I&T APPLICATIONS TO ENHANCE SAFETY IN STATIONS

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1. BACKGROUND & OBJECTIVE

The Electrical and Mechanical Services Department (EMSD) has two functional arms - Regulatory Services and Trading Services - to provide E&M services for enhancing the safety and quality of life of Hong Kong. As part of the regulatory services, the Railways Branch (RB) of EMSD oversees railway safety, including the heavy rail, light rail, tramways, automated people mover etc. MTR Corporation (MTR) is the major railway operator in Hong Kong and serves as the backbone of local public transport. MTR's network consists of 99 heavy rail stations and 68 light rail stops with total route length of over 270 kilometers. The safety and reliability of rail transport is therefore of paramount importance in Hong Kong community.

EMSD and MTR strive to bring enhancement on railway safety, especially for managing those less controllable human factor and passenger behaviour related issues. Various innovation and technology (I&T) solutions were explored by EMSD and MTR with trials in operating railway environment so as to co-create a world-class railway service to the public.

The continuous efforts from both EMSD and MTR on intelligent safety applications had achieved international recognitions, for example EMSD has won the 2022 Geneva Invention Gold Award for Smart Driver Assistant for Automated People Mover project, and 2022 Geneva Invention Silver Award for Semantic Artificial Intelligent for Predictive Maintenance of Railway Track System project. MTR has also won the 2020 IET Innovation Award for Smart Junction project, and 2019 IET Innovation Award & 2021 RFID Journal Award for Integrated Speed and Position Supervision System (iSPS) with Smart Bollard project.

This paper focus on safety related I&T applications in MTR railway network, especially in stations.

2. SHARING OF SUCCESSFUL I&T APPLICATIONS

6 successful I&T applications for enhancing heavy rail and light rail safety would be introduced in this paper, including:

1. Escalator Comb Object Identification System (EOIS) for mitigating escalator incidents due to jamming of foreign object at escalator comb; and
2. AI-based Accident Prevention System for mitigating chance of escalator accidents due to passenger behaviour such as passenger lost balance and passenger carrying bulky luggage; and
3. Dangerous Goods Detection System to avoid passengers carrying dangerous good into railway premises and onto trains; and
4. Video Analytics and AI-based Platform Crowd Control System for enhancing platform and junction safety as well as mitigating track intrusion risk; and
5. Integrated Speed and Position Supervision System (iSPS) with Smart Bollard for Light Rail Open System Environment for enhancing operational safety; and
6. Smart Trackside including Smart Tunnel, Trackside Access Door Detection System (TADDS), and Red Flashing Light Remote Control System (eRFL) for mitigating railway safety risk related to trackside activities.

2.1 Escalator Comb Object Identification System (EOIS)

MTR owns the largest number of escalators in Hong Kong, i.e. over 1200 nos. of escalators in MTR stations up to August 2022. Escalator incidents sometimes occur in the network as more passengers carrying luggage trolleys or pushing prams on escalators, and loosen metallic parts from passenger belongings such as screw, washer, etc., dropped onto an escalator step may jam at the comb teeth as the step approached escalator landing. Although comb plate safety switch has been provided to stop an escalator in case of object jamming at the comb, damages of the steps are still inevitable especially for those escalators running at relatively high speed for managing high capacity of passenger flow in MTR stations.

To mitigate the risk, MTR invented the Escalator Comb Object Identification System (EOIS) at skirt panels of escalators starting from end of 2019. It was observed that those foreign potential dangerous objects such as metallic screws, coins, nails, etc., usually stayed at the comb section for some time before completely get jammed at the comb teeth. If the foreign object could be identified and removed in time, jamming incidents could be avoided. The EOIS which adopted Video Content Analysis (VCA) and AI technologies was then developed.

The EOIS comprises video cameras at the skirt panels on both side of the escalator and a processing unit located inside the escalator machinery space which equipped with processors, data storage and wireless data transmission device connected to a backend server. Figure 1 illustrates the system configuration. The cameras record footages for the comb section area and transmit the data to the processing unit for local analysis using VCA technologies to detect and identify any potential dangerous objects within a few seconds. Once a potential dangerous object is identified, an alert together with the captured image of the object will be sent to the backend server for dispatching to station controllers immediately. Appropriate actions will be taken by station controllers to avoid damage and malfunction of escalators.

