European Head Office:
AFC House, Honeycrock Lane
Salfords, Surrey
RH1 5LA
United Kingdom
Tel: [redacted]
Fax: [redacted]

Intelligent Gatelines

Achieving Optimal Flow Through a Station

Final Report

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0 Preliminaries

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0.7 Bibliography

0.7.1 Referenced Documents

[1] 1018 67022 Intelligent Gatelines Controller Evaluation Simulation trials
[2] 1018 67013 Intelligent Gatelines Feedback Controller Design
[3] 1018 67015 RTP - Bluetooth Gates Final Report

0.7.2 Associated Publications

1018 63004	Intelligent Gatelines Project Kick off stage review
1018 63005	Code Quality / Test Coverage for Future Gatelines/ Intelligent Gatelines Min Viable Product
1018 63006	IG VSCU and IG Server Pilot CQTC
1018 67004	Intelligent Gatelines Project Management Plan
1018 67005	Intelligent Gatelines - Competitor Product Analysis
1018 67006	Intelligent Gatelines - Project Vision
1018 67019	Intelligent Gatelines Marylebone site details
1018 79001	Intelligent Gatelines vSCU User Guide
6408-67159	IG Advanced Prediction Feedback Controller Design

0.7.3 Journals to be Submitted

- **Transportation Part C: Emergent technology (November 2019)**
  "Real-time Crowd Prediction and Optimal Configuration of an Intelligent Gateline System Using Queueing Theory"
- **European Journal of Operation Research (EJOR) (November 2019)**
  "Multi-server queue system based optimisation model for optimising passengers' throughput in real-time using overhead people counting sensors data"

0.7.4 Glossary and Abbreviations / Acronyms

BLE	Bluetooth Low Energy
BHR	Blackhorse Road
CCTV	Closed Circuit Television
GDPR	General Data Protection Regulation
POE	Power Over Ethernet
SC	Station Computer
SCU	Station Control Unit
TfL	Transport for London
TOC	Train Operating Company
UI	User Interface
UPS	Uninterruptable Power Supply
vSCU	Virtual/Tablet SCU
WAG	Wide Isle Gate

Table of Contents

Table of Figures

1 Introduction

1.1 Executive Summary

Gatelines are used to manage revenue protection and to control access to platforms for safety reasons. Gatelines can be configured so that any individual walkway can allow entry towards the platform, away from the platform, or to allow passage in either direction. In the most modern versions, gatelines can be pre-programmed and manually re-configured to meet changing needs.

This project will demonstrate a radical change to the gateline that will be capable of automatic self-reconfiguration maximising peak throughput and managing average total throughput in order to prevent overcrowding within the station. It will do this without manual supervision, freeing the staff at the gates to support customers. It will also remove the requirement on those staff to make decisions on gateline configuration or temporary station closure, which, if made in a sub-optimal manner, can adversely affect network capacity, safety and customer experience.

The project started in October 2017 and finished on 31st October 2019. As part of the project, two different controller designs were developed, each design was led by Cubic and University of Portsmouth respectively. Extensive testing and simulations were undergone to give confidence on the solution before installation. The resulting installed systems were tested and evaluated collaboratively by all parties with the help of an external validation by Connected Places Catapult.

Blackhorse Road station was chosen as a pilot site, it has a very set defined pattern of passenger flow but even with this Intelligent Gatelines still manages to reduce waiting times at the by optimising the gateline configuration. This goes on to prove that it will greatly aid busier and more unpredictable stations.

We experienced several difficulties during the project, with power outages, nearby building works kept shorting the power out at the station and while we had a UPS was in place it didn’t always last the full period required. The surges also knocked out the SC on numerous occasions and while the sensors collected throughput data the rest of the system couldn’t function correctly. TfL union representatives were opposed to the idea initially fearing potential job cuts, meetings and a demonstration of the proposed functionality and limited timeframe of the trial allayed these concerns.

1.2 Project Objectives

The scope of this project is to develop and operationally demonstrate a gateline that is capable of self-reconfiguring in order to maximise peak throughput and manage average throughput to prevent station overcrowding. The gateline will reconfigure the direction of individual walkways in a safe and controlled manner, freeing the staff at the gates to engage and support customers. It will inform and aid staff to make operational decisions on gate configuration or temporary station closure, which if sub-optimal, adversely affect network capacity, safety and customer experience. This project aims demonstrate to TOCs, supply chain and relevant stakeholders the commercial viability and operational benefits of this enhanced product offering.

2 Test Setup & Procedure

This section outlines our research, lab trials and station pilot setup.

2.1 The Intelligent Gateline Controller

After the simulation trial [1] the final changes were made to the controlling algorithm that decides which decision to take at any point in time. It was decided to choose the decision that was closest to the current gateline to minimise the volatility of the gateline given the stations customer flow changes are gentle compared with that of a terminus rail station for example.

Two stations were initially chosen to test the algorithms. One TFL led station with commuter like continuous flow (Blackhorse road - BHR). And the other one was an Arriva / Chiltern led station (Marylebone) with more passenger fluctuations throughout the day and especially peak times due to the station layout and type of journeys.

For both stations there are three components:

- The vSCU to remotely control the gateline.
- The IG server using two types of algorithms developed by Cubic and UoP.
- Sensors to count passengers in relevant areas of the station.

2.2 Blackhorse Road

To give the information to the system at BHR, Xovis sensors were installed overhead to measure throughput, velocity and build-up of crowds at the gateline and at the top of the escalators.

