STATION INNOVATION

OVERCROWDING AND INCREASING PASSENGER THROUGHPUT AT STATIONS

April 2016

EXPLORING INTELLIGENT MOBILITY

CATAPULT Transport Systems

Contents

FOREWORD

Stations are critical to the success of a thriving passenger rail network and provide route to network and engage local communities and businesses. As the railway's entry point for passengers they form a 'moment of truth' about customer experience which can either delight or disappoint.

They can enable a successful, purpose driven journey, or act as pain point that frustrates the passengers experience with rail. Stations inevitably are a multi-modal access point that must enable users easy access and exit, be and feel safe and be role models of interchange experience.

A successful railway station will add to the passenger experience while supporting the economic, social and environmental benefits of rail. Rail's growth has been strong and persistent. It is expected to grow to even higher levels well beyond our current experience and well beyond the capacity we currently have. Its integration with other modes and the surrounding area must provide for an end-to-end journey experience that will help exploit its attractive offer as the most sustainable transport mode. Stations offer the opportunity to provide better fit with all modes of transport, acting in a complementary element of transport and not a competing one.

Major stations are rapidly becoming overcrowded and congested, struggling to keep themselves safe and operational while providing a minimum standard of passenger throughput capacity. Their age and heritage, can be a constraint. Many were designed in a very different age, for very different expectations, for very different volumes of people. They must now move forward and progress into the 21st century and do so with the full expectation that people do not just compare their station to station experience, but they compare rail against very best of customer experience or transport interchanges they see around the country and the world.

Overcrowding and congestion in transport of all modes is becoming a major problem —on the road, in the air, on the rails— wastes time, increases pollution, and is costly to society. Commuters in Brussels and London waste more than 50 hours a year in traffic jams; across Europe as a whole, infrastructure congestion costs 1 percent of GDP. It doesn't have to be this way. Much could be done and significant monies saved by "making more of existing infrastructure" through improved demand management, maintenance, or digitalisation in the form of big data. While the UK is making unprecedented investments in rail infrastructure, these

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take time to realise and customers cannot afford to wait, nor will their demands for improvement cease. They need interchanges and stations with easy access, dynamically available information and the application of tried and tested techniques - all applied with a sense of urgency which has previously not existed.

Excessive pedestrian congestion at stations can, if not tackled, stifle demand, waste traveller time and negatively impact the reputation of the whole industry.

Relieving overcrowding need not involve large capital investment, but it does require energy, innovation and leadership. This report outlines some of these ideas harnessed from a wide range of innovators and leaders from across industry. These challenges can be resolved. They can be overcome if industry and government work to engage innovators and leaders at all levels within industry, to work as part of a high performance team, determined to innovate and find new ways of cracking the code of change around overcrowding and congestion at stations.

EXECUTIVE SUMMARY

01 It is clear that many stations across the rail network already suffer from varying degrees of passenger congestion and overcrowding. Congestion is caused by a constraint on the free flow of people through a system, so it is important to consider the system as a whole rather than reviewing each individual element in isolation. Solving the problem at one point in the system may only provide a bottleneck elsewhere. This initial scoping research report examined what could be done to ease congestion and overcrowding through innovation, by the adoption of some international best practice and by setting out a number of options and ideas as a call to action both for innovators and industry. This high level summary provides a select few of potential short term actions.

HIGH LEVEL RECOMMENDATIONS

R1. Conduct a number of high tempo station trials incorporating innovative dynamic wayfinding signage and information systems at stations which are, or are at risk of overcrowding.

R2. Government should support a new 'Pilot Station Framework' to act as a catalyst for change, providing for a new model of action to reduce key local barriers for innovation. It will help demonstrate that rapid benefit can be and will be achieved.

R3. Leverage the power of rail franchising competitions and set out to provide for a number of national exemplars of best practice, innovation and industry collaboration at selected stations in the next franchise competitions. This must focus on industry investment into creating a new, demanding level of overcrowding and congestion management.

R4. Align the significant national rail resources available for innovation and station investment to ensure that industry and innovators have the encouragement and endorsement to make big change happen, driven by **open innovation and open data.**

R5. Invest in new SMART station research and development facilities to accelerate access to test facilities that will provide for more 'proof of concept' demonstrators to be brought rapidly to market.

R6. Make service loading data open and conduct a narrow open data trial around selected pilot stations as a means of testing, learning, iterating with open data to provide for a new level of rail service provision that exceeds customer expectation.

R7. The modelling work on both a passenger flow optimised timetable and real-time passenger flow optimised platform allocation illustrated that significant benefits might be realised and should be thoroughly modelled and analysed in conjunction with industry partners.

02 There was also a strong message from participants and stakeholders in this study, that for too many people, the pace of change is too slow. Quality of service isn't meeting expectations, collaboration isn't high enough and that innovation is being constrained. Participants wanted, and expect to see action on behalf of customers. The initial recommendations will require further research, in depth exploratory consultation and greater work, yet the potential to address the gap has been illustrated in the modelling and in other international benchmarks. The rate of technological change is accelerating and this is an opportunity that rail must grasp with tempo and energy, to realise a new modern experience for passengers that helps make stations fit for the future.

CONTEXT & INTRODUCTION TO STATIONS

RAIL GROWTH, ECONOMIC GROWTH AND ITS IMPACT ON STATIONS

03 Major railway stations in the existing railway network often face serious capacity problems at peak times, causing safety issues, or creating negative impacts on customer experience. In the 2014 Network Rail 'Rail Utilisation Study', 118 stations across the UK network were identified as having issues with passenger congestion. With over 2500 stations in the network (many of which are over 100 years old) service providers need to find solutions to these problems in order to ensure public transport remains an attractive mode of transport.

04 The economic, social and environmental benefits of public transport are widely supported by government[i]. However, without the necessary spare capacity on public transport, increased use will be constrained. The UK rail network is a prime example of this, where current services are over-subscribed[ii], stations overcrowded[iii] and demand is still growing. According to the ORR, rail passenger journeys grew by 4% between 2013-14 and 2014-15. Future forecasts predict high growth. HS2 Ltd has predicted that demand will have doubled from 2008 levels by 2043. Department for Transport models predict that rail demand will increase from around 50 billion passenger kilometres in 2010 to around 85 billion in 2033. Yet a fully deployed Digital Railway in 2030 is predicted to enable 40% more trains during the peak period; overall a gap is likely to exist as UK rail is not progressing with step changes quickly enough.

The station status quo should be challenged.

OVERCROWDING AT STATIONS

05 Estimates of station usage consist of the total numbers of people either travelling from or to the station (entries and exits) and interchanging at the station (interchanges). These estimates are based on ticket sales only, which include people who use the station facilities but do not buy a ticket for travel.

06 UK station usage has been growing steadily since 1997, as can be seen in Figure 1. In 2015, the top ten stations alone in the UK each saw over 30M entry and exits per annum. The top 473 stations represent 80% of all passenger entries and exits while major London stations dominate usage. As the investment cost for changing existing stations can be high, station lay-out needs to be optimised wherever possible at the design stage and iterative innovation needs to be used during refits or improvements.

07 Many stations in the UK are over capacity and Network Rail draft planning for Control Period Six (CP6) has identified 16 highest priority stations that require immediate attention. These stations include major terminals and interchanges such as Victoria, Clapham Junction and Birmingham Moor Street. Trains are often held outside platforms until the build-up of passengers has reduced to safe levels.

08 High densities of people moving through stations for their onward journey can be affected by a range of factors such as high levels of incoming passengers, incidents, delays, or major events. Overcrowded trains arriving at stations with passenger numbers in excess of capacity[iv] (PiXC) can also add to overcrowding at stations. For example, Euston has 27,300 arrivals in the peak (4.2% PiXC). Essential station improvement work creates additional pressure. Despite construction or renovation constraints, London Bridge needs to cope with 143,300 peak arrivals and well documented issues have resulted from overcrowding. The challenge for the rail industry is to accommodate the increased passenger demand without significantly increasing the size of the station footprint.

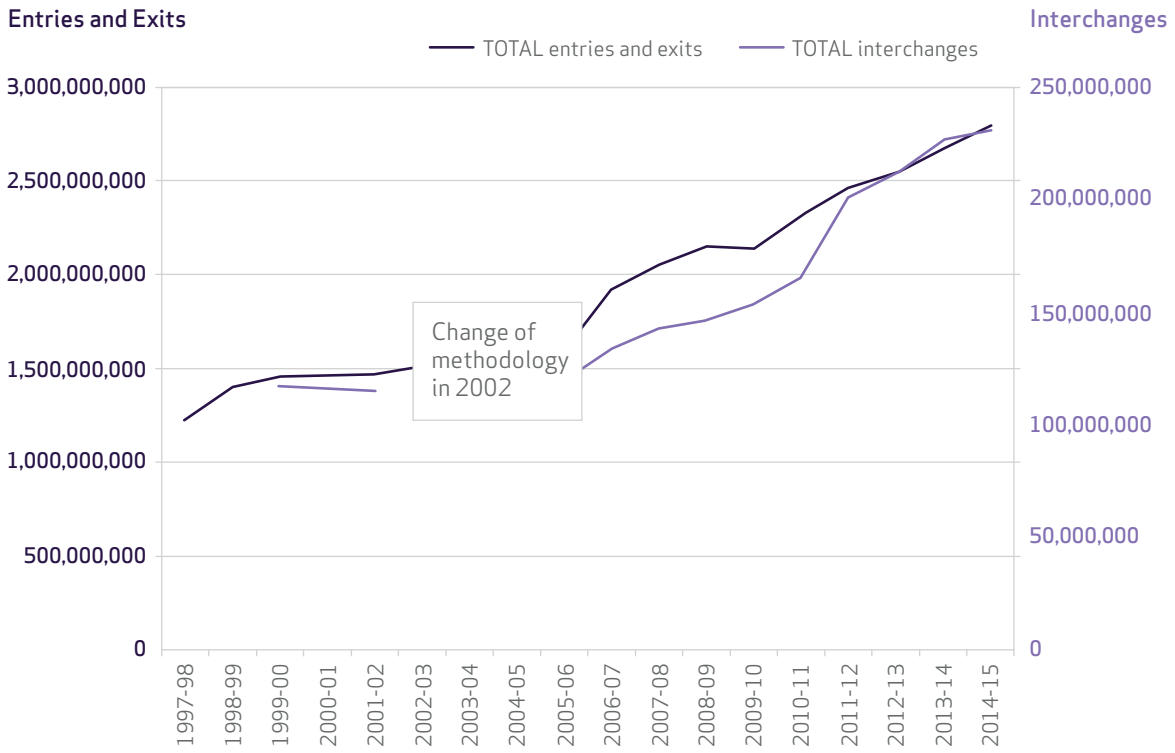

FIGURE 1, ORR, Station Usage 2014-15, Publication date: 15 December 2015

Network Rail - Liverpool Street example.

NR analysis on stations overcrowding is being developed more fully to ensure appropriate investment. This case example illustrates some key points. Train dispatch issues resulting in delays are being caused by platform crowding on platforms 1-10 where the gate line is congested at peak times and gates are kept open in the AM peak to relieve paid-side crowding. Platform clearance times are 4-5 minutes when the gates are kept open. On platforms 11-18 the gate line is very congested and the vehicle gate is opened in the AM peak to relieve paid-side crowding. Platform clearance times reach 5-7 minutes even with gates kept open.

Overall the concourse is congested during the evening peak and can become very crowded during train service disruptions. Furthermore, popular access points to Bishopsgate and Broad Street are congested and queueing occurs at the top and bottom of escalators in peak periods.

Without investment and action, the concourse will struggle to accommodate the typical weekday evening peak demand; stairs and escalators to the main exits will become so busy that they may need to be closed. During disruption the station may need to close after only a few minutes.

09 While there are infrastructure projects planned which will increase station capacity, many of these are 10 or more years away. This situation drives an urgent need to use innovative solutions to run railway stations more intelligently, bridge the interim demand as well as developing fresh thinking for major improvements. A free flowing railway system is required for a high growth economy. Given the growing capacity issues at stations, innovation will need to be embraced to overcome the challenges this presents.

CUSTOMER EXPERIENCE AND STATIONS

10 Transport Focus research (Figure 2) measures customer satisfaction via two key categories which include station and train factors. Recent 2015 data on stations illustrates that major station satisfaction is variable. Improvement efforts typically focus on the satisfaction factors which most affect or drive customer satisfaction. Of the 21 service factors measured, just four service factors amount to 71% of the key drivers of customer satisfaction[v]. The major train factors of punctuality, speed, train cleanliness and ease of being able to get on and off the train dominate. Given that the ease of getting on and off the train occurs at the station this is considered key to improving satisfaction with stations. The important station factors which form part of the key drivers of satisfaction are information about train times and platforms (3%), the overall station environment (3%) and personal security (1%). At stations, information at stations is a key dissatisfaction driver (2%) while how the train company is perceived to handle delays is a major factor (58%). Seamless information and good communication are therefore vital for both strong customer experience and also for service recovery in times of disruption.

