

Smart Stations

Willesden Green Station

End of PoC Review



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What is a Smart Station?

Safety and security are paramount to Transport for London (TfL) and in 2021, TfL's Technology and Data (T&D) department in collaboration with operational frontline colleagues and Virgin Media O2 began exploring the use of smart technology at Willesden Green Station. Smart Stations is an exciting proof of concept (PoC), which uses an enhanced video analytics platform, with the aim to provide station staff with real-time insights and notifications on customer movement and behaviour.

The smart technology uses existing CCTV images (100 cameras in total), Artificial Intelligence (AI) algorithms and numerous detection models. Staff can receive notifications and insights related to incidents via a dashboard that visualises the information. This dashboard can be accessed via a desktop or iPad.

Using image recognition and machine learning to identify trends and hazards, enables staff to respond to incidents that require their attention. Smart Stations does not make decisions for staff but equips them with comprehensive information about their station and customers.

The PoC went live in October 2022 and finished at the end of September 2023.

Background

The Customer Services (now Customer Operations), Customer Safety Group was responsible for driving continuous improvements with a clear outcome to reduce customer injuries across the network. In February 2021, Virgin Media O2 (instigated by T&D) presented to the group a new concept which they had delivered for Network Rail, which provided real-time analytics and intelligence using smart cameras, internet of things (IoT) sensors and 5G connectivity to help station staff to understand passenger movement, security, and safety issues and to improve their customer service.

Following further engagement between T&D and Network Rail, we had seen promising results from their trials at Waterloo, Dawlish, and Marsden. Based on the business benefits demonstrated at Network Rail it was agreed at the Customer Safety Group to explore how a similar PoC could be delivered within London Underground, Sponsored by Ray Adabra (formerly Head of Customer Services Jubilee Line).

Although TfL has a long history of using data science techniques and data analysis for decision making, this is the first time we have used AI algorithms and behaviour detection using live CCTV images to provide real-time alerts for operational staff.

Scoping & Design

Early engagement with Network Rail enabled us to learn lessons and gather important insights such as selecting a large, central London station caused several issues for their

engineering teams and installing new Smart Meraki cameras added huge cost to the project.

Following several design workshops led by T&D, which involved key stakeholders from specialist areas such as Customer Operations, SHE and Network Security etc. we agreed on the following design principles:

- The smart technology stores the image of the incident for 14 days (aligned with LU's CCTV retention policy and **ALL** faces are blurred).
- The analytics can tell the difference between staff and customers.
- **NO facial** recognition is performed.
- Smart Station technology will not be used in any disciplinary procedure.
- The Smart Stations dashboard will not be used as a tool to measure or manage the performance of station staff.
- No audio is analysed or recorded – our cameras have no microphones.
- Smart Station technology will not replace station staff, they are essential to decide how to resolve an identified incident.

An important output at this stage was to define our use cases and triggers. Our initial classification of **77** use cases, established **33** with a high and medium category. Following several prioritisation discussions with staff from Willesden Green and subject matter experts, we agreed on the following **11** use cases:

- **Crowd Movement**
 - A count of all customers entering and exiting the station (Insights only)
 - A count of all customers entering and exiting the gate-line (Insights only)
- **Unauthorised Access**
 - Customers accessing unused platform (Real-time alert)
 - Customer using platform end barriers (Real-time alert)
- **Safeguarding**
 - Person(s) sat on bench for longer than 10 minutes (Real-time alert)
 - Person(s) leaning over the platform edge (Real-time alert)
 - Loitering in safeguarding area for longer than 10 minutes (Real-time alert)
 - Loitering in the ticket hall for longer than 15 minutes (Real-time alert)
 - Person(s) over the yellow line for longer than 30 seconds (Real-time alert)
- **Mobility Assistance**
 - Person(s) with a wheelchair (Real-time alert)
 - Person(s) with pram (Insights only)
 - Person(s) with excessive luggage (Insights only)

- **Crime & Anti-Social Behaviour**
 - Arms raised, acts of aggression (Real-time alert)
 - Carrying or using a weapon (Real-time alert)
 - Smoking & Vaping (Real-time alert)
 - Unfolded bikes & e-scooters (Real-time alert)
- **Person on Track**
 - Person(s) on track (Real-time alert)
 - Animal on track (Real-time alert)
- **Injured & Unwell**
 - Person(s) on floor (Real-time alert)
- **Hazards**
 - Wet floor and puddles (Real-time alert)
 - Litter and debris in the station (Real-time alert)
- **Unattended Items**
 - Any package/bag left unattended in the station (Real-time alert)
 - Animal without a lead (Real-time alert)
- **Stranded Customers**
 - Person(s) unable to exit or enter the station (Real-time alert)
 - Person(s) stuck at the top or bottom of the stairs (Real-time alert)
- **Fare Evasion**
 - Person(s) jumping over a closed gate (Insights only)
 - Person(s) jumping over a non-gated area of the gate-line (Insights only)
 - Person(s) crawling under a closed gate (Insights)
 - Person(s) tailgating “double gating” (Insights)
 - Person(s) walking through an open gate without tapping (Insights)

Review sessions with staff from Willesden Green enabled the team to understand key processes related to each use case, ensuring there was no change or impact to existing processes, standards, or rule books.

Governance

To support the PoC, T&D established and Chaired the Smart Station Steering Group (attendees listed in Appendix A) to provide specialist advice, ensure delivery of the initiative outcomes and the achievement of outputs, this included:

- Provide input to the development and design decisions
- Monitor the progress against its objectives
- Provide a point of escalation for risks and issues
- Review outputs and outcomes against objectives

- Provide representation from all key business areas
- Actively promote the outputs of the initiative.

Early engagement with Trade Unions (TU), enabled us to build strong interest and support. T&D continued to maintain good engagement, providing regular updates at all levels from Functional Council to meetings with local TU representatives.

T&D worked closely with colleagues from General Council, specifically from Legal and Data Privacy, ensuring the PoC was fully compliant. The team developed an extensive Data Protection Impact Assessment (DPIA), which was updated following changes to the solution.

Although the PoC had been managed and led by T&D's Technology Advisory Team, the project required additional technical resources such as a Cyber Security Analyst and a Network Architect etc. T&D initiated a Gate Zero paper to ensure all technical designs were approved and compliant to our standards and policies.

Why Willesden Green?

Using the feedback and learnings from Network Rail, we selected a 'Local Station', as our focus was on helping a station that has high customer footfall and minimum staffing levels. Our Sponsor, Ray Adabra also wanted the project team to select a station on the Jubilee Line.



GATEWAY



DESTINATION



METRO



LOCAL

Key aspects of Local Stations:


- These are smaller stations, and are in outer London, have consistent customer numbers and serve mainly regular customers. These stations will tend to be quiet outside of peak hours
- Local stations have a station control point and generally have a low number of station assets as well as a low number of operational assets
- [REDACTED]
- If a Customer Service Assistant is rostered, they are visible and available to assist customers with ticketing and journey queries, or are performing platform duties

Reviewing all Local stations on the Jubilee Line, we assessed the station heritage, camera infrastructure and station characteristics e.g. number of gates, public help points, stairs, escalators, lifts etc. Following our assessment, we were left with 3

possible candidate stations and the Steering Group's decision was to select Willesden Green.

Station	Line	Type	Heritage	Camera Type	Camera Quantity	Gates	Step Free Access	Lifts	No. of Escalators	PHPs
Kilburn	Jubilee	Local - A	Not Listed	Tecton Dalek	[REDACTED]	5	Y	1	0	7
Kingsbury	Jubilee	Local - A	Local listing pending	VisioWave	[REDACTED]	4	Y	2	0	12
Neasden	Jubilee	Local - A	Not Listed	VisioWave	[REDACTED]	4	N	0	0	5
Stanmore	Jubilee	Local - A	Locally Listed	VisioWave	[REDACTED]	6	Y	0	0	11
West Hampstead	Jubilee	Local - A	Not Listed	Liberator	[REDACTED]	6	Y	0	0	5
Willesden Green	Jubilee	Local - A	Grade II	VisioWave	[REDACTED]	8	N	0	0	8

Preferred stations



Listing unlikely to have an impact on installation of camera and connectivity technology. Further exploration to be done at chosen station.

