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Review

Wireless Sensor Networks: Toward Smarter Railway Stations

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Abstract: Railway industry plays a critical role in transportation and transit systems attributed to the ever-growing demand for catering to both freight and passengers. However, owing to many challenges faced by railway stations such as harsh environments, traffic flow, safety and security risks, new and adaptive systems employing new technology are recommended. In this review, several wireless sensor networks (WSNs) applications are proposed for use in railway station systems, including advanced WSNs, which will enhance security, safety, and decision-making processes to achieve more cost-effective management in railway stations, as well as the development of integrated systems. The size, efficiency, and cost of WSNs are influential factors that attract the railway industry to adopt these devices. This paper presents a review of WSNs that have been designed for uses in monitoring and securing railway stations. This article will first briefly focus on the presence of different WSN applications in diverse applications. In addition, it is important to note that exploitation of the state-of-the-art tools and techniques such as WSNs to gain an enormous amount of data from a railway station is a new and novel concept requiring the development of artificial intelligence methods, such machine learning, which will be vital for the future of the railway industry.

Keywords: railway station; wireless sensor network WSN; security and safety in a railway station; smart railway stations; railway data; machine learning in railway stations

1. Introduction

It is one of the greatest challenges to manage and enhance safe and reliable environments within a railway station, which contains physical objects (movement or stationary), people (passengers, employees, the public), and multi-systems (e.g., Closed-Circuit Television (CCTV), Heating, Ventilation, and Air Conditioning (HVAC), fire systems, screening systems, etc.) when such environments are exposed to extreme and constant threats (such as man-made hazards). In addition, the threat of terrorism now becomes sensible and active, especially at public transport hubs. Thus, sufficient security is required for all transportation systems. In this study, railway stations, which are an intermodal transport hub, are the main emphasis where the technologies such as wireless sensor networks (WSNs) can be adopted to boost security [1]. Some station designs are rather complex and are much more than simply a place where trains enter and leave. Modern railway stations are multi-functional environments. They often feature shops, hotels, and other services, and have become a focal point around which cities have been built. Rail stations have become vital nodes for business and transportation systems [2].

Today, the infrastructure in a railway industry is equipped with various sensors and closely coupled with information and communication technologies. However, intelligent monitoring, and security and risk management can be better realised via the usage of networked embedded devices.

The WSN technology perspective of the rail infrastructure will be vital to the railway industry's future expansion, and will enhance other areas in industry such as safety and security towards a more intelligent infrastructure [3]. A WSN is a system formed by many sensor points where each node is equipped with a sensor. Wireless sensor networks are seen as an innovative information gathering technique to design the information and communication system, which will significantly advance the reliability and efficiency of the systems in the railway station. Compared with a wired solution, WSN systems are easier for positioning and have better elasticity. Furthermore, with the prompt industrial growth of sensors, WSNs will become the most significant technology for the internet of things (IoT) [4].

Organisations such as those in the railway industry can exploit the interchange between the IoT and data analysis to enable smarter technology such as WSNs and machine learning [5]. The awareness of IoT was settled in parallel to WSNs, where the term IoT was devised by Ashton in 1999 [6]. In recent years, the technology has advanced at a rapid pace, and now is the time to invest in it. Railways can employ opportunities formed by the Industrial Internet of Things (IIoT) [7]. The worldwide railway technology market is expected to grow from $10.50 billion in 2016 to more than double that number by 2021 [8]. Big data from real-life operations can be transformed and processed by sensor nodes in WSNs. In addition, the smaller size of electronic devices and their reduced power consumption have confirmed that WSNs can easily be deployed in many applications to monitor the environment, public health, commercial marketing, and even transportation [9]. Using sensors for automated monitoring can reduce the optical inspection operation grid sensors that may be adopted for railway monitoring such as accelerometers, acoustics, strain gauges, etc. Apart from detecting defects in the rail and track structure, there are other benefits of monitoring system integration, which are important for adequate risk management [10].

Sensors, which are connected to computer systems along with superior hardware and software, can assess the degree of the risk zone [11]. For instance, if a smoke detector detects heat or smoke, then the alarm will be activated. Currently, the sensors have reduced in price and are easier to produce, which enhances their availability, which is expected to increase their use [12].

Undoubtedly, railway stations are a significant component for communication with the drivers, controlling and managing emergency situations, and aiding in daily operations such as those involving train engineers' safety and security operations. Recently, railway infrastructure has expanded rapidly, including the use of wired communication systems. Previously, wired connecting systems were utilised for signalling and data intelligence in the railway system. However, in recent times, wireless connecting systems have begun to be used as alternatives to supplant wired systems in railway systems and enhancement railway security [13]. Wireless sensor networks have become increasingly common in both military and civilian applications such as surveillance, monitoring, personal location, and many other systems [12,14]. Moreover, wireless micro-sensor technology is deemed as one of the most significant technologies for the 21st century [15]. Wireless sensor networks have also been examined to show that they can be utilised in harsh climatic conditions such as strong wind, storms, and snow. In contrast, the wired technique is vulnerable to damage (e.g., corrosion), destruction (e.g., cut wire), dirt, and natural elements, and also there is no more maintenance to ensure safe placement of wires on the structure or in buried pipes [11,16].