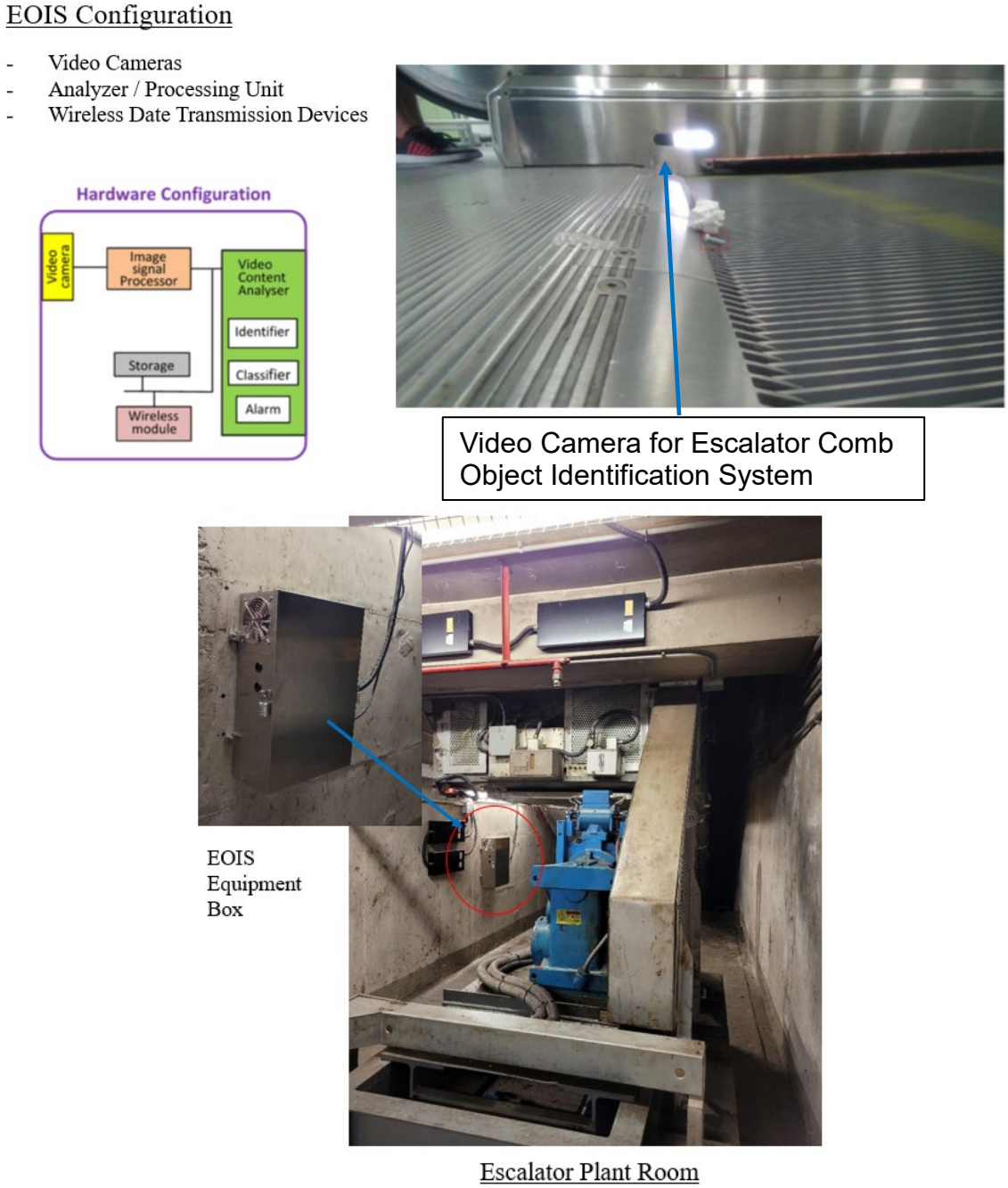

Figure 1 The Configuration of the Escalator Comb Object Identification System (EOIS)

In consideration of security and personal data privacy, the cameras of the EOIS are installed at foot level on the skirt panels and the detection areas do not cover human face level, and viewing angle of the cameras are pointing downward and fixed so that only the comb section areas are viewed. In addition, in case the camera viewing angle has been changed, alert will be raised to notify the registered users. The data library of the EOIS can also be updated when required to include other potential dangerous objects for continuous improvement.

A series of trial projects were carried out at 10 selected escalators in MTR stations, including Yau Ma Tei, Siu Hong, Sham Shui Po, Mei Foo, Kwun Tong, Admiralty, Mong

Kok, Wong Tai Sin, Kowloon Bay, Disneyland Resort stations. All the 10 EOIS's had achieved identification accuracy of ≥95% and some had even achieved 99%. Potential dangerous objects identified in real life environment include screws, coins, metal ring, earphone, metal clips, etc. Figure 2 illustrates the samples of dangerous and non-dangerous objects for testing the system accuracy. Up till August 2022, none of these escalators were damaged by the potential dangerous objects appeared at the comb sections due to proper follow-up actions taken by the station controllers after receiving the alerts raised by the EOIS. The overall percentage of nuisance alerts caused by non-dangerous objects were lower than 1% at the end of the trial project.

