Smart train, metro and tramway systems


常州
Changzhou
Xuahu Quan
Buzhou West
Jiangqiao Zhen

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Preparing for the future

Travelling by train, tram or metro are favourite modes of transport for many of us: no traffic jams, no need to focus on the road ahead… we can just sit back and read a book, consult our smartphones or even fall asleep. One thing we rarely do, however, is to think about the hundreds of electrical and electronic devices and systems which enable trains, metros and trams to depart and travel to their destination safely. All these different devices and systems perform together efficiently and without risk because they follow standards developed by the IEC.

Predicted growth for railway and light rail urban transport

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While it has globally lost out to other forms of transportation over the last 50 years, especially where freight is concerned, railway transport is gaining new ground. Worldwide population growth – expected to reach 9,8 billion by 2050 – is forecasted to boost all forms of railway transport. According to the *ITF Transport Outlook 2019* published by the Organisation for Economic Co-operation and Development (OECD), rail transport is predicted to grow by 3,7% annually until 2050, as a result of new Asian projects, among other factors.

The population growth in large urban centres requires smart mobility solutions, including new urban railway infrastructure projects, such as metro and light rail. According to the International Association of Public Transport (UITP), with which the IEC cooperates, Asia is also leading the way in this area. Its *New Urban Rail Infrastructure* report states that more than two thirds of all new metro infrastructure projects launched in 2018 are located in Chinese cities. Metro lines are also being constructed in other areas of the world: the first-ever sub-Saharan metro was inaugurated in Abuja, Nigeria, in 2018. A related trend is the continued growth of high-speed intercity links and automatic people movers.

State-of-the-art technologies are enabling railway, metro and tram services to mutate and prepare for a more sustainable and smarter future. Energy harvesting and storage, increased digitization and automation, the development of the Internet of Things (IoT) as well as the growing use of renewable energies are transforming all rail-based systems. IEC Standards are paving the way for these new technologies to be used safely and efficiently.

IEC involvement is key

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IEC Technical Committee 9 was specifically established to develop standards for trains, metros and other light rail systems. It publishes more than 100 standards, covering railway networks, metropolitan transport networks (including metros, tramways, trolleybuses and fully automated transportation systems) and magnetic levitation (maglev) carrier systems. Maglev trains float over guideways using the basic principles of magnetism to replace the old steel wheel and track trains. There is no rail friction to speak of, meaning these trains can hit speeds of hundreds of kilometres per hour.

IEC TC 9 standardizes equipment such as rolling stock, fixed installations and management systems for railway operations, including communication, signalling and processing systems. In addition to UITP, the TC liaises closely with the International Union of Railways (UIC), the worldwide railway organization. A cooperation agreement was signed in 2014 between UIC and IEC. A strategic liaison group (SLG) was established as well as three subgroups dealing with topics such as multimedia and railway systems. The SLG meets with the UIC twice a year. The liaison focuses on

standards to increase the safety, efficiency and cost-effectiveness of rail systems. The cooperation with UITP, meanwhile, aims to develop international standards for urban transport.

Connected trains

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Among the key standards developed in cooperation with UIC is the IEC 61375 series on the train communication network (TCN). These standards are widely used around the world for data communication between different train vehicles (e.g. carriages and driver cabs). Because trains can vary their composition during the day, depending on the planned journey they are expected to make, a standard form of data communication is required for train control, diagnostics and passenger information. The communication system is initiated when vehicles are coupled on the track. The TCN enables interoperability between any vehicle and any train, for example when coupling and uncoupling. At the vehicle level, a standard equipment attachment is useful for manufacturers, suppliers and operators. It enables manufacturers to assemble pretested units, such as doors supplied by subcontractors. Having contributed to the later stages of this work together with UIC, the Institute of Electrical and Electronics Engineers (IEEE) has adopted these standards.

IEC TC 9 additionally cooperates with ISO TC 269: Railway applications, in order to ensure coordination on electrotechnical railway-related issues as well as non-electrical issues.

Many other IEC TCs develop standards that are relevant to the railway and metro industries. These apply to a wide number of areas, ranging from the IoT to alarm systems and cyber security. IEC TC 9 liaises with several of these TCs. In addition, the four IEC Conformity Assessment (CA) Systems ensure that the various electrical and electronic systems used in train, metro and tramway systems meet the requirements specified in all these various standards.

IEC Standards and IEC CA Systems are important tools for enabling trains, trams and metros to remain safe, efficient and economically viable as well as future-proof.

A brief history

Trains are a 19th century technology, even if their invention predates the 1800s. They facilitated the industrial revolution by replacing horses for freight and transport. Large distances could be covered much faster and big cities relied on a growing network of railway lines to transport both people and goods. A number of new cities were even founded near rail tracks, in the US, for instance. While early trains were powered by steam engines, electricity was gradually introduced during the 20th century. Locomotives either collected electricity from overhead lines or from a third live rail on the track. Nowadays most trains use fully electric, diesel-electric or gas turbine-electric engines. Hydrogen is also becoming an option.

The first metro was inaugurated in 1890. As with trains, engines were initially steam-powered. Early tram systems were pulled by horses, then by a steam engine or were cable-hauled. Electric street railways, as they were called at the time, became ubiquitous in large cities throughout the early 1900s. They were initially operated thanks to an electric rail or a trolley pole system linking the tramway to an electric line. Trolley buses, still in operation today, continue to use that system. Nowadays most trams operate with a z-shaped or a diamond-shaped pantograph and, in some cases, a third electrified rail. As with railway, hydrogen fuel cell trams are being considered and some operators are demonstrating viable solutions.