The application of WSN sensing devices in the future will increase exponentially due to the need for advanced monitoring in transportation, electricity, industry, and other critical infrastructures. Wireless sensor networks have appropriate features, including the ability to withstand harsh environments, large coverage, self-organisation, self-configuration, and powerful utility independence, as well as being very suitable for data communication monitoring systems for transmission lines.

However, wired systems cannot meet the communication needs of online monitoring of commuter lines [4].

Subsequently, sensors with a high-accuracy measurement of parameters including temperature, strain, vibration, and birefringence have gradually become widespread in the railway industry for display infrastructure and environment applications including monitoring of rail tracks, tunnels, and surveillance to deliver safety and security [13,17]. Moreover, in the railway industry, WSNs can play a substantial role in the renovation of old systems with the state-of-the-art electrical systems. Despite the many purposes of wireless sensor network applications in railway infrastructure in railway tracks, WSNs need to be explored for rational application in railway stations environment [9]. The use of WSNs in railway stations is expected to aid growing consumption and high-energy costs by curbing energy demand and CO_2 emissions, and boosting energy efficiency. In Europe, for example, the energy consumption of industry is 30% and transportation is 30% of the total energy consumption [4].

1.1. Review of Related Survey Articles

Most of the recent past research conducted has taken a descriptive approach to investigate the intensive work on railway tracks or railway stations. For example, Hodge et al. (2015) carried out a survey of wireless sensor network technology for surveillance railway systems, structures, vehicles, and machinery, and Ghofrani et al. (2018) proposed a systematic framework for railway transportation big data analysis and how it could be applied [18,19]. A well-defined WSN installed in the London Underground tunnels has also been presented [20]. In contrast to the descriptive approach, others have conducted research using a modelling method (e.g., Wardman and Tyler, 2000; Krygsman et al., 2004; Givoni and Rietveld, 2007; Brons et al., 2009; Bergman et al., 2011; Arentze and Molin, 2013; and Chakour & Eluru, 2014) [21]. Other studies focused on people evacuation, such as Takayama [22] who studied the impact of delays in information participation on evacuation guidance. Some key reviews of WSNs have been done, including a survey of WSNs for urban areas by Rashid et al., 2016; and a survey of WSNs for condition monitoring by Hodge al., 2015 [19,23]. However, a systematic framework using WSNs for railway transport hubs has not been carried out thoroughly, especially in the face of physical and cyber threats. In this research paper, the focus will thus be placed on railway stations as a whole rather than any particular part of the system.

1.2. The Contribution of the Reniew Article

This study will contribute towards a growing body of information proposing a WSN in railway stations with a minimal use of wireless techniques to improve safety and security. The use of WSNs in railway stations is discussed in the following sections, and a critical review of possible applications in railway stations is highlighted. The rest of this paper aims to relate the display of a WSN to the data that can be retrieved from a smart railway station, and it aims to encourage the development of advanced technology such as machine learning in the future. Furthermore, this review will enhance the understanding of railway station wireless system monitoring and underline the need for future research into a smarter railway station.

2. Sensing Technology and Railway

Wireless networks that use sensors to monitor physical or environmental conditions are frequently referred to as WSNs and were initially expanded and inspired by military applications such as the notable surveillance in conflict zones and natural disaster aid [24]. In practice, WSNs are disseminated throughout and automated by using a variety of sensors to supportively display infrastructure, structures, machines, systems, people, machinery, environments, and tracking targets [19]. It is also noted that there are many categories of WSNs with a widespread variety of applications [25–29]. Advances in wireless grid technologies have set the world at the doorstep of a modern age where tiny wireless instruments will enable access to information anytime and anywhere, as well as actively engaging with authorised people who will eventually manage or operate smart organisations such

as railway stations [30]. The application of wireless sensor technologies can be organised into three groups: communication protocol, systems, and services. The first band includes the systems where each sensor point is an individual system. Then, to link the application and sensors, we need the second band, which consists of the communication protocols. The third band is the services, which are advanced to improve the application and to rally system performance and network competence [25].

Nowadays, many items around us tend to be smart: for example, smart grids, smart homes, intelligent transportation, and smart infrastructure systems that connect our world more than we ever expected. Today, sensors are everywhere; there are sensors in our smartphones, in our vehicles, in factories controlling CO_2 emissions, etc. While it seems that sensors have been around for a while, and research on WSNs started back in the 1980s, it is only since 2001 that WSNs have really generated increased interest from industrial and research perspectives [4]. Wireless sensor network technology is also playing an important role in safety monitoring over power industries and conversion equipment, and the redesign of billions of smart meters. State-of-the-art monitoring minimises the number of workers checking through automated inspections, reduces maintenance through detecting faults at the beginning stage, and improves safety, security, and accuracy, which are vital for the improvement and development of railway networks industry [19]. In addition, huge improvements in transportation systems have come about with increasing integration of communication technologies that enhance transportation system conditions, safety, security, and services. Wireless networks connect many devices simultaneously, and then transfer the data through signals, and use radio wave/microwaves for transmitting and sharing the data between nodes [31].

