Cisco International Limited
Project Name: Network Rail: Managed Stations
Project ID: A31508/ Deal ID: 55477821

Managed Stations Smart Analytics – Service Realisation	NetworkRail

Customer Experience (CX)

Managed Stations

Service Realisation Report

Version 1.0

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About This Document

Authors: [redacted]

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Review

Reviewer's Details	Version No.	Date
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Executive Summary

Priority Use Case Summary

The Managed Stations have a series of challenges and opportunities that have potential to be addressed by analytics, in terms of safety, passenger experience and operational planning.

Through the trial, a certain set of priority use cases were identified that have the greatest value, that analytics can address and where the SiYtE service trial had positive feedback, the most important of which are outlined below:

Trespass and Crime: Detecting trespass on tracks and over walls/fences

Trespass is a significant problem on the railway, including at many stations. In 2022/23, for the railway as a whole, the total delay minutes directly associated with Trespass were 899,522 mins from 21,990 incidents.

This can take the form of trespass on tracks or over walls and fences. Trespass over walls and fences may not cause train delays but it can be a cause of serious injury. At Glasgow ([redacted]: [redacted]), an area of fencing by Platform 1 was monitored. Thankfully, there were no incidents during the trial.

Multiple incidents of trespass over the wall by Platform 1 in Reading were detected, with the data and video evidence used to justify the building of an anti-climb barrier . One instance in particular involved an individual throwing a bicycle over the wall onto the footpath on the other side before climbing over. This could have caused a serious injury to any pedestrians on the other side. For a period between 23rd January and 13th April, there were 7 trespass incidents. Since the anti-climb barrier was completed and there have been no more incidents. The station knew there was a challenge in this location, but had no video evidence of events or a quantified business case as they could not state how many incidents there were ([redacted]: [redacted].

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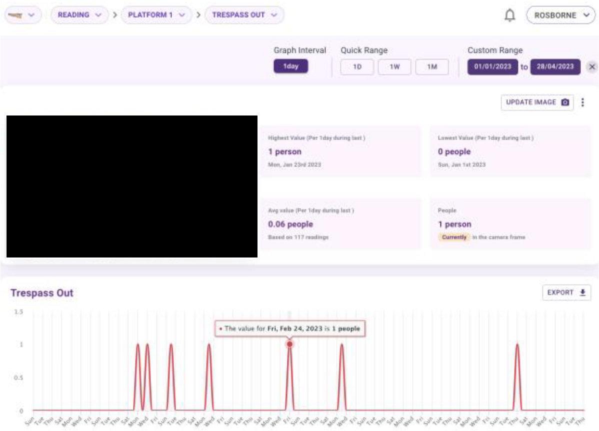


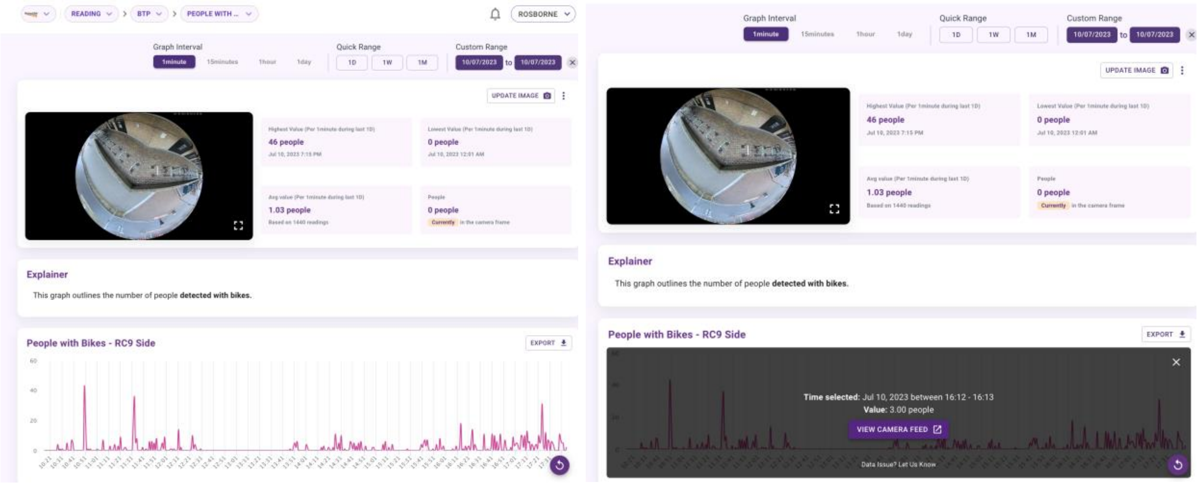
The figure above illustrates the 7 incidents between 23rd January and 13th April.

At other stations where there were cameras with a view of the track, there were no genuine trespass incidents, but the capability was proven by engineering work. However, there was little engagement with stations on trespass hotspots before the placing with cameras. At Leeds and Manchester Piccadilly, there are trespass hotspots that were not monitored.

The ease of linking incidents directly through to camera footage also had excellent feedback. The following is feedback from [redacted] [redacted] of the [redacted] "We *had an affray at the station with football fans and within 30 mins of the arrests we had downloaded the CCTV and identified three other suspects. The system is easy to use and works. Absolutely chuffed with how good this is and looking forward to using it more*."

A secondary crime benefit was discovered at Reading station, working with [redacted] [redacted] of the [redacted] where after engagement with the British Transport Police, cameras and analytics were put in place to address bicycle theft, with Reading station having the highest levels in the UK.

It was established that, whilst analytics could not confidently detect a theft, but they could detect a person with a bike. This enables a BTP constable to click through to the footage just of incidents where people with bikes are detected, rather than search through hours of footage.



Since the cameras were installed in Nov ’22, bike theft has dropped 72%year on year, with 13 people convicted.

Platform Crowding: Detecting crowding situations on platforms and concourses.

Station engagement has shown that this is a very important use case at some stations, such as Leeds and Manchester Piccadilly. The trial has shown how this can be done and justified focus on hotspots going forward at both these stations.

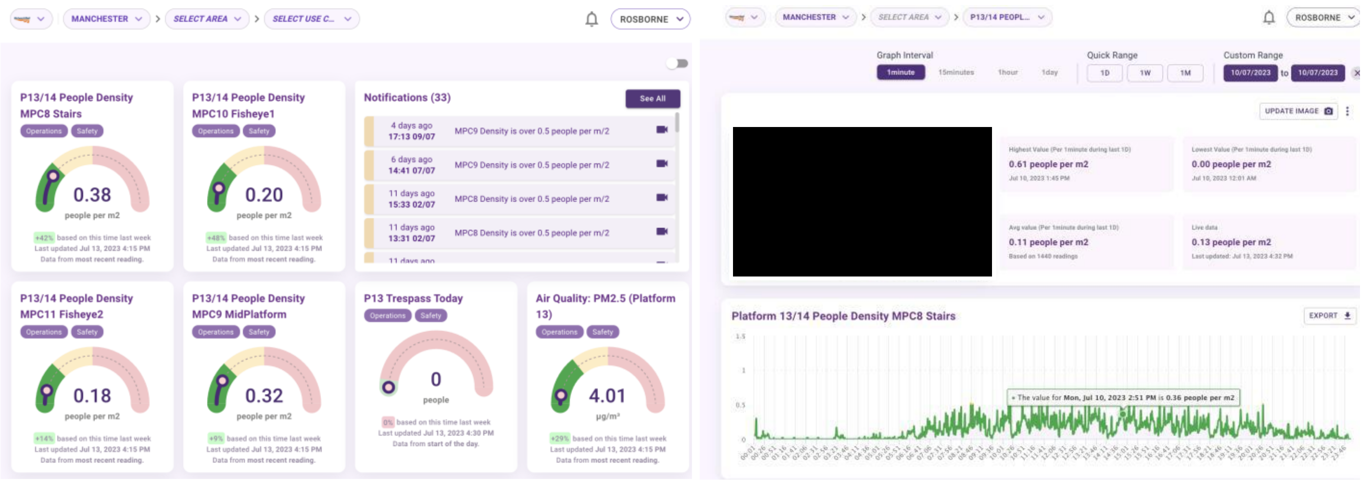
Concourse crowding can lead to safety concerns, but also impacts the flow of people in the station, impacting passenger experience. Detecting crowding enables the alerting of staff to intervene and direct passenger flow. Many stations have crowd control plans in place, but effecting them is reliant on staff being aware of the situation, making accurate decisions on crowding levels and knowing what to do.

It should be noted that this is a concern at some stations such as Glasgow Central, Waterloo and Kings Cross – but not at others such as Euston, Manchester Piccadilly and Euston – where crowding is either not a concern or is already handled very effectively by staff. Concourse crowding proved a challenging use case and there were a lot of lessons learned, which are detailed in the next section.

Platform crowding at key hotspots is very important safety concern, where in extreme cases injury or death could occur if platforms are overcrowded. Analytics can be used to detect crowding situations, but if the added context of train arrival data can be added, staff can be informed when platform crowding has potential to escalate to dangerous levels, enabling them to get to the location in time to manage the situations.

Such hotspots occur in both Leeds and Manchester Piccadilly. In Manchester Piccadilly ([redacted] [redacted]: [redacted]), there are now four cameras in place successfully monitoring platform crowding on Platform

13/14 (pictured below) and work is underway to integrate into Worldline data feeds for train arrival data. In this way, alerts will be sent, not just when a crowding level has been reached, but it will also provide context on how many trains will arrive within the next 10 minutes and, from historical data, what impact they are predicted to have on the crowding level.



Accident Mitigation: Detecting accidents and the causes of accidents (e.g., slippery floors and suitcases on escalators)

Talking with stakeholders we found there are two primary causes of accidents; “sweating” floors (which become slippery with condensation) and over-sized items taken on escalators.

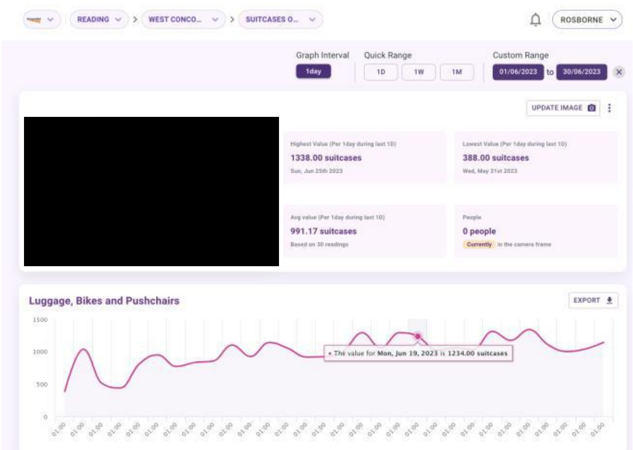
Analytics models have been developed for both of these:

Sweating floors: Reading, Manchester Piccadilly and Leeds stations in particular have confirmed that warning of slippery floor conditions would enable them to a) avert accidents by cleaning floors slippery through condensation.

A model has been built using temperature/humidity sensors that can predict the dew point that causes this issue. Analysis of camera views proved that this was effective, but the frequency of alerts proved challenging for stations. Improved sensor placement would improve accuracy, alerting only when the issue is more serious, which is detailed in the lessons learned.

Detection of luggage, pushchairs and bikes on escalators: Reading station stated that 75% to 80% of accidents happen on escalators, a number that Leeds station confirmed. A major cause of accidents is passengers losing control of suitcases, pushchairs and bicycles – all of which should be taken on the lift.

A computer vision model was built that had a 90% accuracy of detecting luggage and an 88% accuracy of luggage, bikes and pushchairs combined, which is providing the station with trending data on the issue, and also proving it is a very significant issue:



The station has fed back that this data is useful to a) plan and measure the effectiveness of better signage and c) build the business case for mitigating factors such as more lifts.

IoT Sensor Use Cases

Multiple IoT Sensors have been deployed. They are quick to deploy, require no power and are very cost effective. These can be used for a very wide range of use cases on a station. The LoRaWAN radio technology use has very good coverage. One gateway is providing coverage for all of Manchester Piccadilly station, even connecting two temperature sensors in Piccadilly Tower offices.

Temperature, humidity and air quality sensors were deployed at each of the stations. Temperature is useful for informing staff of freezing conditions to alert staff and signage (Manchester Piccadilly and Glasgow Central) and for informing staff when they should take actions such as removing ties and giving out water.

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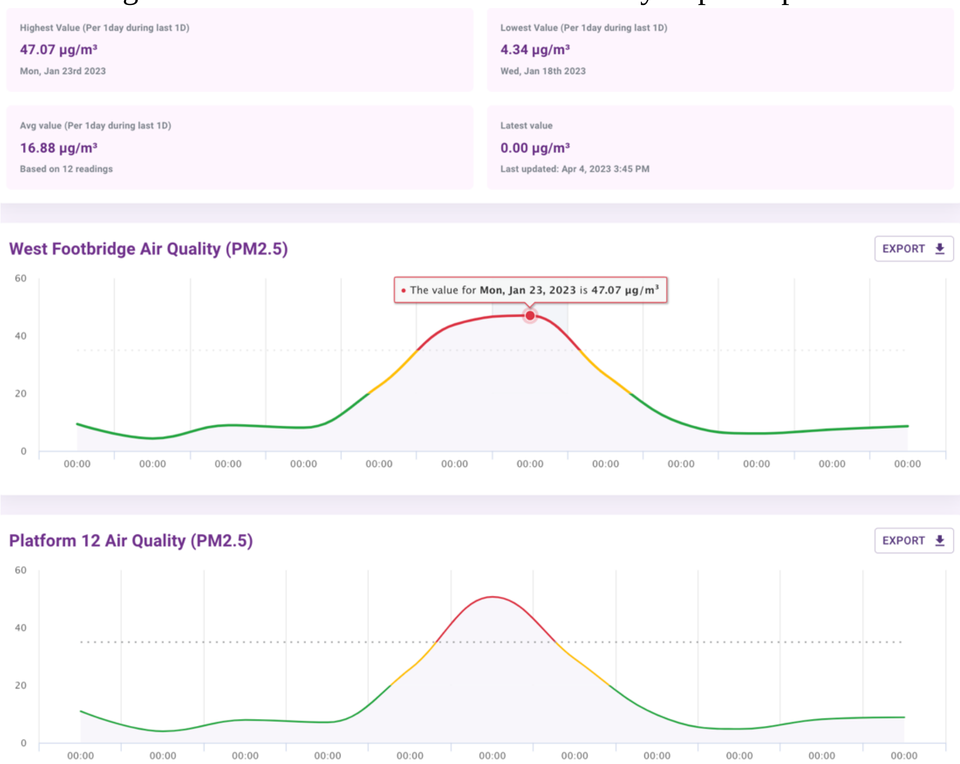
Air quality was of the most interest. Air quality, in particular PM2.5 (solid material under 2.5 microns from diesel fumes), is associated with adverse health effects.

Every station is required by the DfT to perform periodic air quality tests. Feedback from stations was that, with engagement with the DfT, air quality sensors may be able to remove these checks, and they record all of the time and not just at specified times.