Trams are back in fashion

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Tramways fell out of favour in the mid-to-late 20th century and many cities stopped using them, mainly to make way for car traffic. However, they have come back into fashion and are seen as a greener urban mode of transport, less costly than underground railway and less polluting than cars. Many cities have expanded existing tram lines, reconstructed defunct lines or simply built new services.

Fact

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The mechanical lever frame is still used on a few railway lines today

Some of the technologies invented in the 19th century, such as the mechanical lever frame are still used on a few railway lines today. The lever frame was created to enable clusters of points and signals to be controlled from a single spot – the signal box. This new technology was labour-saving and accelerated train dispatch: before the signal box, many workers were needed to switch rail tracks at individual spots and to hand signal trains on the ground.

The use of electricity enabled the power operation of signals. With this came the development of the panel signal box. One of the disadvantages of a panel is the large amount of fixed hardware used – buttons, switches, indicator lights and tailor-made faceplates depicting the track layout. Any subsequent changes to the layout involved significant design work and hardware alterations.

Increased digitization

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The advent of electronic interlocking and computer display technology brought increased digitization, with computers and software replacing panel signal boxes. The evolution from an analogue to a digital world has increased the number of trains which travel on existing tracks by improving safety and reliability as well as reducing waiting times. This, in turn, reduces the need to build new tracks and to purchase additional rolling stock, which are costly options. However, these transformations also pose a number of challenges that railway operators are expected to meet, including cyber security and the interoperation of legacy systems with recent technology.

The IoT revolution

Train control and monitoring systems (TCMSs) are often defined as the brain of the train or metro system: they provide a control and monitoring infrastructure that enhances train or metro operations and increases their safety and reliability.

TCMSs are increasingly empowered by the IoT and big data analytics. The integration of information and communication technologies (ICT) into the TCMS improves the efficiency of the railway infrastructure industry. It enables a new generation of trains to use real-time rail information and online environmental data combined with on-board references to achieve optimal control of the train traction and braking, for instance. This, in turn, improves travel schedules and reduces energy consumption.

Signalling equipment is now installed in driver cabs, which involves less use of trackside equipment. Intelligent on-board devices connected to cloud-based applications are designed to improve communications and control systems between trains and stations.

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Joint work between IEC and ISO

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Subcommittee 41 of ISO/IEC Joint Technical Committee 1 (ISO/IEC JTC 1/SC 41) issues publications relevant to the IoT. Key standards include ISO/IEC 21823-1, which enables peer-to-peer interoperability between separate IoT systems and ISO/IEC 3041, which provides the reference architecture for the IoT. Other subcommittees include SC 38: Cloud computing and distributed platforms, SC 31: Automatic identification and data capture techniques, or SC 32: Data management and interchange.

For example, SC 31 issues standards for radio frequency identification (RFID) devices. The technology has been widely used by railways since the 1990s. The success of the rail applications depends on the efforts of railway operators to tag their equipment, deploy a reader network and design and install the infrastructure and data processing systems needed to make the data useful. These installations enable railways to identify and track railcars. This is especially handy for freight as it enables the tracking of goods. RFID applications extend to passenger ticketing in some countries, as RFID embedded in a smart card or even a paper ticket can virtually eliminate fraud. Oyster cards used on the London Underground and light rail systems are a typical example of an embedded RFID.

Remote monitoring using sensors and AI

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Sensors installed in train engines, vehicles (whether coaches or driver cabs) and on the tracks allow rail and metro systems to be checked and repaired remotely, using artificial intelligence (AI). This prevents delays and time-consuming maintenance checks. Remote monitoring prolongs the life of railway equipment. By signalling problems early on, less labour-intensive maintenance checks are required. At the most basic level, sensors on tracks indicate whether a train is moving or at a standstill. Increasingly complex systems involve more sophisticated sensors that pick up several million lines of data and transmit that information to computers which then analyze the data provided. IEC TC 47 prepares standards

relating to semiconductor devices, which enable the design, production and use of sensors. IEC 60747-14-1 specifies the requirements for sensors made of semiconductor material but the standard is also applicable to sensors made of dielectric and ferroelectric material.

ISO/IEC JTC 1/SC 42 prepares standards in the area of AI. IEC is also the co-founder of the Open Community for Ethics in Autonomous and Intelligent Systems (OCEANIS) which was created to deal with ethical issues relating to AI.

3D printing for missing parts

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The repair of trains, metros and trams is also undergoing a revolution. Spare parts can be difficult to find, especially if the trains involved are more than 20 years old. Some operators have started using 3D printers to produce these missing parts. ISO/IEC JTC 1/SC 28: Office equipment, produces standards for 3D printers. IEC TC 56: Dependability, publishes IEC 62402, an important obsolescence management standard, which minimizes the risks linked to no longer being able to access the required parts in any supply chain.

IECQ for train components

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One of the four IEC CA systems, IECQ (IEC Quality Assessment System for Electronic Components) is a worldwide certification system for the supply of electronic components and associated materials and processes. It uses quality assessment specifications that are based on national, regional, international or industry standards. At present eight families of electronic components are covered by IECQ: active components, including integrated circuits; electromagnetic components; electromechanical components; electro-optic components; hybrid integrated circuits; and passive components. IECQ certifies components used for trains, such as integrated circuits.

Moving ahead with automation

Underground trains were amongst the first vehicles to be fully self-driving. In many large cities around the world, various metro and light rail lines have been operating without a driver for a number of years. Different levels of automation are specified by IEC 62290-1. This IEC TC 9 standard establishes fundamental concepts for urban transport management and control systems. Grade-of-Automation 4, for instance, applies to trains that run automatically at all times, including door closing, obstacle and emergency situation detection. TC 9 also publishes IEC 62267, which specifies the safety requirements for automated urban guided transport (AUGT).