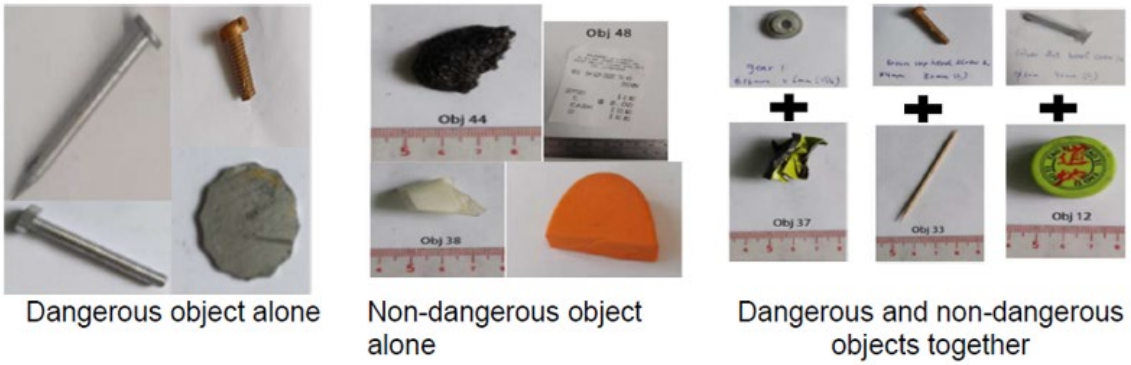

Figure 2 Samples of Dangerous and Non-dangerous Objects for Testing the System Accuracy

With the data and information generated and collected in the pilot projects, the overall performance of the EOIS was confirmed satisfactory, and can effectively mitigate escalator jamming incidents and thus avoid unnecessary outage of the escalators. MTR obtained patent for this EOIS technology in February 2020. In view of the positive results obtained in operation, the trial of EOIS will be extended to more escalators in MTR stations.

2.2 AI-based Accident Prevention System for Escalator

Another type of escalator accident with relatively high occurrence is related to passenger behaviours, such as losing balance when carrying bulky items. At present, public education and safety promotion at Escalator Safety Booths and also scheduled public announcements in stations were mitigation measures of such risk.

In July 2020, EMSD developed a proactive solution "AI-based Accident Prevention System for Escalator" with MTR's support and implemented a pilot project at Entrance C of Choi Hung station. This system aims to identify high-risk passengers, to predict passengers' behaviour and to trigger specific multi-media alert to passengers who are using escalators in MTR stations. Also, this system targets to bring new travel experience to passengers and to educate the public on adopting safer behaviour when using escalators.

The solution utilises Light Detection and Ranging (LiDAR) sensors and are installed at ceiling level. Three-dimensional point cloud of an object would be mapped in real-time to accurately determine its size and type, and even a person's walking pace and path to determine if assistance is required through AI engine. This enables real-time identification of high-risk passengers including passengers with (i) bulky baggage, (ii) baby pram, (iii) bicycle and (iv) extra-long belongings.

When the LiDAR device detects a high-risk passenger entering the turnstiles, it will broadcast and project a target specific multi-media message to the ground in front of the passenger, reminding them to use lifts (Stage 1 alert). If the message is ignored and the passenger continued to head towards the escalators, the system will deliver another broadcast message near the escalators (Stage 2 alert), this will also enable passengers nearby to be aware of the message about safe usage of escalators. Figure 3 illustrates the detection strategy of the system.