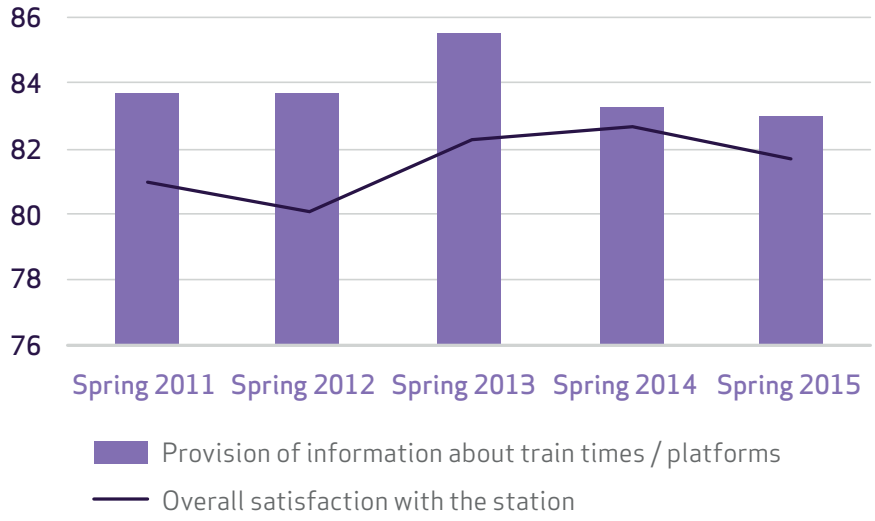

FIGURE 2, Network Rail stations - passenger satisfaction (Transport Focus 2015)

11 Gate lines can also contribute to overcrowding at stations as flow through gates provides a bottleneck, by design. Transport Focus also researched gate lines in 2010's 'Ticket Gates at the Station'. They found common customer issues around gate lines occurring during peak times – passengers said there were either **too few gates** or **not enough gates operating for use, gates being too narrow when carrying luggage**, or **too slow to open**, or they were not **accepting all types of tickets.**

Of the 21 service factors measured, just four service factors amount to

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of the key drivers of customer satisfaction

12 Customers perceive their journey as an end to end experience. National research[iv] into multi modal journeys involving 10,000 respondents, expert interviews and analysis identified that travellers experience pain points as they cross modes. 75% of all journeys in the UK experience pain points, rising to 86% where rail is involved. The key findings relevant to rail included the need to reduce complexity of planning for multi-modal journeys, improve the speed & reliability of interchange and improve the connectivity during interchange. Improvements in these areas will be fundamental in supporting modal shift. Stations act as key modal interchanges so the benefit to customer experience of an increased passenger throughput capacity can be argued to be essential.

RAIL DELIVERY GROUP– A VISION FOR STATIONS - NINE PRINCIPLES

13 The Rail Delivery Group (RDG) examined how the industry should evolve its approach to the development and management of stations. A key output was their future Vision for Stations[vii] that recognised that stations are more than just building assets or a place for people to access rail services, they have the potential to regenerate communities, support local identity and also be a test bed for new technologies. Stations can support and create an experience that attracts even more people to use Britain's railway. With 95% of the population living within five kilometres or less to a station, access and use of stations as a hub extending beyond rail was seen as vital.

14 The RDG argues that, given the scale and scope of the station estate, the challenges are large and long term thinking is essential. Establishing a clear vision can provide a stable policy-base upon which to build long term strategies. To underpin this vision, a set of nine key principles which have been used to assess potential options were developed in this report. These key principles are in figure 3 and the fuller detail in Appendix C.

FIGURE 3, RDG Nine Principles for Stations (Vision for Stations)

The Rail Technical Strategy 2012[viii] has a number of clear aligned elements to this vision including infrastructure, communications, customer experience and innovation linked to managing overcrowding and increasing smooth flow through stations.

> **Platforms, train doors, train positioning and escalator siting are synchronised to help passengers transit busy stations. Full advantage is taken of e-business transactions to minimise the need for traditional ticket offices and barriers**
>
> RTS 2012, infrastructure vision extract

Using these laudable visions, a framework was developed to analyse initial solutions for station overcrowding.

15 **Focus of innovation research**. In October 2015 the Department for Transport (DfT) sponsored the Transport Systems Catapult (TSC) to carry out a project to;

i. Generate innovations that **unlock latent Passenger Throughput Capacity** (PTC) in UK railway stations in the short term;

ii. As a secondary aim, **explore the 'station of the future'** relating to concepts that help change behaviours, improve passenger experience and increase capacity; and

iii. Examine **three key stations** as case study stations to inform thinking and explore how innovations would apply.

RESEARCH SCOPE AND OBJECTIVES

OBJECTIVES

16 The overall objectives of this preliminary investigatory project were to:

i. Use available data and analysis for a select number of stations to examine station access, ease of journey through the station and station to train interfaces. Three stations were assessed, each with different characteristics and passenger throughput capacity (PTC), to identify whether any solutions for increasing PTC might fit these stations

ii. Generate a set of options jointly with industry through ideas shops;

iii. Identify barriers to innovation for further improving capacity at train stations;

iv. Build a prototype virtual station test bed (concept testing) as a modelling to examine what could be done to increase capacity in stations;

v. Create an on-line portfolio of high impact SMEs to help stimulate the rail market; and

vi. Recommend actions for the short, medium and long term.

OVERALL APPROACH

17 The overall approach used is shown in figure 4. The project approach consisted of;

- An in depth literature review of over 30 key reports and academic literature;
- Developing empirical data from a number of fact finding exercises at major sites. This included visits to stations and related operational and management centres in the UK and in Japan. Euston, Liverpool Lime Street and Birmingham New Street were stations chosen within this research. Euston is growing in importance due to it becoming a terminus for HS2 and already has overcrowding problems, while Liverpool Lime Street is predicted by Network Rail analysis to become congested in 2019. Reopening in 2015, Birmingham New Street was included to, identify which innovations had been adopted as a newly modelled station. Eight major stations were visited in Japan to identify best practice, shared challenges and potential approaches that could be adopted in UK rail. Japanese stations in Tokyo and Kyoto were chosen principally because of their high throughputs as the busiest stations in the world and a strong similarity to high density cities in the UK constrained by land availability and scarce station space;
- Gathering the experience, insights and general observations from a wide range of industry, government and academic stakeholders via two idea-shops with 25 participants each, augmented by interviews. This included a further site visit to Milton Keynes Central Station to apply and inspire creative thinking and ideation; and
- Applying the principals of a systems methodology, the project set out to test four of the solutions using modelling techniques (such as Legion pedestrian simulation and a generic virtual station environment to assess "what if" scenarios with and without the solution).

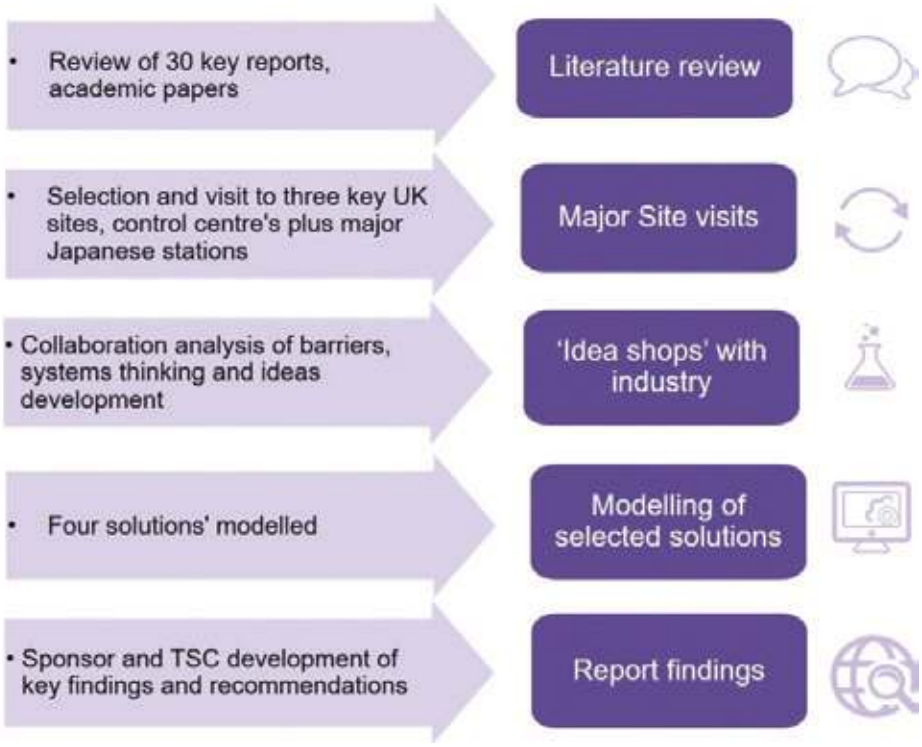

FIGURE 4, Overall approach

REPORT STRUCTURE – THE KEY ELEMENTS

18 The overall structure of this report is as follows;

- A summary of the objectives of the research;
- The approach applied on the project as step by step methodology;
- An analysis of the key literature findings and site visit outcomes principally Japan;
- As assessment of the capacity challenges, applied against selected stations examining both challenges and modelled solutions as an outcome of both research, stakeholder consultations and modelling
- The emerging UK Rail SME directory as an online portal and how it could be further improved in the future to create additional benefits;
- The barriers to innovation focused around passenger throughput capacity;
- The medium and long term ideas identified at a high level only; and
- The key conclusions and recommendations, focusing on how these could be operationalised in rail under the leadership of DfT Rail Group.

Gathering the information from a wide range of sectors via two idea-shops with

25

participants each, augmented by interviews.

STATION RESEARCH AND LITERATURE REVIEW

UK AND EUROPEAN LITERATURE REVIEW - KEY FINDINGS

19 A multiplicity of work has been conducted on the topic of stations and their improvement, both in the UK and across the world. Railway station related legislation, guidance and standards from the Department for Transport (DfT), Transport for London (TfL), Network Rail (NR), the Association of Train Operating companies (ATOC), Rail Safety and Standards Board (RSSB), the British Transport Police (BTP) and CPNI provided a strong foundation which was augmented by over 30 reports, research papers and best practices documents from across the world. A literature list is at Appendix D. This section highlights some of the key insights gained from the analysis as well as learning from the Tokyo and UK site visits conducted as part of the project.

STATION DESIGN PRINCIPLES FOR NETWORK RAIL

20 Network Rail's design principles are a methodology and set of checklists to help create stations based around strong design. The following 12 criteria have been identified as prime drivers and metrics for the design and enhancement of stations. Eight key criteria are seen as essential 'hygiene' factors or else they drive dissatisfaction. These 12 factors include; safety and security, intermodal exchange and wayfinding, punctuality and performance targets and reliability, whole life cost and operation, inclusiveness and accessibility, system approach, capacity and future proofing and sustainability.

21 Safety and reliability are core to ensuring trust is not breached. The key enablers of satisfaction include urban integration, retail, social and business, a standardised approach and passenger experience and delight. The pyramid of customer needs[ix], described as guiding design and enhancement of stations, should be taken into account when increasing passenger throughput capacity (see figure 5). The ideals of providing the stated idealised customer experience of "No hassle, no stress", "The faster, the better" and "Time is valuable" are aligned with the aims of this project.

16,000

transportation companies were started in 2014, with a rate of

17.5%

and amounting to

4.6%

of all UK start-ups

NETWORK RUS STATIONS, NETWORK RAIL

22 Network Rail uses the 'Fruin Levels of Service' (LOS) to assess station congestion. This is a measure of passenger or customer density adopted from airports, which gives the number of passengers within a square metre of space, or the flow rate of pedestrians per minute per metre space of footway. The 2011 analysis by Network Rail identifies stations that are congested using this industry standard while predicting which stations will have congestion in the CP5 and CP6. It further provides a toolkit for dealing with gaps in station capacity.

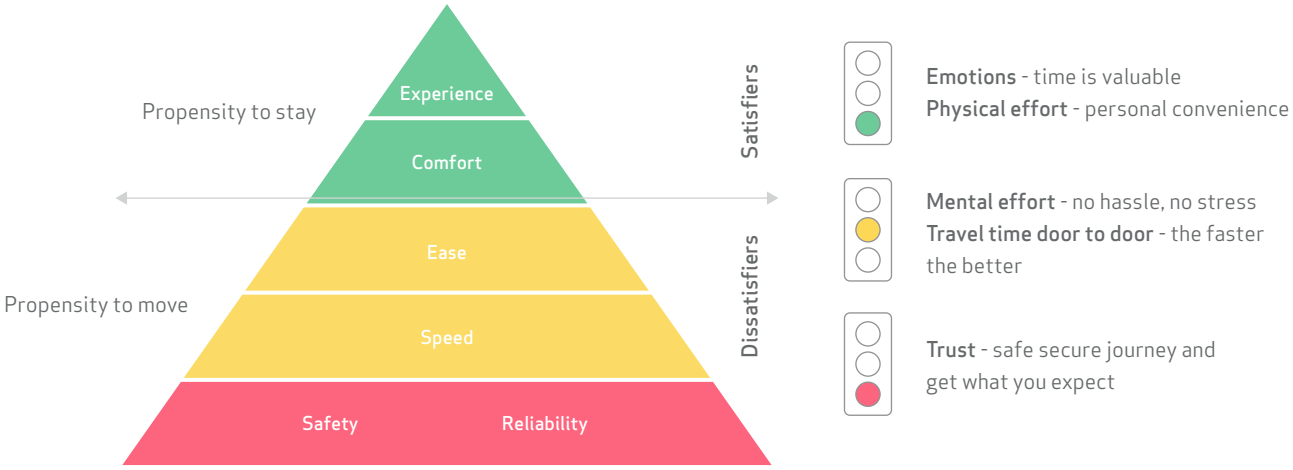

FIGURE 5, 'Station Design strategy for Network Rail pyramid of customer needs

23 The Fruin Levels of Service shown in Figure 6, range from A to F, A being free flow and F being so congested that flow breaks down. Soft and hard measures form part of the toolkit specified to deal with capacity shortages. This current study into station innovation builds on these measures with further proposed solutions

