The Internet of Things in Transport Management in South Africa

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Abstract— **To support sustainable transport systems in South Africa, this paper proposes the adoption of internet of things (IoT) technologies. This research extracted information on the activities undertaken by South Africa's public transport agencies from the Department of Transport website, and for each of these activities identified a number of IoT applications and services that can be of value through literature sampling. The activities identified fall under the subdomains of road network management, road safety management, aviation management, road traffic management, maritime services management, cargo transport management, cross-border transport management and passenger rail management.**

Keywords—internet of things, transport

I. INTRODUCTION

Transportation is the movement of people, animals and goods from one location to the other. The modes of transport include vehicles, roads, railways, airways, waterways, canals, terminal, etc [33]. A sustainable transport system allows basic access and development needs of individuals, organisations and communities to be met. There is a growing interest in the potential of internet of things (IoT) technologies to support sustainable transport systems in South Africa and in the world in general. The contribution of this research is to showcase the potential contributions of IoTs to the domain of transport in South Africa. The coming wave of connected devices, appliances, sensors and countless other 'things' represent the next generation of a hyper-connected world, called the IoT [31]. The IoT extends the benefits of the regular internet – constant connectivity, remote control ability, and data sharing and so-on – to goods in the physical world. The idea of the IoT notion is that everything within the global network is accessible and interconnected, and as such wireless sensor networks play a pivotal role in such an environment [32].

The Department of Transport in South Africa is responsible for the regulation of transport, that is, public transport, rail transport, civil aviation, shipping, freight and motor vehicles. South Africa has a modern and well-developed transport infrastructure. The air, road and rail networks are the largest on the continent [30]. South Africa's total road network is 747000 kilometres, the largest network of roads in any African country [34]. Major shipping lanes pass along the South African coastline in the south Atlantic and Indian oceans.

Approximately 96% of the country's exports are conveyed by sea and the 8 commercial ports are conduits for trade between South Africa and the rest of the world. South Africa has an extensive rail network – the 14th largest in the world and represents 80% of Africa's total [35]. South Africa's 10 airports handle more than 98% of the country's commercial traffic with 200,000 aircraft landing annually [35].

II. PROBLEM STATEMENT

Transport is a driver to economic growth of any country including South Africa, hence the need to manage it effectively and efficiently. The need therefore arises on the way forward to achieving sustainable transport systems in South Africa. This paper proposes the adoption of IoT technologies to transport management in South Africa. The question therefore is: "What role can IoT play in achieving sustainability in transport management". The objectives therefore would be:

- To identify areas where IoT can be applied in the domain of transport in South Africa
- To showcase the potential role that IoT can contribute to transport management

III. METHODOLOGY

The researchers visited South Africa's Department of Transport website [36] to collect information on the functionalities of the different transport public entities. South Africa's public transport agencies include the South African National Roads Agency (SANRAL), Civil Aviation Authority (CAA), Road Traffic Management Corporation (RMTC), South African Maritime Safety Authority (SAMSA), Ports Regulator of South Africa, Railway Safety Regulator, Passenger Rail Agency of South Africa (PRASA), Air Traffic and Navigation Services (ATNS), Cross-border Road Traffic Agency and the Road Traffic Infringement Agency. By analysing what each of the agencies does, the researchers extracted areas where IoT technologies can be adopted to provide solutions to issues that were identified. A literature search was then conducted against selected activities/objectives of these public agencies on examples of IoT technologies applicable from an international perspective. The areas identified were road network management, road

safety, aviation management, road traffic management, maritime services, and cross-border transport and passenger rail services.

IV. ROAD NETWORK MANAGEMENT

The road network in most countries constitutes one of the largest community assets. Road administrations must maintain, operate, improve, replace and preserve this asset. Therefore under this sub-domain of transport, IoT technologies can be handy in pavement management and the monitoring of road conditions.

A. Pavement management

Pavement management is the process of planning the maintenance and repair of roadways or other paved facilities in order to optimise pavement conditions over the entire network [24]. It incorporates life cycle costs into a more systematic approach to minor and major road maintenance and reconstruction projects. A pavement management system (PMS) can pay itself many times over through reduced repair costs, optimised maintenance schedules and interagency coordination (e.g. making sure that newly paved roads are not immediately torn up for sewer or cable maintenance). Sonoma County of San Francisco USA implemented an Enterprise Geographic Information System (GIS) asset tracking system to help monitor and maintain the country's pavement network system [5]. The new GIS-PMS allows county management to use a web-based map interface to identify problem pavement areas in real-time. In a PMS application called StreetSaver [4] engineers collect and enter information about specific sketches of roads (e.g. pavement condition, available maintenance treatments and cost and history of road networks) into a StreetSaver form. Using relevant data, StreetSaver can perform budget analysis including projecting costs of network maintenance and rehabilitation as well as creating budget alternatives. The results of the analyses are visualised using maps that show detailed street maps and pavement condition and maintenance information. Although the maps are interactive, the collection and capture of data is manual, and can be automated through IoT technologies.