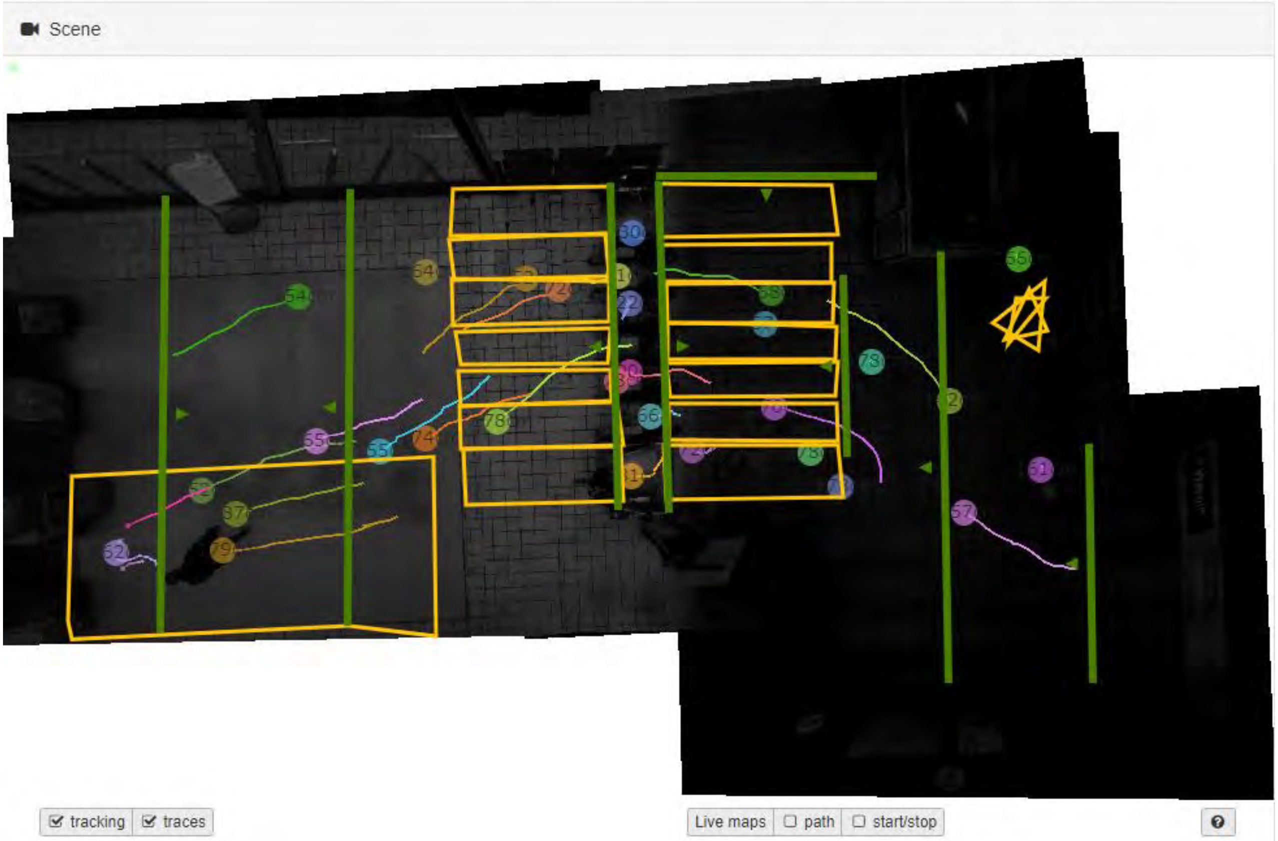

Figure 1 Xovis Overview at BHR

In order to be able to turn on the Intelligent Gatelines functionality in a live operational environment a number of requirements needed to be met

- Stakeholder Engagement – In order to reassure senior TfL staff an engineering demonstration was given and showcased the different gate modes available to users. This was mainly focused on the Supervised gate mode detailing how gates suggestions would be made to staff and direction changes would only be made if the decision was agreed. A complimentary video was created to support this.
- Union Engagement – Union members raised concerns about staffing levels, these were allayed with an operational demonstration of the supervised gate mode and vSCU focusing on the mobility of staff and the enhanced functionality available.
- Network Integration – Initial plans were to enable the vSCU on existing staff tablets but due to the complexity of the security protocols, backlog and lead time of the network team to implement changes required we decided to supply separate tablets running off a separate secure isolated network. While this workaround got the system on the station it meant that staff would have to have another tablet to make full use of any of the interactive elements of Intelligent Gatelines.
- Staff Engagement – Given TfL's request to run the gates in a supervised mode rather than a fully automated gateline staff needed to be involved to see any benefit in passenger flow. Staff were given briefing sessions about the vSCU and IG systems with usernames and passwords.

Once these obstacles and challenges were overcome, we could start to collect data from the combined algorithm. Using Cubic's damped feedback controller [2] and UoP's advanced controller to compare decisions and choose the new configuration closest to the current state.

2.3 Marylebone

To collaborate with Arriva, Marylebone was chosen as a site to show Intelligent gatelines working effectively at a rail terminus with a high volatility of passenger flow through the two gatelines. A system was designed to independently control the gatelines given their respective inputs based on the Blackhorse Road model. Quotes were obtained for the installation of Xovis sensors while mindful of the time constraints of landlord and listed buildings consent processes. Given the installation height and complexity the costs were deemed prohibitive, so we looked at alternatives to the Xovis sensor array.

2.3.1 BLE Triangulation

BLE triangulation and estimation technique was developed and tested in the lab based on a previous innovate uk project Retrospective Ticket Pricing [3] and sensor locations were surveyed and selected. There were requirements that sensors be placed on the platforms to ascertain when trains were arriving and which gateline would be affected but the power supply was deemed too risky, the resultant cabling job to workaround this to supply POE was too expensive.

2.3.2 CCTV Augmentation Analysis

Given time and budget was against us we decided to use the existing infrastructure available to us, as part of the preparation for the vSCU installation the controlling box for the CCTV had been upgraded to digitise the feeds this was now possible to digitally analyse the camera streams in real time. We worked with a 3rd party company Ultinous to develop a solution to count movements around the station to allow IG to make informed decisions. During the financial agreement process we simultaneously developed an inhouse prototype to count passengers by augmenting CCTV. When this solution was prepared and ready to be installed GDPR concerns were raised even though assurances were made about no data being recorded through Ultinous or IG. These delays at a critical time resulted in the install being pulled and focus given solely to BHR.

3 Results

The results were gathered as quantitative and qualitative data with the former being used to mainly determine the effectiveness of improving throughput. Qualitative data, although useful to understand the usability and the perception of decision making was mainly used to derive the overall staffing experience and create more of a backlog for future developments.

3.1 Background

Blackhorse Road is a residential station based in zone 3 of the London underground network. The passenger flow is predominantly entry in the mornings and exit in the evenings during the working week. The weekends flow is significantly lower and more evenly spread. Figure 1 Xovis Overview at BHR shows passenger flow over a 2 week period showing the very consistent and predictable pattern.