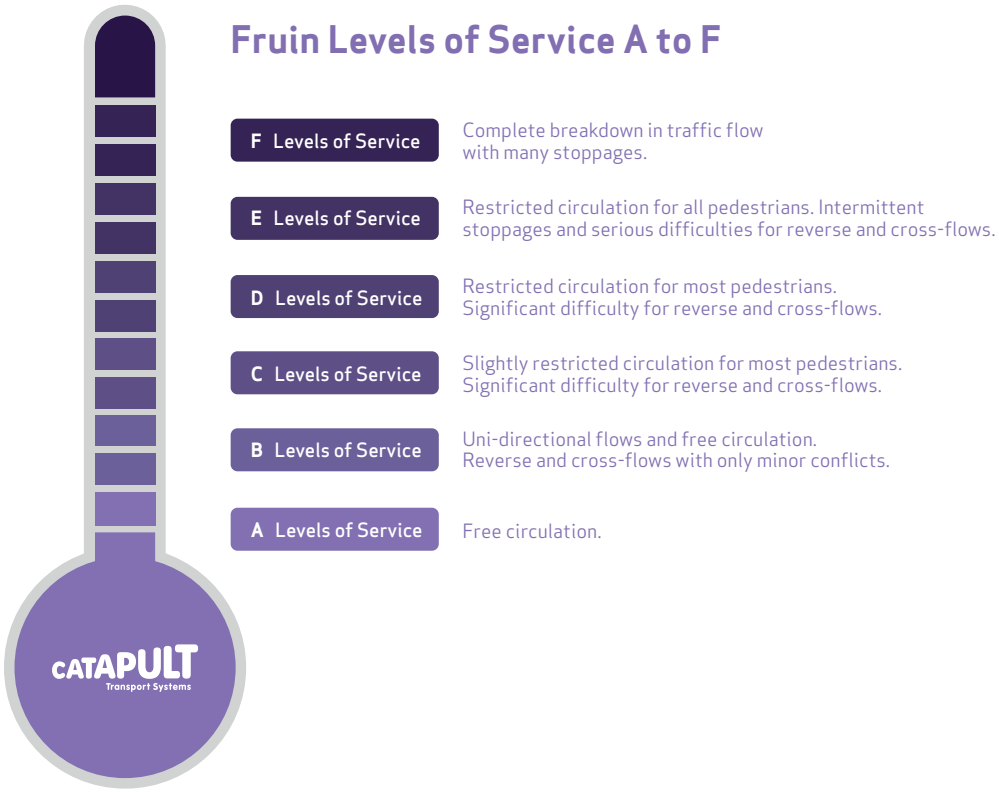

FIGURE 6, Fruin Levels of Service (NR, Network RUS Stations)

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RSSB - RESEARCH INTO STATION DESIGN AND CROWD MANAGEMENT

26 This 2012 research project[xi] built upon earlier stages of published research which identified three key areas of congestion which have the greatest impact on station capacity. These were passenger queues at ticket offices and ticket machines, passenger queues at gate-lines and passengers dwelling at customer information screens (CIS). Focus groups examined behaviours and the key recommendations included:

i. Real time information availability on changes to train times, connections, and platforms;

ii. Improvements to ticket machine pricing, interface and staff assistance at ticket machines;

iii. Hands free' auto gates for ticket validation, cited as a technology feature that would speed up movement through the gate-line; and

iv. Linking ticket validation to seat reservations so that seats reserved for passengers who are not travelling on the specific train are released.

27 With a focus on developing business solutions, the modelling and technology analysis element identified that the adoption of the technology solutions could successfully increase station capacity to accommodate passenger growth for a period of time, after which further investment in a blend of technology solutions and modifications to the station is likely to be required to add station capacity. The review found that ticketing and validation solutions that involved the use of contactless technology devices would be most appropriate to eliminate queues. This technology means that validation can take place over a greater range, therefore eliminating the need to touch a card reader. With similar project aims as Station Innovation this report recommended that pilots be explored.

LESSONS FROM A NATIONAL US STUDY ON OVERCROWDING IN STATIONS – DESIGN FACTORS

28 In the USA, the Mineta Transport Institute (MTI) sponsored by the US Congress, works to provide policy-oriented research for all levels of government and the private sector to foster the development of an optimum surface transportation system. In a 2015 US wide Mineta Transport Institute study[xii] they examined infrastructural, operational, behavioural, and spatial factors that affect and possibly constrain passenger flows in different types of underground rail transit stations. They also evaluated practices for efficient passenger flows and compiled short, medium and long term recommendations for optimising flows in different station environments.

29 Sharing similar characteristics to the UK, many American transit stations have been in service for decades. Within the same physical space, they need to accommodate more passengers than they originally were designed to handle. Thus, transit station designers and transit operators not only must devise strategies to provide safe and comfortable movement of passengers through transit stations, they also must implement these strategies within an environment of physical and financial constraints. They reiterated the need to, on station platforms, use a short-term strategy to reduce passenger congestion by dispersing passengers more evenly along the entire length of the platform through strategic placement of signage or other amenities. In the medium term, it may be possible to increase the capacity of the platform by removing obstacles such as columns or platform furniture. In the long term, it may be necessary to widen the platform, but this is often cost prohibitive.

30 In station design, they cited disconnects between planners and station managers. For example, a lack of consideration of the impact that each design strategy implemented in one station area will have in other areas of the station and on the adjacent street environment. They emphasised the need to **plan stations as systems.** Transit station designers face not only external constraints, such as budget and physical characteristics of the area around the station; they also must consider the ways in which their design in one part of a station affects or is affected by the other parts. A number of key findings included;

- The adjacent street environment is the aspect of a transit station that is most often neglected, if planners think of the station as a closed system that accommodates only part of passengers' entire journeys;
- Turnstiles are the slowest means of processing passengers, swipe cards are faster, and tap cards are, for now at least, the fastest, supporting the SMART ticketing drive as an enabler of increased passenger throughput capacity;
- Passenger congestion on station platforms can be managed by either increasing the capacity of the platform – possibly by increasing the platform width, removing obstacles, installing platform screen doors – or reducing the number of passengers who wait on a platform at a given time. One way to reduce the number of passengers on a platform is to reduce passenger wait times by decreasing train headways. On very busy rail lines, new forms of automatic train control can reduce headways opportunity to reduce passenger congestion on the platform through operations. Conversely, they cited research which has shown that shorter headways are among the most effective ways to increase the attractiveness of public transit and attract more passengers, which could cause crowding problems.

31 Across the study, three consistent themes were identified for the planning of passenger movements and queueing in rail transit stations:

i. The importance of considering transit stations as complete systems rather than reductively in terms of individual station components;

ii. The importance of cooperation and coordination among analysts, planners, and designers with responsibility for different aspects of station design and operations;

iii. The importance of the contexts in which passengers experience a transit station. Moreover, passenger flows and queueing often occur as a result of routine commuting but may also present different characteristics and challenges during special events or emergency evacuations where crowd behaviour is different.

32 While a number of these factors are known to the UK market they reinforce key actions to take around real time data, station refit requirements and interaction of train design factors with station design factors. An extract of Station design recommendations for better passenger flows are summarised below;

STATION ELEMENTS	DESIGN RECOMMENDATION SUMMARY	NEW STATION DESIGN	STATION REFIT
Overall station	Systems led design: integration connects with local streets and parking	✓	
Entrances	Location of entrances in relation to local streets. Multiple entrances	✓	
Signage / messaging	Real time displays of train arrivals	✓	✓
	Location and distribution of signs on platform to avoid overcrowding	✓	✓
	Visual displays and audible instructions for boarding and alighting	✓	✓
Gates	Replace turnstile with smart cards / cashless payment / tap cards	✓	✓
Vertical movement elements	Appropriate location, variable escalator flows, escalator sensors	✓	✓
Platforms	Elimination of obstacles and blind spots		✓
	Column free design	✓	
	Platform screen doors		✓
Concourse	Arrangement of surface and lift / escalator arrangements	✓	
	Careful planning of ticket purchasing locations	✓	
Train factors	Longitudinal versus traverse seating		
	Number of doors per car		

FIGURE 7, Extract of Station Design recommendations for the better passenger flow

EMPIRICAL CHARACTERISTICS OF DIFFERENT TYPES OF PEDESTRIAN STREAMS

33 What is clear from the literature is that the multi-directional flow of passengers through and within stations and platforms reduces the passenger throughput capacity.

34 Property and building research from other sectors can help identify alternatives and learning that can be applied to rail. A comparison of pedestrian velocity- density-flow relationships was propounded by leading academics, including Fruin, by Jun Zhang and Armin Seyfried in 2012[xiii]. They used a series of well-controlled laboratory pedestrian experiments of uni- and bi-directional flow, performed in straight corridors with up to 400 people. A new velocity-density-flow relationship for bi-directional flow following measurement was identified and proposed. Zhang and Seyfried quantify how much lower the maximum bi-directional flow rate is before it begins to drop with increasing density compared with uni-directional flow. They found self-organized lanes can help to relieve head-on conflicts effectively and increase the ordering of the stream. However, these conflicts do not affect the fundamental diagram of bidirectional flow.

35 The properties of pedestrian flow through different types of geometries, including corridor and bottlenecks, were also compared. Short bottlenecks have higher flow values compared to long bottlenecks, while the straight corridor has the highest flow.

36 There was no evidence found of how Zhang and Seyfried's measurements compare with commercial pedestrian modelling tools and therefore this could be an area of further study, potentially combining a range of data tools to experiment with new modelling approaches. It is important to take into account a wider variety of research, to clarify how to use available space more efficiently in stations to increase passenger throughput capacity.

NS DUTCH RAILWAYS - PRORAIL INNOVATIONS

37 European stations often share a number of common characteristics to the UK: scarce land, historic buildings with high passenger concentrations. The Den Bosch station in the Netherlands was subject to an innovative experiment aimed at improving flow on and off trains. Den Bosch is an important inter urban station, ranking in the top ten stations of over 400 as part of the NS station portfolio with an annual number of passengers a day exceeding 14m (http://www.treinreiziger.nl/statistieken).

38 In 2013 Dutch Railways, ProRail and Edenspiekermann wanted to improve the transfer process on platforms, aiming to make it more comfortable, faster and safer. It aimed to improve passenger experience and meet business goals by: delivering less crowding at train doors, preventing potentially dangerous situations for passengers, shortening waiting times, providing a clearer overview for passengers and making more efficient use of the platform to ensure shorter stopping times for the trains. A three-month trial of a platform and app based real-time carriage occupancy system was conducted after collecting customer insights and co-creating solutions with key stakeholders.

39 The solution was a system, consisting of a coloured 180 metre LED display along the platform. This display informed passengers of precisely where the next train doors would be positioned, the relevant occupancy levels of each carriage by a colour coding scheme, where first and standard class carriages were positioned, where to load bicycles and where facilities for disabled travellers were positioned. The LED display is available up to 15 minutes before train arrival, enabling passengers to move to the right position.

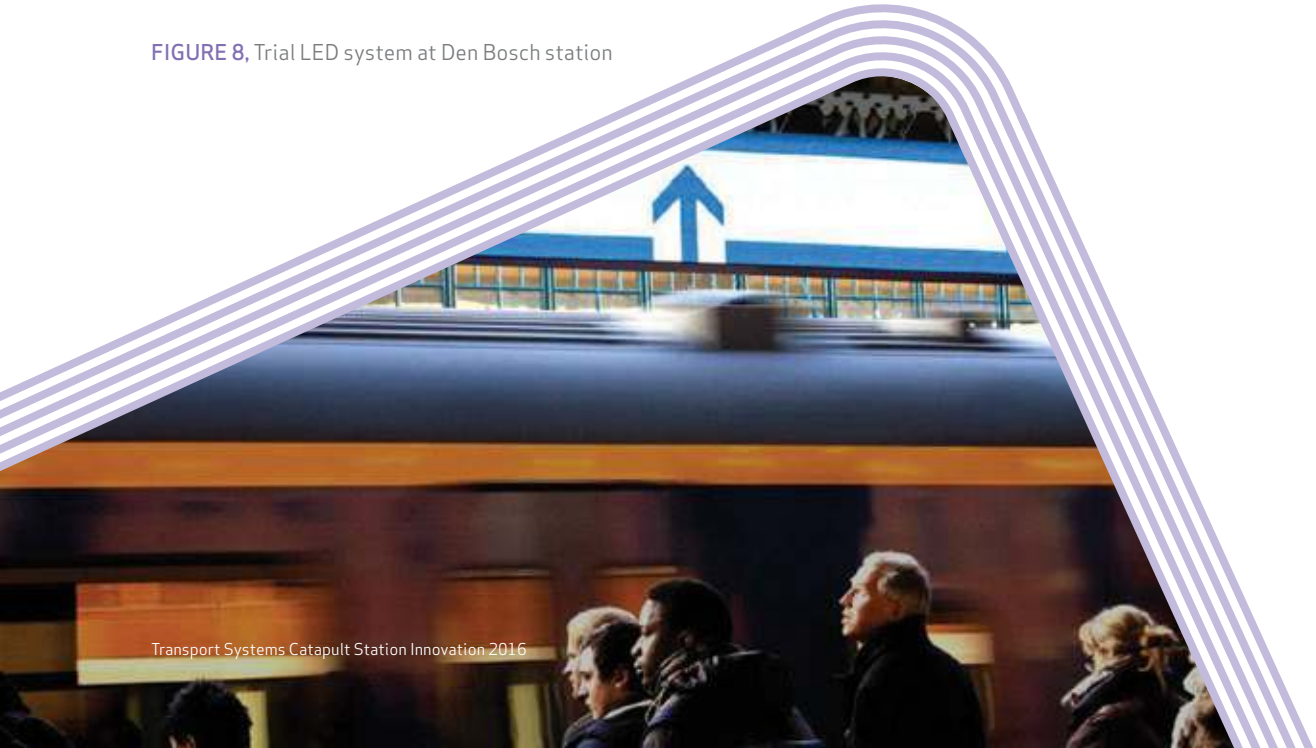
40 The system was found to improve flow on crowded platforms and also to reduce delays to trains caused by boarding and alighting queues. After a successful initial trial, Dutch Railways and ProRail are investigating nationwide roll out. Customers found the LED display much more useful than the app version as it was deemed easier to navigate the platform without having to look at a smart phone at the same time.

INTERNATIONAL INSIGHTS - LESSONS FROM TOKYO

41 Privatised in 1987, Japan's National Railways was divided into six rail companies for passenger services and one freight company. Private companies also provide train services (as an equivalent version of UK open access providers) with over 23.7 billion people using the system every year. Rail operates on a fundamentally different basis to the UK and its scale - Japan relies on railways for around 30% of its transportation needs, with the high reliance on railways driven by geography and economy, which offer rail an extremely high level of demand especially in urban areas.

42 Japan hosts 82 of the busiest 100 stations in the world, the top being Sinjuku at 1.26 billion passengers annually. By comparison, the UK's busiest station is London Waterloo at 99.2 million passengers (2014-15)[xiv]. Tokyo, as one of the world's largest cities, has over 36m inhabitants, with a population density nearly three times that of London. This study selected Tokyo and Kyoto to identify which innovative approaches have been used in Japan to manage large numbers of passengers, and which methods of station congestion management might be applicable to the UK.