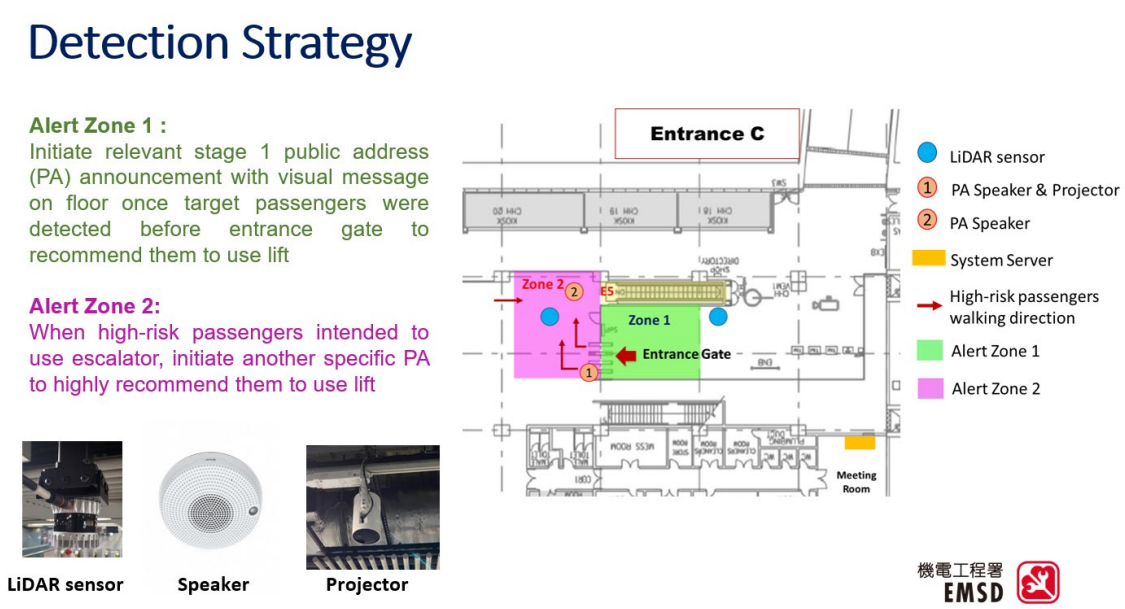

Figure 3 The Detection Strategy of the LiDAR

Besides, if passengers who are approaching the entrance gate at Alert zone 1 are detected with specific belongings such as extra-long objects and oversized baggages, instant messages will be sent to station operators through an alert device in order to provide timely assistance to the passengers.

To analyse the system performance, detection data before the system implementation was collected as baseline in December 2021 to record user patterns of all types of high-risk passengers, and operates under trial period from January 2022 till July 2022.

Due to the pandemic situation in February to May 2022 in Hong Kong, the number of target passengers has dropped substantially below the normal level recorded in baseline and the result might not truly reflect the system performance. However, from the data for bulky baggage category, it is observed that the average Stage 2 alert trigger rate for this target group was lower than that of the baseline for four consecutive months. This shows that the target-oriented activation of specific broadcast messages and visual alert have been able to increase the passengers' awareness and have successfully change their behaviour in using the escalator. Also, changes in specific broadcast announcements and visual alert images may also help to further improve the system performance.

2.3 Dangerous Goods Detection System

In order to bring a safer travel experience to passengers and educate the public to adopt safer behaviour when taking train ride, similar monitoring strategy with LiDAR sensors

could be explored for detecting passengers who are carrying prohibited belongings, such as dangerous or flammable goods.

"Dangerous Goods Detection System" was developed by EMSD with MTR support and implemented as a trial in one of the MTR stations. It utilises Light Detection and Ranging (LiDAR) and Artificial Intelligence (AI) object detection. When the system detects the targeted passengers entering the station with dangerous goods like Liquefied Petroleum Gas (LPG) cylinder, it will send alert message to station staff for confirmation and take immediate actions to stop the passengers entering the station premises to keep passengers safe.

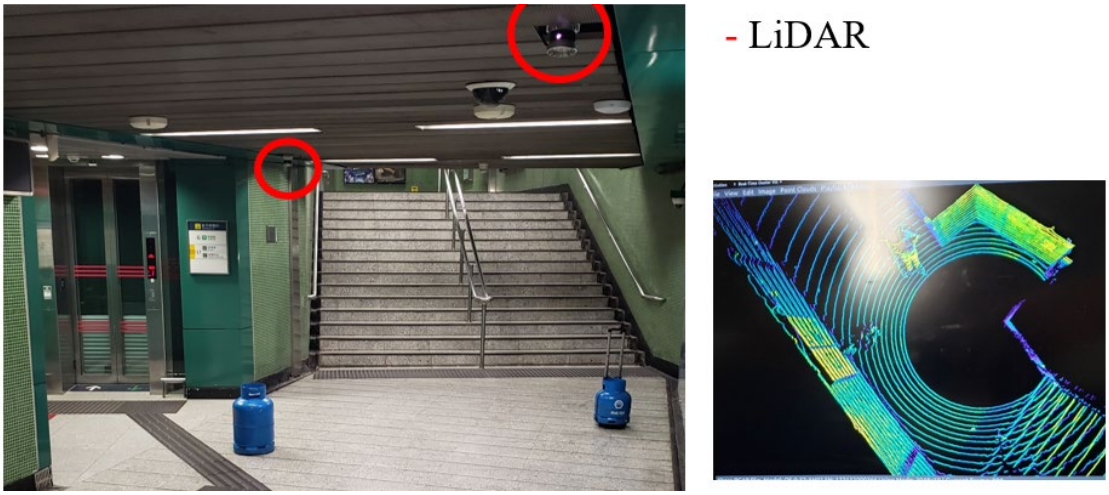

Figure 4 LiDAR and AI Object Detection

After equipment installation, data collection and system tuning for building Liquefied Petroleum Gas (LPG) cylinder model or other dangerous goods were performed. The equipment installation was completed in late October 2021. Two typical LPG cylinders, one big and one small, were arranged for Accuracy Test. The tests were conducted by simulating a person carrying an LPG cylinder walking across the detection zone. 3 scenarios were tested for carrying each type of LPG cylinders which are i) by two hands, ii) on shoulder and iii) by a handcart, thus total six types of test. The test revealed the successful detection rate was over 95%.