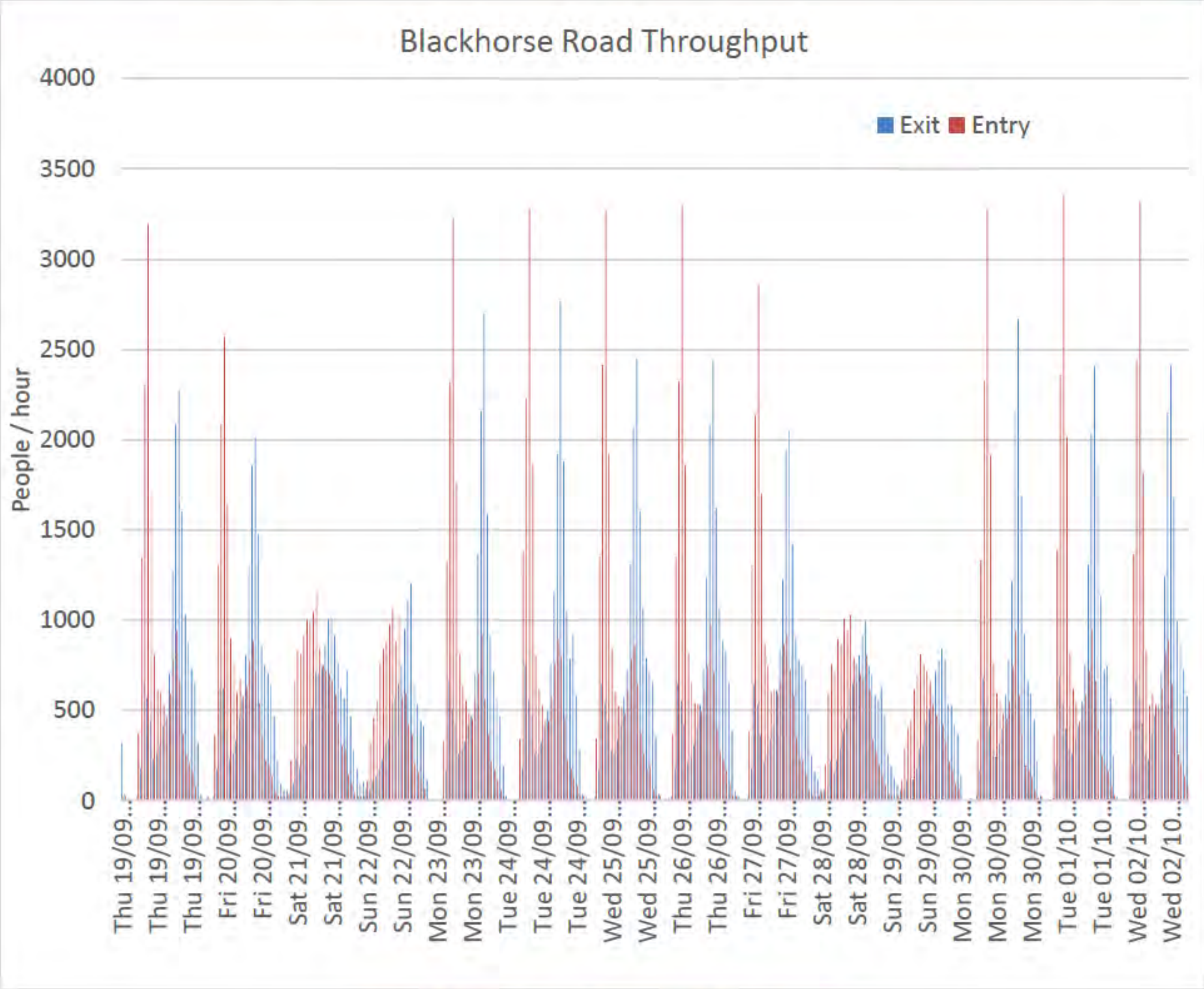

Figure 2 BHR Typical Passenger Flow Pattern

3.2 Gateline Changes

The configuration of the gates changes throughout the week, with the WAG set to Manual so IG just ignores them, the middle gate (42) set to Automatic most of the time and the remaining gates set to Supervised which requires staff interaction to enable the required change.

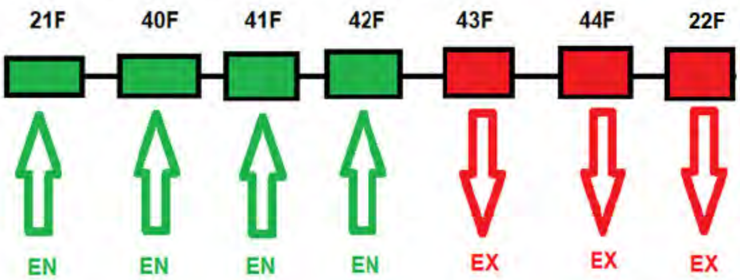

Figure 3 Shows the baseline, morning gateline configuration default setting at Blackhorse road.

Figure 3 depicts a baseline, morning configuration default setting scenario at Blackhorse road underground train station. In this scenario, it is assumed that the gateline configuration illustrated in figure 1 above is static. With 4 gates (**21e**, **40e, 41e** and **42e**) set to entry directions and 3 gates (**43x**, **44x** and **22x**) set to the exit directions.

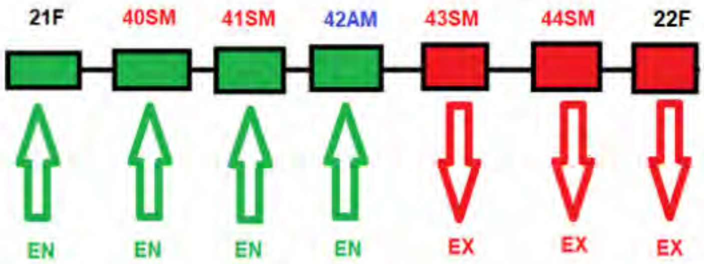

Figure 4 Showing the Intelligent gateline semi-autonomous mode

Figure 4 depicts a semi-autonomous configuration setting scenario at Blackhorse road underground train station, whereby gates **21e** and **22x** are fixed to entry and exit respectively. Gates **40, 41, 43** and **44** are set to Supervised mode –meaning that any request sent to these gates need staff approval before being executed. Finally, gate **42** is set to automatic mode. That is, no staff approval is needed for this gate to be changed.

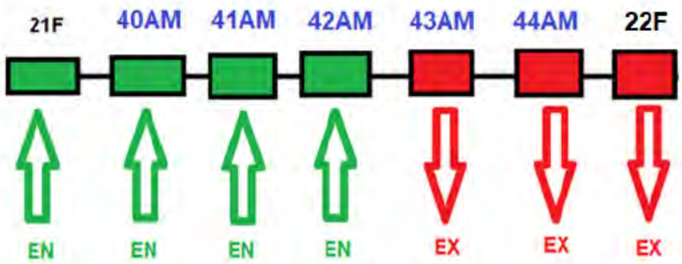

Figure 5 Automated Gateline Configuration

Figure 5 shows a fully automated gateline configuration setting scenario at Blackhorse road underground train station, whereby bar gates **21e** and **22x** fixed to entry and exit respectively, the remaining gates **40, 41, 42, 43** and **44** are set to automatic mode.

The scenarios described in Figure 3, Figure 4 and Figure 5 above will be taken into consideration in the following sections when discussing the influence of the intelligent gateline on waiting times and throughputs.

3.2.1 Throughput Optimisation Changes

In order to evaluate the impact of the intelligent gateline on passengers' throughput, 2 cases were taken into consideration. The first case consisted of monitoring –through a number of time windows, how the intelligent reacts to sudden spike in the number of passengers. In the second case, the project team established a direct comparison between peak-time baseline data –where the gateline management was set to manual mode as described in Figure 3, and peak-time data when the intelligent gateline system is set to semi-autonomous mode as described in Figure 4.

Total number of Optimal gate configurations	366
Gates Changed	1
Gate Requests	106
Double Gate Request	1

Figure 6 Sample Rush Hour Gate Requests

Figure 6 provides a sample rush hour of gate requests for the first case. Here, the morning peak-time (6h30 m to 9h30 am) from October 3rd, 2019 was considered. Computations were performed every 60 seconds. A total of 366 computations were logged, of which 106 required Gate changes. Only 1 gate change was made in this time which was the automatic gate (41) and since the flow was heavily weighted to entry for most of that time a forth exit gate was rarely required. Nearly all of the unheeded requests were to add another entry gate (43). The double gate request was made when there was a spike in exits most likely when an overland train arrived.

Time	Entry	Exit	Gateline	Gates Changed
07:57.3	44	41	21e,40e,41e,42e,43x,44x,22x	---
07:58.3	42	22	21e,40e,41e,42e,43x,44x,22x	---
07:59.3	35	9	21e,40e,41e,42e,43x,44x,22x	---
08:00.3	49	5	21e,40e,41e,42e,43x,44x,22x	43e
08:01.3	41	7	21e,40e,41e,42e,43x,44x,22x	43e
08:02.3	36	7	21e,40e,41e,42e,43x,44x,22x	43e
08:03.3	45	10	21e,40e,41e,42e,43x,44x,22x	43e
08:04.3	52	8	21e,40e,41e,42e,43x,44x,22x	43e
08:05.3	38	5	21e,40e,41e,42e,43x,44x,22x	43e
08:06.3	54	10	21e,40e,41e,42e,43x,44x,22x	43e
08:07.3	38	11	21e,40e,41e,42e,43x,44x,22x	43e
08:08.3	51	1	21e,40e,41e,42e,43x,44x,22x	43e
08:09.3	48	11	21e,40e,41e,42e,43x,44x,22x	43e
08:10.3	68	31	21e,40e,41e,42e,43x,44x,22x	43e
08:11.3	51	17	21e,40e,41e,42e,43x,44x,22x	43e
08:12.3	69	1	21e,40e,41e,42e,43x,44x,22x	43e
08:13.3	48	11	21e,40e,41e,42e,43x,44x,22x	43e
08:14.3	63	3	21e,40e,41e,42e,43x,44x,22x	43e
08:15.3	59	7	21e,40e,41e,42e,43x,44x,22x	43e
08:16.3	76	5	21e,40e,41e,42e,43x,44x,22x	43e

Figure 7 Intelligent Gateline Gate Requests Log Sample

Figure 7 provides a small sample size of instances of logged gate configuration requests. The results show that in peak time, during considered spikes in passengers' number, there is on average in every 60 seconds in the entry direction, 35 passengers when no gate request is made and 50 passengers when gate requests are made. On average, an increase of roughly 42.86% in entry throughputs. As for the Exit direction, there is on average 7 passengers when no gate request is made and 11 passengers when gate requests are made. On average, an increase of roughly 57.14% every 60 seconds in exit throughputs.