At Leeds ([redacted]), there is a particular concern. Diesel trains arrive on Platform 12 and diesel fumes can get trapped on the West Footbridge, where people work all shift in retail outlets. An air curtain is in place to avoid this. There are existing air quality sensors on the other footbridge but the data is not saved, they simply set off an traffic light alert. The station said they did not have a clear view on the actions to take with this.

The SiYtE dashboard is not based just on alerts but can correlate between areas of the station. The below diagram shows air quality compared between the West Footbridge and Platform 12. The comparison gives the intelligence that at times the air curtain actually traps the polluted air and should be turned off.



The use of analytics from IoT sensors has great potential for insights from cost effective sensors, with use cases as diverse as detecting:

- Full bin levels (Manchester Piccadilly station),
- drains about to overflow (Leeds station for drains in the short term car park,
- usage of tanking points (unused tanking points can develop legionnaires disease – source, Leeds Station).
- Escalators failures (from a current clamp sensor), aligned with motor room temperatures ([redacted]

Smart Analytics Trial Approach

The trial was based on developing alerts, trends and insights from analytics of data from CCTV imaging and IOT sensors, with 5 to 7 cameras and IoT sensors installed at each of the following stations: Waterloo, Leeds Central, Glasgow Central, Manchester Piccadilly, Euston and Reading.

In the case of CCTV, Meraki "Smart" cameras are used, which have internal AI capabilities to detect 'objects'. By default, 'objects' are people or vehicles, but cameras can be trained to detect other times of objects such as bikes, pushchairs and luggage (which we have done at Reading station to detect these on the escalator).

The location of these 'objects' along with IOT sensor data is sent to an analytics service that uses this to present this information on a dashboard in terms of a set of use cases such as trespass and people density. This service can then generate alerts (e.g., a person object is on the railway tracks or a gate has been left open), track trends (e.g., air quality on a platform over time) or develop insights (e.g., predict upcoming crowding on platforms).

Whilst Meraki cameras were used in the trial, any "Smart" camera (i.e. one providing object detection capability) could be used, as it is a standard for all such cameras to stream data via "MQTT", like the Meraki cameras used. If cameras are not "smart", video streams can be sent to a server which performs the object detection and then streams the MQTT data of objects identified. This could range from a small edge device such as AWS Panorama or a large server that can take many tens of streams. The SiYtE analytics service can utilise an MQTT data feed.

Similarly, Meraki cameras or IoT sensors could stream their MQTT data to any other analytics service, MQTT being a standard protocol, not just the SiYtE service.

The graphic below demonstrates a sample of the dashboard at Leeds:

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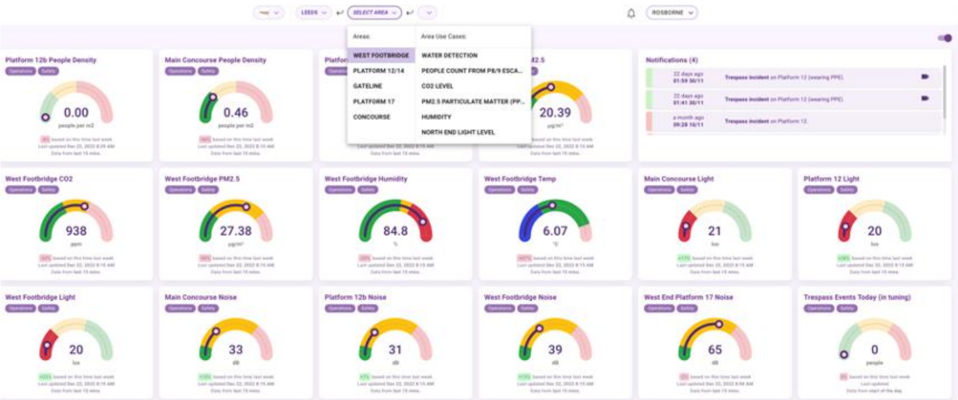
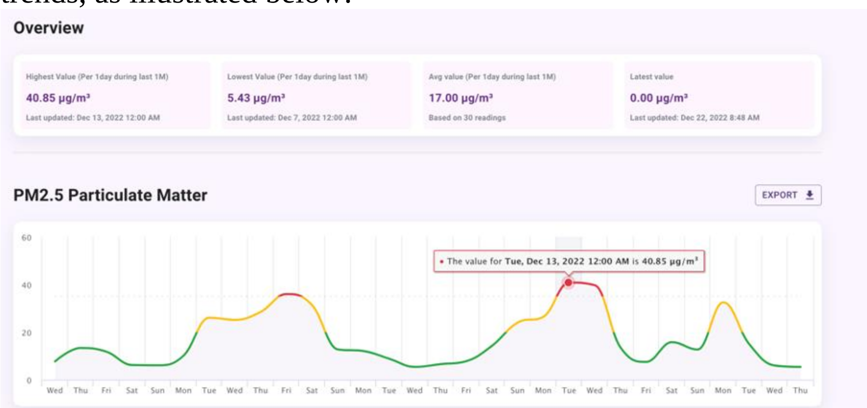
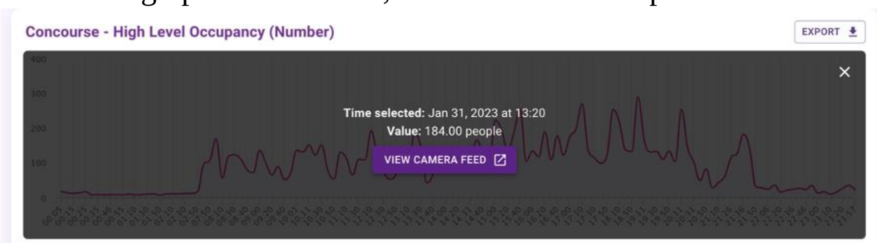


The dashboard covers IoT analytics (e.g. air quality, noise and light) and CCTV (e.g. people density) analytics use cases. The notifications pane at the top right is for alerts, which can also be sent via SMS or email (or through to a station management platform such as MICA):

The station can be split into areas and clicking on any 'widget' displays more detail and historical/searchable trends, as illustrated below:



Where the graph is associated, with a camera the operator can click to view the footage:



A camera access widget can provide a click to view for any camera in an area, or to access a redacted snapshot for those without access to camera feeds.

Open Interfaces

This trial was performed with:

- Meraki Cameras
- Cisco LoRaWAN gateways and range of LoRaWAN sensors, mostly from Netvoxx
- Purple Transform's SiYtE dashboard

However, all interfaces are open:

Cameras

A Smart Camera is one with embedded analytics to detect people or other objects. Smart cameras that support open standards send this information using the protocol MQTT. The SiYtE platform could integrate into any such system, but a) the accuracy of the analytics models would need to be tested and b) some features would be reliant on the ability of the system to provide snapshot images via an API. Other systems on the market such as Hanwha so have this capability.

Support for "non-Smart" cameras would be reliant on a) the ability of the camera or encoder to send a secondary RTSP stream and b) the provision of an edge compute device providing the object detection. The edge compute could be a large server supporting many streams, such as those that will be trialed at Leeds, or small devices, such as AWS Panorama that can process up to 10 streams.

LoRaWAN Sensors and Gateways

The SiYtE platform can support any sensor that provides it information via MQTT (which almost all sensors do). This could be connected via

- LoRaWAN: This is a private network using 868MHz wireless and has very good propagation for small amounts of data. There are a very wide variety of low cost sensors on the market.
- Mobile LTE: This is a mobile operator 4G network using a range of frequencies, but with limited sensors, soon to be replaced by:
- NB-IoT: This is the upcoming standard for mobile IoT networks. The only UK network at present is Vodafone, who claim 98% UK coverage. EE plan to commence rollout in 2023 and O2 in 2024. There is a more limited range of sensors than LoRaWAN but this is growing.

[redacted]

SiYtE Platform

All cameras and devices deployed could be used with another analytics platform other than SiYtE as they all report data in a published and standards-based way (MQTT).

Similarly, SiYtE can integrate with other platforms in terms of injesting data (anything with an API can be integrated with) and providing data. There is already an integration with MPro5 which can subscribe to topics on the Kafka service, which SiYtE uses for data storage and transfer. SiYtE can integrate with other systems also for alerts and workflow. There are already integrations with MICA and MPro5 for alerting, with an integration into Netcool planned.

Service Creation and Adoption

The upcoming trial at Leeds will consider wider deployment of analytics at a single station and will be used the measure the impact of such a deployment.

In the meantime, based on the lessons learned from this Managed Station trial, the best approach for subsequent services in stations would be to focus on hotspots, each with a limited deployment, based on identified station opportunities.

These services could use existing camera feeds, as will be trialled in Leeds, but there are two considerations that might suggest an alternative approach both of which will be incorporated once the full trial has been concluded:

- The complexity and time taken for any integration into Network Rail’s network, especially cyber security review, means that this cannot be done in an agile manner.
- Many use cases require careful camera selection and positioning, for which current fields of view may not be viable.

As such, limited deployment of Smart Cameras:

- Enable a more agile deployment as new cameras can be deployed on the Managed Station WIFI infrastructure. It is recommended, considering the challenges with the public WIFI service, that either a) these cameras are wired or b) they are extended on WIFI using new and dedicated access points.
- Enable camera and location selection to be adapted to the use case (for instance, using fish eye cameras and head counting for crowded areas)

It is recommended that service packages be considered to solve specific station challenges. These are being developed by PTG for their SiYtE service, based on the experience of the trial and upcoming requirements such as platform crowding at Manchester Piccadilly Platform 13/14.

Customer engagement is essential to service adoption. It is essential that presentation and alerting is adapted to and integrated in a station staff processes, in a way that is both useful and simple.

For instance, staff have fed back that if alerts could be sent as a simple text message, with links to footage and context, to the duty manager phone would be the most useful alerting mechanism; and that a weekly/monthly/quarterly report would be useful to prompt station management on investigating trends and insights.

Other Recommendations

The SiYtE dashboard combines vision analytics and IoT analytics use cases, but also have significant potential as a flexible presentation, workflow and alerting capability for integration into other systems, from other analytics services to building systems to SIS boards.

This should be investigated as a consolidated presentation layer and alerting tool for other innovation projects, especially around vision and IoT analytics. There is particular potential for this in control rooms, especially consolidating multiple locations, to alert staff to events and the footage of these events (rather than expect them to watch 100s of CCTV feeds).

It could also be used to measure the effectiveness of responses to events (e.g., Station Management tools such as MICA) by trending response times to alarms (such as average time to respond to emergency calls from help points) and the effectiveness of completion of agreed actions from alarms (e.g., whether cleaning up sweating platforms reduced incidents).

Key Deployment Lessons Learned

Camera Lessons Learned

Smart cameras deployed over WIFI at Marsden station, with a WIFI service designed and dedicated to these fixed assets, have not had an outage since being deployed over 2 years ago. The Smart Cameras deployed over the public Managed Station WIFI service have very frequent outages, with variable delays in traffic, impacting both service and analytics. Delays of several seconds were not unusual during ping tests to the cameras. This is wholly unsuitable for reliable connectivity.

The Managed Stations WIFI network was designed to support passenger mobile devices. It was not surveyed or designed to support operational assets such as cameras. In particular:

- The WIFI coverage is not extensive.
- Each WIFI APs are servicing a very large number of client devices.
- The WIFI service antennas are implemented so as to provide a cone of coverage for people on the ground, but not for cameras deployed at a similar height.
- The cameras were deployed quickly and sometimes had obstructions between camera and AP

It is recommended that, for any production service, either wired connectivity or APs dedicated to the smart cameras are used.

For some use cases where 100% availability is not necessary and where gaps and delays in the MQTT feed do not cause issues, this network could be used. For instance, snapshot-based occupancy would be suitable but trespass would not.

LoRaWAN and IoT Sensor Lessons Learned

The LoRaWAN coverage has proven excellent, but the gateways have had some availability issues. These have been due to firewall issues, where certificate checks have been blocked by the firewall. These were resolved but the slow response of the firewall operator (Lumen) is a challenge for any further issues.

IoT Sensor battery life is dependent on how often is transmits. IoT sensors can be tuned to transmit less often and have longer battery life. Given the limited time nature of the trial, these were not tuned with long battery life in mind and this needs to be considered for any service, with battery changes alongside regular maintenance.

Battery life of 2 to 5 years should be expected.

Appendix 1: Use Case Matrix

The Managed Stations Smart Analytics trial is focused on how vision and IoT analytics can be used and presented across a number of use cases outlined below (including where these are in use):

		Use Case Live at Station					
UC Ref	Use Case	Glasgow Central	Leeds	Manchester Piccadilly	Euston	Reading	Waterloo
SO-SCA-23	People Counting	Y	Y	Y	Y	Y	Y
SO-SCA-07	Face Mask Detection	N/A	N/A	N/A	N/A	N/A	N/A
SO-SCA-16	Passenger Demographics	Y	Y	Y	Y	Y	Y
SO-SCA-21	Heat Maps Videos	Y	Y	Y	Y	Y	Y
SM-IoT-03	Lighting & Light Levels	Y	Y	Y	Y	Y	Y
SM-IoT-04a	Noise Levels	Y	Y	Y	Y	Y	Y
SO-SCA-05	Gate Line Queueing	Y	N	Y	Y	Y	Y
SO-SCA-02	Station Concourse & People Density	Y	Y	Y	Y	Y	Y
SO-SCA-03	Platform Occupancy	Y	Y	N	Y	N	N
SO-SCA-09	Standing in Front of the Yellow Line	Y	N	N	Y	N	N
SO-SCA-01	Escalator Monitoring (Queues and Crowding)	N	Y	N	N	Y	N
SO-SCA-05	Ticket Machine Queue Management	Y	N	Y	N	N	N
SO-SCA-13 (including SO-SCA-08)	Person on Tracks, with PPE Detection	Y	Y	N	Y	N	N
SO-SCA-14	Person in Restricted Area, with PPE Detection	Y	N	N	N	Y	N
SO-SCA-15	Suicide Risk	N	N	N	Camera Failed	N	N
SM-IoT-04b	Noise & Sound Analytics (Fire Alarm)	N/A	N/A	N/A	N/A	N/A	N/A
SO-SCA-24	Notification of Deliveries	N	N	N	N	Y	N
	Notification of Deliveries / Gate Open Alert	N	N	N	N	Y	N
SO-IoT01 & SO-IoT-02	Temperature & Humidity	Y	Y	Y	Y	Y	Y
SM-IoT-05	Indication of Ice & Sweating Platforms	Y	Y	Y	Y	Y	Y
SM-IoT-01 & SM-IoT-03	Station Air Quality	Y	Y	Y	Y	Y	Y
SO-SCA-22	Slips, Trips & Falls	Y	Y	Y	Y	Y	Y
Not Assigned	Luggage Detection	N	N	N	N	Y	N

The Suicide Risk use case is highlighted separately and was only at Euston. The station also made it clear that being a terminus station this was not really a use case of concern for them. The camera failed early on and the decision was made not to replace it.

Appendix 2: Service Creation Commentary

Significant thought has been put in through the trial on how a service might be implemented, valuable and affordable.

