Safety and Reliability – Safe Societies in a Changing World – Haugen et al. (Eds)

Automation of the rail—removing the human factor?

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ABSTRACT: Automated vehicles will be increasingly used as transport in the future. However, it is unclear if this imply full autonomy or different levels of automation. A unified definition of autonomy in transport is missing. The SAREPTA project (Safety, autonomy, remote control and operations of industrial transport systems) is established in 2017, and cover safety challenges of future intelligent transport systems that are autonomous, remotely controlled and normally not manned. The project covers both road, sea, aviation and rail. This paper focuses on issues related to rail transport, including both metros and railway. The purpose of the paper is to describe current rail accidents as a basis for questioning whether future digitalisation will improve safety. The paper will discuss the autonomy concept in relation to grades of automation. Relevant questions are: What is automation and which accidents may be prevented by automation? To what degree do automation and remote control imply removal of the Human Factor? And from a safety perspective—What is the safety potential of future automation, and how can humans contribute to safety in future intelligent transport systems?

1 INTRODUCTION

Digitalization is a global change affecting a variety of social conditions and businesses. In addition to changing products and services in businesses and the labour market, digitalization will also create radically new business models in many industries (Stene et al 2017).

1.1 *Safety and automation of transport systems*

Safety and environmental challenges of future intelligent transport systems are addressed in a newly established project founded by the Norwegian Research Council for 2017–2021. The SAREPTA (Safety, autonomy, remote control and operations of industrial transport systems) project focuses on systems that are autonomous, remotely controlled and/or periodically not manned.

In the project, four thematic areas of autonomous systems are central: (1) Risk identification and risk levels, (2) Infrastructure vulnerabilities and threats, (3) Technical, human and operational barriers to mitigate system risks, and (4) Organizational and human factors, and regulatory measures. The project includes road, sea, aviation and rail. This paper focuses on the rail. The purpose of the paper is to describe current rail accidents as a basis for questioning whether future digitalisation will improve safety. Relevant questions are: What is automation and which accidents may be prevented by automation? To what degree do automation and remote control imply removal of the Human Factor? And from a safety perspective—What is the safety potential of future automation, and how can humans contribute to safety in future intelligent transport systems?

1.2 *Current rail transport safety—fatal and frequent accidents*

European railways are the safest mode of land transport and the safety level has improved over the last decades (EU ERA (European Railways Agency) 2016). However, accidents have heavy impact on confidence in the system. Further, every accident represents a significant business cost in a highly competitive environment. It is argued that emphasis needs to be on human factors as well as on new technology which can be both an opportunity and a threat.

Compared to other transport modes, the fatality risk for an average train passenger (0.12 per billion km) is at least twice as high as commercial aircraft passengers (EU ERA 2017). However, the risk is higher for passengers traveling by bus/coach (one third of the risk) and sea vessels (nearly three times as high). Further, using individual transport means on the road is most risky. Car occupants have at least 20 times higher likelihood of dying compared to train passengers.

Even if rail transport statistically is safer than road transport, some large rail accidents have occurred. The rates of fatal train accident (five or more killed: totally 362) have fallen substantially from 1980 to 2009 on Europe's main line railways (Evans 2011). Fatality risks per million train-km (system risk) in the period 2010–2014, based on persons involved, was 0.28 killed per billion train-km at the EU level (EU ERA 2016). For rail passengers, this was 0.14 killed passengers per billion train-km.

Although rail transport safety has steadily enhanced over the years, the number of accidents started increasing in 2014 and 2015 (Eurostat 2017). Still, the number of victims (killed or injured persons) continues to decline. Table 1 shows the number and persons killed and injured in rail transport accidents in Europe 2016. Two types of accidents are dominant – (1) Rolling stock in motion and (2) Level-crossings—followed by (3) Train collisions and (4) Derailments.

The majority are accidents to persons caused by rolling stock in motion. These are either hit by a railway vehicle or an object attached to it. Persons that fall from railway vehicles are included, as well as persons that fall or are hit by loose objects when travelling on-board vehicles.

Fatal level crossing accidents are more numerous and account for more fatalities than fatal train collisions and derailments (EU ERA 2016). Further, in contrast to collisions and derailments, the rate per train-kilometre remained unchanged in 1990–2009. Thus, level crossing accidents represent an increasing proportion of serious accidents.