In fact, wireless sensor node systems have many advantages, including low cost and low power, small size, intelligence, data processing and wireless communication capabilities, and the inclusion of power supplies. Where WSNs exist, a significant number of collaborative sensor nodes can be deployed. As a result of the convergence of micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics, WSNs represent a significant improvement compared to traditional sensors. A sensor node typically has four main components (sensing unit, processing and communication with the power source). A communication unit links a wireless sensor node with other nodes, while a transceiver encompasses the functionality of both transmitter and receiver. The wireless transmission media may be radio frequency, optical (laser), or infrared [32]. In the railway industry, this technology allows to monitor infrastructure, structures, and machinery in real-time and then turns data into intelligence, which aids to identify faults and support the operations [33].

Periodic monitoring of the railway infrastructure is generally conducted to ensure its safety and security. For this role, the conventional wired technique is still the standard way in which wires connect sensors to the achievement units, and it is done by attaching wires directly to the structure. The information gained with this system is generally accurate, and faults can be detected with a significant level of accuracy. Nevertheless, this method involves periodic maintenance, which accrues additional costs. Furthermore, wireless techniques are becoming more competitive as they experience growing popularity [10,34]. In unfortunate circumstances, some buildings and infrastructures can be exposed to natural hazards such as severe earthquakes, flooding, and strong winds, as well as man-made hazards such as fire, crime, and terrorism. To mitigate these hazards, monitoring diverse risks in a building or an infrastructure such as a railway station by a smart sensor network is inevitably necessary [35].

It is important to note that there are many types of sensors that have been used in railway industry for monitoring and the measurements such as temperature, pressure, and humidity where the data can be integrated with other measures regimes [36]. It is possible to also use the sensor networks for monitoring in challenging environments such as in Sweden's railway system, with temperatures between +25 °C and −40 °C with a massive amount of snow [37]. In addition, sensors can monitor train's bogies, where a train is classified as hard surroundings for electronics [38]. Accelerometer sensors have been utilised to measure vibration of railway tracks or other infrastructure parts and train wheels. Moreover, it used in combination with strain gauges [39,40]. Fibre optical sensors aid to

measure temperature, strain, and acceleration [41,42]. Gyroscopes can be used to measure vehicles' angular velocity around axes in the train. To detect changes in the incline of railway structures, inclinometers have been used [43]. Also, magnetoelectric sensors can be used to monitor the current. A later section of this paper will highlight more advanced sensor applications including those wireless applications in railway stations.

3. Wireless Systems in Railway Stations

3.1. The Sensors Approach and DETECT System in Railway Stations

Threats such as extreme weather, vandalism, and fire or explosions can be efficiently moderated and effectively managed using extensive monitoring sensors. Merging of sensors can be accomplished to provide more supervisory implementations. An example includes vibration detection barrier for border intrusion detection on track lines or inside the train station. A part of the railway track passes through the railway station (via platforms) so the checking systems play a vital role in maintaining the safety of the railways (from intrusion or any other illegal activities). In addition, infrastructure monitoring can use WSNs to recognise and investigate any defects in large structures such as cracking and displacement [19].

In general, both the hardware and the middleware can be merged to fit any monitoring usage. Moreover, merging of sensors can assist security applications in the case of abnormal events such as high temperature or vibration, and high-strength noises (e.g., screaming, gunshots, or explosions). Aiming to recognise any security threats to the railway infrastructure station, the use of the DETECT system has been suggested as a model-based engagement of events retrieved by the sensor system to detect, or possibly curb, threats [44]. The DETECT system aims to detect the basic events which lead to a threat. A different sensor collects basic events from subsystems to identify the sequence of events and then indicates the probability of the risk; it can also be integrated with the warning system, trigger tool, or security management software (SMS), as illustrated in Figure 1.

The output actions may include aural or visual alarms, locked gates, controlled HVAC, or activated suppression systems, etc., To reduce the false alarm rate and improve the reliability of the system, the operation of various redundant devices is proposed. The system has a data source store or an event history database (scenario repository) where the models are produced and different methods, such as Bayesian and neural networks, can be complied. The next action process of the system consists of:

- Identifying the detected scenario
- Warning (alarm) level
- Probability of threat [44].

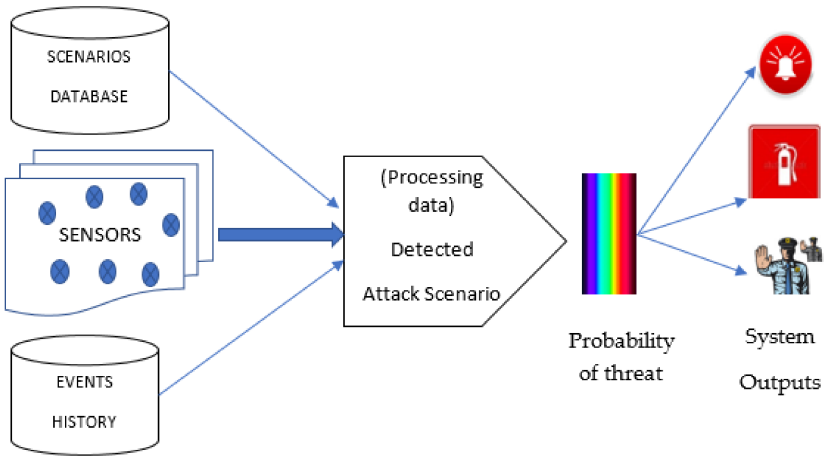

Figure 1. DETECT system diagram.

