor_A_Salomons_Does_productivity_growth_threaten_employment_Final_Draft_20170619.pdf

[12] James Manyika. May 2017. *What’s Now and Next in Analytics, AI and Automation.* San Francisco: McKinsey Global Institute Briefing note.

[13] Emerging Risks Initiative. Nov. 2013. *Food and its impact on the risk landscape.* Amsterdam: CRO Forum. URL: https://www.thecroforum.org/2013/11/04/food-and-its-impact-on-the-risk-landscape/

[14] International Federation of Robotics (IFR). 29 Sep. 2016. “World Robotic Report 2016: European Union occupies top position in the global automation race”. Frankfurt: IFR Press release. URL: https://ifr.org/ifr-press-releases/news/world-robotics-report-2016

[15] Emerging Risks Initiative. Nov. 2015. *The Smart Factory.* Amsterdam: CRO Forum. URL: https://www.thecroforum.org/2015/12/07/the-smart-factory-risk-management-perspectives/

[16] Chris O’Brien. 12 Sep. 2016. “One-Third of all Long Haul Trucks to be Semi-Autonomous by 2025”. *Trucks.com International.* URL: https://www.trucks.com/2016/09/12/one-third-trucks-autonomous-2025/

[17] World Economic Forum (WEF) Global Competitiveness and Risks Team. Jan. 2017. *The Global Risks Report 2017, 12th Edition*. Geneva: World Economic Forum. URL: http://reports.weforum.org/global-risks-2017/

[18] Melanie Arntz, Terry Gregory & Ulrich Zierahn. 2016. "The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis*". Organisation for Economic Co-operation and Development (OECD) Social, Employment and Migration Working Papers, No. 189*. Paris: OECD Publishing, 34p. URL: http://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7-en

[19] James Manyika, Michael Chui, Mehdi Miremadi, Jacques Bughin, Katy George, Paul Willmott & Martin Dewhurst. Jan. 2017. *A Future that Works: Automation, Employment and Productivity.* San Francisco: McKinsey Global Institute.

[20] Erik Brynjolfsson & Andrew McAfee. 2014. The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. Lexington: Digital Frontier Press.

Consequences for corporate, regulation and society on ethical and moral issues

[21] New Scientist. 22 Jun. 2016. "Forget killer robots: This is the future of supersmart machines". *New Scientist Analysis.* URL: https://www.newscientist.com/article/mg23030794-500-forget-killer-robots-this-is-the-future-of-supersmart-machines/

[22] Richard Susskind & Daniel Susskind. 11 Oct. 2016. "Technology Will Replace Many Doctors, Lawyers, and Other Professionals". *Harvard Business Review*. URL: https://hbr.org/2016/10/robots-will-replace-doctors-lawyers-and-other-professionals

[23] Stuart Russel. 9 Sep. 2015. "What if: machines outsmart us all?". *World Economic Forum.* Agenda, Annual meeting of the New Champions, 9-11 Sep. 2015, Dalian. URL: https://www.weforum.org/agenda/2015/09/what-if-machines-outsmart-us-all/

[24] The British Standards Institute (BSI). Apr. 2016. Robots and robotic devices: Guide to the ethical design and application of robots and robotic systems. London: BSI Standards Limited, BS 8611:2016.

Engineering and Physical Sciences Research Council (EPSCR). 2017. "Principles of robotics". URL: https://www.epsrc.ac.uk/research/ourportfolio/themes/engineering/activities/principlesofrobotics/

[25] Wikipedia. 27 Jun. 2017. "Trolley problem". URL: https://en.wikipedia.org/wiki/Trolley_problem

[26] Jean-François Bonnefon, Azim Shariff & Iyad Rahwan. 23 Jun. 2016. "The social dilemma of autonomous vehicles". *Science*, Vol. 352, Issue 6293, pp.1573-1576 [doi: 10.1126/science.aaf2654]. URL: https://www.researchgate.net/publication/301293464_The_Social_Dilemma_of_Autonomous_Vehicles

[27] Hillary Abraham, Bryan Reimer, Bobbie Seppelt, Craig Fitzgerald, Bruce Mehler & Joseph F. Coughlin. 25 May 2017. *Consumer Interest in Automation: Preliminary Observations Exploring a Year's Change.* Cambridge: Massachusetts Institute of Technology AgeLab White Paper 2017-2.
URL: http://agelab.mit.edu/sites/default/files/MIT%20-%20NEMPA%20White%20Paper%20FINAL.pdf

[28] Scalable Cooperation. 2016. *Moral Machine*. Massachussets Institute of Technology Media Lab: Online platform. URL: http://moralmachine.mit.edu/

[29] Daniel H. Pink. 2009. Drive: The Surprising Truth about what Motivates Us. New York: Riverhead Books, 242p.