All cameras are analogue. TfL Engineering has a preference for VisioWave as this is newer technology, others are at end of life and due for replacement.

Preference will be to have a station with stairs and/or lifts, to align with such use cases as stranded customers, vulnerable customers, customer/staff injuries etc..

Number of PHPs installed in stations, further investigation needed on how many are in operation.

At this stage, T&D had been working collaboratively with colleagues in TfL Engineering and Asset Strategy. It was important to assess the existing CCTV infrastructure and at Willesden Green they use analogue cameras, which are circa 20 years old.

Our Telecoms Engineer was responsible for engaging and instructing our communication assets maintainer 'Telent' to work on the design and installation of hardware at Willesden Green station.

Camera Analysis

Our next step was to analyse and assess the [REDACTED] cameras in total at Willesden Green and select the cameras in scope for the PoC. Using the CCTV snapshots which TfL Engineering maintain for all stations across the network, we reviewed the station layout maps, CCTV images and agreed with staff from Willesden Green, which cameras we had to include and were aligned to the use cases in scope.

See example below:



Installation & Architecture

[REDACTED]

[REDACTED]

Prior to install, architecture designs had to be produced and approved by TfL Engineering and T&D's Architecture Review Board. Telent installed and tested the hardware at their test site and following a successful test install, we arranged for Telent to install the kit at Willesden Green during non-operational hours.

[REDACTED]

Commercial & Funding

As this was a PoC, we wanted to prove the benefit by leveraging our existing technology partner, in this case Virgin Media O2. To mobilise the project, we engaged early with T&D Commercial who worked closely with our supplier to define a statement of works and contract variation.

[REDACTED]

[REDACTED]

Component	Description	6 Month Initial Trial Programme	3 Month Extension (optional) to Trial Programme
Mobile Wireless Connectivity	The hub of this solution – O2 resilient data connectivity for communications between the Edge device and remote servers.	██████████	██████████
New Hardware	No new hardware included. Edge processing device included free of charge.	██████████	██████████
Spatial Insights (data license)	Includes hardware, software licenses, training and on boarding, AI modelling and data hosting. Up to 15 camera views to address 14 individual Use Cases	██████████	██████████
Initial site survey - set up, review and selection	For camera selection / positioning –2 site visits during the Trial Period	██████████	██████████
Trial Set up, Customisation and In Life Support	Project Management / 1 day a week for 6 month Trial System Architecture 0.5 days a week for 6 month Trial Period Estimated total in region of ~40 days	██████████	██████████
Visualisation Dashboard / Alerts	Data dashboard to provide customised visualised and tabulated outputs Real time Alerts once triggers have been met	██████████	██████████
O2 Innovation Contribution to project	Discount of 50% against Supplier resource inputs (Trial Set Up, customisation and in life support)	██████████	██████████
TOTAL PRICE		██████████	██████████

Towards the end of the 6 months, the Smart Station Steering Group agreed to extend the solution for a further 6 months. Several additional requirements had been established to support the fare evasion use case, examples below:

1. Unblurring of faces for images
2. To generate a unique reference number per fare evasion
3. New fields and data items to capture on fare evasion alerts.
4. To be able to identify a fare evasion is a repeat offender fare evasion
5. To be able to retain images and metadata for repeat offender fare evasions longer than 14 days
6. To be able to link fare evasions together – if it is identified that multiple fare evasions involve the same person
7. Able to remove fare evasions from linking e.g. if done incorrectly or not part of it
8. To be able to hold repeat offender fare evasions to be able to link to others
9. To be able to view export fare evasions/linked fare evasions
10. To be able to search for fare evasions and information

Extending the trial for a further 6 months and incorporating the additional requirements the cost was ██████████.

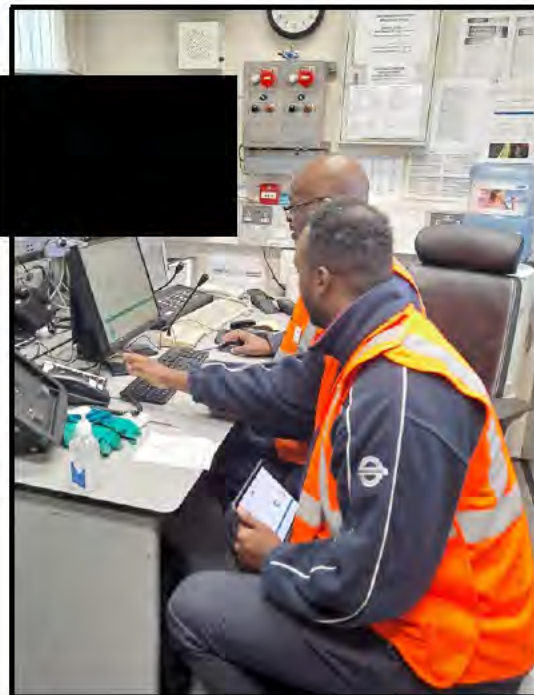
Component	Description	Price	Notes
Initial site survey - set up, review and selection	For camera selection / positioning	£0	No charge - surveys already undertaken Assumes no new cameras are added
Mobile Wireless Connectivity	02 Resilient Data Connectivity for communications between the Edge Device and remote servers.	████████	As per corporate tariff of £50 per month
New Hardware	Edge processing device.	████████	Currently on loan for this PoC. The price for the hardware if needs to be swapped out would be ██████████
Spatial Insights (data license)	Includes software licenses, AI modelling and data hosting. Use cases and cameras remain unchanged from current PoC	████████	Data license term is for 6 months. Retained pricing from Dec 2021
API	Provision of API output	████████	No charge for the API to date. This cost is a one off for all API access for the solution to TfL. The cost includes: a. R&D investment in creating an API architectural framework b. Implement the specific API e.g. to PowerBI etc c. Associated background work for API support
Visualisation Dashboard / Alerts	Data dashboard to provide customised visualised and tabulated outputs Real time Alerts once triggers have been met	£0	No charge - already undertaken. Assumes no new alerts or changes to dashboard beyond those defined for Fare Evasion
PoC Professional Services and In Life Support	Project Management / 1 day a week for 6 month PoC Estimated total 26 days across the 6 month PoC	████████	Project Management resource of 1 day a week across the 6 months
Refinement of Fare Evasion use case	Refinements and enhancement of AI, alerts, functionality across 6 months	████████	Includes refinement/ enhancement of Fare Evasion - anticipated to cover points 1 to 9
TOTAL POC PRICE		████████	

Staff Engagement & Adoption

Early engagement with the staff at Willesden Green was supported and encouraged by Ray Adabra (Head of Customer Services Jubilee Line), the previous Area Manager and the now current Area Manager, Chris Weaver. During the design and scoping phase, Nas Ali (Customer Service Manager) was assigned to help and support the PoC. Nas played a pivotal role by defining the user requirements and use case triggers, planning and facilitating briefing sessions to staff, and leading on multiple simulation sessions.

Leading up to the launch of smart stations, the delivery team developed briefing packs and met with over 20 Customer Service Supervisors face to face. Meeting face to face, enabled staff to ask questions and provide feedback. Separately, the team developed interactive guides which can be accessed via the Smart Station SharePoint site, a one-stop-shop for all information and help.

Throughout the PoC, T&D continued to engage with staff and sent regular updates via emails, informing staff of changes to the system and the launch of a new use case trigger. Representatives of the T&D delivery team would often locate and work at Willesden Green station, this provided additional support to staff who required help.