The PMS of the Gauteng Provincial Government (GATRANS) looks at rural roads [3]. Traffic counts are taken on a regular basis and the number of light and heavy vehicles determined. Information on load characteristics is obtained from weigh stations. Parameters on cracks, patches, potholes, drainage, skid resistance and binder conditions is also collected. The network level analysis is based on heuristic optimisation process which makes use of Deighton software. The pavement performance includes seal age, condition index and road roughness. IoT technology can be adopted towards an automated system that integrates all these parameters.

B. Monitoring of road conditions

An electric-powered, three-wheeled unmanned ground vehicle BearCat III detects potholes using a video frame grabber. The vehicle has a GPS. This added with an internet capability, means it can communicate the coordinates to the responsible centre [15]. This is IoT at work. The GPS coordinates are obtained via satellite, and the video information obtained is transmitted to the responsible centres via the same. On the other hand detection of potholes through pattern recognition techniques and communication from the pothole to BearCat III is done wirelessly.

Nericell is a system that performs sensing using smart phones. The sensing component uses the accelerometer, microphone, GSM radio and GPS sensors in the phones to detect potholes, bumps, braking and honking and report back to a server for aggregation. The Nericell addresses virtual orientation of the accelerometer on a phone, performing honk detection and localisation in an energy-efficient manner [16].

V. ROAD SAFETY MANAGEMENT

Road traffic safety refers to methods and measures for reducing the risk of a person using the road network being killed or injured [38]. The road users include pedestrians, cyclists, motorists and passengers in both private and public vehicles. Factors that impact on road safety are pedestrian visibility, pedestrian and driver education, law enforcement, state of vehicles, speed, emergency response speed, vehicle maintenance and infrastructure [39].

A. Pedestrian visibility

Night vision with pedestrian detection helps the driver see better during bad visibility. Through sensors attached to them, vehicles sense their surroundings and identify appropriate paths that avoid obstacles. These can be sensors to detect heat intensity of the human body, or items of clothing they put on for visibility.

B. Safety awareness education

StreetSmart is an integrated project in Baltimore conveys location-specific messages to high-incident communities through broad-range media coverage[2]. Information detailing the realities of pedestrian safety is brought to citizens' attention through radio and web TV public safety announcements, coverage in blogs and websites, electronic advertisements and newspapers. Roadside billboards and sheet banners remind travellers to share the road with pedestrians.

C. Law enforcement on the roads

South Africans consume 5 billion litres of alcohol per year according to the Medical Research Council [8, 17]. There are a number of IoT devices that can assist in the control of alcohol abuse. Sensors that measure blood alcohol content by smelling one's breath have been around since 1938 when the Drunkometer was invented. In New Mexico, the Driver Alcohol Detection System for Safety (DADSS) breathalyser-based interlocks in vehicles are attached to the ignition that prevents a car from starting pending breathing into a tube for a minute to determine blood alcohol levels [7]. Touch spectrometry technology seeks to measure blood alcohol levels via near infrared light which penetrates the epidermis to analyse the composition of the fluids present in the dermis layer of the skin.

Matt Legget invented a jacket that can tell if one is too drunk to drive [40]. They blow into a nozzle that is hidden in the collar. Inside the jacket is an Arduino microprocessor, an alcohol sensor and a series of light-emitting diodes (LEDs). A breathalyser situated in the jacket pocket analyses the breath samples and then lights. The LED glows only when alcohol is detected and the brighter the glow the worse. Drager interlock XT [25] is a breath alcohol measuring instrument with a vehicle immobiliser. It prohibits a driver who has consumed alcohol from starting the motor car. The Drager interlock XT comprises 2 main components: the breath-alcohol measuring with the measuring system, which is situated the vehicle and the control unit which is installed under the dashboard and allows or prevents current being supplied to the vehicle starter system.