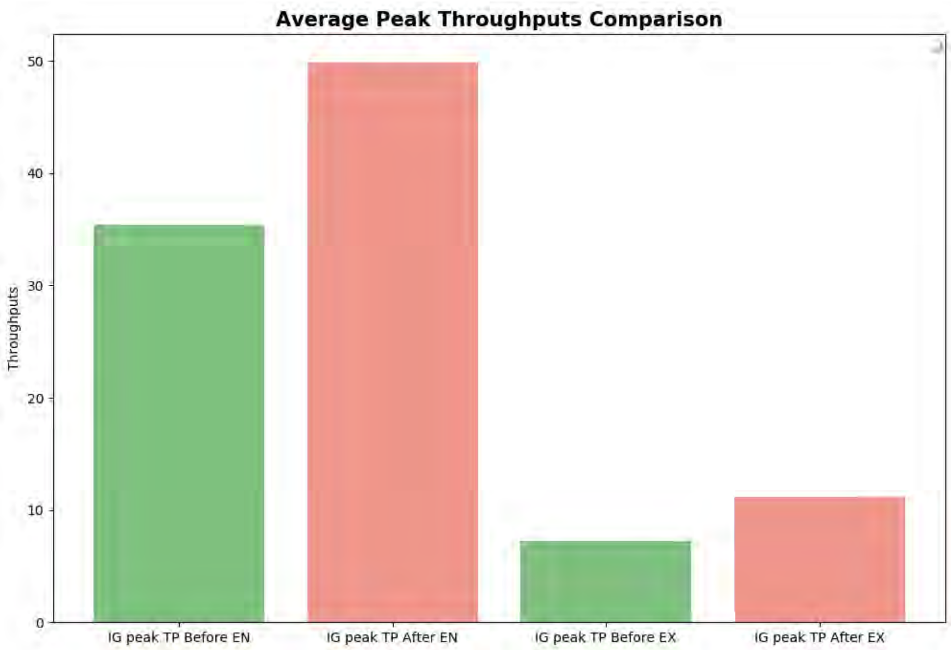

Figure 8 Throughput During Spike in Passenger Numbers

Based on the data provided in Figure 6 and the graphs provided in Figure 8 above, it can be concluded that:

1. Gateline efficiency (in terms of passenger throughput) can be increased using Intelligent Gatelines by approximately **30%** for a typical station with rush hour peaks when the gateline is fully autonomous –see Figure 5. For that potential to be fully materialised using Supervised gates, the staff need to act on the gate requests made.
2. We can infer from the data that a spike in passenger numbers will make Intelligent Gatelines suggest a change in gate direction (one or more walkways) which will reduce queuing and congestion. The staffs need to act on the gate change requests made by the intelligent gateline to fully capitalise on the benefits of the IG system.

The results for the second case whereby a direct comparison on average between peak-time baseline data – where the gateline management was set to manual, and peak-time data when the intelligent gateline system is set to semi-autonomous mode, are shown in Figure 9. Although not particularly visually noticeable on the graph, there is an increase in average Entry and Exit Peak throughput of 0.016 % and 3.108 % respectively.

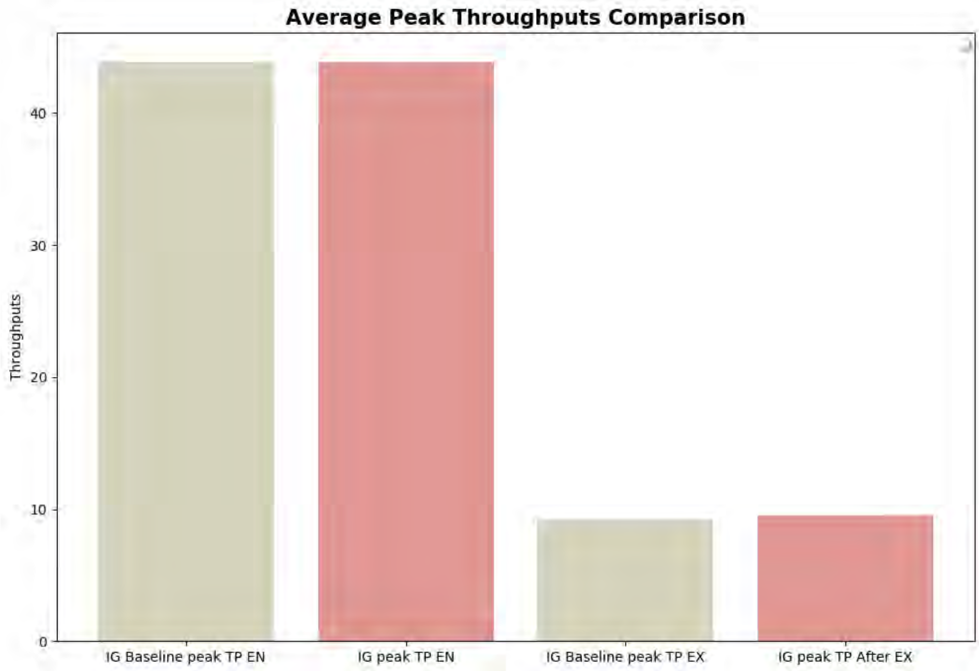

Figure 9 Comparing Manual and Activated Intelligent Gateline System for Morning Peak-time.

3.2.2 Days Throughput Analysis

Given the consistency of the flow during the week we can further investigate one day as displayed in Figure 10 Weekday Gateline Throughput.