Self-driving and fuzzy logic

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Some mainline railways are also implementing self-driving technology. These trains are not fully autonomous, however. For obvious safety reasons, a driver is required at all times to monitor the self-driving system. A number of railway operators are trialling autonomous trains for freight.

Engineers and programmers are looking into fuzzy logic as an AI technique that could be applied to train automation. Fuzzy logic is based on the premise that most people make decisions based on vague and imprecise information, hence the term "fuzzy." AI systems linked to train automation need to be able to predict the unpredictable, in order for fully autonomous passenger trains to be safe enough to function without any form of monitoring. Despite technology advances, this remains a challenge. One of the keys, however, is machine learning (ML). ML is an application of AI that provides systems with the ability to automatically learn and improve from experience, without being explicitly programmed.

ISO/IEC JTC 1/ SC 42 issues ISO/IEC 20546 which provides a set of terms and definitions needed to improve the understanding of these areas. It provides a terminological foundation for big-data-related standards.

Robots for dull and dangerous works

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Train and railway maintenance can be dull, dangerous and dirty work. Railway operators are also moving towards offering 24/7 train services, which leaves very little down time for maintenance. Cleaning robots are an option, as workers are at risk of coming into contact with high voltage electricity while using water to clean the outside of a driving cab or the rest of the train. Systems equipped with robot arms are already used to clean the outside of carriages. Automated inspection and testing processes for wheel sets are also replacing time-consuming manual inspections. IEC TC 65 standardizes industrial automation processes and publishes IEC 61131 which is specifically relevant to programmable controllers and their associated peripherals such as programming and debugging tools or human-machine interfaces.

Improving the passenger experience

Wi-Fi access on trains or metro lines has been available for a number of years but obtaining fast, reliable wireless internet access can often be a challenge for the traveller. This is particularly true when trains pass through areas with few mobile broadband towers, run through tunnels, operate underground or when they travel at high speed. When many people on a train all want to be online at once, actions that require an extensive amount of uninterrupted bandwidth, such as streaming video, become much more difficult. Some operators have developed stopgap solutions, using on-board servers to stream films, news and games to smartphones and laptops.

New 5G networks are expected to much improve access to services and the amount of data passengers will be able to download. The new technology is expected to process volumes of data 100 times greater than is possible with 4G. This means it will be much easier for customers to enjoy consistent and fast connectivity while travelling. Several train and metro operators around the world have already planned a 5G strategy and some of the first 5G services for trains have been launched.

IEC TC 106 prepares international standards on measurement and calculation methods to assess human exposure to electric, magnetic and electromagnetic fields. It publishes IEC 62232, which provides methods for determining the radio-frequency field strength near radiocommunication base stations with the intention of evaluating human exposure. It takes into account the mmWave frequencies used for 5G networks. TC 106 has also established three joint working groups with IEEE to develop international standards for 5G device testing in the near future.

Smart tickets and virtual agents

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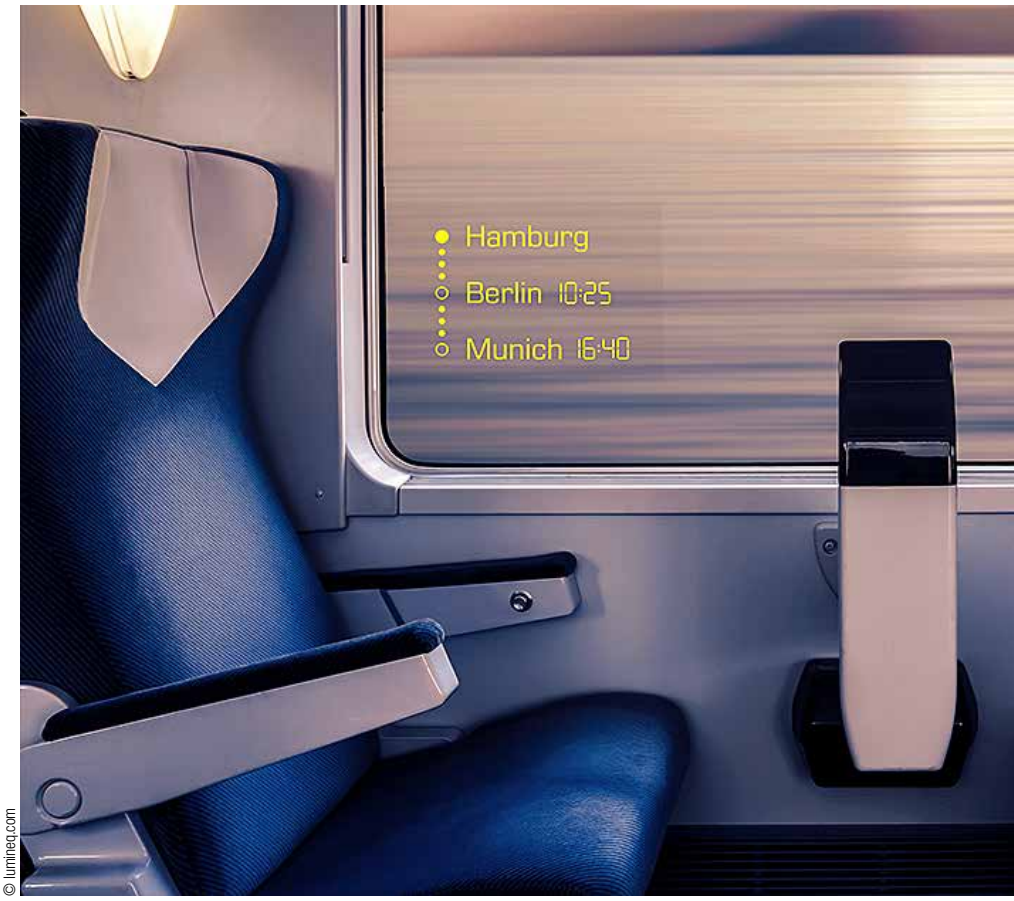
Smart ticketing is widely viewed as a way to improve the passenger experience: doing away with paper not only makes cost-savings for railway and metro line operators, it also speeds up ticket purchase for travellers, is more convenient to use, enables the delivery of additional services such as travel updates and information concerning carriage occupancy. Smart tickets can be downloaded on a smartphone or stored on a microchip embedded in a smart card.