D. Tyre pressure monitoring

One of the common causes of road accidents is tyre bursts/failure. Automotive Supplier Continental AG has developed a technique that detects if a tyre has sufficient tread depth. The software deduces the actual tread depth from the gradual changes in the tyre's rolling behaviour over time and enables drivers to recognise early enough when a tyre is run down to below tread depth required to maintain safety and issues a warning at the dashboard [11]. Indirect tyre pressure measurement sensors (TPMS) do not use physical pressure sensors but measure air pressures by monitoring individual wheel rotational speeds and other signals available outside the tyre itself. Direct TPMS employ pressure sensors on each tyre and report it to the vehicle's instrument cluster or corresponding monitor. This is intra-vehicle IoT.

E. Speed control

Speed can be measured in many ways. Mobile phones in a car transmit their location to a mobile phone network. By measuring and analysing network data, traffic information is derived. Detectors mounted along the road, detect a unique serial number for a device in the vehicle. Travel times and speed are calculated by comparing the time at which a device is detected by pairs of sensors placed apart. Video cameras are another form of vehicle detection. Video detection systems automatically recognise number plates. Cameras feed into processors that analyse the characteristics of video images as vehicles pass. The cameras are mounted on poles adjacent to the road [23].

F. Carrying capacity of bridges

A key component of the internet of things is remote monitoring of infrastructure like bridges and transportation assets. Sensors like accelerometers, tilt meters, temperature sensors and acoustic sensors are used. These sensors allow receiving early warnings of changing conditions, potentially extending the need for periodic inspections by human inspectors. This real-time monitoring approach is also able to capture changes in between inspections which would go unnoticed. In addition this reduces the risk of catastrophic failure and reduces maintenance costs by supporting preventative and predictive maintenance models.

It is important that all weak points in a bridge, especially columns, have sensors in them that can constantly asses the conditions of various members. Sensors in a bridge are connected to a common recording device. This is then linked to a centralised monitoring station which receives all data from sensors through the internet. A problem for these connected recording and transmitting devices is power that is required. The use of batteries means constant maintenance. Solar power to energise batteries may be adopted. Scientists have even developed devices that can use the vibrations on the bridge caused by traffic to power sensors and recording devices. When stress levels on the bridge are detected, this activates maintenance teams to attend to the bridge.

G. Response to emergency

An emergency call is generated manually by vehicle occupants or automatically via activation of in-vehicle sensors after an accident. An emergency call carrying both voice and data directly to the emergency point is dispatched

H. Car maintenance

The car knows when it needs maintenance done and when it needs fuel. Sensors on components of the vehicle detect the state of components and suggest replacements as soon as possible to avoid downtime. The sensors in the car and location services on technicians' tablets constantly send data to the company's many monitoring systems, which are in turn fed into analytical software programs that come together on one dashboard to flag what needs to be done, sometimes before it is needed.

Timing of the firing of spark plugs and fuel injectors in an engine may damage the engine. Timing problems in the braking system can cause loss of control of the steering. The engine control unit (ECU) is in charge of sending out signals to the control engine. ECU software problems can cause it to improperly time some of the signals to the engine.

Google's car maintenance reminder Lite [37] is an all in one car application that helps to 1) keep track of mileage, fuel and efficiency, 2) log services and get maintenance reminder when a due date appears. It sends a reminder for oil change, tyre rotation, wheel alignment, air filter change, belt replacement, spark plug replacement, etc.

I. Pollution management

Modern vehicles are equipped with a large number of sensors that can be accessed through an On-Board-Diagnosis (OBD) port. The OBD port allows access to the values of multiple sensors in vehicles such as oxygen sensors, engine load, consumption, coolant temperature, etc. The OBD2 is a standard implemented in all passenger vehicles in the EU and US. In a simple IoT scenario, vehicles send their information to a centralised system that controls whether vehicles are emitting high concentrations of carbon dioxide. A mobile device in the vehicle obtains data through an OBD2 port and sends via internet to the location [14].

VI. AVIATION MANAGEMENT

Aviation is the business or practice of flying aircraft. The IoT systems can be adapted to aviation in aircraft transmission, aviation weather monitoring, scheduling flights and flight simulation to name but a few.

A. Aircraft transmission systems

An aircraft data automation system regularly sends data from the plane via either ground stations or satellite uplinks known in the aircraft business as ACARS [41]. The ACARS system provides regular status updates on important systems like engines, electrical and hydraulic systems and fuel levels. The ACARS system allows maintenance technicians to analyse data in real-time to detect and fix problems before they become potentially catastrophic.