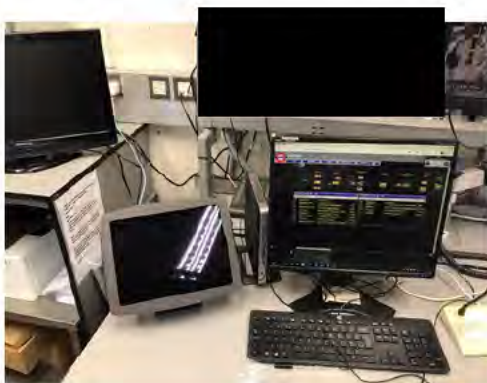
It was agreed by the station management team that the key user of the dashboard and recipient of the alerts would be the Customer Service Supervisors. Each Supervisor was provided with individual log-in credentials, which they could use for either the desktop or their corporate device (iPad).

During the design phase we established 3 user profiles, Administrator, Operational Supervisor and Non-Operational. For each profile, we designed specific permissions which would provide the user with functionality within the dashboard e.g. the ability to acknowledge an alert. It was the responsibility of the T&D delivery team who created the user accounts, ensuring the correct profiles had been assigned.

We made several enhancements and changes to the system following feedback from Supervisors. Meeting with Supervisors at Willesden Green provided the delivery team with excellent feedback. T&D also developed surveys when seeking feedback from the wider group of Supervisors. An example of a change post feedback was when our night shift Supervisors requested all triggers (excluding person on track) to be switched off during non-operational. The night shift Supervisors felt they had a good awareness of the station and who was working in the station at night.

Recognising that staff already have several applications to monitor and only the one desktop screen in the office, T&D installed a large, fixed iPad next to the desktop monitor. This enabled staff to see the application's pop-up notifications, every time an alert was generated. The iPad was configured with restrictions which only allowed staff to access the smart station application. Installing the fixed iPad enabled staff to monitor important applications (e.g. Tracknet) and visibly see when alerts were generated in the dashboard.

Images below show the fixed iPad next to the single desktop monitor.

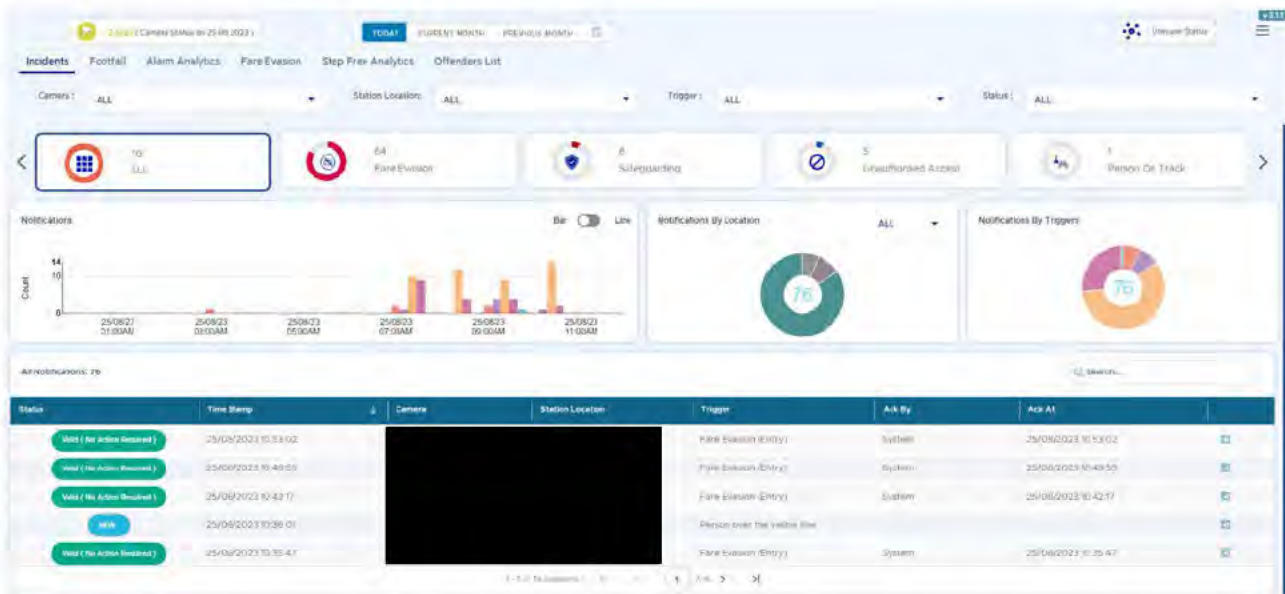


Dashboard

Throughout the PoC, T&D adopted an agile approach to delivery, setting out clear requirements at an early stage and building on those requirements following analysis and importantly feedback from staff. Our key purpose was to deliver a solution built on the requirements and feedback from staff at Willesden Green station. Over time, this involved several changes to the look and feel of the system.

There are two ways staff can access the dashboard, via a desktop or iPad. Both require the user to log-in with their personal credentials. The mobile application includes popup notifications which is standard for many mobile applications. The notifications appear on the screen in real-time, alerting staff to incidents happening in the station.

The user is also presented with various visual aids, which breakdown the type of alerts. Further reports and data are available to examine such as footfall, alarm analytics, data on fare evasion and step free analytics.



The purpose of smart stations is to aid staff by providing additional situational awareness and complement existing applications. With that in mind, we made sure the system did not duplicate existing systems such as the Station Logbook and the Electronic Incident Report Form (EIRF). We recognised that both systems listed, act as the primary source of information relating to incidents that occur in a station.

To ensure the system is easy to use, when an alert is sent, the Supervisor can view the alert details and image(s) provide comments and select one of the following three actions:

- **Valid (Action Required)** - this action is required when the detection model has correctly identified the behaviour, movement or object and it requires the Supervisor to act on the information provided. It's likely the next steps and action taken by the Supervisor will be recorded in either the Logbook or EIRF.
- **Invalid** – this action is required when the detection model has incorrectly detected the behaviour, movement or object defined in our requirements.
- **Valid (No Action Required)** – this action is selected when the detection model has successfully detected the movement, behaviour, or object, however it requires no further action from the Supervisor. An example of this is when it's a member of staff accessing areas which have been included for our unauthorised access use case triggers.

Technical Issues

During the early phases we encountered technical issues which resulted in outages. Examples of these outages are listed below:

There was a power outage following the fire panel testing at Willesden Green station, and this resulted in the switch defaulting to its original settings. This outage identified that the 'Uninterruptable Power Supply' (UPS) was not installed as originally designed and planned. Shortly after the power outage, Telent returned to the station and re-configured the switch and installed the UPS.

Following a few days of online activity, we noticed that planned triggers of the system were not being presented as alerts in the dashboard. After further investigation by the supplier it was confirmed that one of the 'Graphics Processing Units' (GPU) was not working. To fix the issue, our supplier had to deliver a new edge processing device which required Telent to carry out a new install on-site. The new device was successfully installed, and we continued to have two working GPU's as per the design.

Following several days offline, and numerous on-site visits by Telent we established that the sim in the router had reached its data allowance. Once the issue had been identified, Virgin Media O2 quickly changed the allowance to 'unlimited' and we continued to monitor data usage.

In September 2022, we were experiencing numerous daily outages of the dashboard over several weeks. The team carried out extensive analysis and multiple tests on the edge device and network components to identify the root cause. During the investigation, it was established that the encoder was sending the frames (CCTV images) in bursts which was overloading the edge device memory. As the edge device was accepting all the frames and then trying to process them, it limited the edge device's capability to process further streams, reducing the frames per second (FPS) to zero. The system was auto recovering after some duration. It was also identified that around 4 million frames were sent to the edge device in a period of 10 minutes, instead of the expected 330K at the 25 FPS for 24 cameras. This was quickly resolved, and no further outages occurred.