The Smart Ticketing Alliance (STA) is an international association which drives a coordinated effort towards global ticketing interoperability for the public transport sector across national boundaries. It refers to multiple ISO/IEC Standards developed by various SCs of ISO/IEC JTC 1. They include SC 17 which prepares standards relevant to cards and security devices for personal identification (ISO/IEC 7810, ISO/IEC 7812-1, ISO/IEC 7816), SC 6 which develops standards for telecommunications and information exchange between systems (ISO/IEC 8825 series, ISO/IEC 9594-8) and SC 27 which issues standards on information and cyber security as well as privacy protection (ISO/IEC 9798-2, ISO/IEC 10118-1).

Virtual ticketing agents are just round the corner. They combine ticket office, vending machine and call centre functions. A passenger using a virtual agent is able to talk to a real person in real time, over a video link. For rail companies, this would enable a central pool of staff to deal with passenger issues, which would save costs. Agents would be able to offer ticket advice in different languages and even link staff from quiet stations into helping busier stations at peak times. For passengers, the benefits are human contact combined with the immediacy and speed of a ticket machine. IEC TC 100 prepares standards relevant to video, audio and multimedia systems.



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Air conditioning, intelligent lighting and smart windows

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As global warming intensifies, air conditioning on board trains, trams and metros becomes a must to improve passenger comfort. Heating, ventilation and air-conditioning (HVAC) systems on trains are often composed of multi-unit inverter condenser and evaporator sections mounted on top of the train or beneath the floor in the undercarriage, although they can also be mounted on the side of the train. The systems can also be split so that cooling is distributed from the ceiling within the cabin and heat is distributed from the floor. HVAC systems must be particularly efficient at ventilation on subway cars, not only to provide quality air to passengers, but also for safety reasons in case of a fire or other emergencies. IEC TC 61: Safety of household and similar electrical appliances, has set up a subcommittee to develop safety standards for air-conditioning devices. SC 61D issues IEC 60335-2-40, which specifies requirements for electrical heat pumps, air conditioners and dehumidifiers, for instance.

Forward-thinking metro and train operators are beginning to introduce intelligent lighting systems in carriages which adjust their luminosity and tone according to the time of day. Several metro operators are installing LED lights on the edge of platforms as these are more energy efficient and do not need to be replaced as frequently. Moreover, RATP, the French state-owned group that runs public transportation in the Paris region, hopes to equip 302 metro stations and 66 RER commuter rail stations with Li-Fi, the Wi-Fi-like service that can transmit data by using LED lights rather than Wi-Fi radio signals. This technology is capable of transmitting data at high speeds over the visible light spectrum as well as in the ultraviolet and infrared waveband. The technology has many advantages over Wi-Fi, including the lack of electromagnetic interference. It is also much faster. IEC TC 34 develops standards for lamps and related equipment, including LED lights. SC 34A publishes IEC 62031 which specifies safety requirement for LEDs, for instance. IECQ has created a scheme for certifying LED lighting. It helps to ensure that manufacturers and suppliers of the electronic components used in the production of LED lamps and luminaires meet appropriate requirements in terms of reliability, safety and cost efficiency.

Several tramway systems have adopted electronically dimmable windows using a suspended particle film applied to the glazing. When electronically activated, this allows light through, but reverts to opacity when power is removed. The level of transparency can be adjusted automatically through temperature or light sensors in the window. The film can block 90% of incoming heat, allowing reduced HVAC consumption, and 99,9% of ultraviolet light, which protects the interior from fading.

Some subway systems propose a different type of smart window, displaying information or video. One of the technologies that could be employed for this type of video display is a transparent organic light emitting diode (TOLED). IEC TC 110 prepares standards for electronic displays and has issued multiple standards concerning OLED technology.

Smart stations

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Smart stations use technology to increase traveller satisfaction, while also augmenting sustainability and security. In large cities, stations are much more than the point of arrival or departure of travellers. They are also large shopping and entertainment centres and propose additional services such as sport facilities (tennis, squash, etc…), cinemas, restaurants and even discotheques!

Many IEC Standards are used to ensure that such activities take place in the safest environment. IEC TC 76 prepares standards for optical radiation safety and laser equipment. One of its important standards is IEC 62471-5, which applies to the safety of image projectors. IEC TC 61 issues close to 300 standards on the safety of household and commercial appliances, such as microwave ovens, industrial washing machines, etc…

Stations also need to minimize power consumption and greenhouse gas emissions. Escalators or elevators used in multiple-level train stations can consume a large amount of electricity. IEC TC 2 prepares standards for rotating machinery. These motors are used in many appliances including lifts and escalators. TC 2 publishes the IEC 60034 series of standards, ranking electric motors according to their energy efficiency. These standards have been widely adopted throughout the world and regulators have often taken this classification system on board. Smart lighting systems and LEDs can save energy. Madrid's metro system uses LED lighting in a plan to save energy costs in all its stations.