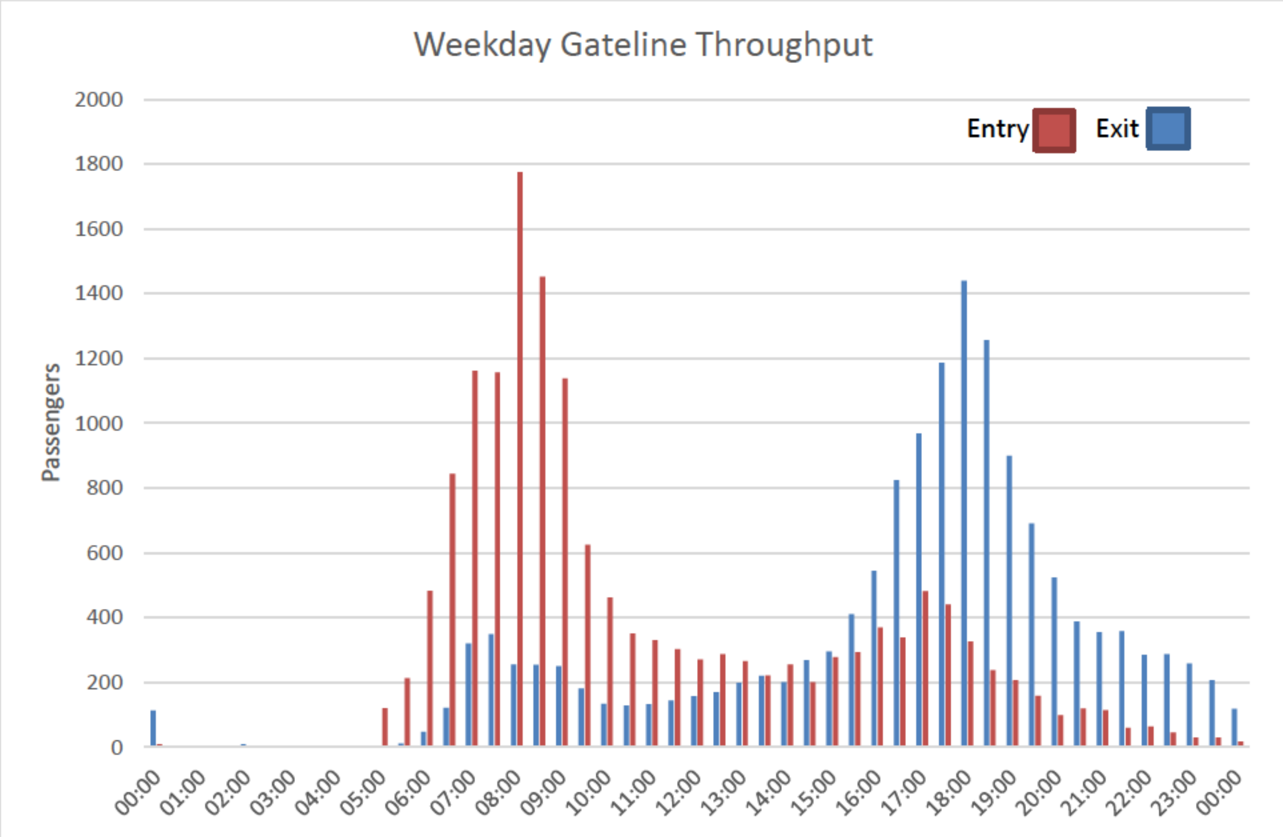

Figure 10 Weekday Gateline Throughput

By analysing the IG logfiles we can see that there were 191 Entry and 270 Exit requests throughout the day with 30 and 33 actioned respectively. All these changes were to gate 42 in the middle of the gateline as it was set to Automatic mode. There was no staff interaction on this chosen day, so no supervised gates were changed resulting in repeated requests which will inflate the numbers.

There are 8 instances of double gates requests all including gate 42 which automatically changed, these requests indicate a significant shift in flow being reacted to from a 5-2 to 3-4 switch or vice versa.

Figure 11 Timeline of Single and Double Gate Change Requests details the timeline of the gate change requests throughout the day and the requests mimic the flow of passengers which implies that the gateline wasn't set as efficiently as possible for the customer flow and required 5-2 configurations rather than 4-3 at peak times. The exit configuration does seem to be inefficient having a significant and intense amount of requests in the exit direction throughout the afternoon and evening.

Intelligent Gatelines with a more automated gateline would be able to make these minor adjustments during the day whereas staff wouldn't unless passengers were complaining at the gateline.

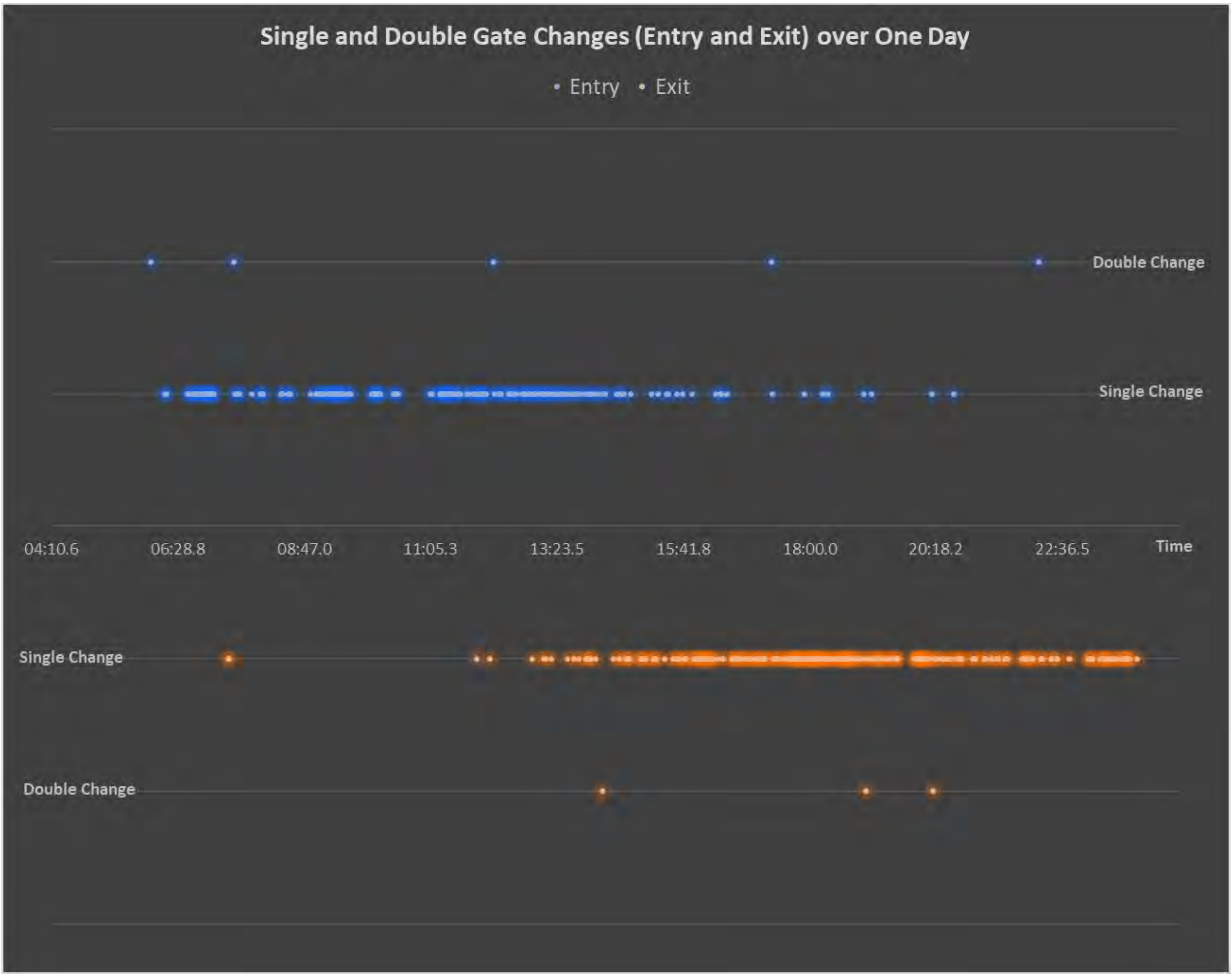

Figure 11 Timeline of Single and Double Gate Change Requests

3.2.3 Safety Changes

For IG to prove the concept of platform safety a zone was created shown in the bottom left of Figure 1 Xovis Overview at BHR at the top of the downward escalator near the entrance to the overground train platforms. Staff had mentioned that this was a safety concern when it became to crowded and would have to close the gateline for safety reasons. IG uses a three-tiered approach to throttle the passenger flow through the gateline, when thresholds are breached a number of gates are set to closed to stop the use of the gate until it’s safe to resume customer entry

During the two weeks period of close scrutiny there were ten occurrences of the Platform Safety thresholds being breached, this is broken down in Figure 12 Safety Threshold Data

Threshold Capacity %	Entry Gates Remaining	Days Occurring	Escalation Occurrences
80	2	8	-
90	1	4	4
95	0	6	7

Figure 12 Safety Threshold Data

Given gates were mostly in supervised mode it would need a member of staff to acknowledge the change and that is the reason for the escalations where no action was taken but there's an occurrence in a log file of some automatic gates being changed due to the safety thresholds being breached, flow reduced, crowd disperses, and gates reopen.

08:24.32 -- Gate No: 43 changed to ENTRY by IG Controller.