Services could be structured on a license fee per camera based on the complexity of use case – with most use cases covered under a "Foundation" license and more complex use cases with an additional "Advanced" license:

- "Foundation" services are those that can be provided using the object detection capabilities on the camera and/or relatively simply analytics analysis in the SiYtE service in the cloud. Examples are people counting and trespass.
- "Advanced" services require custom object detection models or complex analysis in the cloud. Examples are luggage or bike detection and demographics.
- "IoT" services are provided by analysis of IoT sensor data

A challenging aspect of the trial has been that it has been providing pinpoints of data. For instance, we may be able to monitor platform crowding but only at one spot and this location was generally chosen with insufficient stakeholder engagement.

As such, the current dashboards provided are really only useful from a demonstration / proof of capability perspective rather than a dashboard for consistent station use.

To be a valuable service, the one of two approaches needs to be taken:

- Analytics are provided in a more comprehensive fashion on an area of interest – for instance full coverage of a concourse.
- Analytics are focused on a specific hotspot such as platform crowding or trespass

As such, it is judged that the following approaches are the most viable for service development:

Approach 1: Provide analytics on existing Smart Cameras or in parallel with a Smart Camera deployment.

"Smart Cameras" provide object detection and object tracking capability on the camera, removing the need for Edge Compute to deliver any requirement except use cases that a) rely on streaming video such as identifying people running or falling and b) that require a custom model that the camera does not support (for instance Meraki cameras can support custom models such as bike detection, but this will not be the case with all Smart Cameras).

Providing analytics coverage for all cameras in a station would provide the best level of service. However, there would undoubtably be cameras/areas that offer little value – and this approach would also be cost prohibitive.

A variation of this would be analytics on identified cameras that cover areas of interest. In this way a service would be both affordable and valuable. The cameras identified could change as requirements in the station change.

As coverage for analytics will not always match coverage for surveillance, it is expected that some additional cameras would be required. This approach would also require that metadata from the cameras could be streamed to the cloud-based analytics service, which would require cyber security review.

Approach 2: Provide analytics using existing camera feeds from “non-Smart” cameras.

“Non-Smart Cameras” cannot provide object detection capability on the camera. As such, Edge Compute will be required for object detection and object tracking capability, which adds an additional expense.

If the cameras are digital then the feed could be taken direct from the camera; if the cameras are analogue this will require a feed from a digital encoder.

This approach is then similar to **Approach 1**: either providing analytics coverage for all cameras in a station or for identified cameras that cover areas of interest. With digital cameras, making the choice of cameras adaptable over time would be relatively simple. If digital encoders are required to be installed any changes would require physical intervention.

Again, additional cameras may be required for specific use cases and this approach would also require that metadata from the edge compute could be streamed to the cloud-based analytics service, which would require cyber security review.

Approach 3: Provide an analytics service for “hotspots” using dedicated Smart Cameras

This approach is to address an identified challenge through a limited deployment of Smart Cameras with analytics.

Clearly this approach does involve an install cost, but it does have advantages:

- It enables the ideal deployment of cameras specifically for analytics. For instance, with a low canopy, using dome/bullet cameras for platform crowding is a difficult use case to solve as people are obscured behind others impacting object detection. However, fish eye cameras with ‘head-based’ object detection would provide much greater accuracy.

- Cameras can be installed on an 'external' network such as the Managed Stations WIFI or 4G, reducing any cyber security threat or review.

Given these two advantages, this approach might be the best way of addressing specific requirements in an agile manner, especially at large stations.

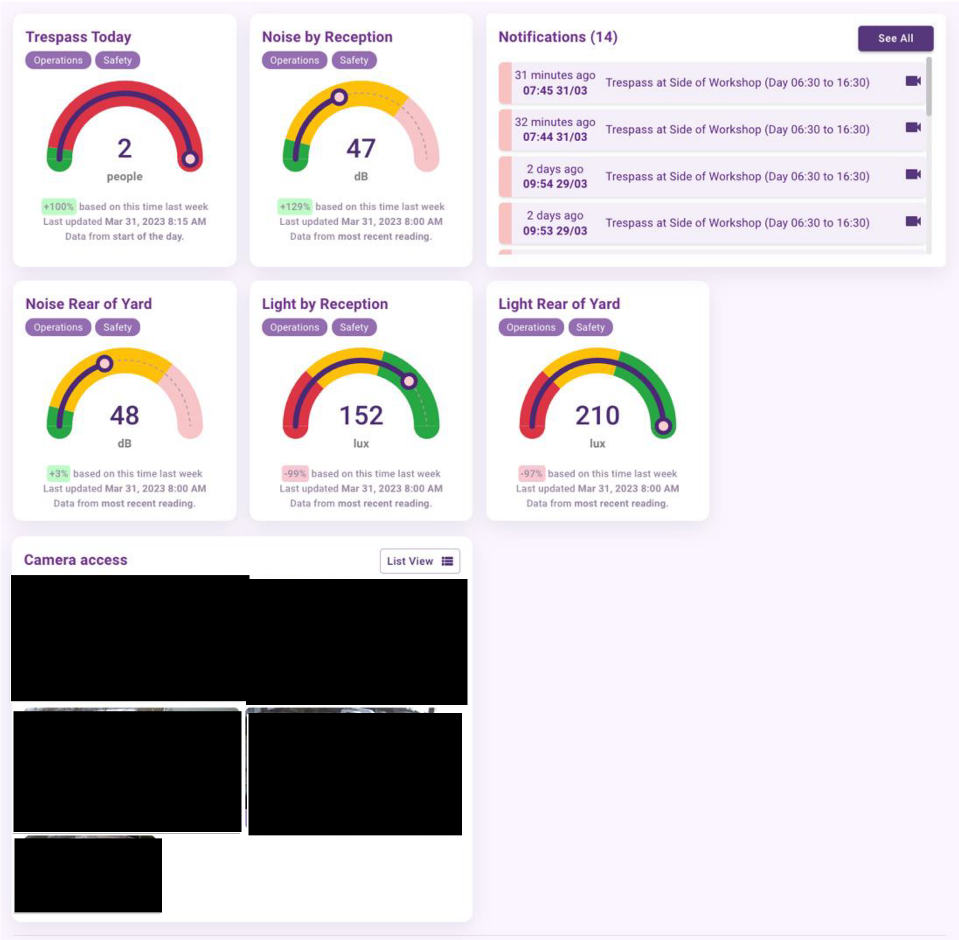
IoT Sensors

Once a LoRaWAN infrastructure is in place, IoT sensors can be rolled out in an agile and low complexity manner. They do not need any interface to Network Rail's network, they are easy to install and they are battery powered.

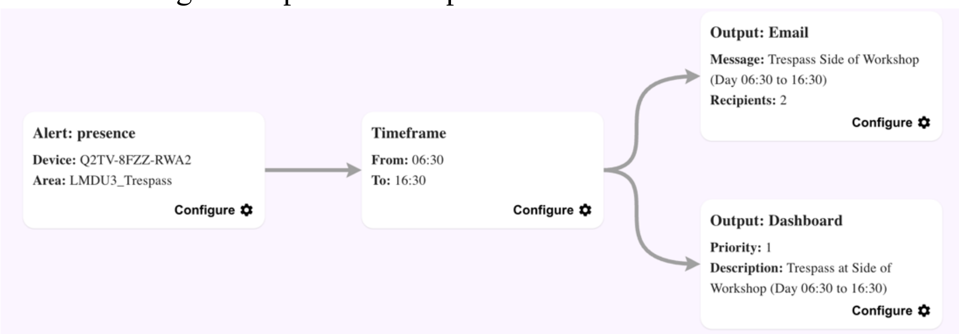
There is significant potential for a sensor 'service' to be deployed in an agile manner, with a LoRaWAN gateway deployed on the Managed Station WIFI or other network and then sensors deployed with a simple license each.

SiYtE Dashboard as a Service and External Integration

The SiYtE Smart Analytics service provides vision and IoT analytics capability but perhaps its greatest asset is as a flexible and agile presentation layer and notification tool, with dashboards built up of programmable and moveable 'widgets':



… and alerting built up from a simple workflow tool:



The service is adaptable to any information source that can be accessed via an API or provide an MQTT data feed.

As such, this service could be used to consolidate other analytics feeds into a single dashboard with other information such as IoT sensors, with the combined data used to develop trends and insights and a single event notification / workflow engine used to communicate events to staff or other systems (such as station management)

This service has not been developed yet, but this is just a matter of defining a commercial construct.

Appendix 3: Benefits and Outcomes Summary

Detail on use case approach, benefits, accuracy and lessons learned are in the appendix, but following is a summary of:

- Capability: The use cases trialled fall into a set of capability categories and have been summarised as such.
- Service: How does this fall into a service category (Foundation, Advanced, IoT)
- Benefits:
  - Financial (representing a reduction in cost and/or an increase in income).
  - Productivity (representing the saving and/or releasing of man-hours or cost avoidance).
  - Compliance (representing reliability, safety, regulatory, continuity of service, avoiding a dis-benefit).
  - Experience (representing staff retention, customer satisfaction, reputation, corporate social responsibility).
- Accuracy & Lessons Learned

Note that a quantified cost/benefit analysis was not within the scope of this trial.

Capability	Service	Benefits (Financial, Productivity, Compliance, Experience)	Accuracy	Lessons Learned
Trespass	Camera: Foundation	Financial: Lost minutes on average during the period 2011-2016* was 380,861. Providing a platform to identify if a trespass is taking place gives the opportunity, not only to intervene in a trespass incident, but also provide an insight into trends to predict when a trespass may occur and predict how many trespasses might occur over a future period (and the cost impact of such). In this way, the justifiable expenditure to mitigate trespasses can be calculated. Reading Station has a wall that can be climbed to leave the station into a public footpath, which is used by fare evaders. The detection of these incidents was used as part of the business case for the anti-climb barrier that is in the process of being built since the use case began. Governance: Trespass is a significant issue for train stations to manage and there is not only a huge financial impact if a member of the public or staff were injured in an incident, but there is also clearly a human cost. Work is underway to present data within the SiYtE dashboard in a way that provides the financial impact of trespass incidents. * https://www.networkrail.co.uk/wp-content/uploads/2019/08/Reducing-the-number-of-Trespass-Incidents-and-their-impact-on-the-railway.pdf	Trespass detection increased to 98% accuracy of True Positives compared as against False Alerts during the duration of the trial	Camera position is important to have a clear unobstructed view, as is consideration of the distance (70 PPM is needed for the camera, which can be planned with camera planning tools such as IPVM)
Area Occupancy & Dwell Times	Camera: Foundation	Governance: Data driven crowd control (specific stations only) on concourses, Event alerting of platform crowding (especially if predictive)	Concourse/ Platform 85%	Large area crowding has

		Experience: Better planning of crowd flow, Alerting on queueing levels	to 95% (see limits)	limitations on existing cameras
People Counting	Camera: Foundation	Financial: Business case development on usage of areas such as ticket offices. Productivity Improved effectiveness of staff by placement based on area usage. Governance: Alerting for unauthorised access	Car park, ticket office: 80% - 95% Gate-lines: 50% - 60%	Cannot be used where people crowd or lack direction (e.g. gate-lines)
Accidents: Slips, Trips and Falls	Camera: Advanced	Productivity: If accidents, can be detected and logged, then they can be tagged for future accident investigation, saving staff time. Financial/Experience/Governance: If accidents are detected, staff can be alerted to an accident hotspot to address causes before someone suffers an injury (and potential compensation case).	Not proven	Model is complex requiring edge compute. A person down model on camera would be simpler
Accidents: Luggage, Pushchair and Bikes Detection	Camera: Advanced	Experience/Governance: Reporting allows the station to determine if changes in signage, etc has a positive effect on passenger behaviour in this regard, allowing the station to determine the best mitigation technique and reduce accidents. Productivity: This use case also enables the station to build the data set required to justify more lifts.	92% for Luggage; 90% for Luggage, Pushchairs and Bikes combined	Requires a smart camera that can be retrained or edge compute
Accidents: Temperature & Humidity: Indication of Ice and Sweating Platforms	IoT	Experience / Governance: If sweating floors can be predicted, this means the station can take mitigating actions such as cleaning the floor and putting out mats, reducing the risk of accidents	Proven accurate but requires tuning to alert only on 'significant condensation'	Two sensors required for accurate prediction
Heat Maps / Passenger Flow	Camera: Foundation	Productivity: This enables station staff to better plan staff effectiveness and understand people flow in the station.	Embedded	N/A
Demographics	Camera: Advanced	Experience: Potentially the customer emotion metric could be used to measure satisfaction Financial: This data could be utilised to maximum advertising and retail revenue. However, this was hard to quantify as NR Properties were never successfully engaged.	Dependent on image quality. Provided by AWS Rekognition	Better engagement with NR Properties is required Requires a very clear view of faces
Notification of Deliveries	IoT + Camera: Foundation	Productivity: This saves time for staff checking that the gate has been left open. Governance: This ensures that the gate is not left open and used for unauthorised entry/exit. An added benefit was identification the causation of damage.	Sensor is 100% accurate. Camera accuracy depends on position (85% accuracy on current position)	Vehicle detection works much better with a side on view

Air Quality	IoT	Experience: Knowledge of safe air quality is a first step in addressing it's dangers for staff working in an area for an extended period, particularly those with breathing conditions. Financial: This constant monitoring would offset the cost of periodic air quality reporting	Embedded (published by IoT sensor manufacturers)	Tuning of amount of data and interval essential for battery life
Lighting Levels	IoT or Camera: Foundation	Governance: This can be used to report on safe lighting levels (o=for which there are NR standards) and understand when lighting is insufficent or has failed.	Embedded (published by IoT sensor manufacturers)	NR standards are at ground level. If using cameras in-built sensors these are higher up
Noise Levels	IoT or Camera: Foundation	Governance: This can be used to report on noise levels and provide an audit trail for complaints about noise.	Embedded (published by IoT sensor manufacturers)	IoT sensors provide only periodic readings (does not suit all use cases)

Overall, the following are benefits for station teams:

- Increased visibility of, and responsiveness to, safety incidents
- Increase visibility of, and responsiveness to, crowding, such as on platforms and concourses
- Increase visibility of, and responsiveness to, factors that impact passenger experience such as queue times and air quality
- Better monitoring of station environment and assets
- Simpler and automated reporting
- Reduction of routine tasks such as inspections.
- Capture of information to inform future station planning and operation to improve efficiency.

In addition, there may be benefits if accompanied for organisational change for

- A centralised team can more effectively manage a larger number of stations through monitoring live station status, intervening where appropriate – and understanding trends and insights across stations to improve operational planning.
- Increased opportunities for centralised, possibly route-based, station management and control.

Appendix 4: Assets and Design

Camera, IoT Sensor Asset List

At each of the Managed Stations as part of the trial, between five and seven Meraki Smart CCTV Cameras and LoRaWAN IoT sensors were deployed. The following provides an asset lift of cameras and IoT Sensors.