[30] James Salmon. 27 Feb. 2017. "Top insurer asks its 16,000 staff if a robot could do their job; Aviva set to retrain employees for new roles if they answer yes". *MailOnline.* URL: http://www.dailymail.co.uk/news/article-4262552/Aviva-asks-staff-robot-job.html

[31] Sebastian Buckup. 26 Jun. 2017. "Four key questions for the Fourth Industrial Revolution". *World Economic Forum.* URL: https://www.weforum.org/agenda/2017/06/four-key-questions-for-the-fourth-industrial-revolution

[32] Julia Powles & Hal Hodson. 16 Mar. 2017. "Google DeepMind and healthcare in an age of algorithms." *Health and Technology*, pp.1-17 [doi: https://doi.org/10.1007/s12553-017-0179-1].
URL: https://link.springer.com/article/10.1007%2Fs12553-017-0179-1

[33] Jack Stilgoe, Richard Owen & Phil Macnaghten. 13 Jun. 2013. "Developing a framework for responsible innovation". *Research Policy*, Vol. 42, Issue 9, Nov. 2013, pp.1568-1580 [doi: https://doi.org/10.1016/j.respol.2013.05.008].
URL: http://www.sciencedirect.com/science/article/pii/S0048733313000930

[34] Ernst & Young (EY). 9 Feb. 2017. *European Parliament calls for legislative framework governing creation, use and taxation of robots and artificial intelligence.* EY Global Tax Alert Library: Global Tax Alert. URL: http://www.ey.com/Publication/vwLUAssets/European_Parliament_calls_for_legislative_framework_governing_creation_use_and_taxation_of_robots_and_artificial_intelligence/

[35] Anthony Wood. 28 Jul. 2015. "Open letter petitions UN to ban the development on weaponized AI." *New Atlas.* URL: http://newatlas.com/open-letter-un-weaponized-artificial-intelligence/38645/

[36] James Vincent. 21 Aug. 2017. "Elon Musk and AI leaders call for a ban on killer robots." *The Verge*. URL: https://www.theverge.com/2017/8/21/16177828/killer-robots-ban-elon-musk-un-petition

[37] Lily Hay Newman. 8 Jul. 2017. "The Army grounds its DJI drones over security concerns." *Wired.* URL: https://www.wired.com/story/army-dji-drone-ban/

Impacts on Re/Insurance Underwriting Risks

Threats for Re/Insurance Underwriting Risks

[38] Matthew U. Scherer. 30 May 2015. "Regulating artificial intelligence systems: risks, challenges, competencies, and strategies". *Harvard Journal of Law and Technology*, Vol. 29, Issue 2, pp.369-373 [doi: http://dx.doi.org/10.2139/ssrn.2609777]. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2609777

Cade Metz. 03 Sep. 2016. "Google and Facebook team up to open source the gear behind their empires". *Wired*. URL: http://www.wired.com/2016/03/google-facebook-designing-open-source-data-center-gear-together/

[39] Nathalie Nevejans. Oct. 2016. *European Civil Law Rules in Robotics: Study for the JURI Committee.* European Parliament Directorate-General for Internal Policies, Policy Department Citizens' Rights and Constitutional Affairs, Legal and Parliamentary Affairs: Study commissioned by the European Parliament's Committee on Legal Affairs, pp.16-18.
URL: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/571379/IPOL_STU(2016)571379_EN.pdf

[40] US National Highway Traffic Safety Administration. 2013. *Preliminary Statement of Policy Concerning Automated Vehicles*.

[41] Insurance Europe. Aug. 2016. *European Insurance — Key Facts*. Brussels. URL: https://www.insuranceeurope.eu/sites/default/files/attachments/European%20Insurance%20-%20Key%20Facts%20-%20August%202016.pdf

[42] KPMG LLP & Center for Automotive Research (CAR). 2012. *Self-driving cars: The next revolution*. URL: https://faculty.washington.edu/jbs/itrans/self_driving_cars[1].pdf

[43] Frank Schlehuber, Director Aftermarket, European Association of Automotive Suppliers (CLEPA). 27 Jun. 2017. *Access to Data / Access to Market.* Brussels: Presentation to European Parliament event on 'Future Driving Platform'. 27 Jun. 2017.