The estimated accident rate in 2016 is 1.07 fatal collisions or derailments per billion train-kilometres, which represents a fall of 73% since 1990 (Evans 2011). This gives an estimated mean number of fatal accidents in Europe in 2016 of 4.7. In contrast to fatal train collisions and derailments, the rate per train-kilometre of severe accidents at level crossings fell only slowly and not statistically significantly in 1990–2016. There are statistically significant differences in the fatal train accident rates and trends between the different European countries.

Totally, the most common cause of fatal accidents is signal passed at danger, followed by signalling/dispatching errors and violation of the speed limit. Further, small numbers are train fires and groups of persons struck by trains, mostly track workers.

Table 1. Number and persons killed and injured in rail transport accidents by type of accident in Europe 2016 (Eurostat 2017).

	Number of persons		
Type of accident	Killed	Seriously injured	Total
Collisions	44	77	121
Derailments	11	27	38
Accidents involving Level-crossings	256	220	476
Accidents to persons caused by rolling stock in motion	651	438	1089
Others	2	16	18
Total	964	778	1742

The causes of level crossing accidents differ from train collisions and derailments. The most frequent cause of fatal train collisions (2) and derailments (3) is signals passed at danger. The majority of level crossing (1) accidents are caused by errors or violations by road users. Most major crossings in Europe have automatic warnings (lights, barriers and bells) operated by approaching trains. Most minor crossings have fixed warning signs only, with no indication when trains are approaching. The primary responsibility for operational safety thus rests with road users, either in obeying warnings or checking that no train is approaching before they cross.

1.3 *Animals along the track—a current challenge*

Less severe accidents and incidents strongly outnumber fatal accidents (EU ERA 2016). However, these occurrences are not collected at the EU level, and great benefits could be made from reporting them to identify and manage risks.

While the number of people killed or injured in rail accidents is well-documented, little research has been done to analyse the number of animal casualties on international railways (Gray 2015). High-speed trains often cut through sensitive wildlife habitats. Accidents involving various species are detrimental to local wildlife, are costly and a danger to travellers.

In Norway, nearly 2000 collisions with animal are recorded on the railway each year, which is a doubling of the frequency over 20 years (Roaldsen et al. 2015). Reduction of crashes—even by a few percent—can contribute to significant socio-economic savings and reduced conditions for both humans and animals.

From 1991–2014, the Norwegian National Rail Administration registered nearly 26 000 events with one or more animals (near 36 000 animals) being hit by train. Over 90 percent involve moose (57%), roedeer (15%), sheep (9%) and domesticated reindeer (8%). Topography and landscape influence the existence of animals in areas near the rail, thus increasing the accident risk. Important factors are related to food, shelter, visibility and animal corridors. Further, weather conditions as snow and rain affect where the animals are.

2 TRANSPORT TECHNOLOGY INNOVATION

2.1 *Digitalization of the rail*

Digital technology may be defined as the use of ITC (computing capacity + telecommunication) to gather, transfer and process data to provide the communication backbone for all users of the network (BearingPoint 2017).

Rail 4.0 may be considered a parallel concept to Industry 4.0 (Stene et al 2017). The concept refers to four industrial revolutions starting at the end of 18th century with the introduction of (1) mechanical manufacturing, and continues with (2) mass production, (3) computers and automation (also labelled digital revolution) and (4) Internet. Four key components in Industry 4.0 are: CPS (Cyber-Physical Systems), IoT (Internet of Things), Smart Factory (e.g. traffic management sites) and IoS (Internet of Services).

Further, Davidsson et al (2016) divide the digital period in four waves: (1) introduction of computers in the 80s, (2) Internet in the 90s made it easy to access and share information, (3) mobile Internet making this possible regardless of where you are, and (4) is represented by Internet of Things (IoT). In addition to people, different types of entities (vehicles, machinery) may also have access to and share information.

In the rail sector, ERTMS (European Railway Traffic Management System) is a common signalling system that is to be introduced in all EU countries by 2030. A standardized system will improve the interoperability between networks and systems. ERTMS includes ETCS (European Train Control System), GSM-R (Global System for Mobile Communication-Railway, which is radio communication between train and signalling), and common European traffic regulation. A common trans-border railway transport allows trains to travel in any European country which has the ERTMS system implemented both in the rail infrastructure and in the train itself.