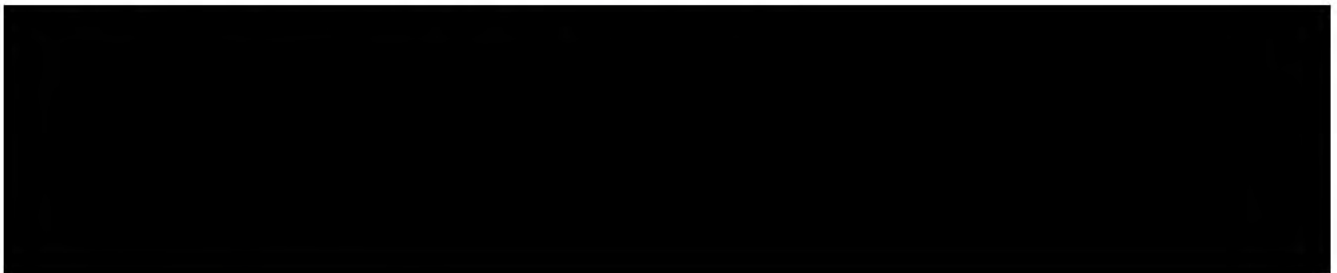
The above outages did highlight our need for improved reporting, enabling the team to identify quickly when the system was offline. This resulted in several reports being developed, for example, camera availability (is the camera online) and a separate report showing the frames per second output.

Simulations

Prior to the launch of each use case trigger, we had to carry out extensive simulations at Willesden Green station. This required detailed planning and support from our operational colleagues. Due to the nature of some of the use case triggers e.g. weapons detection and person on track, we had to conduct the simulations during non-operational hours.

Simulations were required for machine learning e.g. many days at Willesden Green station simulating the exact behaviour we wanted the AI to detect and alert staff on. The more data and examples of the behaviour and movement we wanted detected, improved the AI models, and minimised the risk of alerting staff to false incidents.

Below are 3 stills taken from a simulation for 'Person(s) on floor'. In this example you will see a member of staff walking down the stairs, at first, the system is showing green boxes around each person which is a normal reflection. When our colleague falls to the floor, the system detects the person on the floor and will show a red box, this would then be sent as an alert via the end user dashboard.



Use Case Triggers


In this section, you will see examples from each use case trigger and an overview of the results. The figures presented for each will include data captured during the simulations. For some use cases, the numbers may seem high and above average, this is due to the number of simulations that were required and therefore counted within the system.

Unauthorised Access

At Willesden Green station they have two Boswick Gates in use, prohibiting non-personnel access to platforms 1 and 4.

In scope was the platform end gates. Staff at Willesden Green wanted to be made aware of incidents when someone had opened and crossed the platform end gates.

The unauthorised access use case has proven to be extremely useful to staff, however following feedback from staff, we de-scoped one of the platform gates, as the system was accurately detecting a person i.e. the train operator, every time there was a de-trainment at the station.





A key lesson for unauthorised access, was not recognising the impact and frequency of de-trainments at Willesden Green. When a train terminated at Willesden Green, it was the responsibility of the train operator and station staff to ensure the train is empty before departing the station.

In total, we received slightly over **7000** alerts for unauthorised access. The data shows **38%** of the alerts were linked to the Boswick Gates and **62%** for the end of platform gates.

Safeguarding

During the design and scoping phase, we worked closely with our LU Safeguarding Leads and defined the thresholds and parameters for each trigger. Using the alerts as a preventive measure, allowed staff to act quickly and investigate matters further.

Throughout the PoC we have seen a huge increase in the number of public announcements made by staff, reminding customers to step away from the yellow line. For some triggers, we have defined time parameters which reflect previous behaviour related to suicide attempts on our network.



In total, the system generated over **4500** alerts relating to the safeguarding triggers and **36%** were acknowledged by staff. A breakdown of the alerts is listed below:

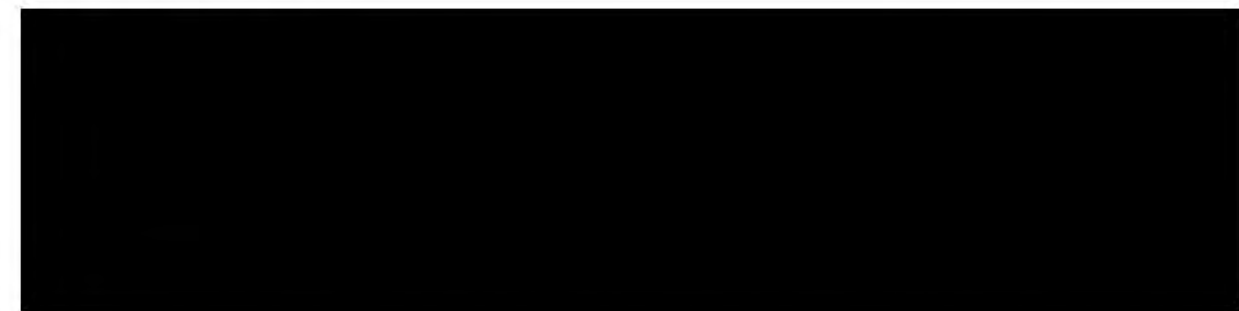
- Person(s) over the yellow line generated **2194** alerts

- Person(s) sat on bench generated **1953** alerts
- Loitering in safeguarding area generated **433** alerts
- People leaning over the edge generated **39** alerts
- Loitering generated **20** alerts

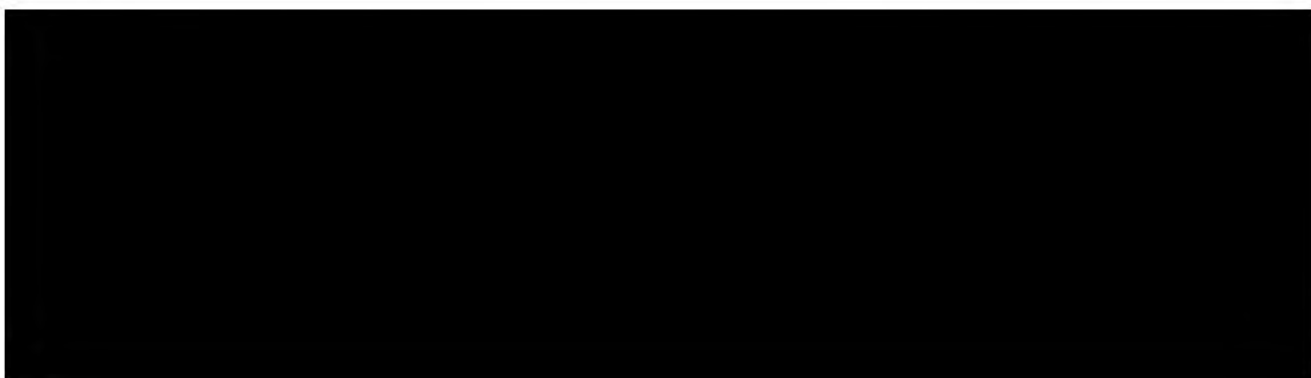
Mobility Assistance

Accessibility is extremely important to TfL, and a key use case trigger was to test if the system can correctly detect wheelchairs. Willesden Green is not a step free access station and with one main staircase leading to the platforms it is not safe for wheelchair users.

Kilburn, which is the next station southbound, is a step free station and the staff at Willesden Green highlighted previous events where customers enter the station not aware that the station does not have a lift. Staff also highlighted events where customers have got off the train at Willesden Green, assuming there would be a lift. In these instances, we wanted to alert staff to when a wheelchair was detected, enabling staff to provide the necessary care and assistance. In total, the system generated **59** alerts for wheelchairs.



We also included two triggers which we believe can showcase how smart technology can assist with the decision making and analysis when it comes to deciding on future stations becoming step free. We were also conscious that Willesden Green has one main staircase leading to Platforms 2 and 3, and the biggest contributor to customer injuries on stairs and escalators is excessive luggage e.g. large suitcases. During the PoC, the system detected **4276** people with prams and **226** for people carrying excessive luggage.