B. Long term parking calculator

In an airport, for example, the preferred parking area of an interactive map is identified by hovering a mouse over the icons. Available parking bays and their GPS coordinates are identified through the wireless link between the map and parking bays. The parking calculator computes the cost of parking corresponding with departure and arrival dates of the passengers.

C. Aviation weather monitoring

With sophisticated weather modelling and massive amounts of data, scientists have made great strides towards predicting and reporting weather conditions through big data and internet of things. Meteorologists collect weather data from thousands of weather stations, balloons, buoys and even private citizens. All data is run through weather forecasting models to identify patterns. Networks and connectivity notify the aviation control centres who in turn notify pilots

CimAWOS [12] is a fully automatic autonomous wireless weather observing system for airports. It combines a pack of weather stations with several runway measurement instruments, all of them real-time connected to a central information system. The system ensures a smooth and progressive mounting of all meteorological sensors necessary for airport weather monitoring and for air traffic control. Airports staff make safety decisions dependent on meteorological observations, weather forecast, weather report emission, control tower work station.

D. Flight scheduling

Using a smart phone, it is now possible to check a flight schedule, book a flight and obtain a boarding pass. Smart phones connect wirelessly to the flight database at the airport or agency.

E. Flight simulation

Flight simulators offer an approach to virtual flying. Examples include Google Earth Flight Simulator (GEFS), Microsoft Flight, YS Flight, FlightGear [13]. GEFS gives a bird's eyeview of the landscape with 3D buildings produced by Google's streaming satellite imagery. On-board controls allow one to adjust speed and altitude. One can move around the globe or solar by scrolling around with mouse and keyboard. GEFS lets one lift off from various airports around the world.

VII. ROAD TRAFFIC MANAGEMENT

Traffic management provides guidance on the condition of the road network. It detects incidents and emergencies, implements strategies to ensure safe and efficient use of roads networks and optimises the existing infrastructure. Incidents can be unforeseeable or planned e.g. accidents, road works, adverse weather, holiday traffic peaks, etc.

A. Accident investigation and recording

The internet of things is about collection of big data. When big data is properly stored, sorted, searched and executed it becomes intelligence. This intelligence can be used to improve understanding of what is happening including frequency, trending and impact analysis – and to provide tools necessary to manage resources, minimise impact and reduce incidents. Crowd sourcing collects voice messages, video and photos from the public to create data picture that is key to road traffic management. A web based application provides data storage, management and analysis capabilities to accident investigation teams. An example was the Shuttle Columbia Disaster. NASA's InvestigatorDisaster [18] is a web-based application that uses a database, a document-sharing system and a web-based data navigation system that allows scientists to browse through information, organise it and file it so that it can be accessed online in a common file-sharing system.

B. Road network policing

In licence and registration checkpoints, police carry handheld devices which connect to a traffic control centre. They scan the bar code of the driver's licence or vehicle registration document. The information is transmitted to the control centre wirelessly for comparison with the data held in the database. The result is communicated back to the handheld mobile device.

C. Communications

Billboards are utilised in the communication of traffic speed and road safety issues. The information is controlled remotely from a web based application.

D. Education and training

The car driving simulator is developed for driver training schools. The simulator consists of hardware and a direct interface between the user and the immersive 3D world. The results are automated, meaning there is a guarantee that the learner has gone through all the routines. Defensive driving lessons to strengthen the driver's responsiveness and adaptability or to avoid occurrence of traffic accidents in adverse conditions is also simulated.

VIII. MARITIME SERVICES MANAGEMENT

There are a number of definitions of maritime services. Maritime activities are port-related activities conducted to ensure the safe and expeditious flow of vessel traffic in port

approach and harbours and a safe stay at berth when moored or at anchor [42]. Safe means that port conditions ensure that vessels using the port, the port environment and the marine environment are protected from danger. Maritime services also mean port-to-port transportation of cargo by vessels operated by an ocean common carrier.

A. Sea rescue

In sea rescue, a ship carries an active help terminal which integrates GPS, GIS, database synchronisation and wireless transmission to give a precise position for a search and rescue ship to get to the point. The land command centre gets the real time information from an active terminal and communicates with the search and rescue ship at any point in time through satellite. Help signals are also sent to the nearest rescue vessel.

B. Vessel traceability

A ship should easily be traceable at any point in time. The geo-location of the vessel is derived via satellite. The transmitter on the vessel communicates to the satellite, which in turn transmits the geo-location to the ground station for the position of the ship.