ERTMS has many similarities with CBTC (Communication-Based Train Control), which is the preferred signalling solution for automated subways and metros. One difference is that ERTMS is standardized, while CBTC is supplier specific. CBTC is a signalling system making use of telecommunication between train and track equipment (wayside) for traffic management. By making more exact positions of each train, the system makes it possible reduce time intervals between trains. The main objective is increased capacity.

2.2 *Automatic Train Operation (ATO)*

Generally, autonomy is often related to attributes like self-government, freedom to act or function independently. For vehicles, autonomy is generally understood as the ability to make decisions about actions to take, e.g. course or speed, independent of a human operator. Levels of autonomy or automation describe the successive shifting of responsibility from the driver to the vehicle. Different concepts are used to describe vehicle automation in each transport mode/ domain.

In addition to concepts used in each domain, Ponsard et al (2017) present a comparative over-

Table 2. Comparison of automation levels at road, rail and air. Based on Ponsard et al (2017).

Railway	Road	Aircraft	Resp.	
Grades of automation	SAE levels	Levels of automation		
GoA-0 Sight train operator	**L0** No automation	**Level 1** Raw data, no automation at all	All time	Warn Protect
GoA-1 Manual train operation Automated train protection	**L1** Driver assistance Park assist/cruise control	**Level 2** Assistance Flight director Auto-throttle	Drivers	Guide Assist
GoA-2 Semi-automated train operation (STO). Autom. train op. (ATO)	**L2** Partial automation Traffic jam assist	**Level 3** Tactical use Autopilot	Monitors all time	Manage movements within limits
GoA-3 Driverless train operation (DTO) Automated control (ATC)	**L3** Conditional automation	**Level 4** Strategic Flight management system	Ready to take back control	Drives itself, may give back control
Some control by attendant (operating doors, emergencies)	**L4** High automation Highway traffic jam system	Uninterrupted autopilot project (Boing) Drones (unmanned)	May not take back control	Drives itself with graceful degradation
GoA-4 Unattended train op (UTO) Automated doors Platform screen doors	**L5** Full automation (all situations)		Not required	All time

view of the responsibility between system vs human (driver/pilot) at different levels of automation (see Table 1). In rail, the concept Grades of Automation (GoA) is used. Notice the double line in the table; this marks a shift from GoA-3 in responsibility from the driver to the system.

Rail and airplanes have already achieved much higher levels (Ibid). However, this is only true for some rail line types. Several fully autonomous metros exist. The next two sections in this paper goes more into this.

2.3 *New technology on the main line railway*

The difference between signalling and control systems in European railway is significant, and until 1980 14 national standards were in practical use (Tao & Jing 2014). ETCS (European Train Control System) is designed to replace these incompatible safety systems, and the first version was published in 2000.

As mentioned above, the GoA concept describe levels of automation in rail. Figure 1 illustrates the existence of a driver at different grades. Further, the operations are described at each grade, i.e. management agents and actions to be taken.

Implementation of ERTMS at GoA-1 implies that signal information is shown on a panel inside the cabin. The driver may use the signal as a replacement of a traditional light outside at the track. The signal tells whether the driver may drive into the next block or not. At GoA-2 the train is operated by automated control based on signals from sensors along the track. In addition to be responsible for monitoring the speed and position, the driver may take control in case of any incident or emergency.

A lot of literature on transport autonomy focus on train automation, i.e. the interaction and responsibility between vehicle—driver (see Figure 2). The inner control loop is responsible for executing the production plan (Rao & Montigel 2017), and the focus is on driving performance by

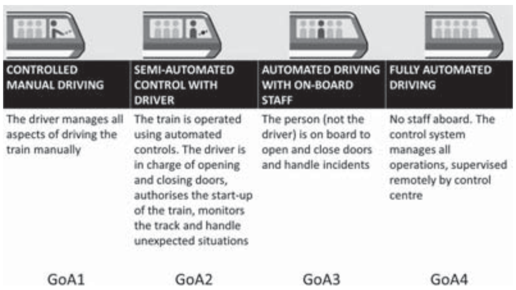

Figure 1. Levels of automation (Brodeo 2016).