Some stations are powered by renewable energy systems. The Guwahati railway station in Assam, India, is fully solar-powered. It handles around 20 000 passengers a day and has grid-connected rooftop solar panels that cater to its electrical needs. IEC TC 82 publishes standards relevant

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to solar photovoltaic (PV) energy systems such as the IEC 60904 series on the measurement of PV devices.

Stations are also travel hubs connecting people to other forms of transport in a process that is becoming increasingly seamless. Many stations offer door-to-door baggage services for passengers travelling on to airports or to other stations. Thanks to closed-circuit television (CCTV), data analysis and cloud storage, some stations are building what could eventually become shared databases where data on criminal behaviour is systematically stored and used to prevent crimes from re-occurring. A number of ISO/IEC JTC 1 Standards ensure that these new technologies meet the appropriate safety and performance levels.

Helping people with disabilities

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Making trains and stations more accessible to people with disabilities is one of the aims of smart rail technology. Examples include sensors automatically blocking doors until wheelchairs are in the carriage, voice announcements helping visually impaired passengers or voice-commanded devices at ticket gates.

IEC has set up a systems committee (SyC) which aims to encourage standardization of products, services and systems devised to help disabled and elderly people live as independently as possible. SyC Active assisted living (AAL) provides a global framework for other IEC TCs developing standards relevant to people with disabilities.

IEC TC 47 issues standards relevant to sensors and IEC TC 79 publishes documents covering electronic alarm systems, both of which help to improve accessibility for people with disabilities. ISO/IEC JTC 1/ SC 35: User interfaces, publishes ISO/IEC 30122-1, which deals with the framework and general guidance for voice command user interfaces. Flexible electronics used in wearables are standardized by IEC TC 110: Printed electronics.

High-speed links

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Bullet trains are widespread, especially in Japan and China. Most of them are electric multiple unit (EMU) vehicles, which consist of self-propelled carriages using electricity as the motive power. An EMU requires no separate locomotive, as electric traction motors are incorporated within one or a number of the carriages. Many countries around the world have high speed links connecting major cities. Maglev trains have been launched in Asia but the advantages of the technology are offset, in part, by its high cost. IEC TC 9 prepares standards for high speed trains, including maglev.

Hyperloop systems are also an option. The technology involves reduced-pressure tubes in which pressurized capsules ride on air bearings driven by induction motors and axial compressors. Theoretically, at least, these systems allow for considerably faster travel but for the moment they remain at the conceptual stage. The cost of building such systems would probably be very high and the risks involved need to be carefully assessed. For instance, redundancy systems need to be considered in the case of power outages.

Cyber security for the railway industry

Railway networks and other transport systems form part of a country's critical infrastructure, alongside power plants, healthcare or water services. They are particularly vulnerable to cyber attacks, a new form of criminality which goes hand in hand with the mounting digitalization of our societies.

The increasing reliance by railways, both under and over ground, on digital and smart technologies puts them at particular risk from hacking. Digital systems which can be hit by cyber attacks include computer systems on trains, traffic control systems, computer-based interlocking and signalling at stations and crossings, sensor-based remote measuring systems, passenger information and entertainment systems, ticketing systems and ordinary items including general purpose office workstations and network infrastructure.

Travellers' personal details could be intercepted and misused or train information panels and systems perturbed. More seriously, trains could be stopped or even derailed by cyber attacks.

Examples of cyber criminals disturbing services or interfering with data in order to ask for ransoms include the infecting of Deutsche Bahn's computers with the WannaCry virus in 2017 and the blocking of the Belgian railway ticketing system that same year.

More serious cases include track points being changed in Poland, causing the derailment of four trams, injuring 12 people in 2008; a cyber attack on the Northwest Rail Company signalling system in the US in 2012; the unauthorized access to switches and removal of administration accounts in the Canadian rail infrastructure. In all these cases, the integrity of safety systems was severely impaired.

This has led IEC TC 9 to investigate the relationship between security and functional safety. The TC contributes to the working group on risks set up by the IEC Advisory Committee on safety (ACOS). The TC is keen for cyber attacks to be considered in the risk assessment for functional safety and for functional safety measures to be designed in a way that they are reasonably protected from cyber attacks. This implies taking into consideration hazards which are caused by voluntary actions as well as involuntary accidents. It also means re-assessing functional safety periodically because of the growing number of new threats.

IEC 62443 Standards and conformity assessment

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The railway industry is addressing the issue by improving cyber security. IEC Standards are key tools in helping rail operators to meet the challenge. Shift2Rail, an initiative bringing together key European railway stakeholders to achieve a single European railway system, is examining how different aspects of cyber security should be applied to railways. It has selected the IEC 62443 series as a tool to enable the implementation of cyber secure processes.

The standards, published by IEC TC 65, are dedicated to industrial automated control systems and are already used by other critical infrastructures. One of their strong points is that they address product and system life cycles and cover security risk assessment processes.

A key concept used throughout the series is that of threat modelling. Among other things, it will help to identify potential attack vectors and how to mitigate them. The threat model is expected to be reviewed periodically (at least once a year).

One of the ways to mitigate threats is by incorporating a layered defence strategy (also called defence in depth) into the design of a product or system. Each different layer provides an additional defence mechanism that reduces the risk of attack on the following layer. Each layer assumes that the preceding layer can be compromised.

The standards have their own certification programme. The IEC is the only organization in the world to provide an international and standardized form of certification for addressing cyber security; it is supplied by IECEE (IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components). The IECEE industrial cyber security programme tests and certifies cyber security in the industrial automation sector, including railway systems.

Another set of cyber security guidelines is the ISO/IEC 27000 family of standards, published by ISO/IEC JTC 1/SC 27. These standards are specifically relevant to IT systems and address both privacy and security aspects. They provide a horizontal framework to protect information and can be used by any IT system, anywhere.