C. Collision avoidance

A device for detecting and monitoring the vessel surroundings has units for receiving sensor signals from the sensor devices of another ship. It alerts control should there be any near violation. The automatic identification system (AIS) sends and receives passenger ship name, location, speed, direction and computes and compares to other ships.

D. Voyage management system

The voyage planning is captured into an intelligent device that links to components of the ship that direct the ship without human intervention

E. Ocean pollution monitoring and combating

Pollution is caused by oil spills and leaks, agricultural pesticides, industrial waste, trash dumping, air pollution and acid rain and sewage. Real-time pollution sensors on ships collect information to a control centre and the ship's coordinates.

F. Port security

To reduce inspection time and economic efficiency, x-rays and radio inspections produce clear images of containers including shape and density of the objects inside the containers. Electronic seals are placed on container loading doors. A unique code is generated upon sealing. If the doors open, the code changes signalling tampering. The remote control seal adds a GPS receiver and GSM transmitter which send a location message to the control centre in the event of tampering. Radar sites in the ports provide precise real-time locations through port zones, covering the access channel, internal anchorage, single buoy moorings and wharves. The information is processed to identify the mooring and launching of each ship to prevent detours, shifts in tidal or weather conditions. Automated identification systems provide exact data about ships, trajectories, type of freight, position,

speed and destination. Integrated video intelligence systems connect cameras at critical locations to a control room from where images are processed and analysed to prevent, detect and monitor criminal activities on port premises. A smart container seal made of radio frequency devices provides for better protection combining robust mechanical parts with sophisticated sensors. The electronic seal transmits container information as it passes a reader device – fixed at customs or ports and issues alerts and error conditions if the container has been tampered with or damaged.

IX. CARGO TRANSPORT MANAGEMENT

Intelligent transport systems (ITS) is used to refer to infrastructure and services as well as the planning, operation and control methods to be used for the transportation of persons and freight [22]. The freight transportation industry bases a significant part of the answers it offers to these challenges on information and decision technologies: two-way communication, location and tracking devices, electronic data interchange, advanced planning and operation decision support systems.

Full traceability of goods (port-to-port), online inventory management, distribution, billing and customer procedures are all part of ITS. ITS systems combine and coordinate different data processing, transmission and control, technologies to boost transport efficiency, security and sustainability. They capture, process and transmit information regarding freight, traffic and vehicle operating variables thereby improving human resource and equipment management. Loading, unloading and handling equipment and warehouse equipment are controlled via the internet of things.

eFreight, is whereby 'en route' information on the location and condition of transported goods is made available online. This leads to the concept of 'intelligent cargo' meaning that goods become self-, context-, and location-ware as well as connected to a wide range of information services [43]. eFreight also includes the vision of a paper-free electronic flow of information associated with the physical flow of goods.

ITS applications in ports include [43]:

- Optimisation of traffic programming for all transport modes
- Identifying and setting priorities for work orders
- Planning and optimising storage, personnel movements, terminal equipment, infrastructure use and inventory and inspection
- Transport reserve and dispatch systems, to assign freight time and location
- Providing freight trucks with intelligent access and automated guidance into reserve areas
- Automated electronic readers to locate and register positions in storage yards
- Computer-assisted assignment policies for parking lots

Active sensors on the cargo, most commonly using RFID or NFC technology provide synchronised information and

material flow in real-time; hence operators are able to gather information on specified cargo at any time instantaneously. As technology advances, smart post boxes, air freight pallets and wooden pallets can communicate with a variety of networks to report their location, avoid collisions and even report the surrounding environments. With the help of these sensors, along with real-time locating systems, GPS tracking systems, and other information relaying tags, the objects are able to communicate with each other and disperse the information through the internet in real time. The data generated can then be processed by analytics or the operator for decisions to be made through configured rules.

Using intelligent transportation technology, dispatchers in the command center are able to assign directions and routes for the drivers, observe driver behaviour, monitor goods in real-time, detect when a vehicle has gone off track or even when a vehicle has been idle for too long. For various sensors to relay information to each other and back to the command centre, having a fast and stable internet connection is crucial.

X. CROSS BORDER TRANSPORT MANAGEMENT

Cross border transport is movement across jurisdictions and legal entities, be it for the transport of goods or passengers. The domains of application of IoT in this domain would be in fleet management, document management, speed control and border crossing control.