08:24.39 -- Current Gateline:
[{"gateNo":21,"direction":"ENTRY","mode":"MANUAL"},{"gateNo":40,"direction":"ENTRY","mode":"SUPERVISED"},{"gateNo":41,"direction":"ENTRY","mode":"AUTOMATIC"},{"gateNo":42,"direction":"ENTRY","mode":"AUTOMATIC"},{"gateNo":43,"direction":"EXIT","mode":"SUPERVISED"},{"gateNo":44,"direction":"EXIT","mode":"SUPERVISED"},{"gateNo":22,"direction":"EXIT","mode":"MANUAL"}].

08:24.39 -- Reducing Entry gates to 2 due to overcrowding, reaching 81% of capacity with 17 passengers.

08:24.39 -- Gate No: 42 changed to CLOSE by IG Controller.

08:24.39 -- Gate No: 41 changed to CLOSE by IG Controller.

08:24.39 -- Closing gate due to overcrowding: Gate No:42.

08:24.39 -- Closing gate due to overcrowding: Gate No:41.

08:27.32 -- Platform Safety Check: 25% of capacity with 7 people.

08:27.32 -- Current Gateline:
[{"gateNo":21,"direction":"ENTRY","mode":"MANUAL"},{"gateNo":40,"direction":"ENTRY","mode":"SUPERVISED"},{"gateNo":41,"direction":"CLOSE","mode":"AUTOMATIC"},{"gateNo":42,"direction":"CLOSE","mode":"AUTOMATIC"},{"gateNo":43,"direction":"EXIT","mode":"SUPERVISED"},{"gateNo":44,"direction":"EXIT","mode":"SUPERVISED"},{"gateNo":22,"direction":"EXIT","mode":"MANUAL"}].

08:27.32 -- Using agreed decision to change 2 gates.

08:27.32 -- Gate No: 41 changed to ENTRY by IG Controller.

08:27.32 -- Gate No: 42 changed to ENTRY by IG Controller.

Figure 13 Safety Excerpt from Log File

3.3 Waiting Times

The waiting times at the vicinity (**Node 2)** and at entry/exit points (**Node 1**) are produced using queueing models. For the Intelligent Gateline system, each **60 seconds,** an optimal configuration of the gateline is generated that specifies in which direction the gates have to be setup.

Overhead Xovis sensors are used to record passengers' data which include: **IDs, timestamps, Cartesian coordinates, lines** and **zones data** in both directions of the flow in real-time**.**

The queue model is developed based on live stream passengers' timestamps –accessed through overhead sensors, a given constant service rate and a fixed number of service gates. Then, the model predicts in advance, using **Node 1** and **Node 2, the** queue lengths and the waiting times in queue.

The optimal gateline configuration at Node 1 and Node 2 is generated that specifies the optimal entry and exit setups and that takes into account the safety constraints.

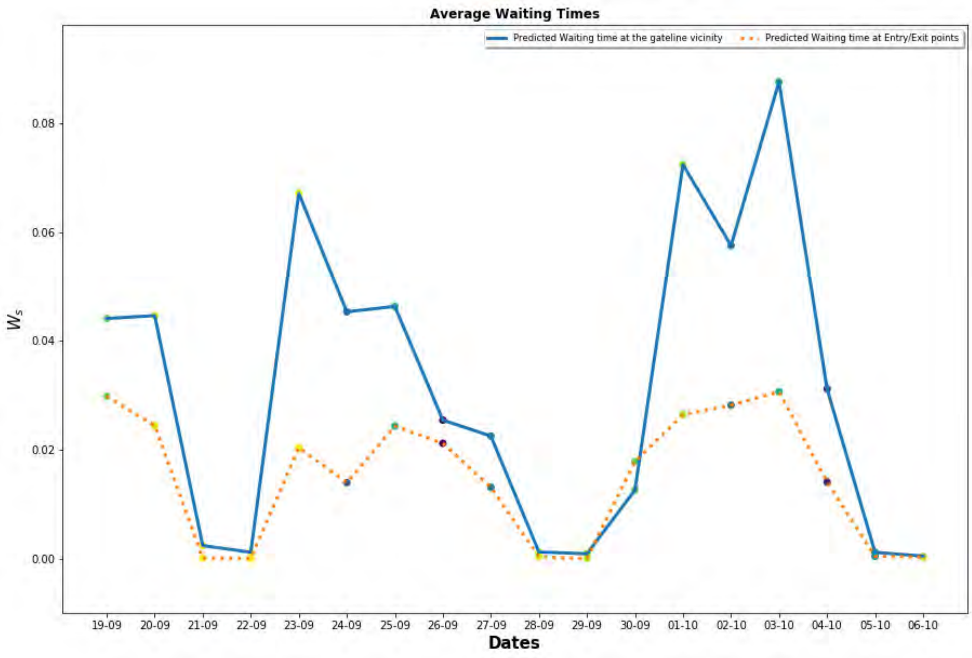

Figure 14 Showing Average waiting times per minute over a 2 weeks span.

In Figure 14, the average waiting times per minute over a fortnight are shown. The computations are based on the scenario described in figure 3, whereby, gate 20e and 21x are set to entry and exit respectively and the remaining gates (40, 41, 42, 43, 44) are set to automatic. It could be observed in Figure 14 that during the busiest time of the week –the first 4 days, the average waiting times per minute is projected to be higher and when the station is less busy the waiting time will be low.

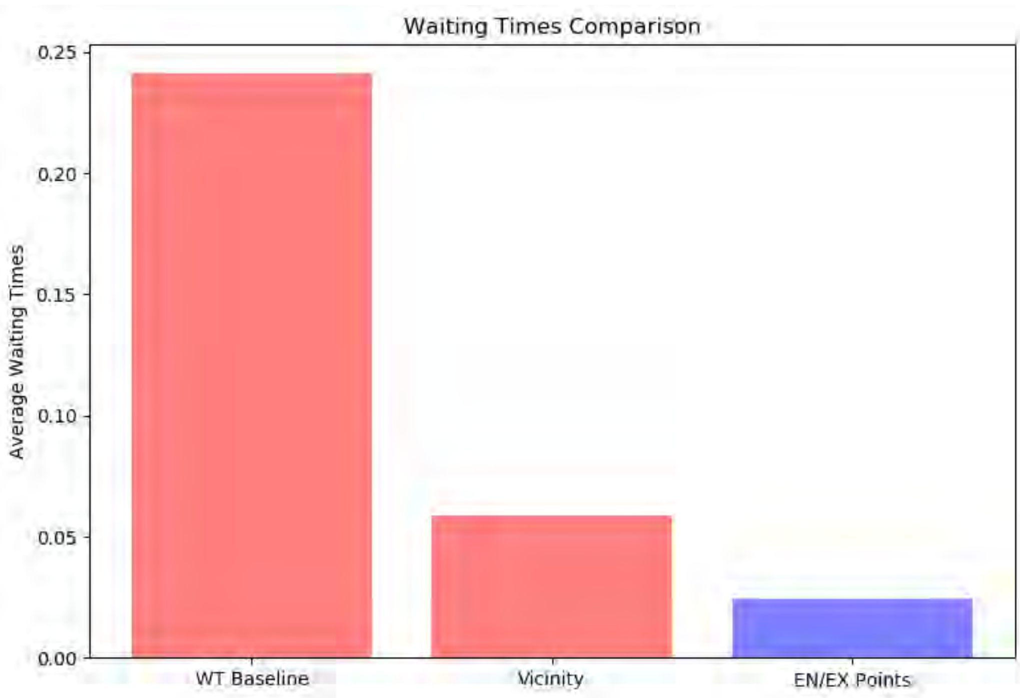

Figure 15 Showing bar charts plots of Average Waiting Times.