Station	Camera Name/Location	IOT Sensor Function	Sensor Location
Leeds	LC1 - Gateline	Temperature and Humidity	West Foot Bridge
	LC2 - Concourse	Air Quality	West Foot Bridge Lift Shaft
	LC3 - Escalator	Air Quality	Platform 12/15
	LC4 - Platform 12b	Noise (dB) Levels	West End of Platform 17
	LC5 - End Platform 12b		
	LC6 - Platform 12c		
	LC7-WestFootBridge		
	LC8 - GatelineFishEye		
Manchester Piccadilly	MPC1 - Ticket Office	Temperature and Humidity	Footbridge over Platform 8/9
	MPC2 - Ticket Machines	Temperature and Humidity	Platform 10
	MPC3 - Concourse 1	Air Quality	Platform 3
	MPC4 - Burger King	Air Quality	Platform 13
	MPC5 - Passenger Assist	Noise (dB) Levels	Platform 13
	MPC6 - Gateline	Noise (dB) Levels	Main Concourse above USB charging station
	MPC7 - Concourse 2		
Waterloo	WC1 - Int Concourse 1	Temperature and Humidity	Main Concourse Power Pole
	WC2 - Int Concourse 2	Air Quality	Platform 11/12
	WC3 - Int Gateline 1	Noise (dB) Levels	Main Concourse Power Pole
	WC4 - Int Gateline 2	Door Sensor	Glass doors by McDonald's – Exit 2
	WC5 - P12-18 Concourse		
	WC6 - Exit 2 Concourse		
	WC7 - Exit2 Underground		
Reading	RC1 - West Gateline	LoRaWAN Gateway	Platform 7
	RC2 - West Concourse	Temperature and Humidity	Transfer Deck
	RC3 - South Delivery Ramp	Air Quality	Escalator Area Platform 10/11
	RC4 - Platform 1 Trespass	Water Detection	Transfer Deck
	RC5 - Transfer Deck	Water Detection	Transfer Deck
	RC6 - West Concourse Main Escalator	Gate/Door Sensor	South Delivery Ramp
	RC7-BikeRackWHSmiths		
	RC8-BikeRackCorner		
	RC9-BileRackSide		
Glasgow Central	GCC1 - NCP Entrance	Temperature and Humidity	Platform 1/2
	GCC2 - Choke Point	Temperature and Humidity	Main Concourse
	GCC3 - Concourse	Air Quality	Platform 9/10
	GCC4 - P5/6 Gateline	Air Quality	Main Concourse
	GCC5 - Platfom 5/6	Noise (dB) Levels	Platform 9/10
	GCC6 - Gordon Street	Noise (dB) Levels	Main Concourse
	GCC7 - End of Platform 2		
Euston	EC1 - Main Concourse	LoRaWAN Gateway	Platform 03
	EC2 - High Level	Temperature and Humidity	Platform 09
	EC3 - Pinch Point	Air Quality	Platform 03
	EC4 - P2/3 Gateline	Air Quality	Platform 09
	EC5 - P8/11 Gateline	Noise (dB) Levels	Platform 09
	EC6 - Platform 9	Water Detection	Platform 09
	EC7 - End Platform Trespass		

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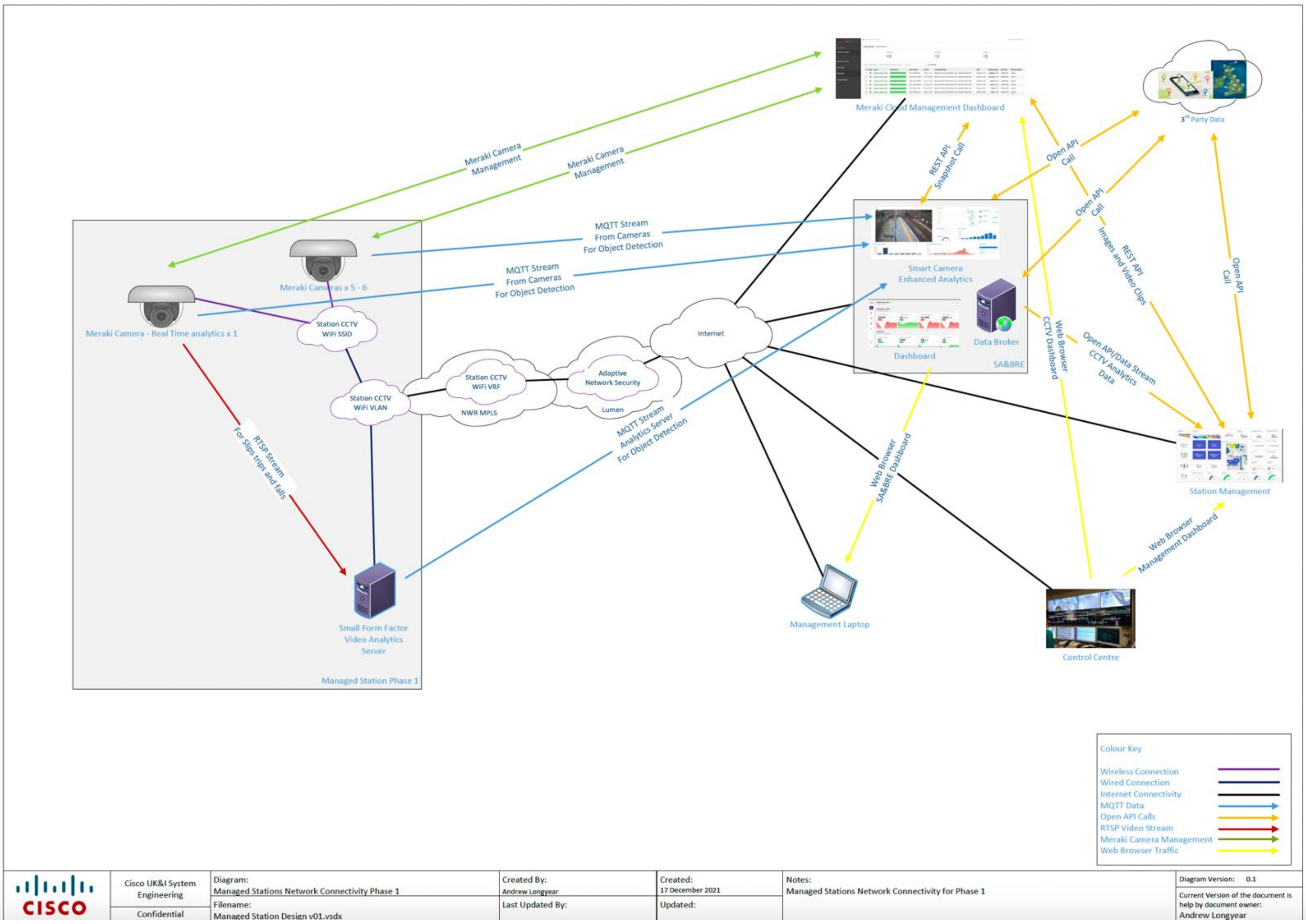
Project ID: A31508/ Deal ID: 55477821

Managed Stations Smart Analytics – Service Realisation	NetworkRail

Smart Camera Vision Analytics Design

The below diagram illustrates the data flows for the Smart Camera deployment.



The Smart Cameras initially installed were all Cisco Meraki MV72X dome cameras. Later Meraki MV93 fish-eye cameras were added for the "bike theft" use case at Reading station.

Meraki smart cameras are cloud-managed, so cloud-access is required for 'management' traffic. Video is stored encrypted locally on the camera. Video can be accessed via the Meraki dashboard or Meraki app and is streamed via a "Cloud Proxy" hosted by the Meraki cloud.

The Meraki Smart Cameras perform "object detection" and provide metadata on objects (an object ID to track the object, a confidence level and location co-ordinates) via an MQTT data feed. Objects by default are people or vehicles, but the cameras can also be trained to detect other objects such as luggage, pushchairs or bikes.

All Smart Cameras were deployed on the Managed Stations Public WIFI network, on a separate SSID created for the Smart Analytics service.

Camera Deployment Lessons Learned

This is a key area of lessons learned. Smart cameras deployed over WIFI at Marsden station, with a WIFI service designed and dedicated to these fixed assets, have not had an outage since being deployed over 2 years ago, but the Smart Cameras deployed over the public Managed Station WIFI service have very frequent outages.

Also, there are a lot of variable delays in traffic – which causes issues in accessing video but also causes challenges with the MQTT data stream. Delays of several seconds were not unusual during ping tests to the cameras. This is wholly unsuitable for reliable connectivity.

The Managed Stations WIFI network was designed to support passenger mobile devices. It was not surveyed or designed to support operational assets such as cameras. In particular:

- The WIFI coverage is not extensive with a very low density of APs for the number of devices they need to service.
- The WIFI APs are also servicing a very large number of client devices each, which even if not connected were beaconing for service. This congestion reduces the opportunity for cameras to transmit/receive.
- The WIFI service antennas are implemented so as to provide a cone of coverage for people on the ground. Cameras deployed at a similar height to the APs had weaker signal than devices on the ground.
- The cameras were deployed quickly and sometimes had obstructions between camera and AP
- The WIFI service had configuration aspects that were sub-optimal for this use:
    - Large channel width (smaller channel wide of 20MHz would provide more channels for connectivity for so many devices)
    - Channel hopping, where AP need to perform a channel availability to check before moving channels (during which time clients are not served)

It is recommended that, for any production service, either wired connectivity or APs dedicated to the smart cameras are used.

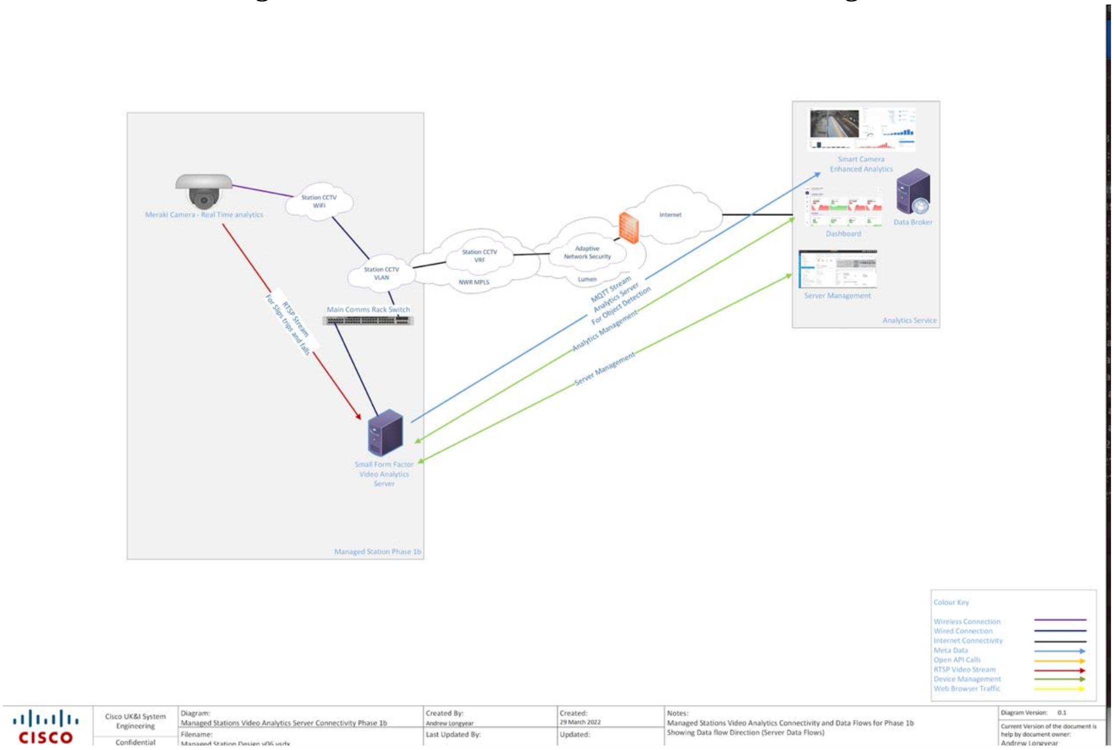
For some use cases where 100% availability is not necessary and where gaps and delays in the MQTT feed do not cause issues, this network could be used. For instance, snapshot-based occupancy would be suitable but trespass would not.

LoRaWAN and IoT Sensor Deployment

The majority of IoT sensors deployed utilise the LoRaWAN protocol and a single sensor in Waterloo station used BLE (Bluetooth) to connect these sensors.

LoRaWAN is a long-range low bandwidth, low power solution that is ideal for battery powered IoT sensors. Each of the 6 stations were surveyed for LoRaWAN. It was determined that a single LoRaWAN gateway would cover the majority of each of these very large stations, but full coverage would require at least two gateways in each station.

A single LoRaWAN gateway was deployed in each station and sensors deployed within its coverage area. The LoRaWAN gateway for each station was deployed using a wired connection on the Managed Station WIFI network, using the same VLAN as for CCTV. The following schematic describes the data flows:



At Waterloo, one sensor was deployed on the McDonalds exit downstairs from the main concourse with the LoRaWAN gateway and out of range. For this a Meraki sensor was used, using BLE connectivity from a local camera. Unfortunately, the camera was deployed behind a metal plate and cannot reliably connect to the WIFI.

All LoRaWAN IoT Sensors are managed and aggregated by an IoT management system (Actility Thingpark)

All the sensors are battery powered and can support multi-year battery life.

IoT Sensor Deployment Lessons Learned

The LoRaWAN coverage has proven excellent, but the gateways have had some availability issues. These have been due to firewall issues, where certificate checks have been blocked by the firewall. These were resolved but the slow response of the firewall operator (Lumen) is a challenge for any further issues.

IoT Sensor battery life is dependent on how often is transmits. IoT sensors can be tuned to transmit less often and have longer battery life. Given the limited time nature of the trial, these were not tuned with long battery life in mind.

For the air quality sensors in particular, in retrospect these should have been tuned to only send the data we require rather than all readings and the frequency should be reduced, as these batteries have lasted less than a year.

SiYtE Smart Analytics Service

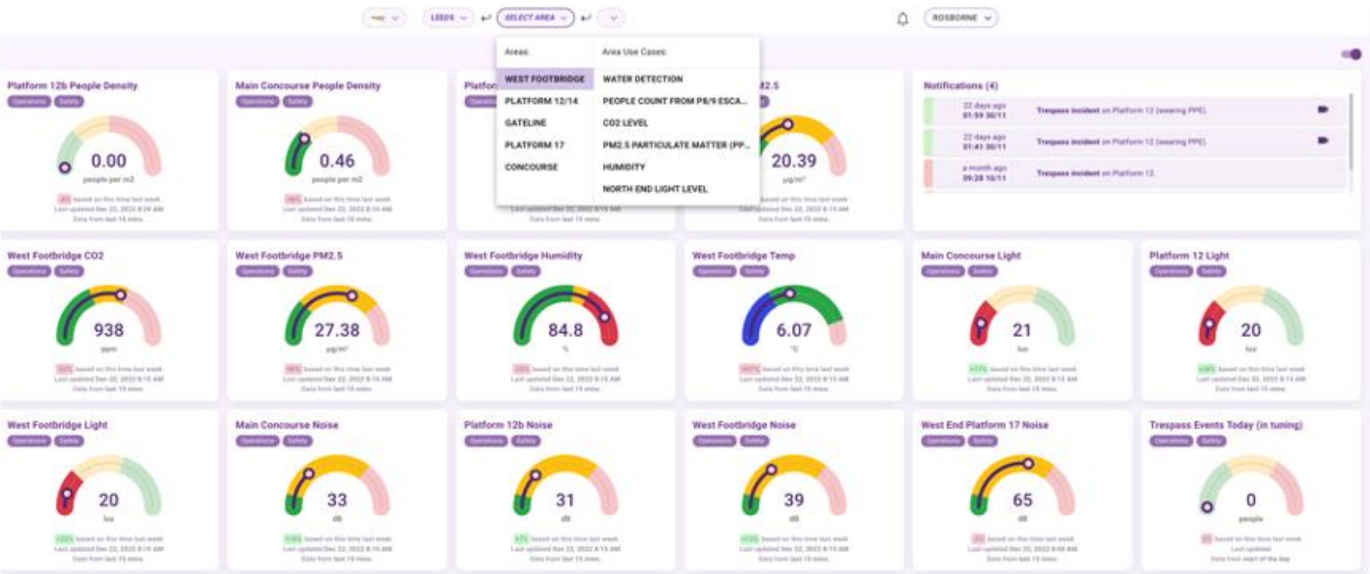
The MQTT data feed from the Smart Cameras and IoT sensors is sent to an MQTT broker hosted by the SiYtE Smart Analytics services. In the above diagram, this is labelled “Smart Camera Enhanced Analytics”.