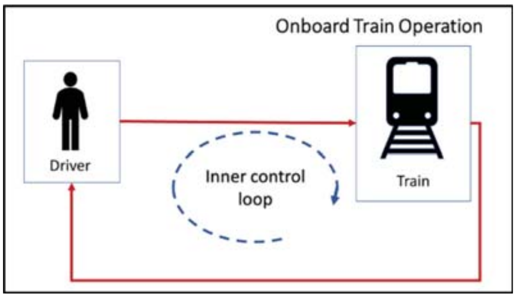

Figure 2. Train automation—Control of onboard train operation.

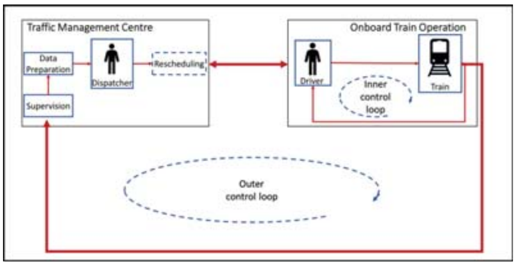

Figure 3. Traffic management—Control of traffic and infrastructure. (Based on Rao & Montigel, 2017).

providing driver assistance or introducing train automation.

Rao (2015) presents a holistic approach to the main line railway. In addition to (1) train automation, the focus is also on (2) traffic management, and the relationship between the two areas (see Figure 3). The outer control loop supervises the status of traffic and infrastructure, detects deviations and conflicts, and develops a new schedule (rescheduling) and transmits it to train operation.

Automation depends on two supports: Onboard support (as the Automatic Train Protection—ATP) system to provide train's overspeed protection and to keep a safe headway between trains, and infrastructure support (as Automatic Train Supervision—ATS) to provide dynamic traffic regulation to avoid traffic conflicts (Rao et al 2016).

Even at GoA-4 trains on are not autonomous in the sense that no control is needs. Traffic management focus both on the outer control loop (improving efficiency for the dispatcher by providing resolutions for traffic conflict) and the inner loop (improving driver performance or assisting the driver). Thus, reducing human failure are central in both control loops.

ETCS (European Train Control System) is a signalling, control and train protection system used on the main railway lines. The train detection equipment sends the position about speed limitation, signal status etc. (Venticinque et al 2014). Three levels define the use of train control system; communication from track to train (level 1), continuous communication between the train and the Traffic Management Centre (level 2), and future implementation of a moving block technology (level 3). Several main rail tracks operate at level 2, including two main subsystems: (a) a ground system collects and transmits track data to (b) an onboard subsystem.

ETCS-2 uses digital radio transmission of signals along the trackside (Tao & Jing 2014). With its onboard positioning equipment, the train can automatically report its exact position and direction of travel at regular intervals, in addition to motion (stop/go) signals. Balises on the tack detect trains and send the position to the control centre (Venticinque et al 2014). Based on the position of all trains, the centre determines the new movement authority (MA) and sends it to the train. The onboard computer calculates its speed profile from the MA and the next braking point. This information is displayed to the driver.

2.4 *Autonomous metros*

In metro systems, automation refers to the process by which responsibility for operation management of trains is transferred from the driver to the train control system (UITP 2017).

The experience period with automated metros is over 30 years. The first was high capacity, but today we also see a trend of increase in mid-capacity trains. Between 2014 and 2015 Europe will lead in terms of growth (Hernández 2014). Asia and Europe together hold 75% of the km of fully automated metro lines.

For metros, many use the term CBTC synonym as an automated driverless system. However, at its most basic form the system provides automatic protection (ATP) only. Fully automated systems also include ATO (Automatic Train Operation) and ATS (Automatic Train Supervision).

A semi-autonomous train (GoA-2) may manage movements, but a human need to be onboard to start the train, open doors etc. (Lufkin 2015). There are also trains that can fully operate completely free of humans. Only 6% of the world's transit rails operate those trains. Several cities are aiming for automation.

There are 55 fully automated metro lines in 37 cities around the world (UITP 2016a). Fully automated metro lines, defined as those metro lines in which trains can be operated without staff onboard—a defining characteristic is the absence of a driver's cabin on the train. This type of operation is also known as Unattended Train Operation (UTO), or Grade of Automation 4 in standard IEC 62267.