2.4 Video Analytics and AI-based Platform Crowd Control System for Enhancing Platform and Junction Safety

In East Rail Line (ERL), safety incidents like trespassing would occasionally occur while the site installation of automatic platform gates is being arranged on ERL. The ERL platforms are curved and narrow such that passengers' activities and behaviour along the whole platform cannot be observed easily. Improper passenger activities or behaviour along the platform edge could potentially incur safety risks as it is close to the track area.

To further enhance platform safety and mitigate track intrusion risk along the ERL, MTR developed a solution based on video analytic technology to mitigate the risk. Video images from existing station CCTV system were utilized to perform Video Content Analysis (VCA) to assist station controllers to alert potential dangers at platforms through an automated remote alert system in real-time.

The key features of the system include detection of passenger standing beyond yellow line, passenger/object on track, wandering, and person collapsed. A mix of algorithms, e.g. skeleton projection, polygon-shaped geo-fencing, object detection, were adopted in the system design. Trial had been completed successfully and being rolled out to more East Rail Line stations as quick win solution. The solution is being applied to some Light Rail (LR) stops platform as well. Triggering of platform Public Address (PA) system for safety reminder announcement upon detection will also be progressively implemented in coming phase.

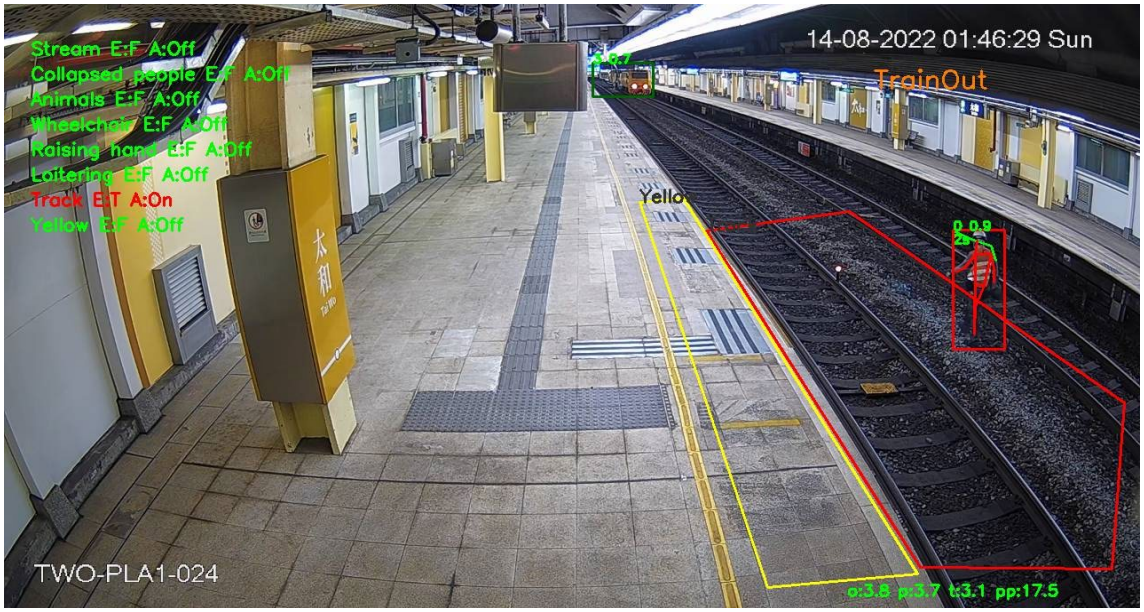

Figure 5 Illustration of the detection of person on track at East Rail Platform

As alternative, EMSD also developed an "AI-based Platform Crowd Control System" with MTR's support. The system which utilises LiDAR sensors is also being explored in parallel as comparison. It provides a live 3D image and Artificial Intelligence Program for detecting highly accurate passenger behaviour on train platform, platform over-crowding and passengers trespassing the track area or standing beyond yellow line, and suspected track intrusion.

The trial system would also trigger announcement and inform appropriate station staff immediately to take timely action to ensure railway safety. System installation and alignment have been completed in August 2022. Model training is underway and the system to be launched by September 2022 and performance is to be evaluated.