In effect, the Smart Cameras are used as sensors detecting objects. The SiYtE Smart Analytics service consumes information from “sensors”, which could be IoT Sensors or Smart Cameras, and uses this information to:

- Display real time and historical information on dashboards adapted to stakeholder needs
- Generate alerts (e.g., a person object is on the railway tracks or a gate has been left open)
- Track trends (e.g., air quality on a platform over time) or
- Develop insights (e.g., predictive alerts for crowding on platforms).

The graphic below demonstrates a sample of the dashboard at Leeds. As you can see this covers IoT (e.g., noise and light levels) and CCTV (e.g., people density) analytics use cases.

The notifications pane at the top right is for alerts, which can also be sent via SMS or email (or through to a station management platform such as MICA, an integration being current developed):



The station can be split into areas and you can click on any 'widget' to see more detail (e.g., Particulate Matter from diesel fumes on the Leeds footbridge, below):

Where the graph is associated with a camera, the operator can click to view the footage:

A camera access widget can also provide a click to view for any camera in an area, or to access a redacted snapshot for those without access to camera feeds.

The station can be split into areas and you can click on any 'widget' to see more detail (e.g., Particulate Matter from diesel fumes on the Leeds footbridge, below):

Integration into Existing Systems

There are three approaches to integrating into existing CCTV systems:

- Renewal: Combine the roll out of analytics capabilities with the renewal of aging CCTV systems with newer smart cameras

- Integration: Stream existing feeds to local compute devices for analytics analysis, requiring the ability for cameras/encoders/VSS to generate a secondary stream or integrate into existing "smart camera" systems that can deliver object detection capabilities. Both of these are out of scope of this trial.
- Overlay: Deploy dedicated analytics cameras for specific use cases, following the approach of this trial. This does entail the challenge of extra cabling requirements or an overlay wireless network, or limited use of the managed public WIFI service.

Through the trial, it has been judged that with the need for agility, the latter approach has probably the most value, with cameras deployed on off-net from the Network Rail network (4G or the Managed Station WIFI network, preferably wired) for agility.

IOT sensors could be deployed on an existing LoRaWAN network if it exists. Existing monitoring systems could be accessed for data collection via APIs (if they exist) and existing sensors could be accessed via adapters. Both of these are out of scope of this trial.

Integration with existing station systems such as Station Management Systems is out of scope of this project, but this will be an essential part of some deployments, so the methodology for integration is outlined below:

- The SiYtE service provides alerts via an API to the external systems, which can then process these alerts via a workflow configured on this system.
- Optionally, the SiYtE service consumes data streams from the external system that can be used for analysis and insights.

To date, two such integrations have been implemented: to the MPro5 application and Telent's MICA platform.

Appendix 5: Use Case Approach, Benefits and Lessons Learned

Use cases fall into categories which have been documented together:

Capability 1: Trespass

SO-SCA-13 & SO-SCA-08	Person on Tracks, with PPE Detection
SO-SCA-14	Person in Restricted Area

Use Case Description

There are two approaches for determining when a person or people are deemed to be trespassing.

Approach 1: Area detection:

Utilising the person detection capabilities of the camera, the SiYtE service works out if a person is in a specific area drawn within the SiYtE tool. If a train is detected in that area, no notification is sent (as the person will either be boarding a train or a reflection in the train). If PPE is detected, a notification is sent but this context is added.

The notification will be sent through to the SiYtE Dashboard and can also be sent as a text message or email. This approach is deployed at Euston, Glasgow, Leeds stations to detect whether an individual is in a restricted area (on the train tracks).

Approach 2: Tripwire detection:

Utilising the person detection capabilities of the camera, the SiYtE service works out if a person has crossed over a virtual tripwire drawn within an area on the SiYtE tool. This approach is deployed at Reading Station to detect fare evaders climbing a wall out of the station into the general public area. The main concern is not fare evasion but the risk of injury.

Use Case Approach

Following are examples of notifications sent to the SiYtE dashboard when a trespass event is detected and with the context of whether PPE was detected:

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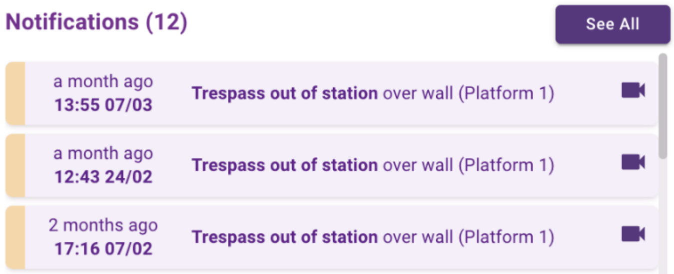
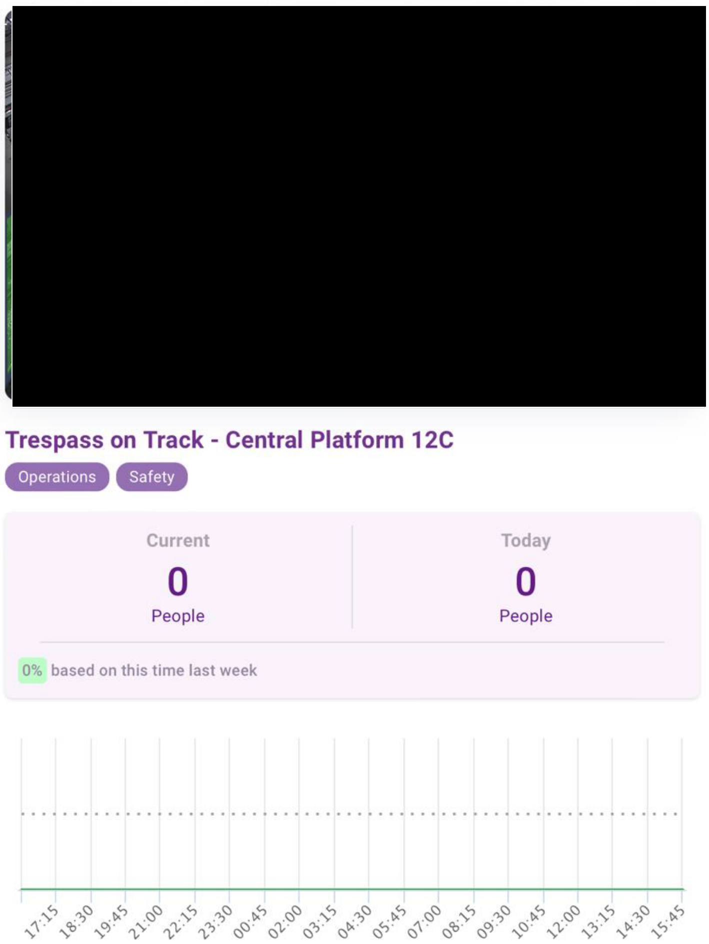


In the dashboard, the area of trespass is clearly shown on the dashboard to show station staff what the monitored area is:



Feedback and Benefits

Financial: Lost minutes on average during the period 2011-2016* was 380,861. Providing a platform to identify if a trespass is taking place gives the opportunity, not only to intervene in a trespass incident, but also provide an insight into trends to predict when a trespass may occur and predict how many trespasses might occur over a future period (and the cost impact of such). In this way, the justifiable expenditure to mitigate trespasses can be calculated.

Reading Station has a wall that can be climbed to leave the station into a public footpath, which is used by fare evaders. The detection of these incidents was used as part of the business case for the anti-climb barrier that is in the process of being built since the use case began.

* https://www.networkrail.co.uk/wp-content/uploads/2019/08/Reducing-the-number-of-Trespass-Incidents-and-their-impact-on-the-railway.pdf

Governance: Trespass is a significant issue for train stations to manage and there is not only a huge financial impact if a member of the public or staff were injured in an incident, but there is also clearly a human cost. Work is underway to present data within the SiYtE dashboard in a way that provides the financial impact of trespass incidents.

Use Case Accuracy

We have been monitoring trespass events and reporting on accuracy. This is of significant interest to the stations. The ability to filter trespass between an identified person wearing PPE or non-PPE is of also interest – in particular at night when works are underway on the tracks.

Engineering work enabled trespass detection to be evaluated as it provided multiple events. The following table tracks events reported that were either valid events (TRUE detections, including engineering workers in PPE) or false alerts (FALSE Positives).

During the early stages of the trial, there were a significant number of false positives caused by passengers seen in the reflection of train windows or stepping onto trains (with the person effectively in the trespass area)

An enhancement was added for train detection – when a trespass is detected, a snapshot was then analysed for a train and if one was there, the trespass event negated. This model was enhanced until accuracy reached

98%. Between 16th March and 1st April, of 165 trespass events detected (all engineering work), only 3 were false positives. This is detailed in Appendix 2.

When a trespass is detected (person located on the tracks), the image is further analysed to determine whether they are wearing PPE so that the context of whether this is due to engineering work is added.

The below is a very good example for Leeds on 30th November.

[redacted]

Site	Events since 1 Feb - 16 Mar	FALSE Positives	TRUE detections
Euston	3	3	0
Glasgow	59	45	14
Leeds	139	88	51
Reading	3	0	3
Total	65	48	17
Site	**Events since 16 Mar - 1 Apr**	**FALSE Positives**	**TRUE detections**
Euston	0	0	0
Glasgow	165	3	162
Leeds	0	0	0
Reading	0	0	0
Total	165	3	162

Lessons Learned, Deployment and Design Considerations

An important consideration is where the camera is installed. For instance, the camera needs as much view of the desired tracked area as possible to effectively detect trains and people. If the camera does not detect a person, the model will not work, so objects must not be too far in the distance. The IPVM Calculator is a good tool to calculate this, with 70 Pixels per Metre (PPM) required for accurate person detection. Also, in a distance, PPE is harder to identify because there are is less of a clear view to identify it. Future installations must incorporate better camera coverage into the design.

PPE detection is less reliable for events further away from the camera and darker lighting conditions.

Service Comments

The model's latest update requires further testing to confirm that previous false positives will not reoccur.

Capability 2: Platform and Concourse Crowding / Area Occupancy and Dwell Times

SO-SCA-05	Gate Line Queueing
SO-SCA-02	Station Concourse & People Density
SO-SCA-03	Platform Occupancy
SO-SCA-09	Standing in Front of the Yellow Line
SO-SCA-01	Escalator Monitoring (Queues and Crowding)
SO-SCA-05	Ticket Machine Queue Management

Use Case Description

Counting the number of people, the people density (people per square metre) and the average dwell time for a defined area, which may be one of the following:

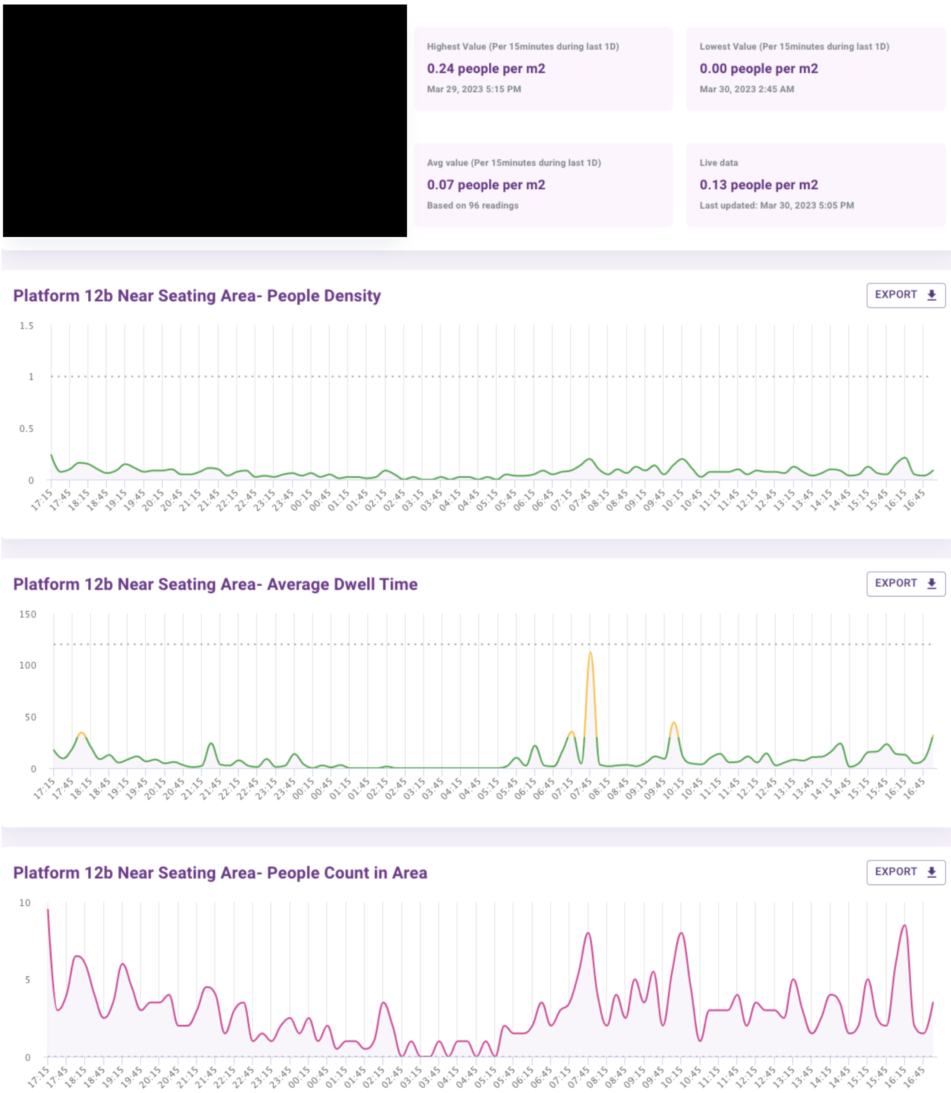
- Concourse
- Platform
- Area between the yellow line and tracks
- Base of escalator or on escalator
- Ticket machine or ticket office queue
- Gate-line queue

Use Case Approach

Two approaches are taking for occupancy:

Approach 1:

Utilise the object detection capabilities of the camera, the SiYtE service works out how many objects are in a specific area that is drawn within the SiYtE tool. Dividing the number of people by the area size gives a density measurement (in people per square metre). Using the object tracking capability of the camera, an average dwell time (in seconds) can also be calculated.