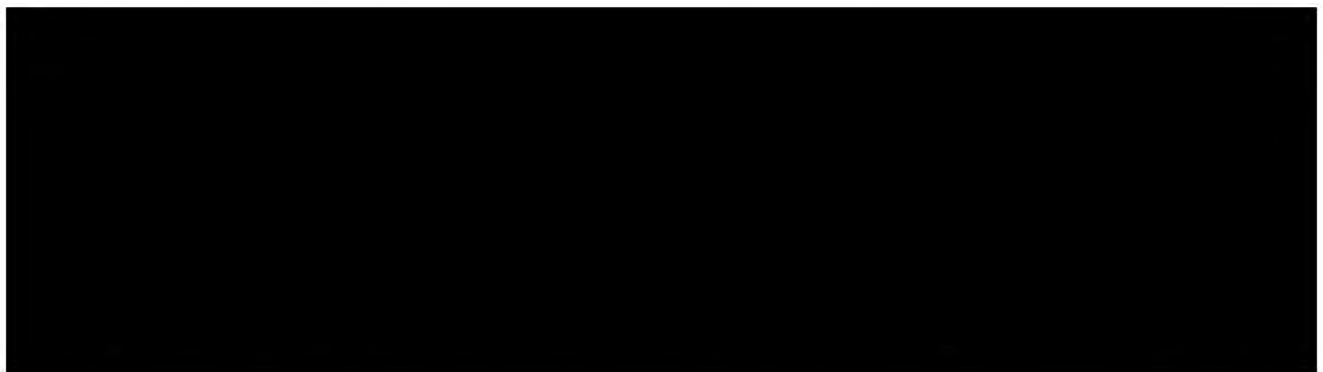


Crime and Anti-Social Behaviour

Initially, we wanted to include acts of aggression, however due to [REDACTED] and the training data needed for the detection model, we were unable to pursue. Although we were unable to successfully detect acts of aggression, we changed the trigger to 'arms raised', which is common behaviour linked to acts of aggression.

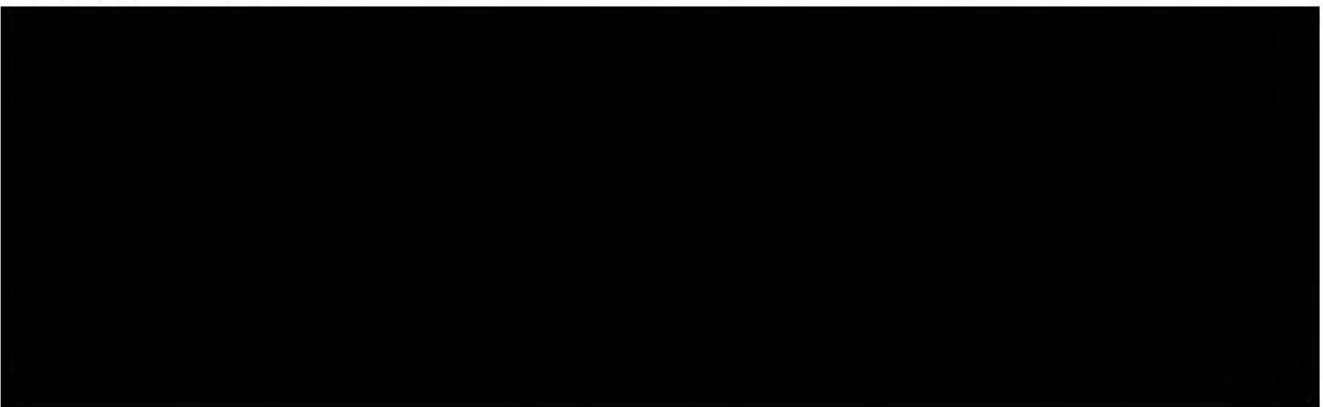
Changing the trigger to arms raised, provided staff with an additional safety precaution e.g. if a member of staff felt threatened and they were unable to use their radio, they could raise their arms which would generate an alert to the Supervisor, who can then raise the alarm or request additional support.

Thankfully, there were no reported workplace violence incidents during the period of the proof of concept at Willesden Green.



Although unfolded bikes and e-scooters were not initially raised as a concern by staff at Willesden Green, we wanted to assess if the smart technology can successfully detect bikes and e-scooters.

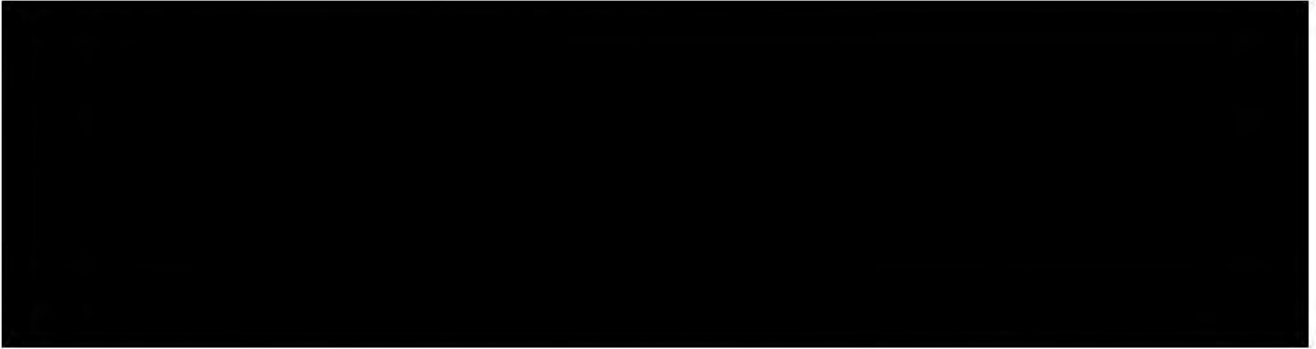
Following several months of staff feedback, testing and analysis of data, we eventually switched off the detection models for both, as the AI could not differentiate between an unfolded bike and normal bike and an e-scooter and children's scooter. This meant that the dashboard generated high numbers of false alerts which did not require the attention of staff.



Working closely with our colleagues in Network Security, we included a weapons detection trigger. This required detailed planning and engagement with our policing partners, the British Transport Police (BTP).

A trained firearms officer was able to help with the simulations and we conducted several tests throughout the station during non-operational hours. Considering the limitations with the quality of images, we were pleased with the results and thankfully, there were no reported alerts or reported incidents for weapons at Willesden Green.

In the images below, you will see the BTP officer holding a machete and handgun in different locations within the station.



In total, the triggers for crime and anti-social behaviour generated **720** alerts and **63%** were acknowledged by staff. A breakdown of the alerts is listed below:

- Unfolded bikes and e-scooters generated **644** alerts
- Arms raised, acts of aggression generated **66** alerts
- Weapons detection generated **6** alerts
- Smoking and vaping generated **4** alerts

Person on Track



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

Unattended Items

A key priority for the PoC was to drive enhancements in safety and security and we recognised the security challenges we have across the network with regards to unattended items.

We did see promising results for this trigger which resulted in staff carrying out further investigations when needed.

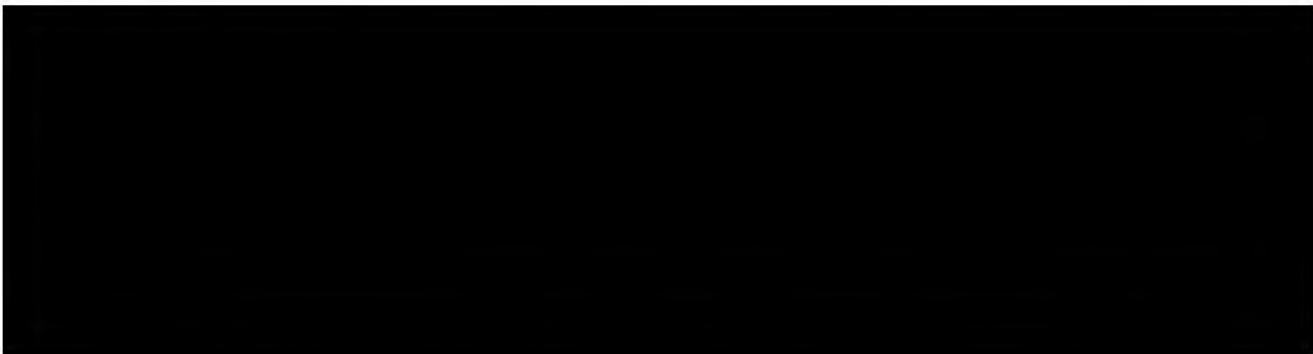


The unattended items use case was active throughout the station and included cameras. Overall, the system generated **76** alerts.