[44] Alex Owen-Hill. 23 Sep. 2015. "Is My Robotic Co-Worker Dangerous? Why Robots Kill People", *Robotiq*. URL: http://blog.robotiq.com/is-my-robotic-co-worker-dangerous-why-robots-kill-people

[45] Loretta Chao, 6 Apr. 2016. "Robots Gain Traction With Supply Chain Managers". *The Wall Street Journal.* URL: https://www.wsj.com/articles/robots-gain-traction-with-supply-chain-managers-1459936836

[46] SCOR P&C. Dec. 2016. "Innovation in mining: Perspectives and new risks". *SCOR Technical Newsletter #35*. Paris: SCOR P&C Strategy & Development.

[47] Colin Lecher. 18 Jun. 2017. "Drones keep dropping drugs and porn into prisons. *The Verge.* URL: https://www.theverge.com/2017/6/18/15818224/drones-prisons-smuggling-contraband

[48] Drew Prindle. 17 Oct. 2014. "Meet the automated safe cracking machine made with just $150 in parts." *Digital Trends.* URL: https://www.digitaltrends.com/cool-tech/meet-automated-safe-cracking-machine-made-just-150-parts/

[49] Rolls-Royce Marine. 2016. "Autonomous ships: The next step". *Rolls-Royce Ship Intelligence: Marine*. URL: http://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf

[50] Oskar Levander. 28 Jan. 2017. "Forget Autonomous Cars – Autonomous Ships Are Almost Here". *IEEE Spectrum*. URL: http://spectrum.ieee.org/transportation/marine/forget-autonomous-cars-autonomous-ships-are-almost-here

[51] Markus Laurinen, Advanced Autonomous Waterborne Applications Project Coordinator. 2015. *Advanced Autonomous Waterborne Applications Initiative AWAA*. Helsinki: AAWA Seminar. URL: http://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/12%20-%20AAWA%20Coordinator.pdf

[52] Allianz Global Corporate & Specialty. 2012. *Safety and Shipping 1912-2012: From Titanic to Costa Concordia*. URL: http://www.agcs.allianz.com/assets/PDFs/Reports/AGCS_safety_and_shipping_report.pdf

[53] Marsh Global Marine Practice. 2017. *The Changing Tide of Risk: Expects Perspectives on the Marine Industry.*

[54] Reactions. 25 May 2017. "ANALYSIS: Autonomous ships an emerging threat". *Reactions.* URL: https://reactionsnet.com/articles/3589807/analysis-autonomous-ships-an-emerging-threat

Opportunities for Re/Insurance Underwriting Risks

[55] Ivana Kottasová. 7 Aug. 2017. "Pilotless planes could save airlines billions. But would anyone fly?". *CNN Tech.* URL: http://money.cnn.com/2017/08/07/technology/business/pilotless-planes-passengers/index.html

[56] Ray Kurzweil. 7 Mar. 2001. "The Law of Accelerating Returns". *Kurzweil Accelerating Intelligence*: Essays. URL: http://www.kurzweilai.net/the-law-of-accelerating-returns

[57] Elon Musk, Tesla, Chief Executive Officer. 2017. In: Ernst & Young (EY). Jul. 2017. *The evolution in self-driving vehicles: Trends and implications for the insurance industry.* URL: http://www.ey.com/Publication/vwLUAssets/ey-self-driving-vehicle-v2/$File/ey-self-driving-vehicle-v2.pdf

[58] Patrick Lin, Director of Ethics + Emerging Sciences Group at California Polytechnic State University in San Luis Obispo. 25 Apr. 2016. "No, Self-Driving Cars Won't Kill the Insurance Industry". *Forbes*. URL: https://www.forbes.com/sites/patricklin/2016/04/25/self-driving-cars-wont-kill-insurance-industry/#17ee9b2746fe

[59] Susan Morse. 3 Apr. 2015. "More hospitals investing in robots to cut costs in the long run". *Healthcare Finance*. URL: http://www.healthcarefinancenews.com/news/more-hospitals-investing-robots-cut-costs-long-run

[60] Carlos Perez-Vidal, E. Carpintero, N. Garcia-Aracil, J.M. Sabater-Navarro, J.M. Azorin, A. Candela & E. Fernandez. 20 Jan. 2012. "Steps in the development of a robotic scrub nurse". *Robotics and Autonomous Systems*, Vol. 60, Issue 6, Jun. 2012, pp.901-911 [doi: https://doi.org/10.1016/j.robot.2012.01.005]. URL: http://www.sciencedirect.com/science/article/pii/S0921889012000176