A. Fleet management

Telematics [44] is the blending of computing and wireless communication technologies. This technology allows an efficient transport management thanks to the processing of all data transmitted by the vehicles (such as acceleration, distance, type of road, braking, impacts, real-time vehicle location and fuel consumption) in order to save time, money and provide a better service. It provides real-time visualisation and tracking of all fleet vehicles including trip log, real-time tracking, driver behaviour, route monitoring, alerts and fuel management. It uses GPS satellite positioning and GSM cellular communication. Real-time information is accessible through mobile, tablet and desktop devices.

Real-time messaging and interconnected devices improves fleet activities through future transport logistics. Every aspect of freight activity is connected via sensors that communicate with the equipment detection/event notification systems. Trucks are equipped with devices that share GPS coordinates and other information with an on-board computer which in turn communicate with the equipment detection/event notification systems. The equipment detection/ event notification system is checked to quickly determine where trucks are, how much freight they are carrying and which dock doors (also sensor-equipped) will be available to receive the truck when it comes [19].

B. Document management

In progress to the paperless freight shipping initiatives, the ability of transport companies to produce point of delivery (POD) documents fast and efficiently is essential. Optical character recognition or bar codes contain key information which is printed onto POD when it is produced. This bar code information is extracted for future retrieval of documents. Also PDA devices, details of which can be downloaded can be filed in the document management system.

C. Speed control

A speed control device connects to a map at a control centre. If there is any violation the dot on the map beeps. The central control clicks on the map and it connects to the audio communication of the vehicle. The violation is noted into a database.

D. Border crossing control

The RFID ID or tracking device of the car or the number plates are all detected by a tag reader at the border and communicated to a central database.

XI. PASSENGER RAIL MANAGEMENT

Metro rail are urban guided rail transport systems segregated from road and pedestrian traffic. A rapid transit system, on the other hand, is an electric railway system characterised by high speed and rapid acceleration. It uses passenger rail cars.

COSMOS [20] is a train control and monitoring system. It consists of a control module, input/output module, man-machine interface, repeater module, gateway module. The control module executes the train logic for detecting, assigning the priority order and evaluating items carried to communications buses as well as defining the variables, redundancy and tasks. The input/output module is used for the physical connection between the various items of equipment on the train. The man/machine interface is the operations and display centre of the COSMOS system and is the interface point for the driver and maintenance personnel. It monitors the status of the trains, the alarms and equipment settings. It is also for diagnosis, recording and monitoring functions. The repeater is the module whose purpose on the train consists in maintaining the optimum signal level on all the cars making up a unit. This module permits isolation of failed segments. The gateway controls coupling and communication between different train units.

Rail transport systems operators rely on data and automated decisions to ensure safe, reliable service, as well as sustainable revenue generation. Trains become 'self-aware", that is, every train knows its own location, speed and also that of very other train in the system – reducing the risk of collisions. This leverages wireless networks, and cloud-based control systems to optimise performance and making critical decisions in milliseconds. The IoT makes the following possible [45]:

- Real-time equipment tracking – cloud based central control systems enable operators to pinpoint any piece of equipment
- Inter-equipment communication – alerting train drivers to take appropriate precautions, trains report delays or accidents
- Predictive maintenance – trains transmit defect data directly to engineers on components in need of repairs

- Fuel management – visibility into fuel consumption and efficiency

Transport for London's central control centres use the aggregated sensor data to deploy maintenance teams, track equipment problems and monitor the transport systems from escalators to lifts to HVAC control to CCTV and communications networks. Traffic collision avoidance system (TCAS) [46] is now being used for trains in Europe to prevent head-on, rear-end and side collisions. TCAS was originally used to prevent mid-air collisions between aircraft. It is based on secondary surveillance radar (SSR) transponder signals and operates independently of any ground-based equipment to provide to the pilot on potential conflicting aircraft. All aircraft are equipped with appropriate transponder which enables the communication between all aircrafts. In case of emergency or danger the active transponder equipped within the aircraft warns the pilot.

Siemens has developed a wireless sensor system that measures the mechanical loads to which a rail vehicle is subjected during operation. The sensors measure, for example, the degree of vibration at various points.

XII. CONCLUSION

The research in this paper identified potential applications of IoT in transport that can make a difference to the South African economy. These sectors include road network management, rad safety management, aviation management, road traffic management, maritime services management, cargo transport management, cross-border transport management and passenger rail services management. The research is meant to influence policy on the adoption of IoT in transport. The study can also be used as the foundation for development of new IoT technologies that are South Africa specific. Integrating various technologies in the IoT for various subdomains of transport is likely to impact on the efficiency, effectiveness and sustainability of the transport sector.

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