Person on Floor

Another important trigger prioritised by staff at Willesden Green. Throughout the trial the system successfully detected several incidents where customers fell on the floor and required assistance.

We also received several alerts for person on floor, highlighting the challenging behaviour of a small minority group of customers who risk their safety when using our services by sitting on the floor with their legs over the edge of the platform (see middle image for an example).




The system also generated several alerts for rough sleepers and beggars at both entrances to the station. Alerting staff early, enabled them to remotely monitor the situation and provide the necessary care and assistance.






Litter and Debris

Station cleanliness and ambiance is very important, and our first trigger launched was the detection of litter. Although Willesden Green has a regular cleaning schedule, the system generated many alerts which caused frustration amongst staff. The detection model was very accurate, detecting newspapers that customers had left, and paper cups. Following feedback from staff, we disabled the litter alert.



Stranded Customers

Staff at Willesden Green raised the need to be alerted to when customers are stranded, either at the gateline or staircase.   Alerting staff enables them to quickly provide the assistance required. In total, the system generated 127 alerts for stranded customers.



Fare Evasion

The triggers for fare evasion were the last to be deployed and it was agreed at the design phase and with our Trade Union colleagues to not alert station staff due to concerns raised with workplace violence.

During the PoC we made several enhancements to the detection models, this involved watching several hours of CCTV recordings and noting when the AI detection model had missed incidents of fare evasion. Using the missed incidents to machine learn and enhance the models resulted in a huge increase in fare evasion alerts.



The fare evasion use case generated the highest number of alerts with over **26,000** from the 1st of November 2022 to the 30th of September 2023. The triggers for fare evasion included tailgating, jumping over the gate, crawling under the gate, and pushing the gate open.

Initially, we had planned for members of the Revenue Control team to acknowledge the alerts, however due to the large number of daily alerts (in some days over **300**) and the high accuracy in detections, we configured the system to auto-acknowledge the alerts.

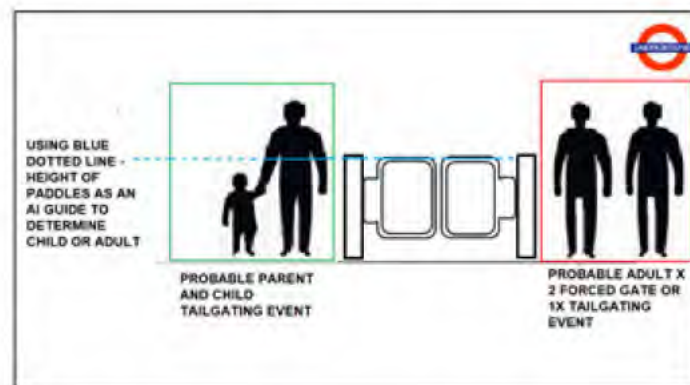
In scope for fare evasion included [redacted] cameras covering [redacted]
[redacted] This resulted in only **17** alerts generated for fare evasion.

For some of the triggers, including fare evasion, we configured the system to provide 3 images of the incident, all taken one second between them. This enabled staff to click through the 3 images and enhance their understanding of the incident that had just occurred. See example below for fare evasion alerts:



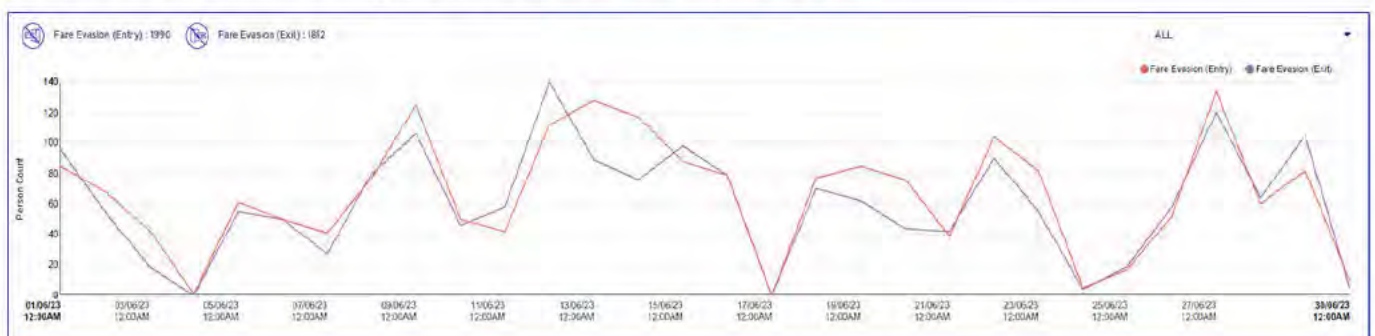
Following the deployment of the fare evasion triggers, we quickly noticed that the system was correctly detecting incidents of tailgating, however, it was obvious that it was travelling adults with children. During school travelling hours, we would see a spike in parent and child tailgating alerts.

To correct this, we acknowledged the alerts that were parent and child tailgating as “Invalid” and configured the detection model to not include any tailgating alerts for people whose height was below the gate. See example below:



An important requirement for the PoC was to visualise all data from the alerts. For each report we had the ability to select time periods e.g. day, month, year. For the fare evasion use case, we trained the AI model to detect if the fare evasion was happening when entering or exiting the station.

Visualising the data in graphs, enabled the team to identify trends in behaviour and highlight periods of travel when fare evasion was frequently occurring at Willesden Green. Below is a monthly view of fare evasion in June 2023.



Usage & Dashboard Alerts

During our early engagement with our TU colleagues, it was agreed that the dashboard would be 'voluntary use' and not mandated.

In total, 25 Customer Service Supervisors and Customer Service Managers used the dashboard, which is extremely encouraging. However, towards the latter months, we did see decline in the number of alerts that had been acknowledged by staff.

The T&D delivery team continued to track usage and responses to the alerts by developing a Microsoft Power BI report which added to the visualisations developed in the Smart Station dashboard.

Throughout the PoC, T&D would frequently engage with staff at Willesden Green and at planned intervals we also sought feedback via online surveys. Continued feedback from staff enabled us to ensure all changes during the PoC benefited the staff. From the feedback gathered we identified 3 types of users:



There were Customer Service Supervisors who were advocates of the system and would use the system for every shift. They valued the alerts and embraced the enhanced situational awareness.



There were Customer Service Supervisors who did not frequently work at Willesden Green station due to changes in local rosters. When this occurred, we encountered experiences when Supervisors had forgotten their login details and how to use the system.



Acknowledging that the agreement to use the dashboard was voluntary, there was a small group of Supervisors who do not want to use the dashboard.

As mentioned previously, we had Nas Ali, who was our operational lead who conducted multiple briefing sessions and was on-site to encourage staff, build momentum and eagerness to use the system. [REDACTED] and

although T&D's delivery team frequently visited the station, [REDACTED] which did result in a decline of usage.

Although the delivery team monitored the average response times to the alerts, we established that some Supervisors were acknowledging alerts hours later and in some cases days later which increased the average response time. To mitigate this from happening, we configured the system to auto-acknowledge alerts that had not been responded to by Supervisors after 1 hour.

In total, Smart Stations generated over **44,000** alerts, **25,000** were auto acknowledged by the system and over **19,000** were sent to Supervisors. Over **60%** of the alerts were acknowledged by staff and on average, staff would receive **55** alerts a day relating to the use cases.

Fare Evasion Phase 2

Towards the end of the initial 6-month trial and following the success of detections relating to fare evasion, T&D presented options to extend the PoC. The options included extending the PoC at Willesden Green or installing the smart technology at either [REDACTED]. The three stations all have high levels of fare evasion and were recommended by our colleagues in the Revenue Control Investigations Team.

At this stage, we had presented updates and findings from Smart Stations to the Pan-TfL Revenue Protection Steering Group (RPSG) which was Chaired by Swian Hayward (Director Security Policing Enforcement). The RPSG, including the Smart Station Steering Group endorsed the extension at Willesden Green.