ISO/IEC 27000 Standards for IT systems

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They provide cryptographic and other security mechanisms, as well as security aspects of identity management, biometrics and privacy, among many other things. These aspects are becoming increasingly important with the introduction of facial recognition technology, smart ticketing and data analysis in railway and smart urban transport.

The ISO/IEC 27000 Standards have been integrated into the IECQ approved process scheme. This meets the growing need of organizations to provide independent proof of compliance with ISO/IEC 27001, one of the main standards in the series, which specifies the requirements for information security management systems. Among other things, the standard makes recommendations regarding actions to address risks.

Examples of such actions include verifying the allocation of keys/passwords attributed to people entering company buildings and checking that a policy is in place governing the disposal of documents as well as the securing of files overnight in order to prevent non-authorized staff from accessing sensitive information.

Last but not least, a member of IEC TC 9 participates in the IEC Advisory Committee on information security and data privacy (ACSEC) and contributes to the preparation of the IEC Guide 120 on security aspects. It provides a checklist on the security topics to be covered in IEC publications, and aspects of how to implement them. The TC also set up an *ad hoc* group to study the guide and assess which of its standards need to be revised.

The transformation of railways and metro systems has changed the nature of some of the jobs required for these rapidly evolving networks, with computer programming and cyber security skills increasingly in demand.

Training with virtual reality

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Training programmes are already using new tools to teach students. The National Training Academy for Rail (NTAR), partly funded by the UK government, is an example. It houses digital signalling equipment, a deconstructed train and a virtual reality and 3D simulation room. The Lu Ban High-Speed Railway Institute in Thailand is home to a state-of-the-art driving simulator. Trainees at the institute use it to learn how to drive high speed trains. ISO/IEC JTC 1/SC 24 prepares standards for virtual and augmented reality applications. SC 29 covers coding of audio, picture, multimedia and hypermedia information. It has published ISO/IEC 23000-13, which focuses on the data formats used to provide an augmented reality presentation using 2D/3D multimedia content.

Overall security and safety

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While cyber security threats are increasing, the risk of other forms of attack remains just as strong. Underground metro lines and over ground stations in large cities are equipped with cameras and alarm systems that can be used to track criminals and to warn in the case of an explosion or a fire.

IEC TC 79 publishes IEC 62676-1-1 on the general requirements of video surveillance systems. TC 79 liaises with TC 9 on the interfaces of the IEC 62676 and IEC 62580 series. These publications, issued by TC 9, specify the general architecture of on-board multimedia systems which includes video surveillance/CCTV, driver and crew-orientated services as well as passenger-orientated services.

ISO/IEC JTC 1/SC 37 prepares ISO/IEC 19794 which includes 14 parts that deal with the various aspects of biometric data, including facial recognition.

Dealing with electromagnetic interference (EMI)

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Railways both over and under ground are regarded as complex electromagnetic environments. For example, interference from traction power equipment could affect the signalling system with potentially dire consequences. The industry is striving to reduce the risk of EMI through processes of hazard identification and risk mitigation. Electromagnetic compatibility (EMC) between electrical and electronic systems is an essential requirement for the reliable and safe operation of railways, light rail and metros included. IEC TC 77 publishes a number of core standards relevant to EMC. They include the IEC 61000 series which describe EM phenomena and the EM environment.

The international special committee on radio interference (CISPR) is broad in scope and issues a wide number of EMC standards, including CISPR 15, which applies to the emission of radio frequency disturbances from transport lighting installed in trains and buses. CISPR SC B standardizes limits and measuring methods for evaluation of radio frequency disturbances from high-voltage overhead power lines, including electric traction of railways and urban transport. Its members include participating IEC National Committees and several international organizations, including the International Telecommunication Union (ITU) and the European Broadcasting Union (EBU).

IEC TC 9 publishes the IEC 62236 series of standards which provides a framework for managing EMC for railway systems. It notably specifies the limits for electromagnetic emission of railway systems vis-à-vis the outside world as well as for equipment operating within the railway systems.

Protection against electric shock, fire and explosions

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Electrified railways – whether powered through an electrified overhead line or a third rail mounted at track level – use different supply voltages depending on whether they are intercity, urban, or suburban. Some electric locomotives can switch to different voltages depending on their requirements. IEC has standardized the permissible range of voltages in IEC 60850, issued by IEC TC 9. The TC also publishes a number of safety standards to protect people against electric shock: these include the IEC 62128 series which specifies safety provisions against electric shock for alternating current (AC) and direct current (DC) traction systems and for any installations that can be endangered by the traction power supply system. IEC TC 89: Fire hazard testing, publishes standards which specify the use of electrical and electrotechnical products in a way that reduces the risk of fire hazard to a tolerable level.

IEC TC 70 publishes standards for degrees of protection provided by enclosures, mainly the IEC 60529 series which can be used with most types of electrical equipment. These standards help to stop people from accessing hazardous parts inside the enclosure as well as protect the equipment situated in the enclosure against the harmful effects due to the infiltration of water or corrosive solvents, for instance.

While a growing number of locomotives are fully electric, many of them are diesel-electric or gas turbine-electric. Gas and diesel are flammable and could potentially leak and cause a fire or an explosion. Trains can also transport flammable goods, including fuel or chemicals. IEC TC 31 publishes the IEC 60079 series which specifies the general requirements for equipment used in explosive (Ex) atmospheres.

One of the four IEC CA systems, IECEx (IEC System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres) has established mechanisms to ensure that devices used in Ex environments as well as people working in Ex locations remain safe.