3.2. The Anti-Slipping Device at Railway Stations

A new anti-runway prevention system (ARPS), which has evolved on track skates and is widely used, employs wireless sensors. The sensors of the system are equipped on track skates; the data is detected and transmitted over a radio frequency network through a micro-power wireless communication module. The system enhances the safety of the railway stations by enabling reduced derailment accidents and lessening the chance of human error which might be caused by negligence in the operations. Moreover, ARPS can improve the security in a railway station by preventing theft of the track skates. Testing of the system shows the reliability of the communication distance. Furthermore, the system significantly saves employment costs due to the automatic recording and analysis of the status of the anti-runaway function [45].

3.3. Passenger Dynamic System

Not only does the application of WSNs assess the intensity of the volume of passengers inside a given bus or train, but they also analyse the origins and destinations of the passengers. Furthermore, the passengers using the public transportation systems can become "crowd sensors" for the accurate information of traffic flows [4].

Railway stations with sensors that are installed in sensitive areas play a vital role in controlling pedestrian traffic congestion or in emergency events. This technology displays the level of severity determined via the controllers and it can monitor and provide a reaction. The density, flow values, and passenger demand and arrival are necessary data for the monitoring system. It has been shown that counting the density manually, either on the ground or via video images, is prone to human error. Thus, it is generally carried out by an authorised automatic system. Calculation of the density or flow via methods such as cameras, infrared or tracking sensor, Wi-Fi/Bluetooth, or a combination of them, has been suggested. Additionally, CCTV can be used if it can be programmed with suitable algorithms [46]. Demand and arrival can be obtained using tracking systems or surveys [47]. Furthermore, smart card validation data can be used [48], and the use of this technology has proven to be a flexible choice to the amendment of key costs with the objective of raising total ticket income [49].

In recent years, a new approach has been introduced, which employs a wearable sensor and is referred to as wireless body area networks (WBANs). The application of this technology is wider and includes catastrophe management, worker safety, mobile health monitoring, ambient assisted living, and many more [50].

3.4. Railway Operator Communications

Existing systems of signalling and train control schemes are shown in Figure 2. As seen in the figure, the European train control system (ETCS) is a new system advanced to boost the safety and security of train operations [13].

To maintain reliable, safe, and secure operations, the communication and signalling systems are used to monitor the health, security, and safety of the train and its passengers. Specific factors include vibrations, smoke, tilt, ambient temperature, and humidity [13]. The primary system used by rail operators is the "Global System for Mobile Communications-Railways" or called "GSM-R" for operational voice and data transformation. Railway communication schemes can be separated into three main application sets:

- Safety and control
- Operator
- Customer-oriented networks [7]

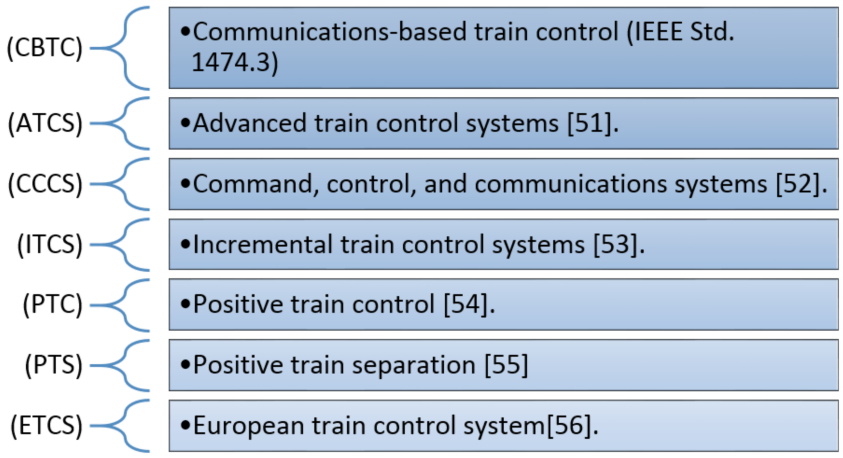

Figure 2. Main communication and signalling systems for train control [13,51–56].

Recent advances in wireless technologies feature reliable communication and transmission for long distances. One of the technologies expected to form quantum leaping the future of the railway industry communication is smarter train connections over wireless signalling, which enables operators to on-and-on receive information constantly from trains. This can diminish the time trains are out of service, limit passenger disruption, improve safety systems in emergency events, and more effectively monitor performance [57].

Since 2000, many digital technologies have been used in the railway industry in many new areas such as Communication-Based Trail Control (CBTC), Positive Train Control (PTC) solutions, and the provision of information about the trains to passengers. After 2005 and the appearance of the IoT and smart systems, various solutions such as passenger information and smart ticketing have been presented in railway stations. Nevertheless, various factors have affected the growth of the rail industry, including operational disorganisation, the ageing of infrastructure and communications systems, interoperability, high initial cost of deployment, and the integration complexities of the systems. The slow adoption of automation and technology could thus pose an enormous security and safety risk [58].