2.5 *Metro automation and safety*

The positive experience of decades of automated operation highlights one of the major elements to consider in this success story: safety (UITP 2016b). There have been no significant accidents, in particular none involving casualties, in any automated metro line in the world.

Copenhagen Metro is one example of a system running fully automated, consisting of automatic train protection, operation and supervision. Although no serious accidents have occurred, incidents and accidents may point out some risk areas. The station area is strongly marked. The safety of the platform/track interface is crucial for fully automated metro lines.

The dominant safety measure is installation of platform screen doors (detection systems) preventing persons and objects from falling on the track. Currently, near 80% of stations in fully automated metro lines in operation in the world are equipped with such doors (UITP 2016).

Platform and track incidents aside, there has only been one operational incidents with UTO systems; in Osaka at the end of the 80s a train did not stop at terminus and hit a bumper stop, provoking injuries in a few dozen passengers (UITP 2017).

2.6 *Open surroundings—challenging the main railway*

Since the main railway has much more complicated infrastructure situations, currently train automation is mainly applied in metro railway (Rao et al 2016).

The open surroundings of current main rail traffic challenge safety. Rails with driverless trains are generally run on closed off networks, i.e. run underground. Thus, no one can fall onto the tracks, and there are no points where the trains cross with others.

3 DISCUSSION

3.1 *Rail 4.0 – Opportunities and challenges?*

The purpose of intelligent systems is to make the human environment more "people-friendly" technologies (Tokody & Flammini 2017). This means that infrastructural systems should be sustainable, safe, economic and easy-to-use. The development of intelligent, autonomous systems may ensure sustainability and safety.

Future IoS (Internet of Services) in a rail context will focus on offering services to the general public or specific target groups as passengers. For example, a dynamic system for Copenhagen metro, will automatically optimize trains frequency depending on numbers passenger and changes of numbers (Razeto & Corsanego 2017). Likewise, in Switzerland, a new Trip Planner app using voice control will let customers compare, combine and book a journey with multiple modes of transport including taxi (SWI 2017b).

Integrated mobility is an example of Smart Management. According to the Federal Railways in Switzerland, integrated mobility is a central field of innovation, and thus they are developing a door-to-door service to the general public ("SBB Green Class").

One example of utilizing IoT, is goods transport in Switzerland installing various sensors in carriages. Instruments will measure temperature, vibrations and the wagon's position. Customers may get information of goods status, location and time for arrival. In Japan high-speed rail use in-ground sensors in quake-prone zones, that immediately activate emergency brakes seconds after the initial quake waves are detected.

However, one of the future challenges is related to telecommunication and traffic management. ITS includes telematics and all types of communications in vehicles, between vehicles and between vehicles and a fixed location (Brodeo, 2016). As even more transport is being digitalized, the use of radio frequencies for signalling systems may be conflicting or overloaded. Several EU countries already use radio communication systems in the same range, all on a limited duration licensing scheme.

3.2 *Scenarios – Can automation prevent future rail accidents?*

For more than three decades, rail transport safety has improved generally and presumably due to a wide range of safety measures like automatic train protection, improved signalling systems and improved operational management. The question is whether new technology may contribute to prevent the most serious and frequent accidents; (1) Rolling stock in motion, (2) Level-crossings, (3) Collisions, (4) Derailments and (5) Animals along the track.

1. The engine (rolling stock) is heavy, and as such needs a long distance to stop in case of an incident or unexpected objects on the track. A driverless train needs to have equipment that detect obstacles and stops automatically. Rail research and innovation in Europe include safety related technology development; automatic obstacle-detection systems for railway vehicles, regenerative braking, monitoring systems and satellite based positioning systems (Tokody & Flammini 2017).

   However, passenger comfort is also highly valued. An efficient and powerful breaking system may cause great discomfort and passenger injuries. This is true for passenger trains, but should be a less problem with freight trains. Even though automated trains may still include some staff onboard.