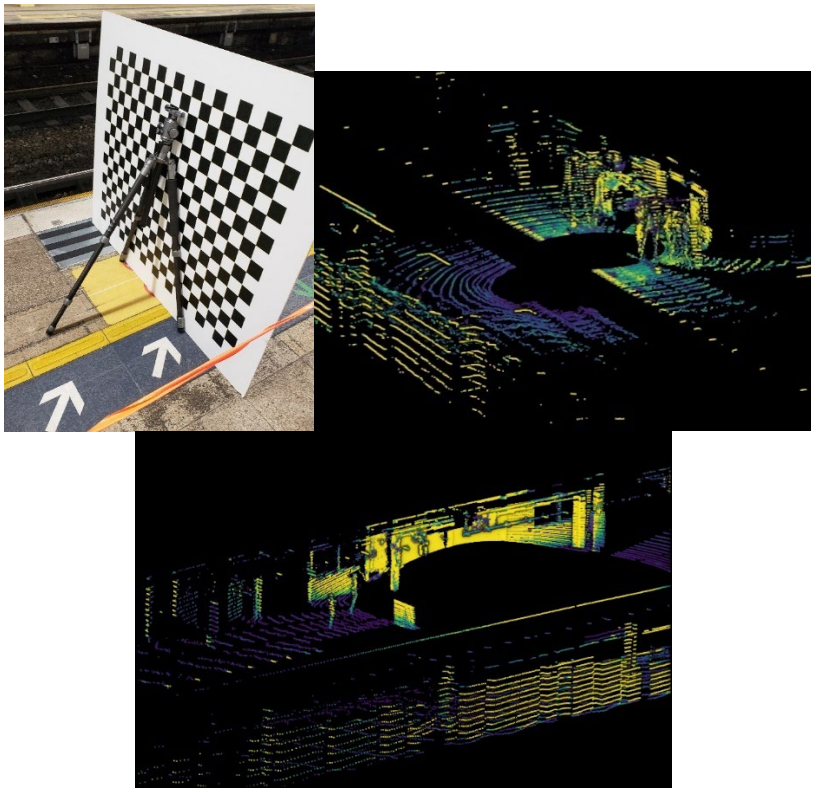

Figure 6 Site Alignment and Photos of AI-based Platform Crowd Control System

In Light Rail (LR), apart from platform risk, the LR system has close interface with road vehicles as there is no physical barriers for segregating the paths between LR vehicles and road vehicles, especially at the road junctions. If there is a vehicle which jumped the red light, undesirable accident of road vehicle hitting against light rail could potentially occur.

A Smart Junction system was developed by MTR to mitigate the risk using video analytics technology to analyse real-time video footage from cameras installed at blackspot junctions and interlink with signals from light rail system and road traffic lights. The smart junction system would generate alarm signal from roadside to LR train captain through wireless network if any potential risk detected. A prediction zone was set up in the analytic algorithm with consideration of the trajectory and moving direction of road vehicles using trip-wire detection to provide accurate detection and pre-alert alarm for the train captain. Illustration of the video analytic detection algorithm shown in Figure 7.

The Smart Junction system is currently installed at one junction, and proved to be effective and successfully detected and prevented some road accidents. The system will be rolled out to more back-spot junctions in LR.

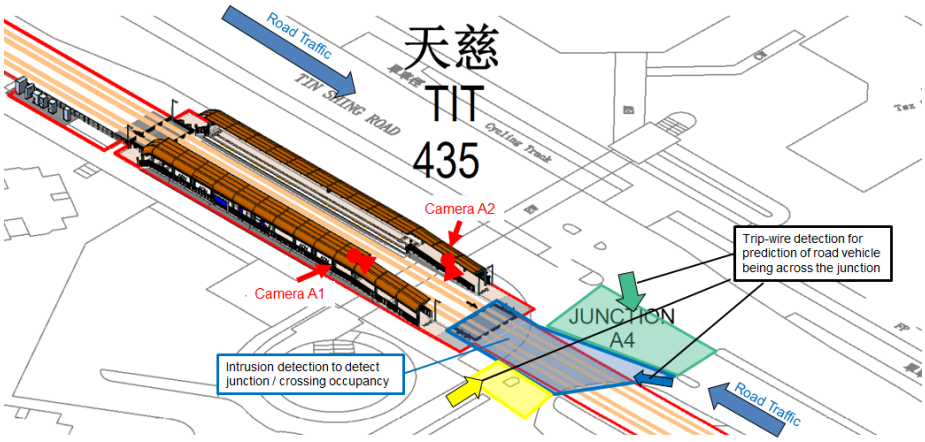

Figure 7 Illustration of video analytics algorithm at Light Rail-road junction

2.5 Integrated Speed and Position Supervision System (iSPS) with Smart Bollard for Light Rail Open System Environment

TheLR system in Hong Kong is a legacy system with traditional operation in manual driving mode under an open system environment. It needs high vigilance by train captain in observing the dynamic road traffic situations to drive safely, deliver platform duty and other passenger related services. With such heavily human-dependent driving environment, there is a need to eliminate human factor issues as far as reasonably possible. Besides, there are unsignalized crossings where pedestrians must take extra care before crossing the road safely.