Safety in railways can be enhanced through driver advisory systems (i.e., CCTV recordings, which are linked to a train control centre, TCC), train diagnostics, and driver vigilance detection (e.g., the driver's health can be supervised via a wireless wearable electroencephalograph (EEG) [59]. Applying IIoT in railway stations is aimed at supporting the safety, security, and reliability of transportation system hubs. This technology can improve safer operations and enable more efficient risk management in stations, tracks, and trains. There are four main systems in which IIoT and automation can bring significant benefits:

- A signalling system can remotely adjust the speed and whistle of the train, where wireless ground-to-train signalling is becoming habitual.
- Level crossing control will significantly influence safety where IIoT can help to decrease the number of accidents by deploying sensors and cameras.
- Interlocking IIoT enables the automation of the interlocking system and boosts it by incorporating the data received from the signalling system [7].

3.5. Fire Systems and Wireless

Fire presents a massive hazard to the railway industry, for both economic and social stability. Detecting the zone at risk in a timely and accurate manner is an operative way to eliminate or minimise the severity of the risk. The main output products of fire in the first stage of the process are smoke, gas (e.g., CO), as well as heat. Detection of smoke concentration, CO concentration, and ambient

temperature can enable real-time monitoring of fires. The density of smoke in an evacuation path leads to a reduction in visibility for the passenger in the railway station and extremely delays evacuation; thus, technology such as WSNs will tackle this kind of scenario. Fujihara [60] projected a technique (self-organised) for tragedy evacuation guidance utilising opportunistic networking where the evacuees gather and share catastrophe information using wireless communication by smartphones on the way in their evacuation. Chu [61] presents cloud computing that analyses for positioning, evacuating people by radio frequency identification (RFID) and defining the best evacuation paths. This research is valuable and it requires smartphone application and wireless communication performance when these communication devices are disabled [1].

The current fire detection and alarm systems generally use two-wire bus technology to shape fire sensor networks. However, in some projects, later installation of fire detection alarm system wiring will be extremely limited. This is particularly the situation with older buildings, museums, etc. Thus, wireless fire detection and alarm systems are valuable for many applications. To improve the system efficacy and convenience for installation, and to broaden the applicability, a new fire detection and alarm system was designed based on self-organising star wireless sensor networks. The system involves wireless multifunctional fire detectors, Pan–Tilt–Zoom (P/T/Z) camera control systems, wireless control boards, and a fire centre console (see Figure 3) [62,63].

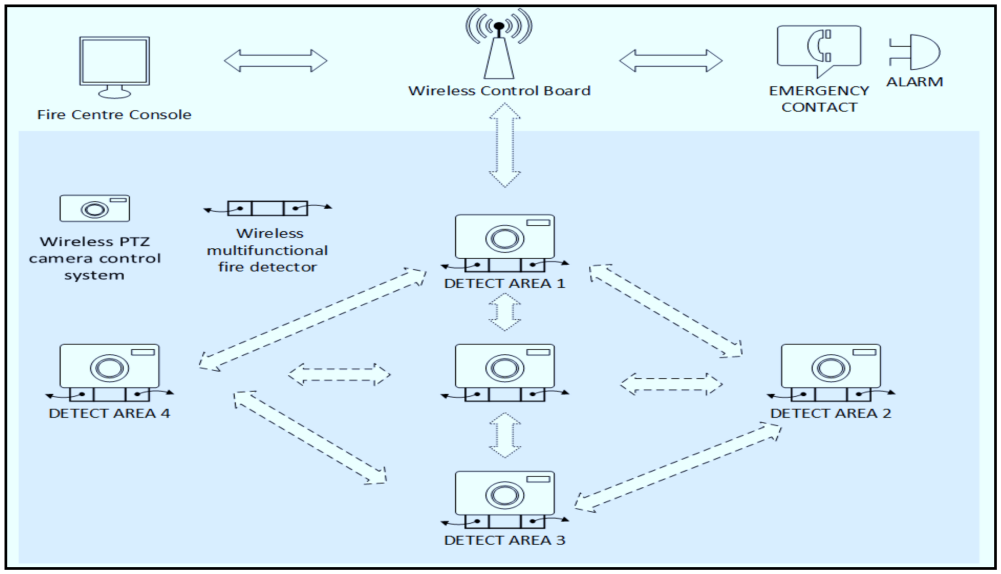

Figure 3. Framework outline of a new wireless fire detection and alarm system [62].

New projects may have a range of wireless sensors, which are part of the overall project management system. The sensors for smoke and fire can detect and communicate with the system. In the event of an emergency, the system can guide railway station occupants to the nearest safe exit and help to manage the station evacuation. Later, the system is expected to aid the firefighting personnel to decide on how best to tackle the situation. However, it is expected that in an emergency event such as a fire spreading through the station, it is possible that the sensors may become disconnected or destroyed. Thus, redesigning the systems for this possible event must be considered. Existing systems typically have limitations with respect to the lifetime, cost, and energy efficiency as the foremost design factors [64].