In the bar charts shown in Figure 15, a comparison is made between the waiting times obtained using the scenario described in Figure 3 (baseline) and that of scenario 3 –described in Figure 5. We observed a reduction of waiting times at the gateline vicinity and entry/exit points of 75.6 % and 89.63 % respectively when the gateline is working autonomously with only gates **20e** and gate **21x** fixed to entry and exit respectively and the remaining gates (40, 41, 42, 43, 44) set to automatic mode.

3.4 Staff Feedback

In Appendix 6.1 the staff questionnaire results show an overall positive response to the system. There was one respondent that clearly didn't like the system for whatever reason, this may be due to thoughts of staffing reductions if a gateline can be automated. Supervised Gate requests seemed to be a distraction which is understandable as it requires manual intervention. 66% of the staff were happy with the idea of a fully automatic gateline and see it as an upgrade on the existing system, for a product in a pilot stage this is very encouraging. The vSCU interface was positively received and staff could see the potential benefits going forward.

After conducting additional staff feedback sessions where a number of improvements and ideas were suggested

- If staff manually change a gate direction the Intelligent Gatelines system shouldn't request of try to change that gate again for a certain amount of time.
- Allow a gate error to be reported. "It would be great if we could report a fault on the gate from the tablet and see previous requests"
- "Could it catch fare evaders?" Revenue Protection would really benefit from screen shots being taken then paddles are forced or tailgating occurs with a facility to report that as well.
- "It's helpful when you're away from the gateline as there's only 2 of us on"
- "Station isn't busy enough to really benefit" The concept needed to be proved before running it on an integral station.
- "It does the job", "Easy to use", Simple interface" These benefit from the design idea to make the vSCU as similar as the existing SCU as possible.
- "Can I choose my own buttons" This is about having a more UX focused design and potentially user chosen skins.

There was also constructive criticism of the IG functionality, it was noticed that a gate change would occur after the crowd that built up had passed through the gates. This implies that the decision making based on 60 second intervals and using a 4-minute average to measure throughput wasn't quick enough during peak times. These times were decided on because of the Supervised modes inclusion thinking that tablets requiring attention every 30 seconds would become irritating quickly. (possibly down on numbers of threshold activation)

4 Conclusion

As the pilot progressed, IG became more intuitive for staff, this being highlighted by the decision on which gate should be automated, at first 41 an off-centre gate was set to automatic detailed in 3.2.1 Throughput Optimisation Changes which when only having one automatic gate is of limited help. Later 42 the centre gate was switched to automatic which provided much more use throughout the day focused on in 3.2.2 Days Throughput Analysis. If a combination of gate modes are to be used in stations then there will be guidelines provided to maximise efficiency.

From the output of the discussed data it can be concluded that gateline efficiency (in terms of passenger throughput) can be increased by approximately 30% using Intelligent Gatelines for a residential station where gateline changes would typically happen twice a day. We can infer from the data that a spike in passenger numbers will make Intelligent Gatelines change direction of the gates which will reduce queuing and congestion. Because these occurrences can happen quickly it would not always be possible for a member of staff to gain access to the SCU or individual gate keypad to change a gate walkway direction.

This gives Intelligent Gatelines a significant advantage in aiding the efficiency of a stations gateline and provides station staff with the information required to ensure optimum passenger flow in their station. As confidence in the system grows, supervised mode gates will be swapped over to the automatic mode and that will help increase efficiency further.

Intelligent Gatelines offers transport providers a cheaper alternative to increase throughput through a station without having to add more gates by making the gateline more efficient. Given predicted rises in public transport passengers and certain stations with no space for expansion Intelligent Gatelines will be essential for busy stations.

4.1 Key Technical Findings

Due to the issues encountered at Marylebone it enabled the project to branch out and investigate different types of sensor, this proved that if the numbers of passengers can be counted the Intelligent Gatelines system can make accurate informed decisions on optimal gateline configurations, this is discussed in further detail in chapter 4.3 Sensor Agnostic Design.

The platform safety concept works, so while IG can optimise throughput it only does so with the safety implications of high risk areas below capacity thresholds. By monitoring these high risk areas with a higher frequency and priority over throughput station safety won't be compromised with Intelligent Gatelines installed.

4.2 Constraints During Testing

Ideally the station would all have all gates set to Automatic to see the full effort of the Intelligent Gatelines system. In order to appease and allay concerns it was decided that Supervised mode would be used which logs requests of decisions but needs staff to accept the proposed change, this was made slightly more difficult as the tablets for the system weren't staff issued. Due to network configuration and security these tablets were required to get the pilot fully live. The tablets were bulky and hampered the mobility aspect of the pilot and this also caused engagement reduction so not all gate changes requests were seen.

4.3 Sensor Agnostic Design

Marylebone forced us to look at numerous sensor types all of which fit in with the Intelligent Gatelines interface design

- Overhead Stereoscopic – Used in the BHR install it anonymises passengers and can provide line crossing and zone population data. This set up can provide IG with all the in-station information it needs.
- BLE – A more blunt measurement that can provide station arrival data via footfall or trains. Build up of passengers can be measured with a good idea of location. Better used in collaboration with other sensors or in stations where the flow is relatively simple.
- CCTV – If GDPR concerns can be allayed this system can give as much information as the stereoscopic sensor array without the additional installations costs. The feed would need to be digital to be effective.
- Machine Learning from Past Data – With stations that have consistently predictable throughput the algorithm could learn what gate configurations are best using previous data to match scenarios of throughput.
- Throughput – Using only throughput data will give a basic set of changes allowing for the gentle flow changes through a day but not be able react to sudden peaks in customer flow. This can be dealt with by dynamically reducing the decision making time to enable the gateline cope with sudden increases in customer flow such as peak or when throughput passes a certain threshold.
- Timetables and Loading Data – Realtime data such as the Darwin feed can be used to inform the gates about impending heavy passenger flow if this could be combined with loading data IG would have a more accurate picture.
- Network Data Feeds – For fully integrated transport networks it would be beneficial to know of increased passenger flow if nearby stations are closed or experiencing operational difficulties.

All these sensors can and should be combined to create an accurate picture of impending customer flow, this can be refined more for different station profiles.

4.4 Station Profiles

During the project it became apparent that Intelligent Gatelines would need to act differently in different types of station the following have been identified to far:

- Residential Metro - station without defined timetables but very consistent entry in the morning gentle changes through the day can realistically work with just throughput data

- Inner City Metro – very busy mainly reverse of residential but not as predictable so throughput and queue build up, in collaboration with transport network data
- Terminus Station – Gateline to be hugely volatile to get people on to trains after waiting build up and full trains passengers exiting the station
- Residential Rail Station – train station that would benefit from real time train data and past data to indicate expected use get people onto the platform first and when train arrives the gates would switch to exit

4.5 Future Rollout

There is interest in the vSCU and IG respectively. Several TOC's have requested quotes for pilots in a selection of different station profiles. Estimates are in progress to fully productionise and create roadmaps for these potential products longer term.

4.6 Future Exploitation

Feedback and discussions with interesting parties has help to create an interesting potential backlog

- Remote Validation – Building on from the Air4 project [Reference] there has been some successful lab and station tests with vSCU integration into the object tracking allowing a gate to be opened when a validated customer approaches. This could also be used with open gates closing when unvalidated customers approach. By removing the validator from the gate, the number can be increased and potentially allow a higher average throughput of the gates.
- Fault Reporting – By being able to interface with the gates error code can be checked and either automatically reported or allow staff to report faults through the vSCU
- Remote Ticket Inspection – Errors from tickets can be shown via the vSCU and allow staff to help the passenger either by letting the passenger through or through a video help point, This functionality would be incredibly helpful for stations which are unmanned later at night where gates are currently left open.
- Preset Gate Configurations – A usability advance for staff, allowing them to create their own presets of a gateline enabling quick and convenient wholesale changes to a gateline.
- Fare Evasion Detection – By using video analytics fare evasion such as tailgating or pushing through paddles can be recorded and stored. This data can be analysed to allow targeted inspections by revenue protection and British Transport Police.
- Realtime Gate Analytics – With the vSCU using a cloud based system, real time data would be available across a transport network with ticket types, throughput data all available. This could be enriched and sent to customers for real-time service updates and journey planners.