Sustainable trains, metros and trams

While trains, metros and trams are generally perceived to be more environmentally friendly than others forms of transport, improvements can still be made. UIC is leading several projects to reduce the CO_2 emissions of railway transport, by implementing a number of energy efficiency and harvesting measures.

The *Moving towards sustainable mobility* strategy for the European rail sector was endorsed by members of UIC and the Community of European Railway and Infrastructure Companies (CER) lobbying group in December 2010. The strategy aims to provide a unified approach to environmental and sustainability topics in the European rail sector. It outlines how the industry should reach environmental targets in 2030 and 2050.

Energy harvesting and improved energy efficiency

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According to UIC, energy efficiency represents the most direct way to reduce CO_2 emissions and to secure a strong environmental performance in support of the UIC-CER sustainability strategy. Many IEC Standards help rail operators to become more energy efficient.

A member of IEC TC 9 takes part in the IEC Advisory Committee on energy efficiency (ACEE) and contributes to IEC Guide 118 and IEC Guide 119, which both deal with energy efficiency aspects and how they should be included in IEC publications. It formed an *ad hoc* group which studies both guides and assesses the need to include energy efficiency requirements in its standards.

Regenerative braking, a mechanism by which the electric motor uses the vehicle's momentum to recover energy that would be otherwise lost to the brake discs as heat, is widely used by trains and metros. This energy harvesting (EH) technique enables extra energy to be used immediately for powering air-conditioning devices, for instance, or to be stored for later use. Some railways even feed the excess energy produced into the power grid. In addition, new and lighter materials are being used to build trains, making them more energy efficient.

Other forms of EH techniques are also being investigated, some of which involve piezoelectric energy (i.e. an electric charge that accumulates in certain solid materials in response to applied mechanical stress). In Israel, a company has installed piezoelectric pads on railway tracks which generate energy when trains drive over these pads. The energy produced can then power trackside lights, etc... IEC TC 49 prepares standards for piezoelectric devices. IEC TC 47 has set up a working group that publishes standards on semiconductor devices for energy conversion and transfer, which includes energy harvesting. The IEC 62830 series of standards paves the way for various types of EH, whether piezoelectric, thermoelectric, etc…

DC is being re-assessed as a more energy efficient way of powering trains. Whereas in the 1990s, legacy DC train systems were being upgraded to AC systems, train operators now find it more energy efficient to simply upgrade legacy DC systems to a higher voltage DC system. No energy is lost in converting from DC to AC and back again. IEC TC 8: System aspects of electrical energy supply, publishes standards relevant to the overall systems aspects of electricity supply systems. It maintains horizontal publications on voltages, for instance IEC 60038 on standard voltages for DC and AC systems.

Superconducting cables are also being trialled by some rail operators. Superconductors are materials that offer no resistance to the flow of DC current at extremely low temperatures and generate minimal losses when subjected to AC currents. IEC TC 20 prepares standards for electric cables. In collaboration with IEC TC 90: Superconductivity, it developed a new standard for superconducting cables, IEC 63075, which specifies tests methods for superconducting AC cables.

Hydrogen-powered vehicles and batteries

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Alongside global efforts to reduce diesel and gas-powered electric engines by gradually replacing them with all-electric engines, some operators are looking at hydrogen as a substitute source of energy. One of Europe's largest rail manufacturers demonstrated what it claims is the world's first hydrogen fuel cell train. Fuel cells convert hydrogen and oxygen into electricity, a very clean form of electricity production that does not involve any generation of emissions at all, other than water vapour.

In China, one of the state-owned railway corporations launched a commercial fuel cell-powered tram. Railway corporations are also looking at hybrid fuel-cell and supercapacitor-based solutions. Supercapacitors are used to provide the strong electric current required to start the tram while hydrogen takes over as the main source of power as soon as the train is running. Supercapacitors have a very high power density and can be quickly and continuously charged and discharged. IEC TC 105: Fuel cell technologies, prepares standards for fuel cells used in transport, while IEC TC 40 issues publications for capacitors, including supercapacitors, and resistors for electronic equipment.

Regenerative braking can feed trackside energy storage systems, which are capable of absorbing large bursts of energy in a short timeframe. The US Long Island Rail Road uses supercapacitors in trackside units that collect and store energy from braking trains. These systems provide voltage support for the traction power system when acceleration is required. This reduces energy consumption and improves energy efficiency. Metros in Korea also use supercapacitor braking energy recuperation technology.

Batteries are also an option for powering trains. Companies have developed a fast charging battery technology which enables them to be used instead of a diesel-electric engine. In the UK, some light rail trams are powered by battery power, in Cardiff for instance. IEC TC 21 prepares standards on secondary cells and batteries, notably for traction. It liaises with IEC TC 9 on traction batteries for trains and metros, as TC 9 produces its own standards for batteries.

Batteries contain chemical substances and electrical processes that may be hazardous to lives and the environment, if they do not function properly. This could potentially lead to combustion and explosions. IECEE enables the batteries to be tested for safety, performance, component interoperability, energy efficiency, EMC, hazardous substances, chemicals and explosion safety.

IEC TC 111 prepares horizontal environmental standards for electrical and electronic products and systems. It issues a number of publications that enable manufacturers and suppliers to determine the level of most of the polluting chemicals in electrotechnical products. It also publishes guidelines for end-of-life information provided by manufacturers and recyclers. These guidelines propose a recyclability rate calculation for electrical and electronic equipment. They concern batteries as well as most of the electrotechnical devices and systems used on trains.

Power from renewable energies

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The electricity fed to trains by overhead lines or through a third electrified line is supplied by the electrical grid. As the level of renewable energy fed into the electrical grid increases, so does the level of renewable energy supplied to the trains. In the Netherlands, railway lines are mostly powered by wind energy systems, for instance.