   Even though capacity is the main objective of CBTC systems used at automated metros, maintaining safety is a major requirement. In addition to distance, calculations cover speed, curves and position. Thus, controlling acceleration, retardation and stops at stations. At slower speed, the distance may be shorter. A challenge is to calculate the block length for max capacity while ensuring safety.
2. Level-crossings. Road user errors or violations contribute to most of fatal accidents, either in obeying warnings or checking that no train is approaching before they cross (EU ERA 2016). The authors point out countermeasures like those for road accidents, particularly education and enforcement. However, more autonomous vehicles may also contribute to prevent rail accidents.

   Autonomous obstacle detection systems may be beneficial for road and rail transport. The Germany SMART project focuses on rail freight and automation of railway cargo haul (Shift2rail 2016), including development of (1) a prototype of an autonomous obstacle detection system and (2) a real-time marshalling yard management system. The first system will use night vision technologies, multi stereo vision system and laser scanner to create fusion system for short (up to 20 m) and long range (up to 1000 m) obstacle detection during day and night operation, as well as during operation in impaired visibility. The second system will provide optimisation of available resources and planning of marshalling operations.
3. Collisions. Related technology development which may contribute to accident prevention are automatic obstacle-detection systems for railway vehicles, traction transformers, energy storage technologies, regenerative braking, monitoring systems, satellite based positioning systems, and smart railway technologies (Tokody & Flammini 2017).

   As mentioned in relation to rolling stock in motion, passenger comfort is highly valued, and unexpected intense breaking may contrast a safety measure. Acceleration and deceleration are essentially limited by the wellbeing and safety of the passengers (Gary 2016).
4. Derailments. One serious accident on a main line using ERTMS, was a derailment of a high-speed train in Spain in 2013. Initial reports cited driver error as the sole cause, but a deeper study of the accident says lack of a functioning onboard ETCS system was a crucial factor (Puente 2015). A high-speed train derailed trav-

elling at 180 km/h (speed limit 80 km/h) through a curve, resulting in the death of 79 people and injuring more than a hundred.

The line was equipped with ERTMS/ETCS Level 1, except for the first and the last kilometre, with a national signalling system used as a backup. However, the onboard ETCS system had been switch off in 2012 due to alleged operating problems. The train driver should manually have changed the speed, but when the train entered the low speed section the driver was speaking on the phone to staff at the train company (Johnsen 2015).

If onboard ETCS had been working, the following would have happened at the ETCS exit boundary 4km before the curve where the accident occurred (Puente 2015): (a) a text message announcing the transition would have appeared on the Driver Machine Interface (DMI) of the train, which was travelling at 200km/h, (b) the DMI would have shown a message with a yellow flashing frame and would have emitted an acoustic signal asking the driver to acknowledge the transition by tapping on the screen, and (c) if the driver failed to acknowledge the message within 5 seconds, service braking would have been applied continuously until the driver had acknowledged the transition or the train had stopped.

5. Animals along the track. Current countermeasures include building fences around the worst affected rail lines, removal of vegetation and warning systems (Roaldsen et al. 2015). The implemented strategies include installation of warning signs for train drivers, night patrols along the tracks and introducing staff to assist animal crossings. Warning signs are the most widespread accident prevention measure (Gray 2015). Most is human warnings, but acoustic signals creating fear in animals (preventing them from approaching the tracks) is also tried. As an example, Norwegian reindeer owners often warn about animals near the rail, implying that train drivers may reduce speed and the probability of incidents (Busengdal et al 2014). More general models have also been developed to predict the occurrence of animals (Gundersen & Andreassen 1998). Gray (2015) argue that manned assistance along high-speed tracks across the world is not a practical solution and better alternatives are needed. Deutsche Bahn Netz AG and OptaSense is one example of testing new warning technology. Distributed Coustic Sensing (DAS) technology uses heat and motion sensors in various areas of operation, including to detect and alert train drivers of animals approaching the tracks.

3.3 *Will automation remove the human factor?*

Automated systems are often designed to relieve humans of tasks that are repetitive. However, the more reliable the system, the more likely is it that humans in charge will "switch off" and lose their concentration, implying greater likelihood of unexpected factors and a potential catastrophe (Vedantam 2009). Technology replacing or assisting the driver can become crutches. Accidents happen when unusual events come together. No matter how clever designers of automated systems might be, they simply cannot account for every possible scenario, which is why it is so dangerous to eliminate human "interference."