Integrated Speed and Position Supervision System (iSPS) was invented by MTR to mitigate the risks by adopting the integration of RFID and GPS signals, to calculate the position of Light Rail Vehicles at trackside, thereby enhancing the positioning of Light Rail Vehicles down to 2 meters accurately in the urban area. It provides real-time speed supervision against speed limits, platform duty management and inter-vehicle close-up and conflicting movement monitoring. In addition, RFID tag interfaces with respective signal of a Point Indicator, thereby providing the trackside Point Indicator status to onboard Light Rail Vehicles to prevent the occurrence of Signal-Passed-at-Danger (SPAD). The system will generate reminders and alerts to train captain and will automatically inhibit traction supply or apply service braking if necessary.

The iSPS had been fully rolled out to the LR network since 2019. iSPS is proved to be very successful as it effectively reduces incidents in the light rail network. MTR obtained patent for this invention since 2017.

Figure 8 Integration of RFID and GPS signal for iSPS

Figure 9 iSPS reminders and alerts for train captain

With the accurate positioning from iSPS, location-based automation of train approaching bell is being explored to enhance LR pedestrian safety. Also, Estimated Time of Arrival (ETA) service is provided on MTR Mobile by using LR iSPS data to enhance customer experience.

Riding on the RFID system of iSPS, Smart Bollard is introduced by MTR at LR to detect and identify any Light Rail Vehicles approaching rail-road crossings. The system provides visual and audio alerts through a flashing bollard to the nearby pedestrians at crossings for Light Rail to further enhance pedestrian safety and customer experience. In order to alert pedestrians focusing on using mobile phone, an on-ground LED strip is also in place.

Figure 10 Smart Bollard at pedestrian crossings

2.6 Smart Trackside

Smart Trackside is an innovation from MTR to digitize and assist daily railway operations with state-of-the-art technologies, including Internet of Things (IoT), Long-range Radio (LoRa), Bluetooth-low-energy (BLE) Beacons, Sensors and Mobile Applications, etc. The invention adds values to the existing railway infrastructure (e.g. leaky coaxial cable) with handy device (e.g. sensor, beacon, IoT gateway) and provides an integrated, seamless and one-stop platform to digitally-transform the management of trackside activities in railway network, which traditionally relies on documents, procedures, phone calls, local control by respective worker, etc.

Smart Trackside assists operation controllers in managing trackside activities, especially during non-traffic-hours (NTH). It provides mobile application to workers to digitize and facilitate their work flow, and also provides a user interface to the operation controllers in control centre for centralized overview and management of trackside activities.

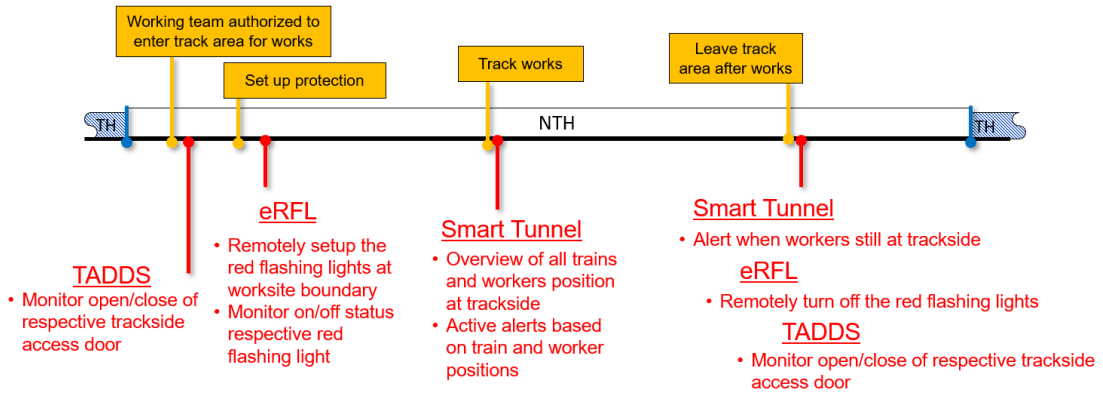

Figure 11 Assisting in managing trackside activities during NTH

The Smart Trackside system consists of 3 major applications:

2.6.1 Smart Tunnel

Smart Tunnel provides indoor positioning of workers within tunnel at trackside. It aims to assist the operation controllers in control centre to get an overview of the real-time positions of all workers along the railway line. Workers shall turn on the mobile app when they proceed to tunnel for track work, and the app will scan the Bluetooth signal transmitted by the BLE Beacons installed at trackside. With MTR home-grown tailored algorithm to handle the calculations of worker positions, the positions of workers at trackside can be reflected in real time and logged at the control centre. Successful trial was implemented at the Tsuen Wan Line of MTR.