A wireless communication infrastructure can be arranged in railway stations with a goal to boost operational (e.g., fire systems, automatic doors, surveillance, etc.) and commercial services [7]. Moreover, a wireless sensor application has been suggested for an underground fire hydrant (FH), in order to monitor the water flow, to detect any leakage and sensor network, and to advise the use of a two-Ray model with the assumption of a level earth [65]. The fire system in the railway station can

be designed with wireless sensors collecting data and presenting the information to the user for the specific zones at risk.

3.6. Ticket Wireless Card System

Wireless technology can benefit and provide data analysis of transportation systems, such as electronic tickets, which employ radio-frequency identification (RFID) cation technology for registering access to stations, where the passenger is a part of a WSN. Smartphones and electronic tickets have shown to further increase the possibilities for gathering information about passenger movement and behaviour which benefits security and business quality [4].

Autonomous decentralised systems (ADSs) have been a successful form of technology in Japan's railway stations. These systems use a wireless IC card ticket system (inspection the Invalid Cards). The system employs wireless communications between the IC cards and the automatic fare collection gates (AFCGs), as shown in Figure 4, where the terminals choose the data to collect and process. Each terminal and station server is associated with the station Local Area Network (LAN)and work on the autonomous decentralised process through another Data Field (DF). This system was presented to the Suica system by East Japan Railway Company [66]. However, it is expected that there will eventually be ticketless travel where smartphones replace completely the need for any traditional tickets, and smartcards with NFC (Near Field Communication) technology do exist [57].

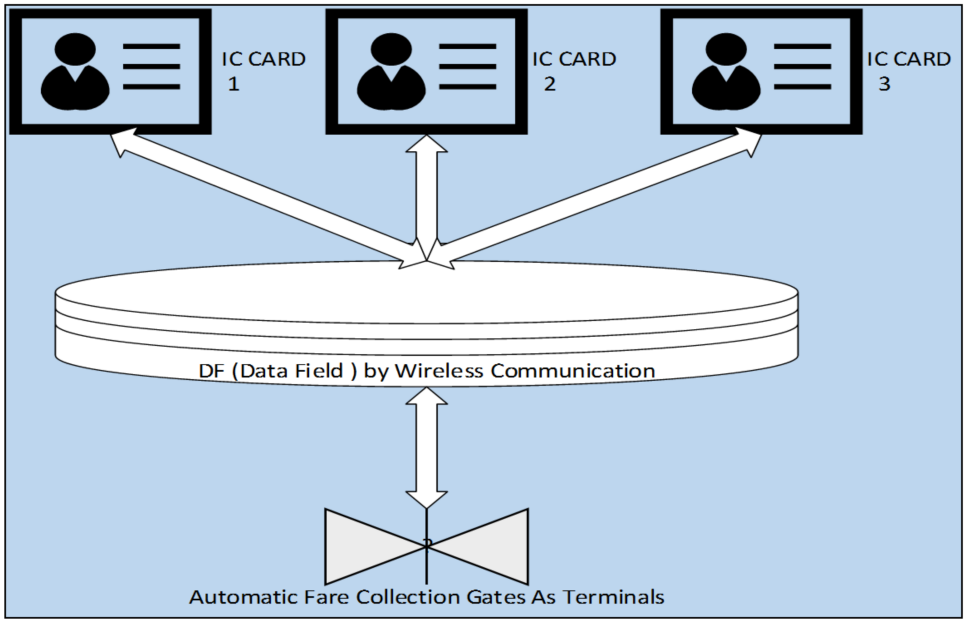

Figure 4. Data field between IC card and station in autonomous decentralised IC card system [66].

3.7. Ticket Wireless Card System

The new anti-runway prevention system (ARPS), which has evolved on track skates and is widely used in industry, also exploits wireless sensors. The sensors of the system are equipped on track skates; the data is detected and transmitted over the radio frequency network through a micro-power wireless communication module. The system enhances the safety of the railway stations by enabling reduced derailment accidents and lessening the chance of human error, which might be caused by negligence in the operations. Moreover, ARPS will improve the security in the railway station by preventing theft of the track skates. Testing of the system shows the reliability of the communication distance. Furthermore, the system significantly saves employment costs due to the automatic recording and analysis of the status of the anti-runaway function [45].

3.8. The Wireless Sensor Network for Heavy Haul Transportation (WHHT)

Heavy haul transportation involves railway freights carrying heavy weight of commodities. The trains have multiple locomotives, which must coordinate their brakes. This method of WSN is offered to upgrade the traffic volume; and reduce and monitor the maintenance and inspection requirements. They install air pressure sensors to the locomotives, and train rear where relay nodes are also installed on the coach overheads, placing accelerometers and ultrasonic sensors along the track over the railway relay nodes. If the leading locomotive brakes, then the sensors in it detect the modification of air pressure, and the relay node on the locomotive transfers a message to the other locomotives through the relay nodes on either the train or the track using a wireless radio connection. The other locomotives can then set their brakes according to the information from the lead locomotive. The track relay nodes are utilised when transmission via train carriages is weak such as tunnels and curvature. The data from railway infrastructure such as from the accelerometers and ultrasonic sensors along the track or in the parts of the stations can be collected and analysed for condition monitoring [19,67].