FIGURE 8, Trial LED system at Den Bosch station



Transport Systems Catapult Station Innovation 2016

43 In March 2016 a short benchmarking site visit was conducted to Tokyo and Kyoto. Of particular interest were the technology, operational practices and policy frameworks that enabled such a high passenger throughput system while ensuring an exceptional customer experience. Two key operators were visited. As context, East Japan Railways (JR East) and Central Japan Railways (JR Central) are private train operating companies as well as track infrastructure owners and maintainers. JR East moves around 17m passengers' daily, providing nearly half of Tokyo's daily train passenger movements. Together they run the busiest stations in the world as well as operating the Shinkansen high speed "bullet" train.

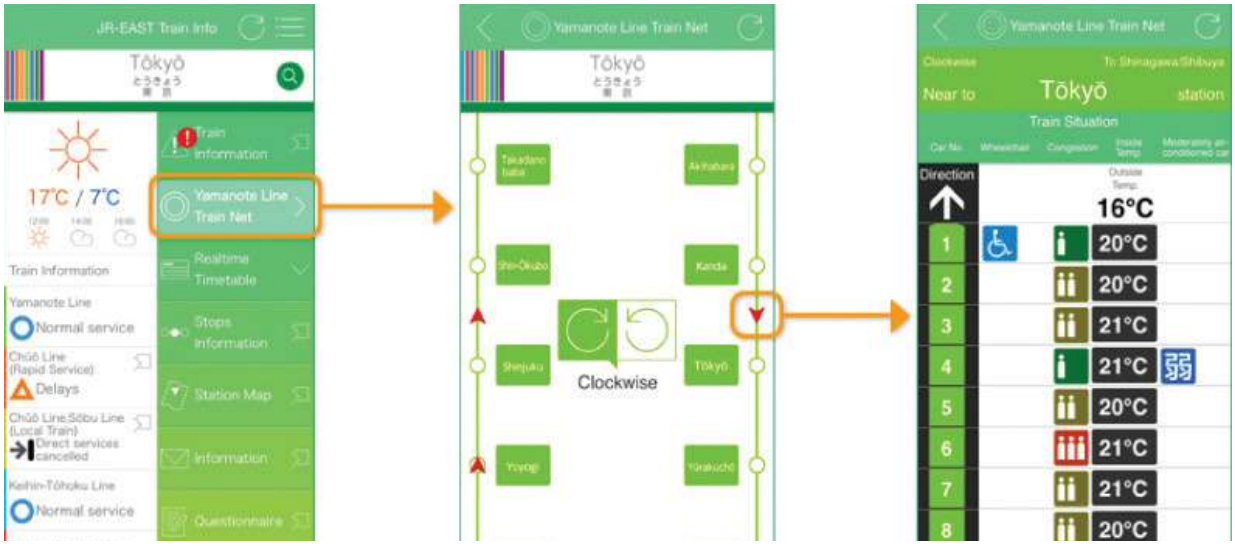


FIGURE9, Tokyo app illustration with seating and temperature

44 Real-time passenger information is considered key to managing the flows of people and improving their journey experience. There are many physical displays peppered throughout the stations ensuring all passengers are clear on where they are heading.

45 Operators provide real-time carriage occupancy information by smart phone apps, which also include the temperature of the carriage and disruptions on the wider network.

46 Passenger information on board trains consists of coloured displays that indicate where there is disruption on other lines, along with the reason. Each carriage also displays a diagram of the location of escalators, stairs and access to other lines at the next station in relation to that carriage.

47 Most platforms have platform doors to ensure the safety of passengers. The positions of doors are indicated on the platform floor along with markings for where passengers must stand and queue to enable more efficient boarding and alighting.

FIGURE 10, Platform gates

FIGURE 11, Clear platform marking for train boarding

48 A departure melody is played 15 seconds before the train doors close to help mitigate passengers running to catch the train while birds sounds are played close to escalators or stairs to inform those with impaired vision.

49 Tactile paving is used not only to inform those with vision impairments of their proximity to the platform edge but also helps guide them throughout the station, through ticket gates and onto footways outside.

50 At some stations, platforms are situated on both sides of the track, which separates boarding and alighting passengers and helps ease flow and reduce station dwell time. An example is at the Odakyu Station which serves 90,000 passengers a day, housing ten platforms which are on two levels under the Odakyu departmental store. Of these, six are over ground and the remaining four are underground.

51 Investment in research facilities. JR East has six dedicated research facilities to ensure they remain ahead of technology development. JR East invested $137m USD in research and development in 2015[xv], significantly beyond that of equivalent UK rail operators, albeit due to some industry separation and structural differences. Example developments include a real-time network-wide optimisation engine being readied for deployment. A physical mock-up of a station as a Smart Station facility was built in 2010, where new ideas are tested and solutions developed. JR East aims to optimise space for its customers in all of its various types of stations and uses these facilities to carry out proof tests and overall evaluations that cannot be done in actual stations or at its research and development centre. The Smart Station R&D facility is a three-story building with a total area of 1500m^2 and including a passage, a ticket vending machine, a ticket gate, a concourse, an information panel, a staircase, an escalator, a 70m x 7m platform and a train.

52 Unlike the UK, JR East, Central and JRTT do not use agent based simulation tools like Legion or MassMotion to assess changes to stations or design new stations. Instead, they use spreadsheet-based calculations using pedestrian flow characteristics gained from pedestrian tracking observations. A laser-based passenger tracking system is used to observe behaviours at congested areas within stations to help inform new schemes. Augmented Reality (AR) and indoor positioning systems have also been trialled.

53 In a number of respects, Japanese stations have strong proven innovations which are adaptable to the UK rail environment. These opportunities need to be grasped.

UK STATIONS FACT FINDING – DEVELOPING CRITICAL CUSTOMER ISSUES

54 A basic systems led approach was adopted in this short scoping study. The systems approach can be defined as a management approach which stresses the interactive nature and interdependence of external and internal factors in an organisation. This supports the systems-wide approach adopted in the Rail Technical Strategy and during the project of these simple systems led methods were adopted. This included, engaging people with systems led solutions including workshop design where the whole station factors were considered, stakeholder interviews to probe systems impacts and issues and holistic visual images produced showing end to end options. Passenger throughput capacity (PTC) has been considered as a component of a wider system which includes the operation of the railway track, government, technology, society and enterprise. While some solutions for increasing PTC are very localised, others involved many components of the system.

55 The UK fact finding reviews at selected stations included workshop analysis of three stations using a number of passenger types. The stakeholder visits and interviews at each station incorporated relevant Fruin data and an examination of the 'station as a system' issues. Station visits also probed barriers and enablers to innovation through one to one interviews. These station visits are summarised as short case studies.

EUSTON CASE STUDY

Euston was chosen for further study as it is the 6th busiest station in the UK with 46 million passengers using the station in 2014/15 and a growth rate of 2.5 per cent (ORR) with the majority of passengers being on long distance journeys. Euston has 18 platforms and is currently congested.

According to Network Rail's RUS: Stations, the Fruin level for Euston in 2010 was F and also predicted to be F in 2019 and 2031. Overall customer satisfaction with the station has declined in recent years with 82% of those surveyed in 2011 satisfied, compared with 72% in 2015 (Passenger Focus 2015) Current plans for HS2 include a terminating station at Euston adjacent to the existing station. Platform 18 and the west exit would be affected. A separate project to improve the existing station is in development.

Overcrowding highlights

- 10% decline in station customer satisfaction
- Fruin level - restricted circulation for all pedestrians. Intermittent stoppages and serious difficulties.

The February 2016 site visit interviewed Network Rail and Virgin Trains staff.

INNOVATIONS

Virgin Trains are currently trialling improved customer **information systems (CIS**) which shows stopping stations arrival times, reservation level of each carriage and layout. This improved CIS is easily understood by customers. On concourse passengers are more equally spread and queuing to get on the train is reduced, thereby benefiting passenger flow. This in turn improves customer experience through increased likelihood of a seat being obtained.

A further development is to include staggered information released via smart phones or a text based system, helping to mitigate the rush of passengers when the platforms are announced, leading to greater safety and controlled passenger flow. A new joint control room with Network Rail and Train Operating Companies (TOC) has made significant improvement to the management of the station, enabling more efficient communication between parties.

FIGURE 12, Trial CIS at Euston station

AREAS FOR IMPROVEMENT

The stakeholder interviews identified:

- The need for earlier confirmation and better allocation of platforms. Currently heavily loaded arriving and departing trains are often allocated to the same platform grouping meaning the platform announcement is delayed until the arriving passengers have cleared. At other times arriving passengers haven't cleared which produces conflicting flows and additional congestion.
- Current retail positioning is hindering throughput. The retail units positioned along the corridor with platform accesses create queues that constrict the width of the corridor leading to reduced passenger throughput capacity. There are agreements in place to close these retail units under extreme crowding conditions. At Heathrow Airport, the commercial process changed to align both airport operator and retail operators by switching from a rent based approach to a sales share approach so that both parties are incentivised to act in their joint interests in managing footfall.

EUSTON CASE STUDY

Lack of inter-department communication within Network Rail can lead to the duplication of similar initiatives. Stations are currently managed by Network Rail on a route basis with no central team. However, a new strategic stations team is being set up over the coming months which should improve communication.

BARRIERS TO INNOVATION

The interests of retailers, station operators and train operating companies reflect a different set of customer needs that each is trying to satisfy. Friction is caused by these differences as retail providers are trying to grow footfall in their stores and sales, which may cause concourse congestion as people slow down or browse while station operators are trying to increase passenger throughout and manage high levels of overcrowding.

POTENTIAL SOLUTIONS

Of the potential solutions identified during this project some are particularly applicable to Euston including:

- **Fast Lanes** - At times when the concourse becomes crowded, fast one way lanes could be erected along the most used 'desire lines' i.e. from where escalators from the underground join the concourse to platforms.
- **Ubiquitous Information** – Smaller, lower clusters of information screens could be installed and the large screen turned off at busy periods to create natural paths for passengers to flow through.
- **Passenger Flow Optimised Timetable and Real-time Passenger Flow Optimised Platform Allocation** - Ensuring as far as possible that platform allocation which creates conflicting flows are avoided would allow platforms to be announced earlier thus mitigating crowding on the concourse.

BIRMINGHAM NEW STREET CASE STUDY

Birmingham New Street was chosen for study as it was recently redeveloped and includes up to date operational practices and design. The station is the 8th busiest in Great Britain with 41 million passengers (entries, exits and interchangers) with a growth rate of 2 per cent (ORR).

According to Network RUS on Stations, the majority of passengers are long distance travellers. The Fruin level in 2010 was F and predicted to be F in 2019 and 2031 without intervention. The redevelopment has provided extra capacity but there is no published data on the crowding level since the redevelopment. Nor were there any predicted future Fruin levels available. The February 2016 site visit, focused on Network Rail staff.

Redevelopment

- Customer satisfaction with the station jumps by 15 points after the official opening

The station redevelopment opened in September 2015 as a city gateway joining the north and south sides of the city centre. Significant improvements included a new retail extension to the Bullring Shopping Centre and a transitional hub for the new tram line.

INNOVATIONS

Colour coded 'waiting lounges' were included in the design and were in operation on opening. Passengers were directed to a particular lounge beyond the gate line based on the service they were due to catch. The lounge areas include seating, refreshments and retail.

The aim was to alleviate congestion on the concourse area and reduces passenger surges by moving passengers through the gate lines before platforms are allocated, which can happen shortly before departure. The measure is currently under review to understand how to generate greater impact

AREAS FOR IMPROVEMENT

The stakeholder interviews identified:

- Better crowd management is needed
- Finding the right balance between pedestrian computer modelling and 'on the ground' local knowledge and expertise
- A lack of natural light on the platforms, as skylights were limited during construction

BARRIERS TO INNOVATION

- Overriding day-to-day priorities. Staff have ideas but don't have the resource to focus on them
- Fear of trying something new without evidence of a viable proof of concept

POTENTIAL KEY SOLUTIONS

Potential solutions include;

- **Real-time Station Heat Map** A senior member of staff suggested a real-time station congestion heat map on a tablet or smartphone for mobile staff around the station could allow better crowd management. This could be of particular use as the platforms which are beneath the concourse are hidden from view.
- **Real-time Carriage Occupancy** As Birmingham New Street is a busy through station, dwell time of trains can have an impact on platform crowding. Providing passengers with real-time carriage occupancy information would encourage passengers to spread out and reduce dwell time.
- **Historical Loading Information** Providing passengers sight of individual service loading levels could encourage a more even spread of demand, easing congestion and dwell time.
- **SMART stations research facility**. Proving a strategic level resource as a station mock up to trial and test proof of concepts might help accelerate on station innovations. Modernised stations may be able to take greater advantage of new technology.

LIVERPOOL LIME STREET - CASE STUDY

Liverpool Lime Street was chosen for further study as a key station in the North of England and predicted to be congested in 2019. The station is the 31st busiest station in Great Britain with 16 million passengers in 2014/15 and a growth rate of 5.5 per cent.

According to Network RUS: Stations the Fruin level in 2010 was E and predicted to be F in 2019 and 2031. Overall customer satisfaction with the station has declined in recent years from 92 per cent of those surveyed in 2011 satisfied or good to 86 per cent in 2015. On a normal day the station copes with the demand although it gets busy in the peaks. When special events are held in the city, such as festivals and sporting events major congestion does occur.

Overcrowding highlights

- Fruin level - predicted to have restricted circulation for all pedestrians, intermittent stoppages and serious difficulties by 2019
- 6% decline in station satisfaction

Station upgrade work starts in 2017, which includes track signalling and platform upgrades to enable longer trains and more frequent services. The February 2016 site visit identified a number of key issues. Interviews were predominantly with Network Rail staff.

INNOVATIONS

Removable platform and concourse furniture can be stored away the night before planned events, meeting the planning principle of removing obstacles that restrict flow allows greater passenger throughput capacity. An extension would be to remove furniture during peak periods.