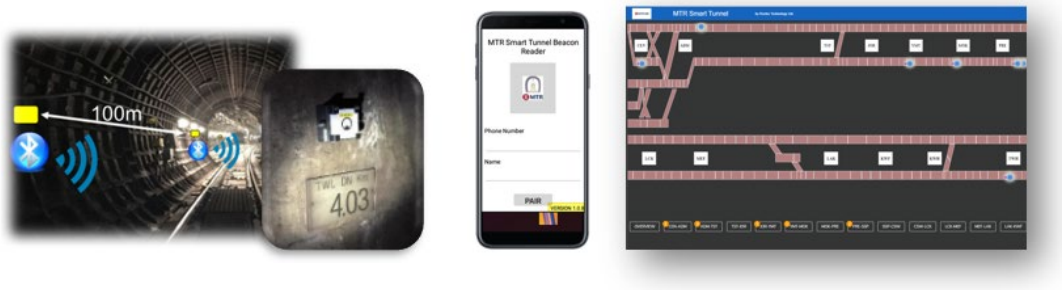

Figure 12 Smart Tunnel Beacons, Mobile Application, Web User Interface

2.6.2 Trackside Access Door Detection System (TADDS)

TADDS detects the real-time open / close status of numerous trackside access doors along the railway line. TADDS transmit detection and status signals through a LoRa wireless backbone which enables long range transmission with low power consumption. The LoRa network backbone was developed by MTR based on existing leaky coaxial cable infrastructure. Battery-powered sensing units are installed on each door at the trackside area. The TADDS assists operation controllers by monitoring real-time open / close status of trackside access doors through the control centre, which is particularly useful especially during exceptional scenarios where passengers might be evacuated inside the railway tunnel. In the event there is any intruder opening a door, the sensing unit would trigger an alarm to operation controllers. The LoRa network infrastructure also facilitates flexibility on expansion with various type of sensing units at trackside in the future. The system is currently being installed at Tsuen Wan Line and Island Line.

2.6.3 Red Flashing Light Remote Control System (eRFL)

eRFL aims at enhancing the efficiency of setting up red flashing light at worksite boundary for protection of maintenance activities at trackside. The eRFL is to be located at selected strategic locations where the working team may take much time to access and place the conventional red flashing light. The invention, as a home-designed product by MTR compared to the conventional red flashing lights which are powered by batteries, is more reliable and allows controllers to remotely monitor the status of the red flashing lights from the Control Centre. Connected to Internet with IoT technology for remote control and monitoring functions, it also allows the controllers in Control Centre to

monitor whether respective red flashing lights have been set up to protect the working parties within the area accordingly. The eRFL is currently in use at the East Rail Line.

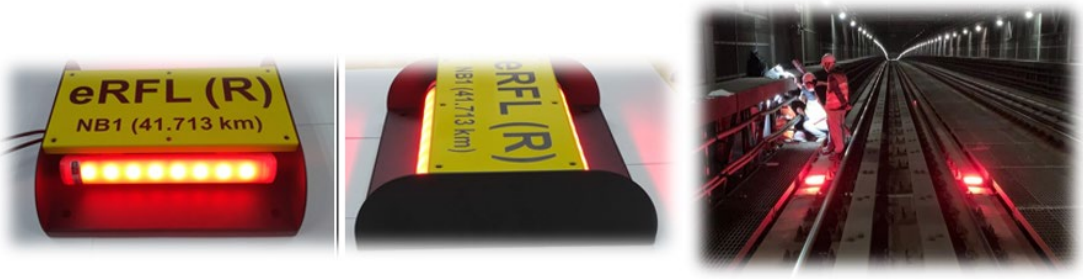

Figure 13 Remote Red Flashing Light

The three aforesaid applications would be integrated into Smart Trackside platform and to be gradually rolled out to more MTR lines to enhance safety management and also work efficiency.

3. CONCLUSION

With expanding railway network, increasing patronage, and increasing expectation on railway safety and reliability in Hong Kong, EMSD and MTR are committed to expedite the I&T transformation to sustain continuous enhancement on railway safety.

The examples of I&T applications quoted in this paper symbolised the beginning of the I&T transformation as exemplar in Hong Kong transportation industry. EMSD and MTR will continue to work towards a smarter and safer railway, enhancing effectiveness and efficiency of work process by digitization and automation, and continuously create cohered partnerships with different stakeholders including the trades, research institutes and universities in I&T collaboration to enrich the I&T development in railway safety.

Keywords: Innovation & Technology; Railway Safety, Smart Railway, Smart Station