4. Smart Railway Stations

Smart rail transportation systems have benefitted from innovative technologies for railway infrastructure managers and the train operation organisations, aiding them to make more effective decisions and enhance security and safety in the railway stations. The insights from data processing improve timetabling, predict the demand and improve decision making. Table 1 below shows some examples of the data from railway operations.

Table 1. Examples of the data in the railway stations.

Data Root	Obtained Data
Smart card	Passenger check-in and check-out times, validation and any security information
GPS	Train locations
Traffic control	Timetable and delays
Incident registration	Data for investigations, breaching safety or security plans

It is possible that the same concept of the smart cities can also be applied to railway stations (Figure 5). The railway station innovation, data businesses, and services will add extra value to the smart cities. Generally, the main smart criteria in the stations include smart mobility, infrastructure, and management [68].

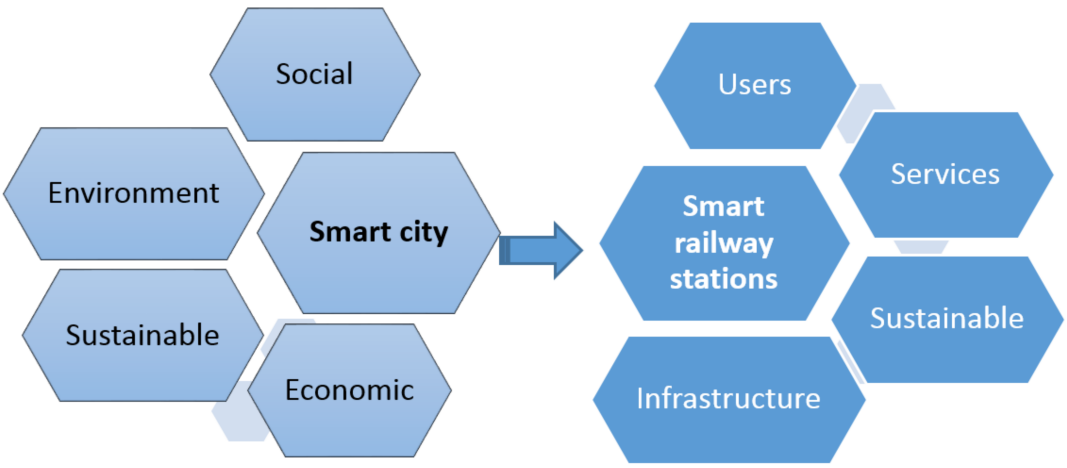

Figure 5. The concept of converting from smart cities to applying to railway stations [68].

The notion of the big data revolution is now common in the railway industry, and there is a need for the capability to process a growing data where the concept of the smart railway stations offers a successful environment of the big data strategy. There is no doubt that it will play an important role in the operations, and risk and safety. Big data has special characteristics as shown in Figure 6 [69].

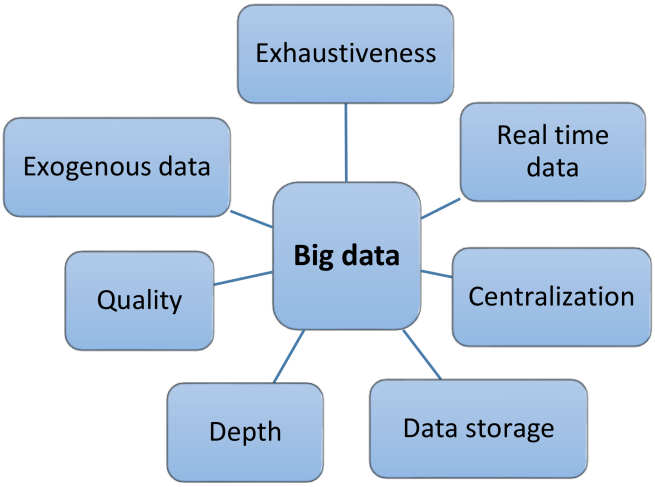

Figure 6. The big data characteristics in the railway stations [69].

From the advent of the 21st century, the railway industry has realised that big data analysis could be vital to improve railway operations. Great amounts of data, such as timetable and train delays data, can be seen as the first applications of big data in railway operations [18]. Moreover, data mining was used to represent the records and retrieve train positions on the track, including the impact of timetable shortcomings and causes of secondary delayed trains and delays at stations online, which is another source of data used. Recently, data analysis has been applied in the alternative train positioning data, including train event recorder data and GPS [70–73].

5. Machine Learning and the Railway Stations

In recent times, data analytics has attracted a great deal of attention from researchers in railway engineering [18]. This is because data processing and integration are providing a full image of an organisation's condition [19,74]. Advanced computing technology has enabled the utilisation of a machine-learning tool in many fields to solve and improve real-world systems such as business, engineering, and sciences [75].