AREAS FOR IMPROVEMENT

- The existing station layout is fragmented
- Better crowd management during disruption which causes significant strain on constrained station facilities

BARRIERS TO INNOVATION

- The station is a heritage site therefore new ideas and plans require additional evaluation. Local knowledge is vital
- It took two years to remove a couple of 'booths' which restricted passenger flow – due to the extensive number of stakeholders levels to consult, and achieve agreement

POTENTIAL KEY SOLUTIONS

Potential solutions include;

- **Be innovative locally**. Innovative solutions could be localized and adapted to the local scenario, with a recognition that a 'one-size-fits-all' initiatives may not work
- **Retail Offers for Delayed Passengers or during overcrowded periods** - There is a significant retail offering at Liverpool Lime Street including a large pub/restaurant directly attached to the concourse. Offering delayed passengers offers on retail could help to clear the concourse, allowing better flow. Alternative options include using app based offers to disperse people to local venues or retail outlets to disperse waiting passengers over a wider geography
- **One Way Accesses** - Designating one of the two main accesses as an entrance and the other as an exit could reduce conflicting flows and prevent the build-up of congestion

FIGURE 13 Liverpool Lime Street station

Transport Systems Catapult Station Innovation 2016

CAPACITY CHALLENGES – DEALING WITH OVERCROWDING AT STATIONS

56 **Overview** The literature and specific case studies undertaken as part of the background research have indicated that optimising the passenger throughput capacity of railway stations is essential to managing the growing number of passengers using stations. In this section we assess three key challenges which affect passengers from the perspective of a customer and what may be done to alleviate those problems using a combination of best practice identified from the literature research. Best practice, international and national site visits and interviews and industry stakeholder participation via the idea shops were also undertaken.

57 Passenger Throughput Capacity (PTC) at railway stations is defined in this project as the maximum volume of people who board, alight and interchange that can be accommodated by a station per hour without compromising passenger safety. In this definition we are including the passenger journey through the Access Zone, the Facilities Zone and the Platform Zone.[xvi]

Summary of zonal types

The Access Zone

This is the area of (and surrounding) the station where departing rail travellers arrive at the station, or where people who have just arrived by train commence the next leg of their journey.

The Facilities Zone

This is the area of the station (typically, but not exclusively, the concourse or booking hall) where users gather information, make purchases, or otherwise avail themselves of the facilities on offer. In many stations the Facilities Zone may also include a waiting area.

The Platform Zone

In this area, users alight from trains, wait for and board trains, or interchange between trains.

Network RUS Stations xvii

58 There is a complex relationship between these three zones which passengers use for different purposes, as well as the station 'stayers' user group. Station 'stayers' are those who use the station for purposes other than boarding or alighting trains e.g. greeting passengers, retail, buying tickets. Each station has its own unique mix of the three zones and their use by passengers can change depending upon the time of the day. The flows of all four groups affect one another and ideally all need to be quantified as interrelated zones when considering passenger throughput capacity.

59 Increasing passenger throughput capacity (PTC) cannot be considered in isolation. There is little scope to improve PTC via trade-offs against passenger safety, security, fire and evacuation procedures. However, trade-offs could be considered in other areas; for example, revenue protection or ticketing.

60 Ideally, all factors would be maximised. However, inevitably there are competing objectives or elements of objectives. Finding an intelligent way to assess and manage these objectives is vital which is where multi-objective optimisation techniques can provide solutions.

Case example – Holborn changing behaviours to improve throughput

In a recent trial by Transport for London (TfL) at Holborn[xviii], passengers were actively encouraged to stand on both sides of the escalators. It was perceived to be an idea that passengers would dislike. TfL's research found that people tend to stand when escalators have a height of over 18.5m, leaving empty space on the left side. During a three-week experiment in November 2015 visitors to Holborn station were asked not to walk on escalators between 08:30 and 09:30. By making them standing-only, the initial test evidenced that 16,220 people could travel on Holborn's 23.4m high escalators during rush hour, compared to 12,745 in normal circumstances. **Queuing was reduced and 30% more people used the escalators** during the trial. The pilot is now extended to six months and the results will help planners identify whether customers can be influenced to stand on both sides in the long term, using just signage and information.

KEY CHALLENGES AND POTENTIAL SOLUTIONS

61 System planning is not only about thinking about the various physical components of the station but also about its multiple purposes that it serves. In addition to its role in the transport system a station can be a place of business, a meeting place, or a gathering place that adds to the local community.

62 Therefore, it is important to consider the context in which various passengers experience a station as an interchange, which may be for day to day travel, social or economic activity or even as a source of shelter from inclement weather. When examining the planning of passenger movements and queuing in rail stations, American research[xix] identified as a key theme the need to consider transit stations as complete systems rather than reductively in terms of individual station components.

63 Based on the literature, site visits, idea-shops and interviews as part of the project a number of key challenges were identified. These were focussed on the problems that people experience and how flow might be improved through the station in order to reduce congestion and increase passenger throughput capacity.

Persona frustrations

The hurried passenger. The rushed passenger is purposeful and using the journey for commuting or business reasons. Seeking to weave their way to a successful boarding of a train, they encounter a range of issues from others using the same scarce space on the concourse or unclear wayfinding.

Challenge

#1

Reducing constraints from congestion and lack of speed

64 The hurried customer will encounter other passengers who may affect his/her ability to traverse the station to their train. This includes slow moving passengers who have other needs such as those seeking information. A reason passengers walk slowly in the station environment is that they don't know which platform their train is leaving from, the terminating destination of the train they want to catch and whether there are delays. They therefore have to slow down and look around in the station concourse area for the information. Without intuitive wayfinding, the lack of clear departure and platform information while at the station will negatively affect their speed of traverse.

65 The hurried customer also encounters people who walk at their natural pace. People are free to walk at their own speed, however when in confined spaces this has the effect of bringing the average speed of all passengers down and hence reduces PCT. Passengers who wish to walk slower wish to do so without other passengers pushing past them.

66 Congested corridors will slow people down. Many academic studies[xx] into the relationship between speed, flow and density of pedestrians show that as the density of people passing through a corridor increases, the velocity of each pedestrian decreases towards zero. The flow rate, i.e. the number of pedestrians passing a point increases as the density increases up to a critical point and then the flow rate drops off towards zero. The flow rate at the critical point is the capacity of the particular access. In order to maximise the passenger throughput capacity of the station the density of passengers should not exceed the capacity each individual requires, and therefore use the space most efficiently.

67 Poor wayfinding contributes to lack of flow. When passengers are looking for where toilets, platforms, ticket machines or where other facilities are and wayfinding is poor, they slow down and could even stop, reducing passenger throughput capacity (PTC).

68 Congestion at train and platform interfaces grows where many passengers are attempting to alight and board the same carriage, the process can prolong the dwell time of the train in the station. The result of this is that passengers build up on the platform which creates congestion, reduces passenger throughput capacity and can impact train punctuality performance.

POTENTIAL SHORT TERM SOLUTIONS

69 Providing real-time information to passengers during their journey towards the station, whether by foot, bus, cycle or other mode, should help to mitigate the passenger throughput capacity reducing the effect of people walking more slowly than others or stopping to find information in crowded concourse areas.

70 Repeated information displays could be installed in the Access Zone, on escalators and walkways that take passengers to the station; these are also effective in moving people efficiently through the station. Existing rail smart phone apps or text systems could be developed to automatically notify passengers of platform and departure updates for services of interest. This may help prevent them from stopping and searching for required information or guidance, and acting as obstacles to others around them and help passengers anticipate which platform they will need.

71 Large, striking, dynamic wayfinding with relatively low expenditure using larger, clearer, colour coded wayfinding that also caters for vision impaired passengers should be installed and tested.

72 Currently wayfinding design is largely developed on a 2D canvas which leads to sub optimal solutions. Virtual Reality and Augmented Reality technology could be employed to assist in designing and testing wayfinding. Individuals can place themselves in the shoes of passengers in a 3D environment at various positions in a station and amend wayfinding size and location to suit.

FIGURE 14, Fast lane example in Liverpool

73 The situation in a station is never static; there will always be potential disruption to services and incidents within station premises. Therefore, dynamic LED lighting could be deployed to make sure directional information to passengers can be tailored, enabling better passenger flow.

74 Ubiquitous Information By providing clusters of smaller and lower information displays in carefully thought out positions, passengers should stand tighter together and not block large areas of the concourse. This should allow those passengers who need to board their train and know which platform they require to flow more freely thus increasing passenger throughput capacity.

75 Fast Lanes Demarcating one way lanes across busy concourses aligned with the most heavily used desire lines could be a way to increase passenger throughput capacity. Fast walking pedestrian lanes have recently been introduced in a Liverpool high street: this has been implemented through use of floor markings to improve the customer experience. Argos research[xxi] identified the main reason for supporting the lanes was to avoid wasting time, with 31 per cent of shoppers saying they were annoyed by people blocking the pavement. These could be implemented in a number of ways, some of these being floor markings, LED floor panels or barriers.

Argos research[xxi] identified the main reason for supporting the lanes was to avoid wasting time, with

31%

of shoppers saying they were annoyed by people blocking the pavement

FIGURE 15, HACON visualisation tracking

76 Real-time Carriage Occupancy. Providing real-time carriage occupancy information to passengers waiting at the platform via smart phone apps and physical display will help to spread passengers along the platform. Passengers will also gather at locations where less busy carriages' doors stop. This will enable faster boarding and alighting and thus reduced dwell time. This can be combined with other advances about train loading as happens in Germany where real time data for trains, their location and loading is shown on apps to help passengers make choices about when to travel. In the UK, a load weigh pilot project was selected in the TOC15 competition and learning could be broadly applied across the network. This competition, funded by RSSB is aimed to encourage innovation around key challenge areas. 'Open Capacity' is a trial being conducted by C2C and is a system to collect, analyse, predict and display the occupancy, accessibility and performance of public transport. It measures passenger load by using existing public transport data sources, such as weight sensors, CCTV cameras, door sensors, and ticketing information. Cross-referencing these sources helps to strengthen the overall accuracy of passenger numbers. Combining these advances with station CIS systems would provide customers with real-time information and help reduce alighting and boarding times.

FIGURE 16, Open Capacity example by C2C

CIS systems would provide customers with real-time information.

77 **Floor marking for doors.** The complication arises when the same platform accommodates services with different rolling stock and thus door positions and carriage locations will differ[xxii]. This is the case for the majority of all platforms in UK. Therefore, permanent floor markings would not be appropriate. Instead a dynamic display and tailored to each train as it approaches the platform could be used. Train drivers need to stop their train in the same door position each time.

78 **Open Historical Service Loading Data.** Service loading data is currently collected via two methods[xxiii];Automatic counts – carriage weight and door sensors and manual counts – On board and platform based. . Giving passengers' visibility of how busy particular train services are will assist in spreading demand more equally and therefore ease congestion at stations. This will ensure that this data reaches the passenger in the format they prefer.

79 TOCs currently collect this information and pass it on to DfT as part of their franchise agreement. DfT releases high level aggregated statistics from this information. However, service level data is deemed commercially sensitive and cannot be released. Some TOCs have individual initiatives to convey service loading information to customers via posters at stations e.g. London Midland at Milton Keynes Central. This also demonstrates that innovation does not necessarily need to be complicated. Since real time carriage occupancy is already a reality in some other European countries, the case for continued confidentiality of this data will erode over time. The potential for engaging others for alternate uses such as freight might open new opportunities to create value for operators.

80 The DfT and TOCs should work together to make service level loading data open so that the plethora of travel apps can deliver this to the passenger. This could be in the form of relative loading so as to allay fears of commercial sensitivity. This solution is linked to Passenger Demand Management.

Standing on Both Sides of escalators London Underground have recently completed a successful short trial which actively encouraged passengers to stand on both sides of escalators at Holborn station, now moving into its second phase (See case example). This solution could be trialled on busy escalators throughout the wider station network.

Challenge

2

Reducing conflicting flows to increase capacity and movement

Persona frustrations

The young urbanities. Rail savvy, they know how to use the system. Predominantly living in cities, they use rail for commuting and leisure. They use major stations to traverse their city and encounter heavy flows of passengers which slow them down.

81 Conflicting passenger flows frequently arise from mixed arriving and departing passengers. What is clear from many academic investigations is that multi directional pedestrian flow results in a reduced flow rate in all directions compared with uni directional flow in the same space. Therefore, to ensure all space is used most efficiently conflicting flows should be avoided. Arriving and departing passengers are by their very nature travelling in different directions and cause a considerable reduction in passenger throughput capacity.

82 Each passenger is free to choose their own path that they wish to follow when they enter the concourse area. Some may want to walk to the ticket machines first from their point of entry, then to the coffee shop and then walk to their platform or ticket gate to board their train. Others may want to walk quickly from their point of entry onto the concourse directly to their platform. Having this mix of conflicting 'desire lines' is not an issue during quiet periods. However, on a congested concourse at busy times when space is restricted, this problem mounts. These conflicting flows drastically reduce the passenger throughput capacity.

83 Timetabling and platform allocation can cause unnecessary flow conflicts, as it too can create bi-directional flow, thus reducing the flow rate capacity of a space in both directions and passenger throughput capacity as identified in the modelling tests.

84 Dual use entrances and exits naturally combine to cause conflicting flows. This is not an issue during quiet periods, however when stations are busy the conflicting flows exacerbate congestion.

POTENTIAL SHORT TERM SOLUTIONS

85 **User lanes**. Separating different passenger types using lanes (including slow or fast lanes) would provide further alleviation from the 'stress' and congestion from people moving at different speeds. Mobile phone lanes have also been introduced in cities in China. The physical installation of lanes would be relatively low cost; however, to ensure passenger compliance may require some basic 'people power' via the use of speaker systems for a period which would prove more costly to implement.