All cameras deployed used a people detection capability, but a better approach for crowded environments such as platforms and gatelines, with a low canopy, can be to use a fish eye camera looking down using a 'head detection' model as this avoids the problem of people obscured behind other people. This has been successfully deployed at Manchester Piccadilly.

[redacted]

Approach 2

The second approach is to take a snapshot every 2 minutes and analyse the snapshot for people density. This is good for very large areas with large numbers of people with the image taken from above, as it is based on analysing the pixels for coverage of the floor area, illustrated below from Euston station:

[redacted]

It is based on the whole field of view rather than specific areas.

This has proven around 85% accurate with populations over 100. For poplulations under 100, smart cameras should be used , with the new generation of Meraki cameras an option for being able to track up to 200 people in a field of view.

It does not work well for small areas, for sparsely populated areas (it is most accurate at >100 people) or for cameras that do not point downwards.

With this approach we can measure a number of people and people density but not dwell times.

With these design considerations taken into account, platform and concourse crowding can be delivered, deploying carefully selected cameras and locations. As with trespass, it is considered that focusing on hotspots will deliver the greatest cost benefit.

Benefits Statement

The benefits vary between areas:

1) **Concourse:**

Governance: For many stations, concourse occupancy is not a significant issue in a 'real time' perspective. The exception is Waterloo who have two areas which can become significantly crowded (near the SIS boards by Platforms 1 to 6 and near the SIS boards at Platforms 12-18). Based on crowding levels measured on the FRUIN scale, a phased crowd control plan is implemented. The challenge is that this is very subjective depending on staff member. A data driven approach based on measurement of crowding levels would remove this subjectiveness – in addition, alerts that included the action to be taken would remove the need for the staff member to find and refer to the crowd control plan for the action to be taken

Experience: Manchester Piccadilly stated that understanding the impact of crowd control measures put in place would be useful, from a historical analysis perspective to enable for better future planning for crowd control. Euston stated that understanding which areas of the station are crowded at which times would be useful (though we need to be clear, they do not have issues with concourse crowding)

2) Platform:

Governance: Leeds, Manchester Piccadilly and Glasgow all have issues with platform crowding

This has been a case of the right use case in the wrong location for Leeds and Manchester Piccadilly, something we are looking to address in upcoming deployments:

- Leeds have issue with platform crowding for Platforms 16/17b and Platforms 7/8. Unfortunately, this is not where we have cameras. We have cameras on Platform 12 but this rarely gets crowded
- Manchester Piccadilly has issues with crowding on an island platform 13/14. This can happen suddenly – generally the platform will become crowded and then train arrivals suddenly create a dangerous situation. Because of this, a rota of 17 people (in total) is dedicated to this platform.

At Glasgow Central, Platforms 5/6 can back up because of people buying tickets on the platform. When this happens, the gates have to be opened.

- This is an area where we do have cameras and an alert has been set up monitoring high density (0.5 people per square metre) situations that are prolonged for over 3 minutes. This alert has not yet been triggered.

3) Area between the yellow line and tracks

All of our stations except Reading (where we have no platform cameras) are terminus stations and standing over the yellow line was not considered of interest by the stations.

4) Base of escalator or on escalator

This was not perceived to be of particular interest, perhaps in the locations we are monitoring

5) Queues (Gateline, ticket machine or ticket office queues_)

Experience: We have been monitoring ticket machine queues in Glasgow and Manchester Piccadilly and reporting on these. This is of passing interest to the stations. Extended dwell times would be of interest, but this data is skewed by staff in the area.

Use Case Locations

Concourse: Euston, Manchester Piccadilly, Glasgow, Reading, Waterloo
Platform: Leeds, Euston

Yellow Line: Glasgow, Leeds
Base of escalator: Leeds
Queues (Gate-line, ticket machine, ticket office): Euston, Manchester Piccadilly, Glasgow, Reading, Waterloo

Use Case Accuracy Approach

Accuracy was compared with manually counting people watching the recorded footage. This is possible for people counting in an area (from which people density is also calculated). Manual analysis of average dwell is next to impossible in all but the sparsest populated areas.

Use Case Accuracy

Accuracy for people counting within an area varied as follows:

- Concourse: 85% to 95% (up to around 50 people, after which accuracy sharply declines)
- Concourse by Snapshot: For images over 100 People: 80% to 90%, for images under 100 this sharply declines
- Platform: 85% to 95%
- Base of escalator: 85% to 95%
- Standing in front of yellow line: 80% to 85%
- Ticket machine queue: 80% to 85%

The Raw Data is included in the associated Analytics reports for each station.

Lessons Learned, Deployment and Design Considerations

The following are our lessons learned on measuring occupancy, which has different approaches:

Approach 1: Angled down view of a large area, using object detection on the camera, such as the main concourse in Waterloo.

For this use case/camera we have hit the limit of object detection for these cameras, where we lose accuracy at around 50 people and max out around 70 people. As such, for the areas we are covering for large concourses this is a real lesson learned as just as it gets crowded, we hit the camera capability limit.

The new cameras, like the MV63s at Manchester Piccadilly are performing very well, measuring crowded areas very effectively, with up to 80 people in the field of view being accurately counted (based on limited manual checking so far). Meraki state that they can cope with 200 people.

Approach 2: Angled down approach of a limited size area (such as the choke point at Euston) using object detection on the camera.

This works really well with the existing cameras.

Approach 3: Top-down approach of a limited size area using a fish eye camera with object detection on the camera.

This is working well at Manchester Piccadilly for the platform 13/14 crowding.

Approach 4: Top-down approach of a large area.

This uses a snapshot with a statistical analysis and has worked really well at Euston on the main concourse. This uses the whole field of view so you cannot isolate specific areas and this does not measure dwell times as object tracking is not possible with this approach.

In summary:

- Occupancy of a limited area works well with the MV72X (cameras so far used for most of managed stations)
- Occupancy for a very large area looking straight down works well with the snapshot model (this is best suited to areas >100 people)
- Occupancy of a large area does not work well with the MV72X as it cannot keep up with the amount of people – and we need to use the next gen cameras (MV63).
- Occupancy of a confined area with a fish eye camera shows promising results outside of Network Rail and we want to trial this at Manchester Piccadilly. In areas where the only options for mounting are under 3m high (such as platform canopies) were dome cameras

It is almost impossible to validate average dwell times manually. Dwell times can be significantly affected by staff, particularly at gate-lines, where staff may be semi-permanently positioned.

Capability 3: People Counting

SO-SCA-23	People Counting

Use Case Description and Benefit statement

This use case counts people “in” and “out” based on the crossing of a virtual trip wire to provide a picture of how many people are in an area.

This benefits operational planning through station staff understanding how many people are in an area at a particular time and helps business case development through understanding usage of areas with entrances (such as ticket offices, car parks, etc).

Use Case Locations

People Counting was trialled across gatelines in all stations, but in Leeds and Manchester Piccadilly the cameras were not mounted as planned and were not suitable.

It was also trialled for entry/exit to the car park in Glasgow Central, for counting people up/down the stairs/lift to the lounge in Manchester Piccadilly (for trial purposes only – this was not requested) and for ticket office usage in Manchester Piccadilly

Use Case Approach

People counting is based on using the object detection and object tracking to measure when and how many people cross a trip wire

[redacted]

There are two trip wires so that direction is included (e.g., we might set this above as “Bottom Up” meaning “People In” to the station and “Top Down” is “People Out” of the station.

This is reported on the SiYtE dashboard as People In and/or People Out, with an example bellow:

Feedback and Benefits

People Counting across gate lines has turned out to be of little value to Network Rail stakeholders, as this is measured by the ticket gates.

However, people counting in other areas such as ticket offices and car parks can have value:

Productivity: Manchester Piccadilly were interested in ticket office usage, to provide information on the impact of ticket machine removal – this could better inform staff deployment. Leeds Station (then Station Manager, Nick Cooper) have stated that people counting onto platforms would be useful to give information on platform usage, in order to better deploy staff and report on station operational planning. This was not in scope of this trial

Financial: At Glasgow Central, we recording car park usage which can be used for business case development for closing this entrance.

Governance: At Glasgow Central, were also alerting on out of hours access through the car park entrance (which cannot be closed due to fire regulations), which is an issue for unauthorised access of rough sleepers and potential trespassers at night. This has been of limited value as the entrance is also used by staff so an alerting creates a lot of false positives.

Use Case Accuracy Approach

Accuracy was compared with manually counting people watching the recorded footage

Use Case Accuracy

Accuracy across gate-lines was uniformly poor, averaging approximately 50% to 60% accuracy compared to manual counting.

Accuracy for counting people in/out of the car park, ticket office and stairs was between 80% and 95%.

The Raw Data is included in the associated Analytics reports for each station.

Meraki are in the process of a major effort in improving people detection and tracking accuracy. This will be rolled out to cameras mid to late 2023, so accuracy can be expected to improve over time.

Lessons Learned, Deployment and Design Considerations

The following factors are required for accurate people counting:

- People need to be clearly moving in a specific direction (a challenge for areas such as gatelines)
- People must not be too clustered together (again a challenge for gatelines)
- Camera angles must be square on and zoomed in on the location if possible (the trip wire must not be too far away).

Gatelines are not feasible for people counting and areas where queues happen such as the base of escalators. Areas where people have clear direction such as corridors, single file queues, exits of escalators will work much better.

Cameras need to be carefully aligned for people counting, so use cases may not always work well by being retrofitted into existing cameras.

Service Comments

People counting is a base functionality and will be part of any “foundational” license. It should be feasible on both smart cameras and through integration into existing CCTV systems, with local compute doing the object analysis.

Capability 4: Accidents: Slips, Trips and Falls

SO-SCA-22	Slips, Trips & Falls

Use Case Description

This capability and the subsequent capabilities fall in to the category of accident detection and mitigation

This capability was modelled on determining if a person has fallen over.

Use Case Locations

This was based single camera at each station, based on discussion of accident hotspots with the stations:

- Reading: Transfer Deck
- Leeds: West Footbridge
- Glasgow Central: Choke Point (mounted above Patisserie Valerie)
- Euston: Platforms 8/9
- Waterloo: Concourse near Exit 2
- Manchester Piccadilly: Concourse outside Burger King

Use Case Approach

The capability requires Edge Compute and was performed on a small form factor industrial server (a "NUC") processing video from a single camera at each station.

It is based on body position: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Feedback and Benefits

Productivity: If accidents, can be detected and logged, then they can be tagged for future accident investigation, saving staff time.

Financial/Experience/Governance: If accidents are detected, staff can be alerted to an accident hotspot to address causes before someone suffers an injury (and potential compensation case). This was a stated concern of most of the Managed Stations.

Use Case Accuracy Approach

The capability was tested by simulated falling at Reading station. This worked, but so far no real incidents have been reported by the model, so the success of this use case is inconclusive.

Use Case Accuracy

The lack of any accidents detected at any of the stations is a concern. Staff, when asked, have not known of accidents in these areas. As such, apart from the simulated falls we have had no events, by which to judge accuracy.

Lessons Learned, Deployment and Design Considerations

No conclusion can be drawn as to the accuracy of this capability, given the lack of events.

The requirement for edge compute also makes this use case more expensive. Given the priority of this use case by stations, this requires further investigation (which will be done in Leeds).

We also consider a simpler model would be to train the camera to detect a person lying prone on the floor in an unexpected area.

Service Comments

This would be an advanced use case, requiring real time compute. Before this could be marketed and deployed as a service, more testing is required, and it is recommended that a camera model detection of a person lying down would be a better approach.

Capability 5: Accidents: Luggage, Pushchair and Bikes detection

No use case identifier	Luggage Detection

Use Case Description

This was not a contracted use case; it was requested by Reading station.

Approximately, 75% to 80% of all accidents in Reading station are on escalators. Leeds concurred that most accidents are on escalators. A significant cause of escalator accidents is people losing control of luggage, pushchairs and bikes, despite signage to take the lift.

This use case consists of counting the number of suitcases, pushchairs and bikes taken on an escalator or stairs (rather than the lift) and reporting trends over time and the times that are most frequent.

Use Case Locations

Reading: West Concourse escalator

Use Case Approach

The Smart Camera was retrained to report on luggage, pushchairs and bikes. Two models were developed – one that just detected luggage and one that detected all three.

The luggage use case was chosen as the one to report and this represented on a graph over time.

Feedback and Benefits

Experience/Governance: Reporting allows the station to determine if changes in signage, etc has a positive effect on passenger behaviour in this regard, allowing the station to determine the best mitigation technique and reduce accidents.

Productivity: This use case also enables the station to build the data set required to justify more lifts.

Use Case Accuracy Approach

Detections were compared to user validation (of whether detections were accurate)

Use Case Accuracy

Accuracy of detection is 90% for the luggage detection model (the model deployed) and 88% for the combined luggage, bikes and pushchairs model.

Lessons Learned, Deployment and Design Considerations

This model works very well. However, for custom models on the camera object tracking is not available meaning the same object could be detected multiple times. As such, the detection was rated to a maximum of one every 5 seconds (by which time the object would have passed over the detection area. This does mean that some objects would be missed. The object tracking for custom models (enabling luggage to be counted crossing a trip wire) will be introduced later this year.

Service Comments

This use case will work better on Smart Cameras where the model can run on the camera. It is also possible on edge compute, with the associated additional cost. It should be considered an advanced use case.

Capability 6: Accidents: Temperature & Humidity

SO-IoT01 & SO-IoT-02	Temperature & Humidity
SM-IoT-05	Indication of Ice & Sweating Platforms

Use Case Description

Recording temperature and humidity. Alerting if there are icy conditions or conditions that lead to “sweating” floors in identified locations.

Use Case Locations

Waterloo: Main concourse
Leeds: West Footbridge
Reading: Transfer Deck
Euston: Platform 9

Manchester Platforms 8/9 Footbridge
Glasgow: South Concourse

Use Case Approach

This was done in two ways:

- Water leak sensor to detect dampness at floor level. This was not successful as the water leak sensors were too easily knocked off by cleaners.
- Using temperature and humidity readings to predict the dew point at which condensation occurs.

Feedback and Benefits

Experience / Governance: If sweating floors can be predicted, this means the station can take mitigating actions such as cleaning the floor and putting out mats, reducing the risk of accidents.

Use Case Accuracy Approach & Use Case Accuracy

Accuracy was compared with viewing the video footage for the sheen of a wet floor. This proved that the model works but there are still too many alerts, so we are needed to tune alerts so that they are only for the conditions that lead to significant moisture.

Lessons Learned, Deployment and Design Considerations

Predictions would be improved with two sensors – one at floor level and one higher up. If we are to use water leak sensors again, they will have to better fixed.

Service Comments

Once the model is better tuned, this is simply provided with sensors and an IoT license.

Capability 7: Heat Maps / Passenger Flow

SO-SCA-21	Heat Maps Videos

Use Case Description

Producing videos that map people "heat maps" and flow over time to determine crowding/usage hotspots.

Use Case Locations

This was trialled for all cameras at all stations.