The sheer volume of data that these devices can show on paper is staggering and even more so with wearable devices or GPS data. If they are put to use in the right way, they can revolutionise railway industry technology for general public and radically improve the railway stations' future designs. The regression algorithms using machine-learning techniques for model prediction has been conducted to investigate the vertical-acceleration of railway wagons [75]. Moreover, artificial neural networks (ANNs) have been utilized to predict the derailment of a train on the track [76], and more techniques have been applied in the field such as: support vector machines (SVMs) Chong et al. (2005), kernel density estimation (KDE) by Anderson (2009), and clustering by Lee et al. (2004) [77–79].

Variety as a factor of big data analysis (BDA) points to the various resources from which data can be gathered in its different forms [80]. As more and more devices join the rapidly rising IoT, there is more and more scope for the railway industry to take advantage of the data. For a high-performance model, a deeper analysis of data comes from different devices, as long as more information is available for the design of the model [81]. This has resulted in an improvement of advanced technologies in the big data analysis (BDA), in both academia and industry [18,82].

The machine learning tool (MLT) is set to be a powerful tool for the future, and it is one way of utilising large amounts of data. With this big data and the internet of things, the railway industry has access to an unprecedented amount of data but without the technology to turn it into actionable insight, the progress might be much slower than expected. New technology, especially cloud technology, makes it easier and cheaper for railway stockholders' operations in the industry and businesses to scale their IT infrastructure to meet the future growing demand and earn a high-performance and improved understanding of risk, security, and safety [83]. Moreover, by surveying data from wireless devices linked to the railway station, cloud computing can lead to advanced and rapid communication between operators, retrieving a better comprehension of risk profiles, consequences and reactions in emergency events, and monitoring the complex infrastructure in the railway station [84].

The use of cloud resources can interface with new technologies such as deep learning and underpin smart railway stations, which are a part of the future smart cities. For example, a standard (PAS 182) for smart cities offers some concepts (such as location, monitoring, metric etc.). To characterise a collective system for linking data across organisations in a city where a city can link concerted identifiers set for a type of entity, different organisations can share information about it such as accidents or faults in the railway stations [84–86]. Some expected potential benefits from this technology for all stakeholders in the railway industry are shown in Figure 7.

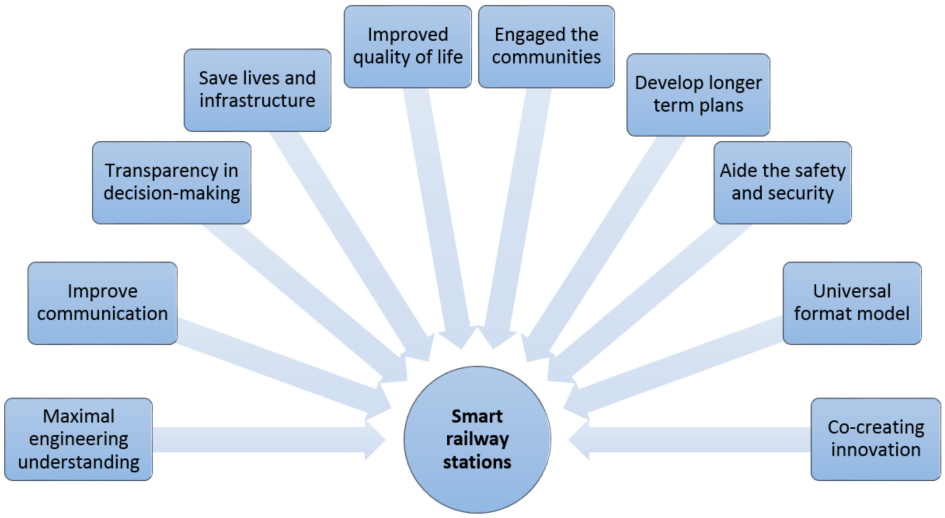

Figure 7. Potential benefit of the smart city concept model (SCCM) in railway stations (British Standards institution (BSI)) [85].

6. Conclusions

This paper offers an overview of WSNs in railway stations and a definition of the applications that can be used. The main aims of the critical review are to identify the enhanced security and safety in railway stations and present an innovative way for smart railway stations to use the big data gathered from WSNs. The size, efficiency, real-time condition, improved safety, security, and reliability and cost of wireless sensors are factors that attract the railway industry to the use of WSN technology. The application of wireless sensors in railway stations was briefly introduced here. In the future, it is best known that wireless sensors will play an important role in railway stations, and will offer a good act in emergency circumstances. The technology features quicker speeds, and the designers must consider this factor in their design for the railway station. Also, this technology benefits the railway stations by making them a safer and more secure environment. At present, few applications use WSN in railway stations. However, clearly, monitoring of individual behaviour is an essential part of the security system and the future of the technology will encourage security and safety in the railway station, so continued development of integrated systems and more research in the field are

needed, along with experimental and simulation tool validation. Wireless sensors provide a low-cost and low-power networking method. For example, wireless fire detection systems typically are more efficient than traditional systems. Moreover, in relation to this survey in the field, it is clear the research in this area suffers from a lack of holistic surveys, which would take a wider perspective of introducing the artificial intelligence to deal with the huge data in the railway stations. Finally, in the future where the WSN has a vast domain of application areas, this will force WSNs to be an integral part of the railway industry.

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