86 **Passenger Flow Optimised Timetable.** Currently Network Rail uses an Integrated Train Planning System (ITPS) to develop the annual National Rail Timetable. This system incorporates many timetable planning rules[xxiv] such as;

i. Headway
ii. Electrification limits
iii. Loop lengths
iv. Rolling stock restrictions

87 Within these constraints the system then optimises via various objectives, some of which compete and which introduce the need for trade-offs i.e. railway track capacity, performance, energy consumption etc. Passenger throughput capacity could be included as an objective when planning the timetable. The timetable and platform allocation which enables the maximum passenger throughput capacity for each station should be calculated using pedestrian modelling that includes the following;

- Historical number of boarders and alighting passengers for each service
- Historical number of interchanging passengers and their connecting services for each service
- Optimum passenger flow characteristics of each station

The modelling results in Test 2 and 4 showed an improvement of up to

15-20%

88 Proof of concept pedestrian modelling using Legion software supports the anticipated benefits of this solution for both through and terminus stations. The results in Test 2 and 4 showed an improvement of up to 15-20%. Initially a decision support tool that works independently but alongside current systems could be produced to aid timetable planners. This is a significant part of a wider overarching concept of intelligent integration of the railway operation and the station operation.

89 **Real-time Passenger Flow Optimised Platform Allocation.** Regular disruption on the rail network remains a source of customer frustration, where trains get delayed and platform changes frequently occur[xxv]. Platform allocations could be planned in real time optimisation engines to include improving passenger throughput capacity (PTC) outcomes. A real-time multi-objective optimisation engine that includes maximum PTC as an objective could be developed. This would increase PTC by adjusting the platform allocation based on the real-time situation including train loadings and a rest of day scenario forecasting. As the system would mitigate the use of the same platform grouping and, therefore, access by heavily loaded trains which arrive or depart at the same time, platforms could be announced earlier, removing the dangerous rush and alleviating congestion on the platform. Initially a decision support tool that works independently but alongside current systems could be produced to aid dispatchers in the signal control rooms or Rail Operating Centres (ROC).

90 **Segregating Arriving and Departing Passengers**. Where possible with current station layouts, arriving and departing passengers should be separated using different platform accesses. Proof of concept pedestrian modelling using Legion software supports the anticipated benefits of this solution.

91 **One Way Access Points.** Entrances/exits should be made one way where possible. Entrance/exit designation should be based on pedestrian modelling. Dynamic signage should be used above the access to indicate "No Entry", "Exit" or "Entrance" and station staff should be used to enforce until behaviour is largely adopted. Motion detection technology linked to speaker systems could provide appropriate enforcement. The dynamic signage allows configuration during any perturbation.

Challenge

3

Minimising obstacles which block movement

Persona frustrations

The international or long distance traveller. Travelling through stations with baggage is just one part of a multi legged journey. Valuing easy movement around the station, they are constrained by obstacles, whether fixed or static.

92 Static objects or passengers who have stopped moving for a range of reasons will affect movement through the station. A number of principal reasons include use of customer information systems, previous train delays causing congestion as the volume of people builds up at the station and ticket purchase.

93 Customer information systems and many information displays at UK stations are currently of such size and position that customers reading the information stand in the path of other passengers or need to stop to read information. Dynamic messaging can affect passenger flows by influencing how quickly passengers move through a station as research has shown that passengers who know a train is about arrive move more quickly. Likewise, dynamic messaging may improve congestion on the platform as passengers tend to stand near the signs to have a continuous view of information updated and displayed. Proper placement of dynamic signs can help to spread passengers more evenly along the platform length.

94 The widespread use of ticket machines and ticket offices at stations can mean that long queues form when ticket queuing time targets are not met.

95 Floor mounted signs, are used when there is a temporary change to the operation of the station (e.g. an entrance has been closed due to an injury to a passenger). Recent airport innovations at Heathrow have included moveable, self-contained electronic signs that have height adjustable facilities to vary the height of the message to achieve both better visual communication with customers in crowds and helping customers anticipate a potential static object in their way.

POTENTIAL SHORT TERM SOLUTIONS

96 **Passenger Demand Management.** Demand management is not a new concept; however most initiatives have so far involved passive measures. There are off and on peak fares which help to spread the demand but most employment constrains staff working hours while behaviourally people have other quality of life goals they wish to retain. There is significant unutilised capacity outside of the peak travel periods.

97 Companies within a zone surrounding stations could work together using an online system to actively organise the demand via time period booking slots for business functions. This could be achieved through central government tax incentives.

FIGURE 17, Tokyo platform queuing lanes

98 **Platform Queuing Lanes.** Currently passengers crowd on platforms in a random fashion. With the introduction of queuing lanes marked on the floor which also leaves a gap for position of the door, passenger flow will be freer flowing and organised and increase capacity. This solution will only be viable for platforms where for the great majority of time the same type of rolling stock is used. The driver will also have to stop the train in the same place.

99 **Digital Retail.** There is always a higher concentration of passengers close to the access points on a platform due to lack of incentive to walk further than necessary. This causes congestion. In order to draw people further along platform, one suggestion is to install Digital Retail in the form of interactive kiosks with touch screens. These could be placed at locations further down the platform to incentivise passengers to spread out.

100 The interactive kiosk would allow passengers to order a plethora of items including groceries which they could pick up at their terminating station or select for home delivery. Such screens have been installed along subway platforms in South Korea[xxvi] .

101 **Improved Accuracy of Real-time Information.** The accuracy of real-time train delay information and passengers' trust in it, could be affecting the ability of passengers to feel confident enough to leave the concourse area, and use retail space till their train arrives. There has yet to be a published study on the accuracy of real-time train delay information and whether passengers trust it. If it was the case that there was room for improvement or somehow a perceived issue then addressing this could reduce the number of passengers standing on the concourse area, easing congestion and increasing passenger throughput capacity.

102 **Retail Offers for Delayed Passengers.** Offering delayed passengers discounts in coffee shops, restaurants and retail, would encourage passengers to move off the concourse area. These offers could be delivered by smart phone app, text message system or simply by showing your ticket at the chosen shop. The use of beacon based mobile offers is already being used in major UK shopping centres' such as Bluewater in Kent.

Offering delayed passengers discounts in coffee shops, restaurants and retail, would encourage passengers to move off the concourse area.

103 **Improved Information Displays in Shops and Restaurants** There are currently information displays installed in some station shops, cafes and restaurants. However, many of these appear small. Therefore, installing larger, clearer information displays could encourage more delayed passengers to purchase goods and wait in the premises for their train.

104 Flexible Furniture Seating that can be removed at busy times would help alleviate congestion while also ensuring that plenty of seating is available off peak, enhancing the user experience. Currently a few stations in the UK employ this measure by manually moving furniture into storage; however furniture that lowers into the concourse floor could provide efficiencies.

105 **Easing overcrowding – developing a vision.** The stations visit programme, stakeholder interviews and modelling analysis has led to a number of potential solutions which have been explored, and identified against each key challenge. As a summary of the developing vision for easing station overcrowding the image below illustrates the potential across a range of options.

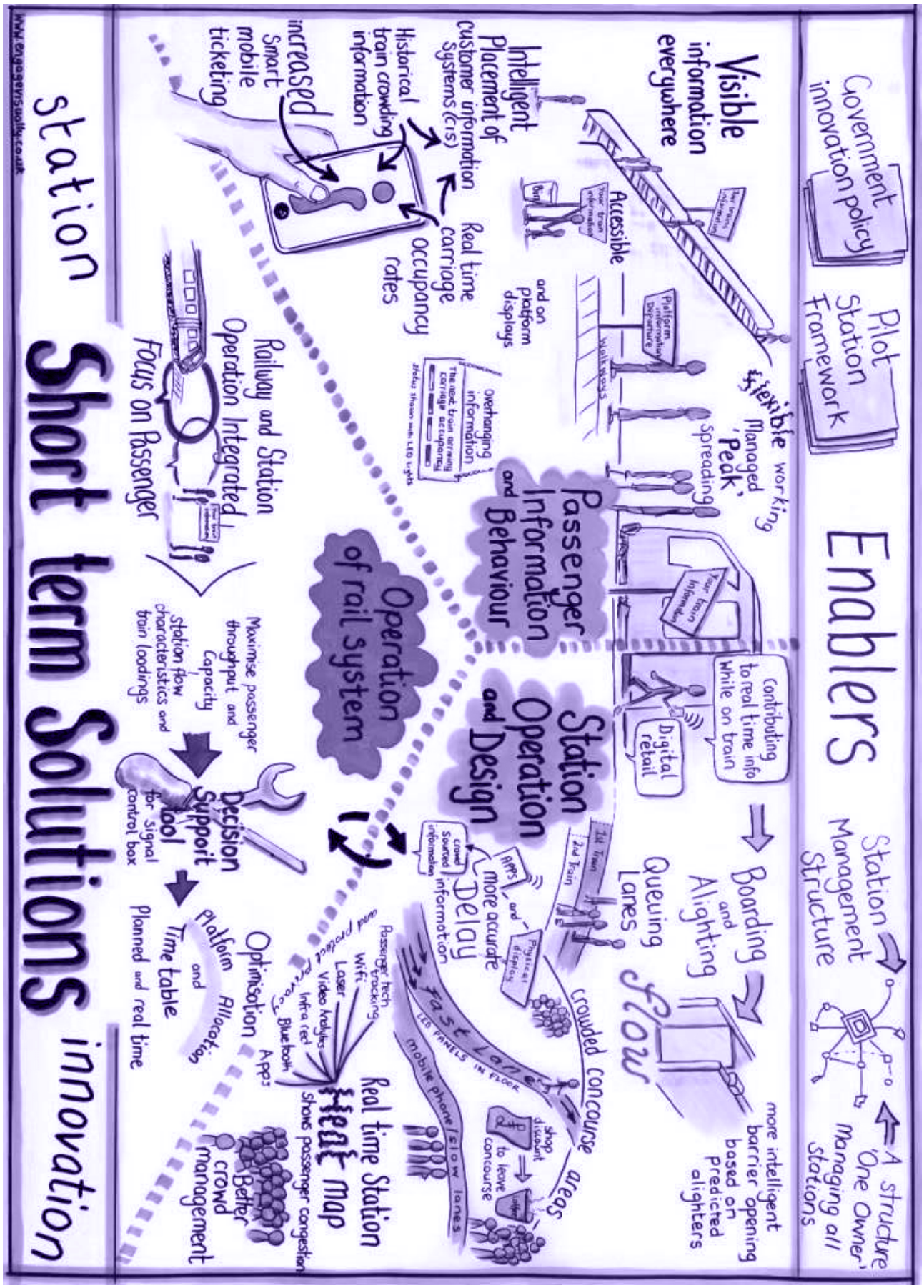


FIGURE 18, Short term solutions

CONCEPT DESIGN TESTING

PROTOTYPE VIRTUAL STATION TEST BED - MODELLING STATIONS

106 To validate some of the key operational concepts developed, a virtual test bed was created and preliminary modelling conducted. To assess the potential benefits of alternative station and rail-system operational solutions, Legion SpaceWorks was used. Legion SpaceWorks is a commercial pedestrian dynamic modelling software used by both Network Rail and TfL capacity modelling teams. Four key types of simulation tests were conducted which included;

- Segregation of arriving and departing passengers;
- Passenger Flow Optimised Timetable (through station)
- Platforms On Both Sides
- Passenger Flow Optimised Timetable (terminus)

TEST 1 – SEGREGATING ARRIVING AND DEPARTING PASSENGERS

107 In Test 1, the impact of uni-directional vs. bi-directional passenger flows on a through island platform layout (figure 19) was considered. In this example, access to the island platform is provided by two main access points, Access 1 (a corridor) and Access 2 (stairs).

108 To assess the benefits of a one-way crowd management system for passengers to access platforms, the following two scenarios were modelled and analysed:

Test 1a – The station operates in uni- directional flows only (one-way system), with all passengers leaving the platform via Access 1 and entering via Access 2.

Test 1b – Passengers can enter and leave the through platform via either Access 1 or Access 2. In this scenario, bi-directional flows are simulated at both access points.

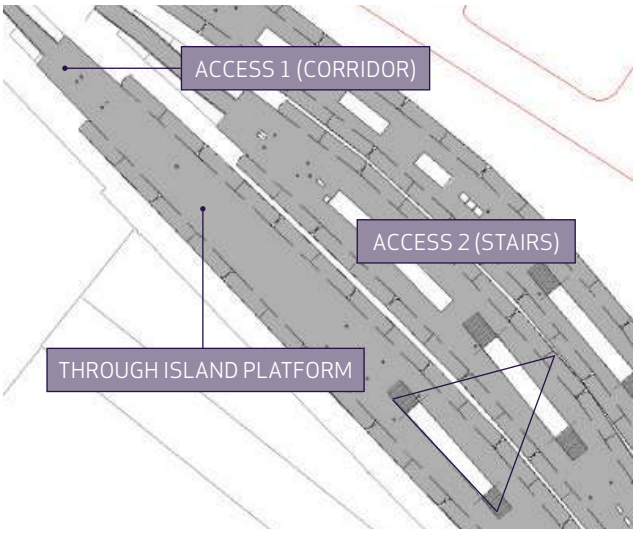


FIGURE 19, Generic through platform layout

109 A key factor affecting the passenger throughput capacity and the performance and reliability of train service is the ability for the trains to safely re-occupy platforms according to the planned timetable. For busy through platforms this is often constrained by the ability to "clear" the platform of alighting passengers between consecutive trains, so that incoming trains can approach the platform without compromising the safety of passengers due to overcrowding on platforms.

MODELLING ANALYSIS

110 Figure 20 Test 1a shows the benefits of implementing a one-way system to load and unload through platforms. In Test 1a, the modelling analysis indicates that the island platform clears before the next train arrival, allowing safe and reliable operation of the platforms. In Test 1b, where bi-directional flow reduces the capacity at both Access 1 and Access 2, the modelling analysis shows an increase in platform clearance times. As illustrated in Figure 20, all passengers do not clear the platform between consecutive trains, creating congestion and unsafe conditions to bring the next train into platform, which ultimately impacts passenger throughput capacity and the train service performance.