Extending the PoC at Willesden Green enabled the delivery team to work with the Revenue Control Investigation team and design new ways of working and changes to the system. At this stage, the delivery team worked closely with colleagues from Data Privacy to update the Data Protection Impact Assessment (DPIA), following the approval to remove the anonymity (blurred face) of people committing the crime of evading fare.

The primary focus for phase two was to establish if the smart technology can help identify, report and support with the intervention of persistent fare evaders. Using the data from the dashboard to establish patterns of travel would result in our Revenue Control Inspectors visiting Willesden Green station and stopping the offender.

Following options analysis and successful system testing, we agreed to align ways of working to the current process to how staff report incidents of fare evasion i.e. Workplace Aggression Anti-Social Behaviour (WAASB) application. This meant the success of the process was reliant on Customer Service Assistants (CSA) visibly seeing repeat offenders and reporting them via the WAASB application.

This involved additional face to face briefings with the CSAs who worked at Willesden Green. Our engagement with the CSAs was extremely positive and all voiced their frustration with fare evasion and supported the process we had planned.

Although we received a handful of WAASB entries from CSAs, we did not receive enough from staff to build any cases against repeat offenders. During this phase we would often remind staff of the process and encourage staff to submit their WAASB entries. Feedback from staff suggested this was mainly due to the [REDACTED]

[REDACTED]. At times this was also reflected in the regular reports we would receive showing when the gates at Willesden Green would be open due to staff availability.

The process was successfully tested and although we did not see the results we had hoped, we also ran out of time. Following the analysis, system configuration, staff engagement etc. we quickly approached the final weeks of the six-month extension.

Appendix B includes story boards which provides a step-by-step view on the process for fare evasion.

Key Learnings

There are several learnings from Smart Stations which we must consider if the decision is to extend the smart technology into other stations:

Support & Performance

Overall support was provided by the small T&D delivery team. As this was a PoC, we wanted to ensure we kept costs to a minimum and recognising that the system was voluntary to use. A mailbox was created and included within our briefing sessions and guidance material; we highlighted the need to submit any issues to the Smart Stations mailbox. The mailbox was monitored by the delivery team and would respond promptly.

Performance was monitored by the T&D delivery team. System outages would generate an email notification that would be sent to the delivery team. It was also the T&D delivery team who would conduct tests for each use case, to determine if the AI models were correctly identifying the desired behaviour and movement. This would involve the team conducting simulations on the station to see if the alerts would appear on the dashboard and reviewing recordings from our CCTV to determine if the system had missed any use case incidents.

If the decision is to expand Smart Stations, we must consider the support arrangements, specifically if Smart Stations becomes an essential part of kit. Logging, tracking, and resolving issues will require the input and design from our service teams and supplier.

Networks

[REDACTED] In future, we must consider our network design options to

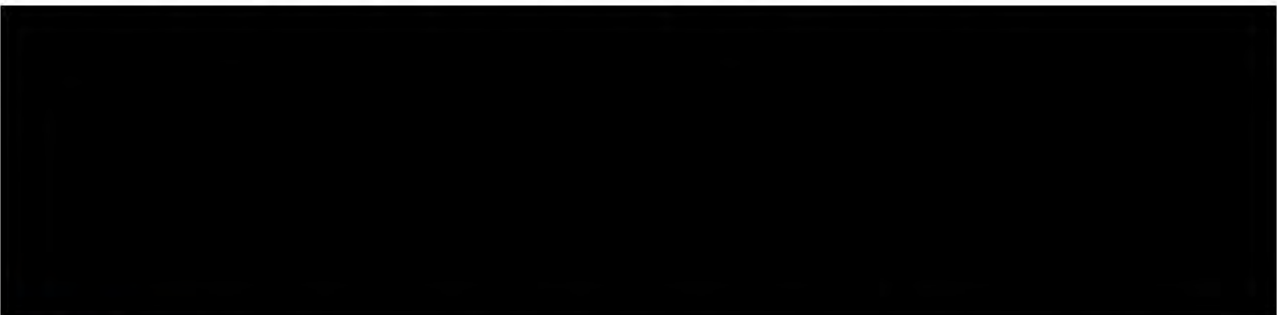
determine the best network design (e.g. LAN vs WLAN). Other considerations when designing our future network include firewalls, remote management capability, server grade edge processors and server grade switchable power supplies. For future phases, the network design will need to adhere to existing project governance and be approved by T&D's Architecture Review Board.

Camera Limitations

We must consider the existing camera infrastructure and the enhanced accuracy of detections when using digital cameras versus analogue cameras. Camera position and the line of sight has a huge impact on the accuracy of detections and although our existing camera positions meet our safety and security standards, we may need to consider adding or moving cameras to increase the accuracy of detections.

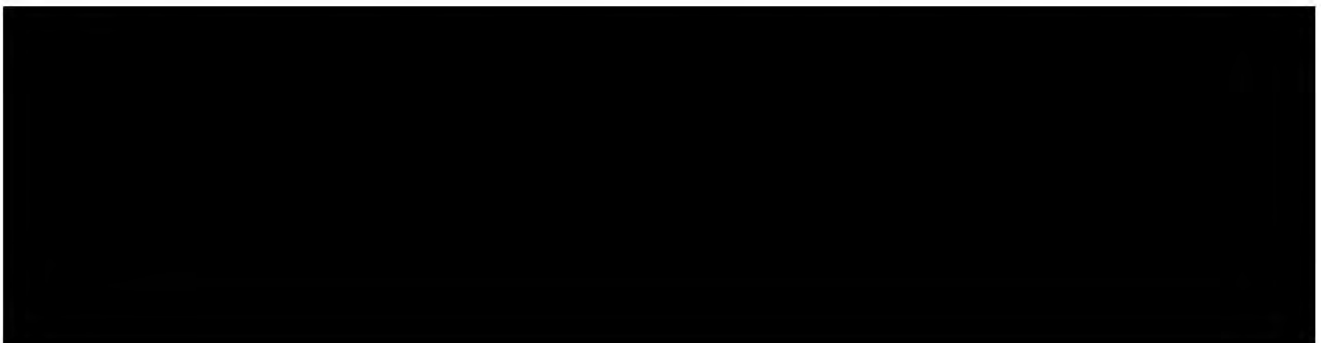
Modern digital cameras are recommended to improve the detection accuracy and the range of accurate detections in each area. For the purposes of the PoC, we **did not move or add** any additional cameras at Willesden Green station. The existing analogue cameras are circa 20 years old and have been in the same position for circa 20 years. This has resulted in several learnings which we must consider if the decision is to expand smart technology into more stations.

For most of our use cases, we had to set regions of interest, this is a clearly defined area which requires the person or object to be present in. Within the region of interest, the trigger is active, if the movement or behaviour occurs outside of the region of interest, it is unlikely to be detected. Regions of interest had to be defined at Willesden Green due to the quality of images from our existing CCTV infrastructure.



Weather

Direct sunlight on the camera resulted in negative detections, and where extreme sunlight caused shadows over the benches, it did impact some use case detection models.



Simulations

Before the deployment of each use case trigger the T&D delivery team conducted extensive simulations at Willesden Green. This required careful planning to ensure all simulations were conducted in a safe environment. As mentioned previously, some simulations e.g. person on track had to be conducted during non-operational hours.

On occasions, it did require the help and support from operational colleagues to notify customers when simulations were happening on the stations. Nas Ali also conducted many simulations at times when the delivery team were unable to visit Willesden Green station.

It is likely that further simulations would be required if smart stations were to be extended into more stations. Conducting simulations will require people to support in the process and it will take time to complete, this must be considered when identifying project roles and responsibilities.

Human Factors

To improve the response rate to alerts, we must consider making Smart Stations an essential part of kit for Station Supervisors. Ensuring all alerts are acknowledged by staff will improve the situational awareness and response to incidents.

This may also result in future integration requirements into other existing applications, removing duplication and driving efficiencies.