[61] Mithun Jacob,.Yu-Ting Li, George Akingba & Juan P. Wachs. 27 Nov. 2011. "Gestonurse: a robotic surgical nurse for handling surgical instruments in the operating room". *Journal of Robotic Surgery*, Vol. 6, Issue 1, pp.53-63 [doi: https://doi.org/10.1007/s11701-011-0325-0]. URL: https://link.springer.com/article/10.1007/s11701-011-0325-0

[62] PARO Robots USA. 2014. "Paro Therapeutic Robot". URL: http://www.parorobots.com/

[63] Jibo. 2017. "Meet Jibo". URL: https://www.jibo.com/

[64] SoftBank Robotics. 2017. "Robots: Who is Pepper?". URL: https://www.ald.softbankrobotics.com/en/cool-robots/pepper

[65] Blue Frog Robotics & Buddy. 2017. "Buddy The First Companion Robot". URL: http://www.bluefrogrobotics.com/en/buddy/

[66] Matthew Hutson. 11 May 2017. "This robotic exoskeleton could help prevent falls in the elderly". *Science*. URL: http://www.sciencemag.org/news/2017/05/robotic-exoskeleton-could-help-prevent-falls-elderly

[67] James Vincent. 4 May 2016. "A robot surgeon has passed a major milestone — sewing up pig guts". *The Verge*. URL: http://www.theverge.com/2016/5/4/11591024/robot-surgery-autonomous-smart-tissue-star-system

[68] Drew Shimshaw, Nicolas Terry, Kris Hauser, Mary Cummings. 26 Feb. 2016. "Regulating Healthcare Robots: Maximizing Opportunities While Minimizing Risks". *Richmond Journal of Law & Technology*, Vol. 22, Issue 2, pp.12-15; Indiana University Robert H. McKinney School of Law Research Paper No. 2016-14. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2739462

Claims Handling and Incidence Response

[69] Agil Francis, Gauthaman Krishnamurthy, Aldrin Aloysius. Oct. 2014. *Drones: The Insurance Industry's Next Game-Changer?* Cognizant. URL: https://www.cognizant.com/InsightsWhitepapers/drones-the-insurance-industrys-next-game-changer-codex1019.pdf

[70] Measure & The American Red Cross. Apr. 2015. *Drones for Disaster Response and Relief Operations*. URL: http://www.issuelab.org/resources/21683/21683.pdf

[71] Center for Robot-Assisted Search and Rescue (CRASAR) Texas A&M University. 2017. "Table of Responses". URL: http://crasar.org/about/table-of-responses/

[72] New Scientist. 27 Nov. 2013. "Smart software uses drones to pilot disaster relief". *New Scientist Technology News.* URL: https://www.newscientist.com/article/mg22029455-100-smart-software-uses-drones-to-plot-disaster-relief/

[73] Federal Aviation Administration (FAA). 24 March 2016. "FAA Releases 2016 to 2036 Aerospace Forecast". URL: https://www.faa.gov/news/updates/?newsId=85227

[74] Allianz Global Corporate and Specialty. 2016. "Rise of the drones – Managing the Unique Risks Associated with Unmanned Aircraft Systems". URL: http://www.agcs.allianz.com/insights/white-papers-and-case-studies/rise-of-the-drones/

[75] PwC. 2017. "Clarity from above: PwC global report on the commercial applications of drone technology". URL: https://www.pwc.pl/en/publikacje/2016/clarity-from-above.html

Conclusion

[76] Denis Kessler, SCOR, Chairman of the Board of Directors and Chief Executive Officer, Amélie de Montchalin, French Member of Parliament in Essonne, former AXA Group, Head of Prospective and Public Policy Monitoring, and Christian Thimann, AXA Group, Group Head of Regulation, Sustainability and Insurance Foresight. Apr. 2016. "The Macroeconomic Role of Insurance". In: Edited by Felix Hufeld, Ralph S. Koijen and Christian Thimann. 2016. The Economics, Regulation and Systemic Risk of Insurance Markets. Oxford University Press. In: AXA Group. 2016. *Insurance is invisible yet everywhere.* Paris: Havas Paris. URL: https://www-axa-com.cdn.axa-contento-118412.eu/www-axa-com%2Feec4f313-4fa7-42a0-a9e8-ed8119968ff9_axa_brochure_insurance-everywhere.pdf

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SCOR: p. 3, SCOR Emerging Risks Team. Oct. 2017 / p.19, from SCOR P&C. Dec. 2016. "Innovation in mining: Perspectives and new risks". *Technical Newsletter #35*.

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PO Box 74500, 1070 DB Amsterdam
The Netherlands

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