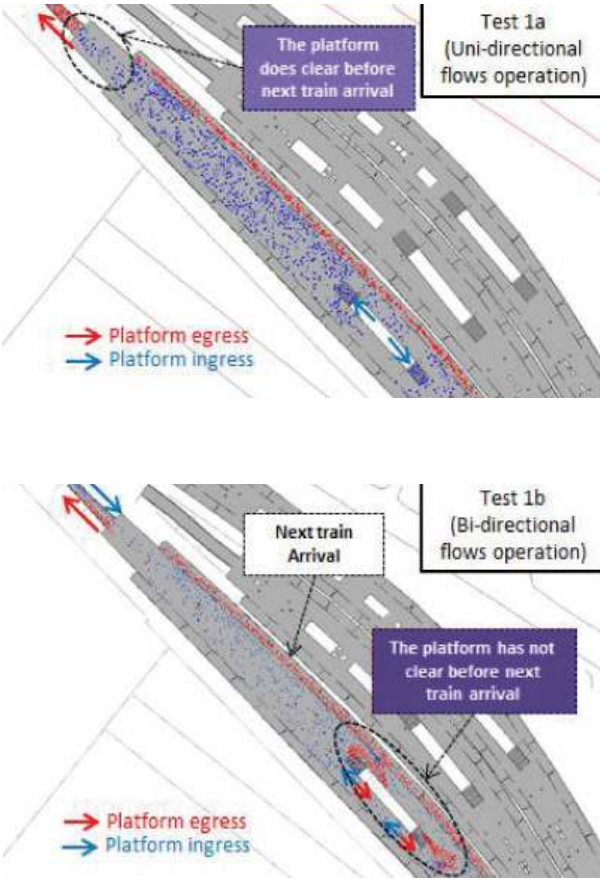


FIGURE 20, Performance comparison between uni and bi directional flows through platforms

RESULTS

In light of the above simulation test, clear performance benefits can be achieved by optimising the station operation (i.e. implementing a one-way system to manage platform loading and unloading) to maximise passenger throughput capacity and train service throughput and reliability.

Insight

Implementing one-way operation can deliver an increase of up to 15%-20% in passenger walking throughput capacity inside the station

TEST 2 – PASSENGER FLOW OPTIMISED TIMETABLE (THROUGH STATION)

111 In Test 2, the operation of an optimum (Test 2a) and non-optimum timetable (Test 2b) with regard to passenger throughput capacity were simulated using the same generic through platform z layout. The through platforms operate using a one- way system as illustrated in Test 1a. The train headway (i.e. time interval between two consecutive trains arriving at a specific platform) was set to 5 minutes for both Test 2a and 2b.

TEST CONDITIONS

112 In Test 2a, the train arrivals alternate between the northbound and southbound platforms (See Figure 22), with a constant offset of 2.5 minutes between consecutive trains arriving on either side of the island platform. In Test 2b, the timetable was altered and random offsets generated between trains arriving alternatively on the northbound and southbound platform sides.

MODELLING ANALYSIS

113 A comparison of Test 2a and 2b in Figure 24 clearly shows the impact of optimising the timetable for passenger throughput capacity (PTC). All alighting passengers in Test 2a clear the platform before the next train arrival at the opposite platform. In this scenario, the timetable delivers both an increase in PTC, safe operation of the platform and maximises the train service reliability.

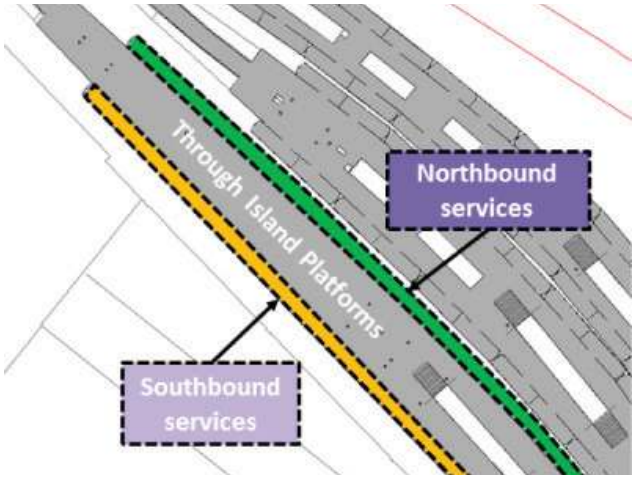


FIGURE 21, Through platform north and southbound trains

The Test 2b results, for the non-optimum timetable, shows that under these operating conditions the island platform does not clear between consecutive trains and congestion builds on the platform.

RESULTS

114 The modelling undertaken in Test 2 demonstrates the benefits of optimising the timetable to increase passenger throughput capacity and use station space most efficiently.

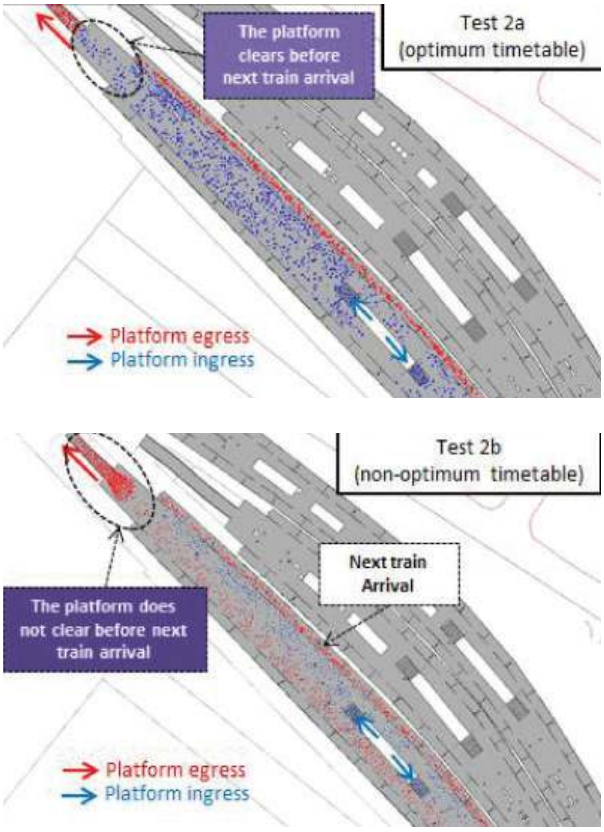


FIGURE 22, Optimum versus non-optimum timetable performance tests

Insight

The work undertaken demonstrates that optimising timetable has the potential to significantly improve the train service reliability. Further analysis would be beneficial to determine ranges with greater confidence.

TEST 3 – PLATFORMS ON BOTH SIDES OF THE TRAIN

115 So far there has been a description of the boarding and alighting operating principles, which have been considered at this stage, including:

Scenario A – Boarding and alighting on one-sided platform

Scenario B – Boarding and alighting on double-sided platform

Note (I) – An assumption was made that all trains arriving and departing are fully loaded with passengers. The train maximum capacity has been set to 1,200 passengers for a 12-car train. At this stage the effect of "train-stayers" on boarding and alighting performance was not considered.

Note (II) - For the one-sided platform (Scenario A), train boarding only starts when the alighting phase is completed. The modelling tests have been developed so that boarding and alighting timings work independently from one carriage to another (i.e. passengers boarding can start at different times for each carriage, depending on specific loading conditions).

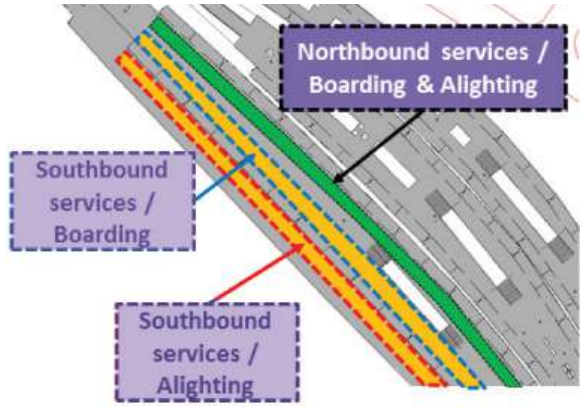


FIGURE 23, One sided vs double side boarding alighting

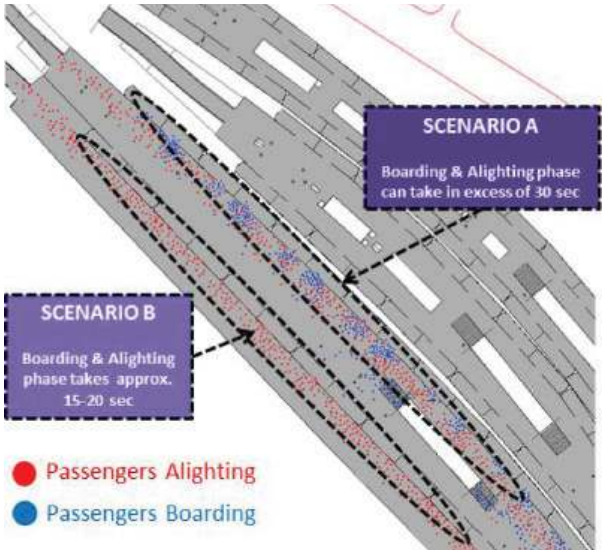


FIGURE 24, Comparison of one and double sided platform performance

MODELLING ANALYSIS

A review of Test 3 modelling results indicates that for the double-sided platform Scenario B, the boarding and alighting phase takes approximately 15-20 seconds. In this scenario, the boarding and alighting phases start simultaneously.

In Scenario A, the results extracted from the simulation show a significant decrease in performance, with the boarding and alighting phase taking up to 30-40 seconds to complete.

Figure 6 represents the outcomes of a simulation with two trains arriving at each platform type, one vs. double sided, at the same time. As can be observed, there is a clear difference in performance, with boarding just starting in Scenario A when the full boarding and alighting phase is complete in Scenario B.

RECOMMENDATIONS

In light of this preliminary high level modelling study, the Transport System Catapult recommends that further research should be considered to expand these simulation results and confirm the potential benefits of double-sided platform on train service performance.

Insight

The high level modelling undertaken indicates there are clear benefits of two-sided platform for boarding and alighting approach, with initial indications that performance can increase by up to 30% (the time it takes to complete boarding and alighting)

TEST 4 – PASSENGER FLOW OPTIMISED TIMETABLE (TERMINUS)

116 In Test 4, different timetable configurations were modelled for terminating platforms to appreciate the potential benefit of segregating arriving and departing passengers to limit conflicting flows - a factor affecting customers experience and station operational efficiency.

117 **Test conditions.** Figures 25 and 26 illustrate the terminating station layout used for the modelling. To inform the study, two timetables were modelled, representing different train/platform allocations, including:

Test 4a simulates a train arriving and another one departing within a 2-minutes period at platform P1-P2. The same assumptions apply to island platform P3-P4.

In Test 4b, platform allocations were altered to minimise conflicting flows in the station. In this test, all trains arriving at the station use island platform P1-P2 and all trains depart from island platform P3-P4.

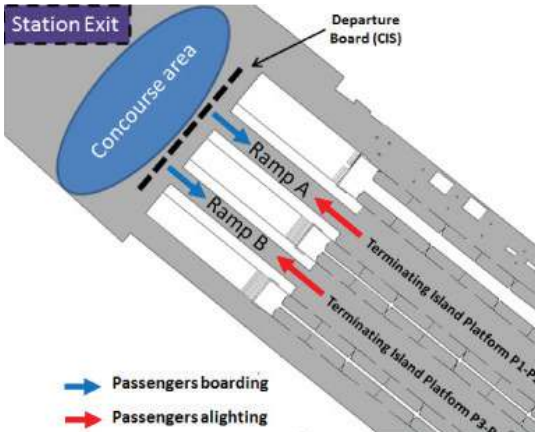


FIGURE 25, Terminating Station Schematic

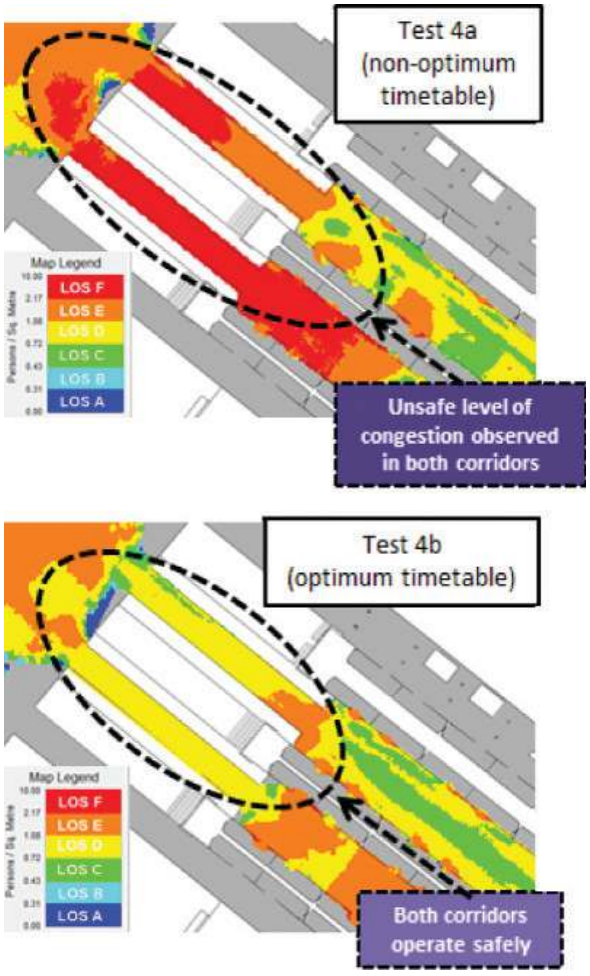


FIGURE 26, Comparison of optimum and non-optimum timetable at terminating station

MODELLING ANALYSIS

118 To review the modelling results, the industry standard Fruin's Level of Service (LOS) metrics were used. It measures passenger density levels over time and associate to them an equivalent passenger "quality of experience" level (LOS A – most comfortable, to LOS E corresponding high level of congestion).

As observed in Figure 28, Test 4b shows significant improvements in passenger experience within both Ramp A & B, which connect the concourse to the platforms.

The density maps for both Test 4a and 4b, provides an indication of the benefit achieved by altering the timetable at terminating station. In Test 4b, where the ramps leading to the island platforms are operating in uni-directional flow the density levels do not exceed LOS D (a congested but safe environment).

However, in Test 4a, where the ramps operate in bi-directional mode (with simultaneous alighting and boarding passengers), the density level reaches LoS F at which flows are severely restricted, passenger comfort and experience is poor and passenger safety can be compromised.