Future phases must build on the existing guidance material and adopt a similar engagement model and conduct face to face briefings. This may prove a challenge if the station has high numbers of staff rostered at that station. Implementing Smart Stations at a larger station will take longer and will require more frequent engagement with staff.


Appendix A

Members of the Smart Station Steering Group:

- Nick Allen – Lead Technology Advisory Manager (Chair)
- Jacqueline Attoh-Ammah (Product Manager, Transport Services)
- Ray Adabra – Senior Stations Delivery Manager
- Daniel Howarth - Head of CO Strategic Delivery & Change
- Simon Abernethy – Strategic Delivery & Change Manager
- Christopher Weaver – Area Manager Jubilee North
- Naz Ali – Area Manager (Seven Sisters)
- Trevor Hardy – Head of T&D Portfolio, Infrastructure Transformation
- Alistair Montgomery – Strategic Delivery & Change Manager
- Simon Ponsonby – Customer Service Manager (Willesden Green)
- Kayode Jimoh – Customer Service Manager (Jubilee Line)
- Patricia Horgan - Head of Business Partnering
- Jacqueline Robertson – HR Business Partner
- Simon Guild – Head of Privacy and Data Protection
- Craig Marshall - Privacy Adviser
- Mandy McGregor - Head of Policing and Community Safety, Policing & Community Safety
- Helen Dimond - Customer Experience Lead, Cust Insight Strategy and Experience
- Dipen Patel – Telecoms Engineer
- Fikriye Erdogan - Senior Sourcing Manager Connect, PC - IT
- Daniel Knight - Open Innovation Manager, Strategy & Innovation
- Luke Nicholls – Senior Business Analyst
- Nicola Brady – Senior Operations Policy & Problem-Solving Manager
- Jon Poett – Operational Policy Manager
- Gordon Barnes – Network Security Risk and Planning Manager
- Felicia Harris – SHE Business Partner
- David Kelly – London Underground CCTV Data Manager
- Roberto Rincon – Technology Strategy Manager
- Daniel Middlehurst – Revenue Control Inspector
- Fabia Barrenger – Change Design Lead
- Tilly MeehanGooch - Strategic Delivery & Change Manager

Appendix B

Appendix B includes story boards which provides a step-by-step view on the process for fare evasion.

 The Smart Stations system spots an occurrence of fare evasion and creates a record with 3 CCTV images, which is displayed in the Smart Stations dashboard.



Station staff spot someone fare evading, however they are not known to the staff. Station Staff gets their iPad out to fill in WAASB, but take no other action.



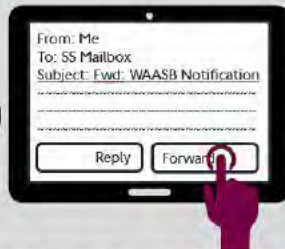
Station staff spot someone fare evading, and they are a known individual to staff, who is one of their 'top 10' repeat offenders. Station Staff gets their iPad out to fill in a WAASB.

THEN



Station staff raise a WAASB for the repeat offender, including key details.

THEN



Station staff receive the WAASB notification email, and forward it onto the Smart Stations Mailbox.

THEN



Revenue Control Inspector opens the Smart Stations mailbox and reviews the forwarded WAASB.

THEN

All Notifications: Search...

Status	Time Stamp	Camera	Station Location	Trigger	Ack By	Ack At
Valid (No Action Required)	10/04/2023 07:26:12			Fare Evasion (Exit)	System	10/04/2023 07:26:12
Valid (No Action Required)	09/04/2023 22:52:40			Fare Evasion (Exit)	System	09/04/2023 22:52:40
Valid (No Action Required)	09/04/2023 22:52:37			Fare Evasion (Exit)	System	09/04/2023 22:52:37

Revenue Control Inspector logs into the Smart Stations dashboard, and filters for fare evasion alerts, these having already been auto validated by the system.

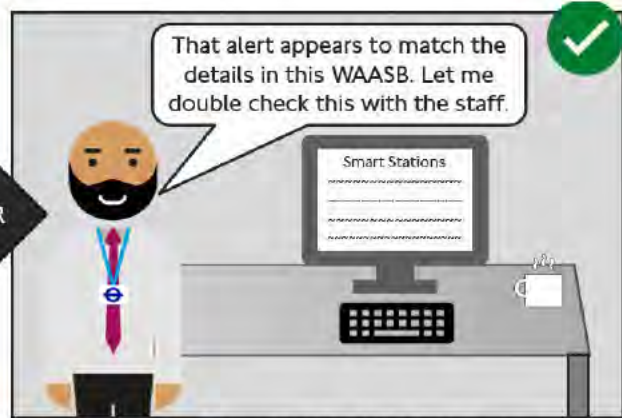
THEN



Revenue Control Inspector looks through the Smart Stations dashboard for a corresponding fare evasion alert that matches the details in the WAASB, but is unable to find an alert.

In this instance, the Revenue Control Inspector reverts to using the legacy CCTV process.

OR



Revenue Control Inspector finds the fare evasion alert in Smart Stations that corresponds with the details shared on the WAASB, and exports the images in order to confirm they are the same individual with the Station Staff that raised the WAASB.

In this instance, the Revenue Control Inspector sends the images to the staff member who raised the WAASB to confirm the images match the offender.

THEN



The member of Station Staff replies to the request to confirm that the images are NOT of the offender they witnessed committing fare evasion.

In this instance, the Revenue Control Inspector receives the confirmation from the staff that this is not the same individual, and at this point looks again at the alerts. If nothing is found, the Revenue Control Inspector reverts to using the legacy CCTV process.

OR



The member of Station Staff replies to the request to confirm that the images ARE of the offender they witnessed committing fare evasion.

In this instance, the Revenue Control Inspector receives the confirmation from the staff that this is the same individual, and proceeds to add the WAASB details to the alert in Smart Stations, mark as repeat offender, and looks for any other alerts.

THEN

Doesn't appear to be any other alerts for this individual, let me move onto the next case.

Smart Stations

Revenue Control Inspector has not seen any other alerts for this fare evader individual, and no further action is taken at this point.

OR

I'm going to link these alerts together, they are of the same individual.

Alert 005
Alert 012
Alert 023

Revenue Control Inspector recognises/notices other alerts of fare evasion for the same individual, and links them together on the Smart Stations dashboard.

THEN

Revenue Control Inspector can export alerts from the Smart Stations dashboard, and these can be fed into the existing repeat offender case building process.

Irregular pattern

18:00
14:00
10:00
6:00

M T W T F S S

Revenue Control Inspector looks at the trends of the linked alerts within Smart Stations, but finds no obvious patterns of behaviour by the offender.

In this instance, the Revenue Control Inspector could contact BTP for any additional information, and if a last known address is found, a request for interview may be sent out.

OR

Regular pattern

8:00
7:30
7:00
6:30

M T W T F S S

Alert 023

Revenue Control Inspector looks at the trends of the linked alerts within Smart Stations, and observes consistent patterns of behaviour by the offender, entering/exiting Willesden Green at similar times every day.

In this instance, the Revenue Control Inspector proceeds to schedule a visit to stop the offender. They could also contact BTP for any additional information they may hold on the offender.

THEN

TfL RESTRICTED

I've got a case here at Willesden Green, could you make a visit? The offender usually passes through Mon-Fri between 07:00-07:30.



Sure!

Revenue Control Inspectors coordinate a team to visit Willesden Green station at a time the offender usually passes through the station.

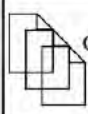
THEN



Excuse me Sir, can I see your ticket please?

Revenue Control Inspectors make a visit to Willesden Green station, and stops the offender for questioning under interview, presenting the evidence from Station Staff and Smart Stations.

THEN



Once the Revenue Control Inspector has interviewed the offender, all the required evidence artefacts will be passed to the Prosecutions Team to start the prosecution processes.

Nick Allen

Lead Technology Advisory Manager

Technology Planning & Management

Technology & Data

Customer Strategy

Transport for London

Email: [REDACTED]@tfl.gov.uk