5 Acknowledgements

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The partners in this project were Transport for London that provided a site for us to perform the trial on with feedback for iterations and improvements, Arriva Rail London for the Marylebone site and work in finding viable alternatives and University of Portsmouth for the instrumental Advanced Controller algorithms and analysing the quantitative data that was collected. We also had a key supplier for this project, Xovis who provided the object tracking system.

Appendix A Staff Feedback Results

Intelligent Gateline Survey

6 Responses   05:59 Average time to complete   Active Status

1. Number of years of service

0-3 years	0
4-6 years	3
7-10 years	0
11+ years	3

2. What is your Role

CSA	4
CSM	2
ASM	0

3. If the control interface (App) was available on a TfL tablet, how satisfied would you be with a Tablet Controlled Gateline?

Very satisfied	2
Somewhat satisfied	3
Neither satisfied nor dissatisfied	0
Somewhat dissatisfied	1
Very dissatisfied	0

4. Does the use of Intelligent Gatelines improve customer service by increasing interraction with Customers?

Strongly agree	0
Agree	4
Neutral	1
Disagree	0
Strongly disagree	1

5. Thinking about decisions made by the Intelligent Gateline, were they sensible?

Strongly agree	1
Agree	3
Neutral	1
Disagree	1
Strongly disagree	0

6. Would the gate direction benefit from being changed more during the course of the day?

Strongly agree	1
Agree	3
Neutral	1
Disagree	1
Strongly disagree	0

7. Did gate changes hinder you/colleagues at any point?

Strongly agree	0
Agree	1
Neutral	1
Disagree	4
Strongly disagree	0

8. Did gate changes hinder customer at any point?

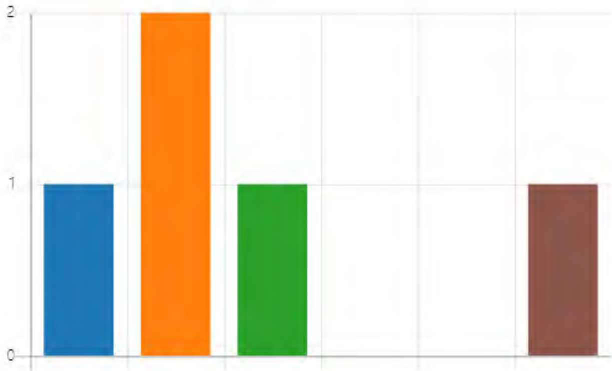
Strongly agree	0
Agree	1
Neutral	1
Disagree	3
Strongly disagree	0

9. Based on your personal experience over the trial period, do you think the Intelligent Gateline has led to a reduction to passenger waiting times?

Strongly agree	0
Agree	3
Neutral	2
Disagree	0
Strongly disagree	1

10. Based on your personal experience over the trial period, do you think the Intelligent Gate has led to less occasions of opened gatelines when crowding occurs?

Strongly agree	1
Agree	2
Neutral	1
Disagree	0
Strongly disagree	0
N/A	1



11. Does acknowledging the supervised gate changes divert your attention from customer service?

Strongly agree	1
Agree	2
Neutral	2
Disagree	1
Strongly disagree	0

12. Were the different gate modes useful? (Manual, Supervised, Automatic)

Strongly agree	0
Agree	5
Neutral	0
Disagree	0
Strongly disagree	0

13. Would you be confident in a fully automated system without having to acknowledge gate changes?

Strongly agree	2
Agree	2
Neutral	0
Disagree	1
Strongly disagree	1

14. Was the overall look and feel of the tablet interface intuitive?

Strongly agree	2
Agree	2
Neutral	2
Disagree	0
Strongly disagree	0

15. Was the camera view of the gateline helpful?

Strongly agree	1
Agree	4
Neutral	1
Disagree	0
Strongly disagree	0

16. Do the popups on the tablet give enough information?

Strongly agree	0
Agree	4
Neutral	2
Disagree	0
Strongly disagree	0

17. Intelligent Gateline system what frequency of popups would you prefer?

Every 30seconds	0
Every minute	0
Every 2 minutes	1
More than 2 minutes	1
User Configurable	4

18. Did you engage with the popups?

All the time	0
Most of the time	0
Sometimes	6
Rarely	0
Never	0

19. Could the tablet control interface be helpful to aid revenue protection?

Strongly Agree	1
Agree	4
Neutral	0
Disagree	1
Strongly disagree	0

20. Do you feel the Intelligent gateline system would benefit customer experience?

Strongly Agree	2
Agree	3
Neutral	0
Disagree	1
Strongly disagree	0

21. Do see the tablet control interface app replacing the station control interface, thus reducing station clutter?

Strongly Agree	1
Agree	4
Neutral	0
Disagree	1
Strongly disagree	0

22. Is the Intelligent Gateline an upgrade to the current system?

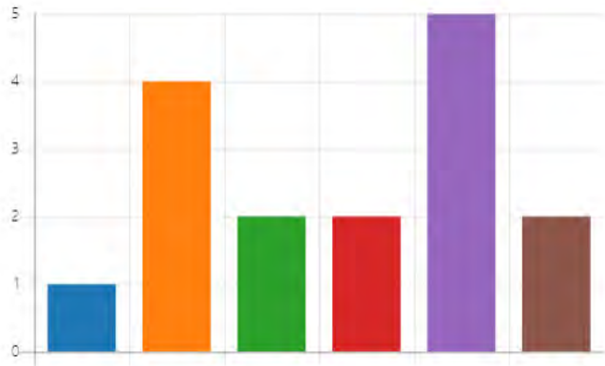
Strongly Agree	1
Agree	4
Neutral	0
Disagree	0
Strongly disagree	0

23. Which day of the week has the Intelligent system been most useful

Weekdays (Mon to Fri)	4
Weekends (Sat - Sun)	1

24. Which times of day was the intelligent gateline system useful?

AM	1
AM peak	4
Noon	2
PM	2
PM peak	5
Evenings	2



25. Would the addition of platform sensors and train loading feedback aid in crowd control at the gateline and platform?

Strongly Agree	4
Agree	2
Neutral	0
Disagree	0
Disagree	0

26. Overall, how satisfied are you with the Intelligent Gateline System?

Very satisfied	1
Somewhat satisfied	4
Neither satisfied nor dissatisfied	0
Somewhat dissatisfied	1
Very dissatisfied	0

27. Would more stations benefit from an Intelligent Gateline System?

Strongly agree	2
Agree	3
Maybe	0
Disagree	1
Strongly disagree	0

28. Would more stations benefit from a Tablet Controlled Gateline

Strongly agree	3
Agree	2
Neutral	0
Disagree	1
Strongly disagree	0

29. Would you like to see the system rolled out to more stations?

Strongly agree	3
Agree	2
Neutral	0
Disagree	1
Strongly disagree	0

30. What would you like to see added to the Intelligent Gateline System?

5
Responses

Latest Responses

"The system is not dynamic enough, it reacts too slowly with the chan...

"gate fault reporting"

"Automatic model is very useful and a more responsive system would ...

Appendix B vSCU Supervised Mode