Use Case Approach

The Smart Camera itself creates a heat map, with different colours showing people density. The SiYtE service used this capability to create a video that quickly showed heat maps of an area over 24 hours.

Feedback and Benefits

Productivity: This enables station staff to better plan staff effectiveness and understand people flow in the station.

Use Case Accuracy Approach and Use Case Accuracy

There was no real way to measure accuracy of this capability.

This use case is only as good as the object detection on the camera. The generation of cameras deployed struggle beyond 50 people so in very crowded areas, without using later camera models that can detect up to 200 people, accuracy may be impacted.

Accuracy will become more limited beyond the range of accurate people detection.

Lessons Learned, Deployment and Design Considerations

This is a helpful capability for station planning, but is unlikely to be a reason in itself for deploying analytics

Service Comments

None

Capability 8: Demographics

SO-SCA-16	Passenger Demographics

Use Case Description

Through analysis of snapshots, this use case produces a statistical analysis of age range and male/female demographics. The use case is also able to analyse for emotion in people (e.g., happy, sad and angry) is also available but is viewed with more caution.

Use Case Locations

This was used for one camera at each station (generally the gateline camera), where a snapshot was taken every second whenever people were crossing the tripwire and sent for analysis by AWS Rekognition.

Use Case Approach

This use case requires a trip wire and monitors people crossing this trip wire. Either when people are detected or every 5 seconds (whichever is longest), an image is sent for analysis by AWS Rekognition. This provides information on gender, age range and emotion.

Feedback and Benefits

Experience: Potentially the customer emotion metric could be used to measure satisfaction

Financial: This data could be utilised to maximum advertising and retail revenue. However, this was hard to quantify as NR Properties were never successfully engaged.

Use Case Accuracy Approach and Use Case Accuracy

There was no real way to measure accuracy of this capability as we cannot tell which images were sent to AWS Rekognitiom. AWS claim over 80% accuracy but this is very dependent on clear views of faces.

Lessons Learned, Deployment and Design Considerations

Better engagement with NR Properties is required on the requirements for this use case.

It does require a very clear view of people’s faces for accuracy.

Service Comments

Demographics requires significant extra analysis and will be part of an ‘advanced’ license and will probably be used sparingly.

Capability 9: Notification of Deliveries

SO-SCA-24	Notification of Deliveries

Use Case Description and Benefit Statement

Determining when a delivery vehicle has arrived. This use case can also be enhanced by combining with a gate open/close sensor to determine if the gate has been left open after the driver leaves.

This use case was requested by Reading Station, where there are the following challenges:

- When a delivery arrives and staff do not realise, it can be left in the open and get rain damaged or block fire exists.
- After the delivery driver leaves, the driver should close the gate. Frequently this does not happen allowing entry/exit to the station.

Use Case Locations

Reading: South Delivery Ramp

Use Case Approach

A camera looking down the delivery ramp detects vehicles arriving and leaving. A gate open/close sensor on the gate determines when the gate has been left open

An alert was set for the arrival of deliveries, but these are so frequent, it was disabled.
An alert based on when a delivery truck has left and 3 minutes later the gate remains open was set to allow staff to shut the gate and also identify which drivers fail to close the gate.

Feedback and Benefits

Productivity: This saves time for staff checking that the gate has been left open.

Governance: This ensures that the gate is not left open and used for unauthorised entry/exit. An added benefit was identification the causation of damage.

Use Case Accuracy Approach

Manual check versus alerts created

Use Case Accuracy

The gate open/close sensor is 100% accurate, with no false readings found.

Initial accuracy for vehicle detection has been measured at 85%, with vehicle detection failing due to only the back of the delivery truck being in view. A key lesson learned is to provide a camera angle showing more of the side of the vehicle.

Lessons Learned, Deployment and Design Considerations

Vehicle detection accuracy is lower for trucks reversing into the ramp (the truck looks like a big square rather than a vehicle. A camera angle from the side would have yielded much greater accuracy.

This use case does not have an enormous value but it is simple to deploy with a single camera and single sensor.

Service Comments

This can be simply deployed using either:

1) A new Smart Camera and a gate open close sensor (a Foundation and IoT license), or
2) Using a sensor and then taking a snapshot image of the ramp to detect existing of a vehicle whenever the gate has been open for over 3 minutes. This would require access to the video footage/images.

Capability 10: Air Quality

SM-IoT-01 & SM-IoT-03	Station Air Quality

Use Case Description

Recording air quality in terms of Air Quality Index, Particulate matter (PM2.5 or PM10) and CO_2 levels, both of which can be dangerous to health. PM2.5 (Particulate matter, solid pollutants, under 2.5 microns) is considered to be the main metric as has significant health concerns and diesel fumes (from trains) is a main contributor.

Particulate matter (PM) is everything in the air that is not a gas and therefore consists of a huge variety of chemical compounds and materials, some of which can be toxic. Any PM smaller than 10 microns in diameter can be inhaled into the lungs and has adverse health effects.

Use Case Locations

Locations were generally based on platforms where diesel trains arrive:

- Leeds: Platform 12 and West Footbridge
- Waterloo: Platform 11
- Euston: Platforms 3 and 9
- Reading: Platform 8
- Manchester: Platforms 3 and 13
- Glasgow Central: Platform 9 and Main Concourse

Use Case Approach

This was measured with an IoT sensor with data consumed every hour.

Alerts were set up as follows:

PM2.5:
Threshold 1 : 20 µg/m3. (Annual Average Maximum according to Air Quality Standards Regulation 2010)
Threshold 2 : 35 µg/m3. (24 Hourly Average Maximum for those vulnerable to the health impacts of air pollution)

CO_2:
The Health and Safety Executive (HSE) mandates 15,000 ppm as the 15-minute (short term) and 5,000 ppm as the 8 hour (full working day) limit. But well before these limits are reached, increased CO_2 can cause cognitive function and concentration levels to be impaired.

As an example, at Manchester Piccadilly in December on Platform 3, the 24-hourly average over was higher than Threshold 2 for 2 days:

However, Air Quality England also has sensors in Manchester and these show that the overall air quality in Manchester exceeded threshold 2 over this time period – and so this was not due to trains. As such, in future the surrounding area air quality will be correlated with recorded air quality for comparison.

This shows the importance of continuous monitoring but also comparison with the external environment. A snapshot air quality report could catch a peak (or a trough) and would not have the context of surrounding air quality.

At Leeds, air quality sensors can be compared between the West Footbridge and Platform 12. As you see for a period of two days the air quality was not safe for people with breathing conditions and the air curtain for the West Footbridge did not protect it from adverse air quality:

Feedback and Benefits

Experience: Knowledge of safe air quality is a first step in addressing its dangers for staff working in an area for an extended period, particularly those with breathing conditions.

Financial: This constant monitoring would offset the cost of periodic air quality reporting

Use Case Accuracy

Sensors are calibrated at factory with published limits.

Lessons Learned, Deployment and Design Considerations

Sensor battery life is dependent on reporting interval and the amount of data reported. The sensors were set to a one-hour reporting interval which could be widened but were also set to report every possible data set, many of which were not required. Battery life could be much improved by tuning this.

Service Comments

These are simply deployed once a LoRaWAN capability is in place with only an IoT license

Capability 11: Lighting Levels

SM-IoT-03	Lighting & Light Levels

Use Case Description

Reporting on light levels in Lux. This can be from the light sensor on the camera or from an IoT sensor.

Use Case Locations

Euston, Waterloo, Reading, Glasgow, Manchester, Leeds.

Use Case Approach

The trial used the in-built sensors in the cameras.

Feedback and Benefits

Governance: This can be used to report on safe lighting levels (o=for which there are NR standards) and understand when lighting is insufficient or has failed.

Use Case Accuracy Approach and Use Case Accuracy

This uses an in-built sensor that is factory calibrated.

Lessons Learned, Deployment and Design Considerations

It should be noted that NR standards apply to light at ground level, while cameras report light at mounting level: this is therefore of limited use.

Service Comments

This is reported by default with a camera or with a sensor with an IoT license

Capability 12: Noise Levels

SM-IoT-04a	Noise Levels
SM-IoT-04b	Fire Alarm using Noise Analytics

Use Case Description

Reporting on noise levels in decibels (dB). This can be from the noise sensor on the camera or from an IoT sensor.

Fire alarm reporting was also attempted from the camera sensors, but this proved to be very unreliable (lots of false positives)

Use Case Locations

Euston, Waterloo, Reading, Glasgow, Manchester, Leeds.

Use Case Approach

The trial used the in-built sensors in the cameras and a sensor on Platform 17 on Leeds Station.

Feedback and Benefits

Governance: This can be used to report on noise levels and provide an audit trail for complaints about noise.

Use Case Accuracy Approach and Use Case Accuracy

This uses an in-built sensor that is factory calibrated.

Lessons Learned, Deployment and Design Considerations

Noise IoT sensors only measure noise levels at periodic intervals. This is good for monitoring engineering work (so consistent noise) but if peaks of noise are required a powered sensor (or camera is required)

Service Comments

This is reported by default with a camera or with a sensor with an IoT licence.

Capability 13: Vulnerable Person Detection

SO-SCA-15	Suicide Risk

Use Case Comments

This use case was not trialled as the camera failed. It was not replaced as the WIFI coverage was poor and Euston station did not deem it of value.

This has been deployed on MTR as a simple combination of passenger dwelling for an extended time (configurable) in a specific location (e.g., end of platform)

Appendix 6: Kit List / BoM

The BOM will vary per use case. The following are the main camera types:

Part Number	Description	Comments	Qty
MV63X-HW	Meraki Fixed Lens MV63X Mini-dome, Outdoor 4K Camera- 1TB	Latest generation dome camera with 1TB Storage	1
MV63-HW	Meraki Fixed Lens MV63 Mini-dome, Outdoor 4MP Camera- 256GB	Latest generation dome camera with 256M Storage (will not achieve 30 days storage in very busy areas)	1
MV93X-HW	Meraki 360-degree MV93, Outdoor Rated Fish Eye Camera- 1TB	Latest generation fish-eye camera with 1TB Storage	1
MV93-HW	Meraki 360-degree MV93, Outdoor Rated Fish Eye Camera- 256GB	Latest generation fish-eye camera with 256M Storage (will not achieve 30 days storage in busy areas)	1
MV52-HW	Meraki Varifocal MV52 Outdoor Bullet Camera With 1TB Storage	Bullet camera with 1TB storage	1
MV72X-HW	Meraki Varifocal MV72 Outdoor Dome Camera - 512GB Storage	Zoomable dome camera (mostly used in these trials - flexible camera, less suited to very busy areas)	1

And the following is the BOM for a LoRaWAN gateway

Part Number	Description	Qty
IXM-LPWA-800-16-K9	Cisco 800MHz LoRaWAN Gateway, IP67, 16-Channels, TDOA	1
CON-SNT-IXMLPWA8	SNTC-8X5XNBD Cisco interface modu	1
ACC-SP-POE-GE	PoE surge protector	1
AIR-ACC1530-PMK1	Standard Pole/Wall Mount Kit for AP1530/1560 Series	1
ANT-GPS-OUT-TNC	IP67, 4dBi zenith, 15ft cable, 25dB LNA gain, TNC(m)	1
ACC-LA-G-TM-TF	GDT lightning arrestor for GPS, 4G and WPAN antenna	1
ACC-LA-H-NM-NF	Outdoor antenna lightning arrestor, 700-2700 MHz	2
ANT-LPWA-DB-O-N-5	Outdoor omni-directional, 863-928 MHz, dipole, N-female,5dBi	2
AIR-CAB010LL-N	10 ft LOW LOSS CABLE ASSEMBLY W/N CONNECTORS	2
PLG-PWRJCK	Cisco v2 LoRa interface DC power input jack plug	1
SW-IXM-LPWA-K9	Cisco Software for LoRaWAN Gateway	1
ACC-LPWA-HDWR-KIT	The cable gland and ground lugs for Cisco LoRaWAN Interface	1
IOT-TRANSPORTATION	Transportation Industry Solutions; For tracking only.	1
IOT-TRANS-OTHER	Not related to an IoT Transportation Solution; Tracking only	1
PWR-INJDC-30	DC PoE power injector, 30W output	1
ACT-TPE-SAAS	ATO PID for Actility TPE SaaS	1
Initial Term - 36.00 Months		
ACT-TPE-GW	16 channel gateway TPE license	1
AIR-CAB010LL-N=	10 ft LOW LOSS CABLE ASSEMBLY W/N CONNECTORS	2

The SiYtE services are clearly also required. PTG are developing a set of starter packs to be used for specified deployments such as trespass or platform crowding.

Appendix 7: Station Lessons Learned and Feedback forms

Manchester Piccadilly

Interviewed: Scott Green (Station Manager) / Mark Ridings (Station Shift Manager)

Station: Manchester Piccadilly

Date:19 April 23

Use Cases to be Continued	Description	Feedback	Other Comments	Recommendations
Temperature & humidity - Indication of Icy conditions - Indication of sweating conditions	Icy conditions (Temp <0 deg) Prediction of dew point for sweating platforms	Icy conditions will be of interest but would need to be towards platform end, where people slip on coping stones Prediction of dew point is of interest for 'sweating platforms' and show be set up for alerts		Deploy new temperature sensors at Platform end (P4,5,6 or 7 and/or P13/14) Existing Man Pic Temp sensors are on the footbridge over P8/9 and near the start of Platform 10.
Slips, trips and falls	Detection of person falling or down	Use case would help ensure footage is kept for claims (people can claim for up to 2 years, but undetected fall footage is deleted after 30 days)	35% Escalator falls on P13/14 escalators	Once use case proven, it would be better redeploy camera MPC4 to P13/14 escalator
Demographics	Gender and age distribution of passengers	Useful for customer service	Impossible to validate accuracy	Need to engage customer service teams
Noise levels	Noise at camera level in dB	Noise: Useful for complains about pianos and tannoys.	Suspicion on values – they are sent every second, but are not recording peaks for tannoys	Need to evaluate accuracy. If determined inaccurate should focus on sensors IF use case works well with periodic reporting (finding more detail)
Light	Operations	Light: Has use for understanding lighting conditions and failures	Challenge is that cameras are often high up and are. Not under the same lighting conditions as ground level	Need if levels at camera level have validity. If Lux at ground level is required should focus on sensors
Air Quality (Platform 8)	Safety / Passenger Experience	Air quality monitoring has to be done by the station using vials at regular intervals.	Reporting has always proven there is not an issue	Engage with Lucy Jordan. If sensors can replace manual tests there will be a time and cost saving.