The on-board personnel may be unprepared to take control and manually drive. Regular training exercises that require operators to turn off their automated systems and run everything manually are useful in retaining skills and alertness (Ibid). In addition to detect system failure, understanding how automated systems are designed to work also allows operators to recognize when it is on the brink.

As the system cannot cope with all situations, the driver must be ready to resume operations when instructed (Ponsard et al 2017). The author address issues as situational awareness (the system should make sure that driver's decisions are based on right mental pictures), human reaction capabilities (e.g. alarms may cause confusion, defect view of the entire situation, or panic), warning annoyance (trust in the system in case of e.g. frequent/inappropriate alarms) and task inversion (focus on monitoring alarm and lack of attention to real world situations). The authors claim that machine learning techniques can pay an important role for making sure the driver and the system are operating optimally together.

3.4 *How to cope with unexpected scenarios?*

The concept of black swans refers to rare and unpredictable events. Black swans are extremely rare, catastrophic, and unpredictable events that never have been encountered before (Taleb 2007). In principle, black swans cannot be anticipated. However, even though a catastrophe was not predicted, does not mean that the event could not have been prevented (Murphy 2016).

Implementing new technology and autonomous transport, black swans will occasionally occur. We have to prepare both to cope with alternative scenarios and to handle completely unexpected situations accompanied by high stress and emotions. Thus, in addition to training to identify clues of and handling anomaly situation, training should cover completely unexpected and catastrophically events with an extremely high emotional state.

Experiential training may be necessary for coping with unexpected events, especially to handle personal high stress and to communicate with others (Stene et al 2016).

Emergencies are events which happen suddenly and may destroy normal operations. Despite the presence of automated metro operation control system, the emergency management is still heavily dependent upon capabilities of dispatchers at the management centre (Wang & Fang 2014). The system may lose a part of automated safety protection function. Thus, human error behaviours during emergencies cannot be ignored. Competent humans in transport control centres may represent a safety barrier, preventing incidents and accidents (Stene et al 2017). Machines may be excellent in detecting signs and signals, but humans have to evaluate and decide action based on the context and complexity of the actual situation.

4 CONCLUSION

4.1 *Future automated trains and metros*

With more people living in urban areas than ever before, metro systems around the world will need to adapt (Lufkin 2015). The next generation of subways will develop from cities that are already at the cutting-edge, e.g. the super-fast speeds of Japan's shinkansen or the punctual, low-cost driverless trains of Copenhagen.

Self-driving trains are already being used in some countries, with varying degrees of autonomy. Autonomous driving on a complex rail system, with passenger trains and freight trains is more difficult than on a subway—but it is possible (Gary 2016). Several pilots are currently running. On a test field in Germany, trains will be fitted with cameras and other technologies to detect obstacles on the track and stop the train if necessary. The AutoHaul project in Australia, a long-distance railway system is intended to transport iron ore from 15 mines.

Switzerland will test self-driving trains on a main line without too many people, but still get a feel for how it would work in public (SWI 2017a). The trains will be fitted with sensors that should detect objects on the rails and bring the train to a stop. If rolled out, a system to automate train traffic is assumed to increase passenger and freight capacity by 30%.

4.2 *The human factor in future rail systems*

Technology can improve safety, but there may be examples where human interaction is necessary (Gary 2016). The main purpose of implementing a common European railway signalling system are: (1) Maintaining a safe distance between following trains on the same track, (2) Safeguarding the movements at junctions, and (3) Regulating the movements of trains according to the service density and the speed required (Abel, 2010).

The development relies too heavily on old inertia, meaning too much emphasize on technology. More attention should be paid to the organization, the passengers and the infrastructure (Malla 2014) and passenger evacuation procedures (Hernández 2014).

Factors contributing to the likelihood of catastrophic rail accidents are system complexity, a trend towards higher travel speed, growing infrastructure capacity constraints and the constant cost pressures on risk management activities (EU ERA 2017). Accident investigations should continue to report on both success or failure of systemic risk management methods, e.g. high-reliability organisations, redundancy, robust regulatory and enforcement regimes.

Based on experiences from operating both automated and conventional metro lines, one conclusion is that the human factor is that key for the success of an automated line. (UITP 2016b). The rail is far from being autonomous, in the sense of being independent of a human operator. Humans will still be a necessary resource to manage transport and cope with unexpected incidents.

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