One train was powered directly by solar panels situated on its roof for a short three km journey. Trackside solar energy, generated by solar panels installed near the rail track is also beginning to make some headway. IEC TC 82 prepares standards for solar photovoltaic energy systems, including off-grid stand alone systems.

IEC TC 57 develops a number of standards that facilitates the integration of renewable energy sources into the electricity network. IEC TC 88 develops standards in the field of wind energy generation systems, including wind turbines, wind power plants and interaction with the electrical systems to which energy is supplied. IEC also produces hundreds of standards dealing with the transmission of electrical energy, published by several TCs, including IEC TC 11: Overhead lines, IEC TC 14: Power transformers, or IEC TC 17: High voltage switchgear and controlgear, to name but a few.

One of the four IEC CA systems, IECRE (IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications) enables manufacturers and suppliers of renewable energy systems to check that they are produced according to the existing standards.

Reducing noise pollution

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Railway operators are also vying to reduce noise levels. Several technologies are being used, from rail damper systems, which involve placing rubber at both sides of the rail track, to optimized rail pads. New magnesium alloys making the train lighter and quieter are also being investigated. Research into graphene and carbon nanotubes could be promising. IEC TC 113: Nanotechnology for electrotechnical products and systems, is producing standards in this area. IEC TC 29: Electroacoustics, develops standards relating to noise measurement instruments.

IEC Standards = safe, sustainable and affordable rail systems

Rail, metro and tramway systems are getting smarter thanks to IEC International Standards. All around the world, these systems are making headway as they offer increasing advantages in terms of sustainability and passenger satisfaction. IEC Standards not only enable these systems to be more energy efficient and improve their environmental footprint, they also pave the way for sizeable cost savings, while ensuring these means of transportation remain safe and secure.

About the IEC

The IEC, headquartered in Geneva, Switzerland, is the world's leading publisher of international standards for electrical and electronic technologies. It is a global, independent, not-for-profit, membership organization (funded by membership fees and sales). The IEC includes 173 countries that represent 99% of world population and energy generation.

The IEC provides a worldwide, neutral and independent platform where 20 000 experts from the private and public sectors cooperate to develop state-of-the-art, globally relevant IEC International Standards. These form the basis for testing and certification, and support economic development, protecting people and the environment.

IEC work impacts around 20% of global trade (in value) and looks at aspects such as safety, interoperability, performance and other essential requirements for a vast range of technology areas, including energy, manufacturing, transportation, healthcare, homes, buildings or cities.

The IEC administers four conformity assessment systems and provides a standardized approach to the testing and certification of components, products, systems, as well as the competence of persons.

IEC work is essential for safety, quality and risk management. It helps make cities smarter, supports universal energy access and improves energy efficiency of devices and systems. It allows industry to consistently build better products, helps governments ensure long-term viability of infrastructure investments and reassures investors and insurers.

A global network of 173 countries that covers 99% of world population and electricity generation

Offers an affiliate country programme to encourage developing countries to get involved in the IEC free of charge

Develops international standards and runs four conformity assessment systems to verify that electronic and electrical products work safely and as they are intended to

IEC International Standards represent a global consensus of state-of-the-art know-how and expertise

A not-for-profit organization enabling global trade and universal electricity access

Key figures

173
members and affiliates

>200
technical committees

20 000
experts from industry, test and research labs, government, academia and consumer groups

>10 000
international standards published

4
global conformity assessment systems

>1 million
conformity assessment certificates issued

>100
years of expertise

Further information

Please visit the IEC website at www.iec.ch for further information. In the "About the IEC" section, you can contact your local IEC National Committee directly. Alternatively, please contact the IEC Central Office in Geneva, Switzerland or the nearest IEC Regional Centre.

Global

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IEC – International Electrotechnical Commission
Central Office
3 rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

T +41 22 919 0211
Fax +41 22 919 0300
info@iec.ch
www.iec.ch

IEC Regional Offices

—

Africa

IEC-AFRC – Africa Regional Centre
7th Floor, Block One, Eden Square
Chiromo Road, Westlands
PO Box 856
00606 Nairobi
Kenya

T +254 20 367 3000 / +254 20 375 2244
M +254 73 389 7000 / +254 70 493 7806
Fax +254 20 374 0913
eod@iec.ch
fya@iec.ch

Asia Pacific

IEC-APRC – Asia-Pacific Regional Centre
2 Bukit Merah Central #15-02
Singapore 159835

T +65 6377 5173
Fax +65 6278 7573
dch@iec.ch

Latin America

IEC-LARC – Latin America Regional Centre
Av. Paulista, 2300 – Pilotis Floor – Cerq. César
São Paulo - SP - CEP 01310-300
Brazil

T +55 11 2847 4672
as@iec.ch

North America

IEC-ReCNA – Regional Centre for North America
446 Main Street, 16th Floor
Worcester, MA 01608
USA

T +1 508 755 5663
Fax +1 508 755 5669
tro@iec.ch

IEC Conformity Assessment Systems

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IECEE / IECRE
c/o IEC – International Electrotechnical Commission
3 rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

T +41 22 919 0211
secretariat@iecee.org
secretariat@iecre.org
www.iecee.org
www.iecre.org

IECEx / IECQ
The Executive Centre
Australia Square, Level 33
264 George Street
Sydney NSW 2000
Australia

T +61 2 4628 4690
Fax +61 2 4627 5285
chris.agius@iecex.com
chris.agius@iecq.org
www.iecex.com
www.iecq.org

International
Electrotechnical
Commission

3 rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

T +41 22 919 0211
info@iec.ch
www.iec.ch

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