Use Cases to be Discontinued	Description	Feedback	Other Comments	Recommendations
People Counting	People counting across gateline and into ticket office	Gateline counting might be useful for TOCs, but is not of value for the station.	People counting across gatelines using cameras not effective and can be done using IR counters	Redeploy affected cameras: MPC1-MPC7

		Ticket office counting was of interest based on justifying non-removal ticket machines, but this is no longer of interest		
Station concourse and people density	- Operations	Concourse people density is not a challenge for the station and information on this is not of particular concern		Redeploy affected cameras: MPC1-MPC7
Gateline Queuing	Passenger Experience	Gateline queueing would be of interest only on entrance to the station, but is not a high value use case		Redeploy affected camera: MPC6
Ticket machine queuing	Passenger Experience	Ticket machine queues and dwell time was of interest based on justifying non-removal ticket machines, but this is no longer of interest		Redeploy affected camera: MPC2

Use Cases to be Introduced	**Description**	**Comments**	**New/Redeployed Came**
Platform 13/14 Occupancy	Alerting of crowding levels on platforms 13/14, with additional insight of incoming trains	Platforms get extremely crowded and dangerous crowding happens very suddenly. Alerting should have context of upcoming passengers on trains arriving	Needs new cameras. Pro
Trespass on Tracks	Trespass for crossing tracks between Platforms 10 and 13	Only one known incident per year, but may be more undetected incidents	If decided value deploy r
Slips, trips and falls	Detection of person falling or down	Use case would help ensure footage is kept for claims (people can claim for up to 2 years, but undetected fall footage is deleted after 30 days)	redeploy camera MPC4 t
Platform End Icy Conditions	Icy conditions (Temp <0 deg) •	Icy conditions will be of interest but would need to be towards platform end, where people slip on coping stones.	Deploy new temperatur and/or P13/14)
Escalator Queuing	Escalator crowding at top of escalators	Primary location is escalators to main concourse from Metrolink	Deploy new camera (ide
Escalator Monitoring	Escalator operation (stop or start)	Current monitor sensors on escalators. There are 8 escalators and 3 travelators. Would need to decide on priorities or to deploy to all. Would be useful to link escalator stops to camera events (in particular there is youths who press the stop buttons)	Deployment dependent Ben Robinson
Wind speed	Wind speed alerting on platforms	During high winds on platforms, ramps for mobility assistance can be blown by wind on taking out of fixings. Alert staff to high wind speeds	Platform end assuming c be found (with power)

Alerts	**Description**	**To Whom**	**What channel**	**Other Comments**
Sweating Platform Condition	Send an alert on dew point indicating sweating platform	TBD	TBD	

Platform 13/14 Crowding	Crowding reaches FRUIN D (?) and X trains in Y minutes	SSMs (just P13/14 SSM and control room?)	Text to DSM Phone?	Need to agree FRUIN level and what train data is required

General questions	Stakeholder feedback
Has the dashboard been accessed via a mobile device or just a desktop PC?	PC is the best approach for the dashboard
Would the availability of a mobile based App make the dashboard more useful in the station environment?	No, but potentially for alerts
Is there confidence in the alerts being raised?	
How accurate do you think the alerts need to be for a permanent deployment of the dashboard?	Alerts will need to strike the right balance for frequency to be useful. Medium term alerts should be to control room staff who would then triage actions Short term, we should focus alerts on SSMs and Station Control
Has the dashboard been used for access to live CCTV images in addition to responding accessing analytic alerts or IoT data?	CCTV imaging should be under review and provided to all control room staff, SSMs and Supervisors (21 people plus control room staff_
Can you think of any additional IoT sensors or additional information feeds that could be ingested into the dashboard to enhance the benefit to the station?	Included in text above
Can you foresee any potential financial efficiencies that may be available if the current TSIP functionality was rolled out to include greater station CCTV coverage?	Not discussed at this time
What do you think is the main benefit of the TSIP dashboard to you as an end user?	

Cisco International Limited
Project Name: Network Rail: Managed Stations
Project ID: A31508/ Deal ID: 55477821

Managed Stations Smart Analytics – Service Realisation	NetworkRail

Do you have any other general comments or views on the dashboard in addition to the points raised above?	

Reading

Interviewed: [redacted])

Station: Reading

Date:12 April 23

Interviewed: [redacted]

Station: Reading

Date:12 May 23

Use Cases to be Continued	Description	Feedback	Other Comments	Recommendations
Trespass in Restricted Area	Trespass over the wall at Platform 1	This has proved effective in detecting and reporting on trespass over this wall. This has helped the business case for the anti-climb barrier	Reporting on the number of trespasses is enough. There is no need to translate this to a financial metric	Once the barrier is complete, the use case should stay active for a period (e.g. 12 weeks) and then can be removed.
Alerting on Gate Left Open after Deliveries	An event is generated if the gate remains open 3 minutes after a delivery vehicle has left	The alerting is working well and this is useful use case	There are false positives. This is because the vehicle detection for the back of a delivery truck does not work as well from the rear. A side view from the camera would be much better	Moved the camera to a more side facing position.
Luggage Detection	Detection and reporting on bikes, pushchairs and luggage on the escalator	This is a very useful use case . Reporting would be useful on a trends basis, especially as a monthly report in line with rail periods	Discussion on "what is a case" but agreed to continue with the metrics as is (anything pulled along on wheels)	Creating reporting in line with rail periods
Air Quality (Platform 8)	Air Quality measurement (presently primarily PM2.5	This is not an issue at Reading so low value, but it does have to measured under a mandate from DECE	RSSB Study into air quality underway. Would be good to get a contact	
Temperature & humidity	Prediction of dew point for sweating platforms	Prediction of dew point is of interest for 'sweating platforms' and should		Set up alerts

Indication of Icy conditions Indication of sweating conditions		be set up for alerts, to embed into cleaning team and DSM process		
Ian Stack, BTP: Bike theft	Indication of times at which person with bike spotted to reduce evidence gathering time	Camera quality has been very useful in identifying suspects, resulting in 13 convictions and a 72% reduction in theft (number to be confirmed since camera install Nov 22). The bike detection algorithm is helping identify peak times when bikes are taken		Retain this use case and work on improving bike detection
Provisional: Camera Access	BTP use of cameras – especially RC1, RC2 and RC7/RC8/RC9	All these cameras are useful for evidence gathering		RC1 in particular does not have good WIFI connectivity and would need to be cabled or use a 4G gateway (which could also cover RC2)

Use Cases to be Discontinued	**Description**	**Feedback**	**Other Comments**	**Recommendations**
Slips, trips and falls	Detection of person falling or down	Lack value for Reading		Discontinue
People Counting	People counting across gateline	Gateline counting might be useful for TOCs, but is not of value for the station.	People counting across gatelines using cameras not effective, especially this one	Remove: RC1 (except for BTP comment)
Concourse occupancy	Crowding on concourse and transfer deck	These two areas do not get significantly crowded but this is still of interest		Remove: RC1 (except for BTP comment) and RC5
Demographics	Gender and age distribution of passengers	Should engage properties but station hasn’t seen value	Impossible to validate accuracy	Discontinue unless value found from Properties engagement
Light and Noise	Measurement of light and noise levels	Not seen value		

Use Cases to be Introduced	**Description**	**Comments**	**New/Redeployed Came**
Ian Stack (BTP): Bike Theft and Anti-Social Behaviour in Underground Car Park	Gangs on mopeds or E-scooters who are often carrying weapons steal bikes and there have also been assaults	Installation in the underground car park will be challenging due to lack of signal. But detecting mopeds and e-scooters entering the car park, especially if 2 or more at a time, with two people per vehicle, with alerting to BTP would enable crime prevention	New camera at car park
Escalator monitoring	Monitoring whether escalators are running	Escalator monitoring as there are frequent stoppages, causing accidents (one a week)	Would require new sens

Alerts	**Description**	**To Whom**	**What channel**	**Other Comments**
Trespass over wall	Trespass detected	Need to agree phone number(s) and email(s)	Text and Email	
Gate left open	Gate left pen 3 mins after a vehicle has left	Need to agree phone number(s) and email(s)	Text and Email	
Sweating Platform Condition	Send an alert on dew point indicating sweating platform	Cleaning team and DSM process	TBD	

General questions	Stakeholder feedback
Has the dashboard been accessed via a mobile device or just a desktop PC?	PC is the best approach for the dashboard
Would the availability of a mobile based App make the dashboard more useful in the station environment?	Text and email would be preferred
Is there confidence in the alerts being raised?	TBD
How accurate do you think the alerts need to be for a permanent deployment of the dashboard?	Alerts need to be agreed
Has the dashboard been used for access to live CCTV images in addition to responding accessing analytic alerts or IoT data?	Need an alert or report to prompt action. CCTV has been used but Reading already has a good system
Can you think of any additional IoT sensors or additional information feeds that could be ingested into the dashboard to enhance the benefit to the station?	Escalator monitoring as there are frequent stoppages, causing accidents (one a week)
Can you foresee any potential financial efficiencies that may be available if the current TSIP functionality was rolled out to include greater station CCTV coverage?	There are also problems with: - Graffiti outside - Anti-social behaviour in the car park - Suicide risk from top of multi story car park
What do you think is the main benefit of the TSIP dashboard to you as an end user?	
Do you have any other general comments or views on the dashboard in addition to the points raised above?	We should engage with TP at the Control Signalling Centre as they would like concourse views Detecting bikes may be of interest (problems with cycling with deliveries)

Glasgow Central

Interviewed:[redacted])
Station: Glasgow Central

Cisco International Limited
Project Name: Network Rail: Managed Stations
Project ID: A31508/ Deal ID: 55477821

Managed Stations Smart Analytics – Service Realisation

Date:18 April 23

Use Cases to be Continued	Description	Feedback	Other Comments	Recommendations
Trespass on Tracks	Trespass on tracks and over fence towards the end of Platform 1	No actual trespass events have been recorded. Trespass events become less likely due to the gates being installed, but severity of any event with two fatalities from climbing the fence may make sense to retain this camera and use case	This use case effectiveness has been proven by significant recent engineering work.	Trespass off the end of Platform 11 is an issue and it would be of interest to install a camera for this
Platform Occupancy	Alert when Platform 5/6 crowding reaches platforms and becomes persistent	This can cause issues and requires gates to be opened. This sometimes does not happen due to not being spotted	Alerts have been set up but perhaps had thresholds too low as these conditions have been rarely alerted on	Set alerts for crowding with dwell time over 3 mins, but lower threshold
Slips, trips and falls	Detection of person falling or down	Useful but to offer real value would need to cover all areas, not just the one we are covering,as there is no specific accident hotspot	Local staff could help with simulating incidents	Discussion Point: Should we continue or discontinue this use case?
Temperature & humidity Indication of Icy conditions Indication of sweating conditions	Icy conditions (Temp <0 deg) Prediction of dew point for sweating platforms	Prediction of dew point is of interest for 'sweating platforms' and should be set up for alerts		Set up alerts
Concourse occupancy	Crowding on each concourse	These two areas do not get significantly crowded but this is still of interest	Control signalling centre would like access to concourse camera	Cable GCC2 concourse camera to increase reliability. Would like another camera on the bottleneck between concourses between Oliver Bonas and the Flower Shop
Demographics	Gender and age distribution of passengers	Useful for customer service. Would be interesting to historically report on when there is a high proportion of female travellers for safety	Impossible to validate accuracy	Create historical reporting
Indication of Anti-Social Behaviour at Gordon St Entrance	High dwell time and crowding at Gordon St Entrance	This would be useful, but hard to garner feedback as the camera has been offline for some time after the associated AP failed		AP now replaced but I believe we need to get the SSID re-enabled
Light	Operations	Light: Has use for understanding lighting conditions and failures	Challenge is that cameras are often high up and are not under the same lighting conditions as ground level	Need if levels at camera level have validity. If Lux at ground level is required should focus on sensors
Air Quality (Platform 8)	Safety / Passenger Experience	Air quality monitoring has to be done on the station using vials at regular intervals	Reporting has always proven there is not an issue	. If sensors can replace manual tests there will be a time and cost saving.

Use Cases to be Discontinued	Description	Feedback	Other Comments	Recommendations
Trespass in Restricted Areas	Counting people in/out of car park and alert on	Too many events due to staff access at night and impossible to distinguish	Technically the capability worked, but the use case is no longer valid as a door	Remove or Redeploy GCC1

	unauthorised access at night	between staff and unauthorised access	is being to the car park entrance	
People Counting	People counting across gateline and into ticket office	Gateline counting might be useful for TOCs, but is not of value for the station. Ticket office counting was of interest based on justifying non-removal ticket machines, but this is no longer of interest	People counting across gatelines using cameras not effective, especially this one	Remove: GCC5
Gateline Queuing	Passenger Experience	Not a challenge where deployed		Remove: GCC5
Ticket machine queuing	Passenger Experience	Ticket machine queues and dwell time of limited interest to station but may be to TOC (?)		Validate if TOC level report useful

Use Cases to be Introduced	Description	Comments	New/Redeployed Came
Trespass on Tracks	Trespass on tracks and off end of platform	Trespass off the end of Platform 11 is an issue and it would be of interest to install a camera for this	New camera at end of Pl installed there
Trespass in Restricted Area	Trespass onto roof via spiral staircase off end of Platform 15	Access to roof via spiral staircase. Need clarity on location	If GCC1 can be re-aligned would be useful.
Concourse occupancy	Crowding on each concourse	Would like another camera on the bottleneck between concourses between Oliver Bonas and the Flower Shop	Deploy new camera if bu
Predictive crowding	If train data could be used to predict crowding for P1/P2 and generate an alert when London trains scheduled to arrive at same time	This does not necessarily require new cameras	Data modelling only
Light levels	Light levels useful at entrances, concourse and Platform 2	Camera based sensors often in wrong location	Consider deployment of
Authorised vehicles	Detect vehicle pass in window at Hope & Union St Entrances	Need to determine viability of analysis of vehicles entering between 00:00 and 05:00 when unmanned – to see if pass in window	Viability to be discussed

Alerts	Description	To Whom	What channel	Other Comments
Trespass on P1 (and P11 End if implemented)	Trespass detected	Need to agree phone number(s) and email(s)	Text and Email	
Platform 5/6 Crowding	Crowding reaches FRUIN C and dwell time over 3. mins	Need to agree phone number(s) and email(s)	Text and Email	
Predictive P1/2 Crowding	Train data could be used to predict crowding for P1/P2 and generate an alert when London trains scheduled to arrive at same time	TBD	TBD	
Sweating Platform Condition	Send an alert on dew point indicating sweating platform	TBD	TBD	

General questions	Stakeholder feedback
Has the dashboard been accessed via a mobile device or just a desktop PC?	PC is the best approach for the dashboard
Would the availability of a mobile based App make the dashboard more useful in the station environment?	This might be useful
Is there confidence in the alerts being raised?	TBD
How accurate do you think the alerts need to be for a permanent deployment of the dashboard?	Alerts need to be agreed
Has the dashboard been used for access to live CCTV images in addition to responding accessing analytic alerts or IoT data?	CCTV imaging should be under review – list of users to be provided to the station
Can you think of any additional IoT sensors or additional information feeds that could be ingested into the dashboard to enhance the benefit to the station?	Included in text above where relevant
Can you foresee any potential financial efficiencies that may be available if the current TSIP functionality was rolled out to include greater station CCTV coverage?	Not discussed at this time
What do you think is the main benefit of the TSIP dashboard to you as an end user?	
Do you have any other general comments or views on the dashboard in addition to the points raised above?	We should engage with TP at the Control Signalling Centre as they would like concourse views Detecting bikes may be of interest (problems with cycling with deliveries)

Euston, Waterloo and Leeds

Euston and Waterloo became disengaged from the trial. Leeds had a change in Station Manager which limited feedback, especially with a focus on the upcoming full station trial.

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