RECOMMENDATIONS

Minimising the occurrence of major conflicting passengers flows in critical transfer areas of railway stations not only mitigates safety risks, but also significantly improve costumers experience and can enhance the train service reliability.

Insight

Enabling one-way operation to access terminating platforms can deliver an increase of up to 15%-20% in passenger walking throughput capacity inside the station.

MODELLING STATION DESIGN OPTIONS SUMMARY AND RECOMMENDATIONS

119 A high level appraisal of station and rail-system operational opportunities (timetabling, platform allocation, station management) was conducted to unlock additional passenger throughputs at railway stations;

- The modelling study shows the benefits of optimising the timetable against any "local" station operational constraints (e.g. platform with limited egress capacity, etc.) to achieve a good service reliability;
- Minimising major conflicting flows in critical transfer areas of railway stations not only mitigates safety risks, it also significantly improves costumers, experience and enhances the train service reliability;
- Crowd management (e.g. implementing a one-way system) also offers opportunities to improve passenger experiences and service performance and reliability;
- Following a preliminary high level modelling study, further research should be considered to expand these initial results. In particular, applying advanced optimisation and modelling techniques to improve station efficiency (e.g. Clapham Station to build on previous vision case for new technologies using a whole systems approach conducted by the RSSB[xxvii] or one of the three stations assessed) could offer system-wide efficiency opportunities.

120 **Further work to inform these results** could include;

i. Testing platform allocation and timetabling on busy stations;

ii. Developing optimisation platform allocation tool for normal and poor operating conditions;

iii. Working with Network Rail to investigate opportunity to test some of the concepts in real life in a carefully selected station.

ENGAGING SMEs IN STATIONS

CONNECTING INNOVATIVE SMES WITH THE RAIL INDUSTRY

121 **Context.** Small medium enterprises (SMEs) accounted for 99.3% of all private sector businesses at the start of 2015 and employed 15.6 million people; 60% of all private sector employment in the UK. With a combined SME annual turnover of £1.8 trillion, SMEs make up 47% of all private sector turnover in the UK[xxviii].

122 Support for innovation transport is available to SMEs via the European Union programmes and UK government. The European Union support is deployed through the 'societal challenges' as part of the Horizon 2020 funding programme which includes transport. This enables around 20% of the € 8.33 billion in EU support for Research and Innovation activities to find its way directly to SMEs, most of them as part of consortiums participating in EU collaborative Research and Innovation projects[xxix]. In the UK transport sector, SME growth and support are key strategies of the Department for Transport and Innovate UK. The Transport Systems Catapult amongst others, works to support SME growth through commercialising their ideas in the domain of intelligent mobility while critical industry bodies such as the Rail Industry Association and Rail Supply Group provide routes for engagement to connect industry with innovative SMEs.

123 Innovation in rail is often incremental innovation, with improvements within a given frame of solutions (i.e. doing better what we already do). In the road sector autonomous vehicles may soon experience radical innovation (i.e. doing what we did not do before) driven by rapid technological change. SMEs are often viewed as where potential disruptive innovation lies. While there is strong evidence to indicate that incremental innovation is very often easier to achieve, the combination of the two can offer powerful new solutions to rail. By enabling and continuing to linking SMEs to the industry via the Rail Industry Association, Rail Supply Group, Future Railway and Catapults we aim to foster innovation and help create consortiums that can address key industry challenges. Alternate approaches include the tools adopted by InnovateUK through a Growth Showcase. This is an online service which we developed in partnership with 'Growth Accelerator'as a tool. This ensures SMEs can reach the investment community and boost their growth potential, and provide innovator brokering (to connect SMEs and the rail industry) as part of the Future Railway programme or intelligent mobility challenges sponsored via the InnovateUK competitions in partnership with the Department for transport.

124 **Innovative SME directory goal.** One of the projects, aims was to create an online portfolio of high impact SMEs to stimulate the SMART rail market and enable business to business collaboration.

125 This initial portfolio was created to help facilitate collaboration and innovation in the rail sector and thus in station design, construction, operation and management. It is now hosted on the TSC website. This will help build communities of interest, act as a focal point for innovations on this theme and connect large and small businesses to solve selected challenges. Within a limited and modest set of initial aims, 14 UK rail SMEs were first identified and added to the directory, which includes information on their services, project highlights, executive leadership, email and website. The site includes details of the £900b global intelligent mobility market and how to access the 200 datasets collated by TSC.

FIGURE 27, SME Directory and example SMEs

126 To build an sustain this early initiative, there is an opportunity to;

i. Grow the directory as it becomes better known in the industry and market via SME engagement activities;

ii. Develop further functionality, such as a consortium builder tool which could be added in the future;

iii. Align academic partner programmes from a range of innovation bodies to support selected SME projects as a joint research and innovation programme. The Rail Research Association (RRUKA) should also be engaged;

vi. Use the T-TRIG research and development calls (worth up to £25k) to be focused on stations innovation, overcrowding and congestion solutions;

v. Support SME innovation projects via Horizon 2020, InnovateUK and other research calls; and

vi. Build a wider community of interest focused on distinct narrow crowding innovation challenges linked to stations (and multi modal interchanges) to draw in wider cutting edge innovations.

UNLOCKING INNOVATION AT STATIONS

BARRIERS AND ENABLERS TO INNOVATION AT STATIONS

127 Many innovative ideas and solutions for increasing passenger throughput capacity and transforming stations moving forward have been generated during this project. Other equally good ideas have also been proposed outside of this project. Research[xxx] conducted on behalf of the Rail Technical Strategy (RTS) has identified barriers to innovation in leadership, industry capability and risk reduction. The actions begun in 2010 should continue to address barriers. An extract of the key enablers of innovation from both Future Railway and Network Rail[xxxi] at principle level include;

RAIL TECHNICAL STRATEGY	NETWORK RAIL
Create a leadership system	Managing research and development put in place new management systems and processes to enable efficient and effective investment in, and delivery of, R&D projects and programmes
Enhance industry capability; use open innovation, support culture change and 'de- risk' projects via pilots	Connecting with wider array of business and the cross-industry process, identifying and removing barriers to innovation without compromising safety
Reduce the risks of introducing innovation to the system – good access to appropriate test facilities, with mechanisms to manage the commercial risk of testing	Collaborating across the industry and through the supply chain transfer technologies where possible. Combine efforts for mutual benefit

FIGURE 28, High level enablers to address barriers to innovation

128 The challenge for rail is whether the industry is innovating rapidly enough compared to passenger needs and their perception of rail versus the strides made by other modes. A key question in the research was what are the barriers that prevent these solutions being realised and what can be done to enable rapid innovation?

129 **Barriers and enablers to innovation** were identified through interviews and two workshops. In this section the focus is on enablers. A number of barriers to innovation identified were not in scope of the project, such as those which related to the specific challenge of increasing flow and reducing overcrowding. These included industry fragmentation and structure, potential new business models for stations and overall industry culture. In this section the focus is on which enablers might best support resolving overcrowding and passenger throughput and where alignment might support beneficial change for customers to support the Rail Technical Strategy[xxxii] 2010 vision for innovation.

> **The rail industry has overcome inhibitors to innovation, including the misalignment of risk and reward, to become dynamic and attractive to entrepreneurial talent. Support for innovators includes identified priorities and test and trial facilities to simplify the introduction of novel technical solutions for operations and engineering applications**
>
> RTS Vision on Innovation

130 Example barriers to stations innovation included:

i. Health and safety approvals, legal consents, lengthy timescales to enable new technology or solutions to be installed, challenges with obtaining data. A barrier for SMEs, was that they perceived there was no focal contact for innovation.

ii. Incumbent attitudes and a reluctance to experiment. Various stakeholders lamented the reluctant stance to experimentation and change held by some rail partners and management levels. The industry is moving through a period of change and supporting this change needs continued support and emphasis. The RSSB has already conducted pilot innovation academies, companies' commitment, investment and focus on innovation is slowly growing through the leadership of the Technical Leadership Strategy Group which focuses on innovation. The industry Innovation Capability Maturity Model which measures innovation capability and aims to transition the rail industry from a low level of innovation capability (level 2) to having leading companies at a very high level of capability (level 5) by the end of CP6 (2019-2024). Continued efforts need to be made to the various tools, measurement approaches and engagement methods to increase the desire for action.

BUILDING BLOCKS FOR CHANGE

131 Initial recommendations for enabling innovation on this topic were developed through interviews, workshops and analysis.

INNOVATION AND COLLABORATIVE RESEARCH & DEVELOPMENT FUNDING

132 Funding is perceived as a barrier and potentially the solutions relies on strong leadership by the Department to help facilitate key players to coalesce around proactive, positive solutions and unlock access to funding where needed. A number of readily accessible funds can support initiatives such as the Network Rail £150m National Stations Improvement Programme (NSIP), Network Rails stations budgets. The trial pilot innovation funds amount to nearly £48m as part of the following franchises: Northern (with 463 stations managed) Trans Pennine (with 30 stations managed) and East Coast (53 stations on the route network where the operator is station franchise operator for 12). With this level of funding and a wide range of suitable stations, selection of potential pilot locations should be relatively simple and significant funds are available to supporting concept development, pilots and implementation.

133 In addition, the Department for Transport has enabled a significant residual value mechanism with values up to £75m at bid stage and by negotiation in franchise life. This mechanism can be used in franchise by any TOC. It might be appropriate as a means to develop a fuller implementation post a successful pilot to ensure fair reward and signal strong Departmental support for rapid change.

134 Competitively bid research and development innovation calls for innovation in transport are a rich source of new funds. These span the European Union, Future Railway, InnovateUK which are of significant value and smaller funds which could be steered towards a range of carefully selected pilots.

135 The UK is investing significantly in the SMART cities programme which may also offer collaborative opportunities working to both station and city space usage via digital means and combining additional datasets to develop solutions. For example, Milton Keynes SMART (MK Smart) data cloud now incorporates 492 datasets in total which are being combined to create new insights and solutions. The Cloud Enabled Mobility pilot (CEM) focuses on the development of a city-wide transport information service. This service, called MotionMap, will be delivered as an app that continuously describes the real-time movements of people and vehicles across the city. It will include embedded timetables, car parking, bus and cycle way information and estimates of congestion and crowd density in different parts of the city. Sensor network development, testing and demonstration are already underway. These include using small cameras and visual analytics to provide data on car park occupancy, congestion and how crowded are the local buses. Harnessing and improving upon relevant SMART city development can help accelerate relevant solutions to rail challenges.

136 **Short term innovation funding could be secured** in the following ways in order to ensure rapid action;

i. Provide direct input to the innovation project selection for East Coast, Northern and Trans Pennine franchises with the aim of implementing a demonstrator in each franchise utilising the innovation fund as the investment vehicle;

ii. The Department for Transport, Network Rail and industry should develop a set of selection criteria (for example Fruin current and future status, NRPS trends on station satisfaction and impact/ease of implementation, risk level of the pilot) to focus on a single Network Rail managed station to develop a limited demonstrator around overcrowding as a systems trial from station entrance, through concourse and a single or two platforms using Network Rail funds to fund the initial demonstrator;

iii. The Department for Transport could support franchises that are currently in franchise life to develop their own pilot at a small scale and utilise the residual value fund to support implementation costs (and where necessary, make a contractual change to reduce any commercial or penalty risks to the operator) for any successful trial that they complete;

vi. The Department for Transport, InnovateUK and RSSB could develop an innovation call based on funds within their control to encourage innovators around the integrated use of station based data (such as Fruin levels, entries, exits, sentiment, PPM and others) to fund a hackathon around a pilot station to develop pragmatic solutions that could be taken forward;

v. The Department for Transport and Transport Systems Catapult jointly work on funding and managing innovative pilots. An example is the T-TRIG innovation funds provided to the TSC by the DfT which could link to this theme and provide a direct overcrowding innovation challenge to the initial SME directory on how data could be used to safely disperse people from a station in times of serious disruption; and

vi. TSC, RSSB and InnovateUK should collaborate to develop an interchange specific overcrowding innovation call as part of the wider investment in seamless end to end journeys where learning and innovation could be applied in both a rail and n on-rail modes.

137 **Stimulating the market via the franchising programme.** In the highly competitive franchising programme bidders invest significantly to help meet franchise objectives and franchise bidding is often the most innovative stage of the franchise. The Department could;

i. Specify a requirement for bidders to develop as part of the stations plan, an exemplar station that will serve as a national beacon for station performance around overcrowding, passenger throughput capacity and information to passengers; or

ii. Drawing upon the learning of the innovation fund pilot, extend the existing innovation fund approach to new franchise competitions (principally the East Midlands and South Eastern franchise competitions commencing in 2016-17) but limited to stations innovation.

138 **Create 'A Pilot Station Framework' to create urgency.** Workshop participants identified the concept of a Pilot Station framework which would serve as rapid method of helping piloting new ideas at stations and as a means of managing though the constraints of a highly regulated system. In essence this would need to map out the key constraints for actions and then work to enable quicker methods of doing business and conducting pilots. Options to develop this theme include;

i. Creating clarity and ensuring a strong communications profile of pilot stations, reinforced with a set of unambiguous innovation challenges, an innovation portal to stimulate greater open innovation and a clear focal owner of the innovation programme;

ii. Rapid contracting and procurement methods to accelerate some testing;

iii. An open data approach based on pinpoint station areas, partnering with the Open Data Institute and wider Catapults. The Digital Catapult's Data Catalyser is a suite of services enabling organisations to create value from mixing closed datasets to unlock the ability for companies to grasp opportunities for new products, services, tools, insights and innovations. Given load and other data train operating companies see as commercially sensitive this may be a route to providing an industry pilot to greater open data and involve all station stakeholders;

vi. Provide support to the programme via innovation experts and coaches to help work through industry change barrier issues and behaviours; and

v. In the longer term adopting a dedicated stations research and development facility to enable prototyping to be tested and developed similar to Japan. Network Rails facilities test facilities could be expanded and alternately a step further would be to create an interchange research and development centre where invention from all the modes could form a hub for innovation research and development to benefits from the solutions to similar challenges.

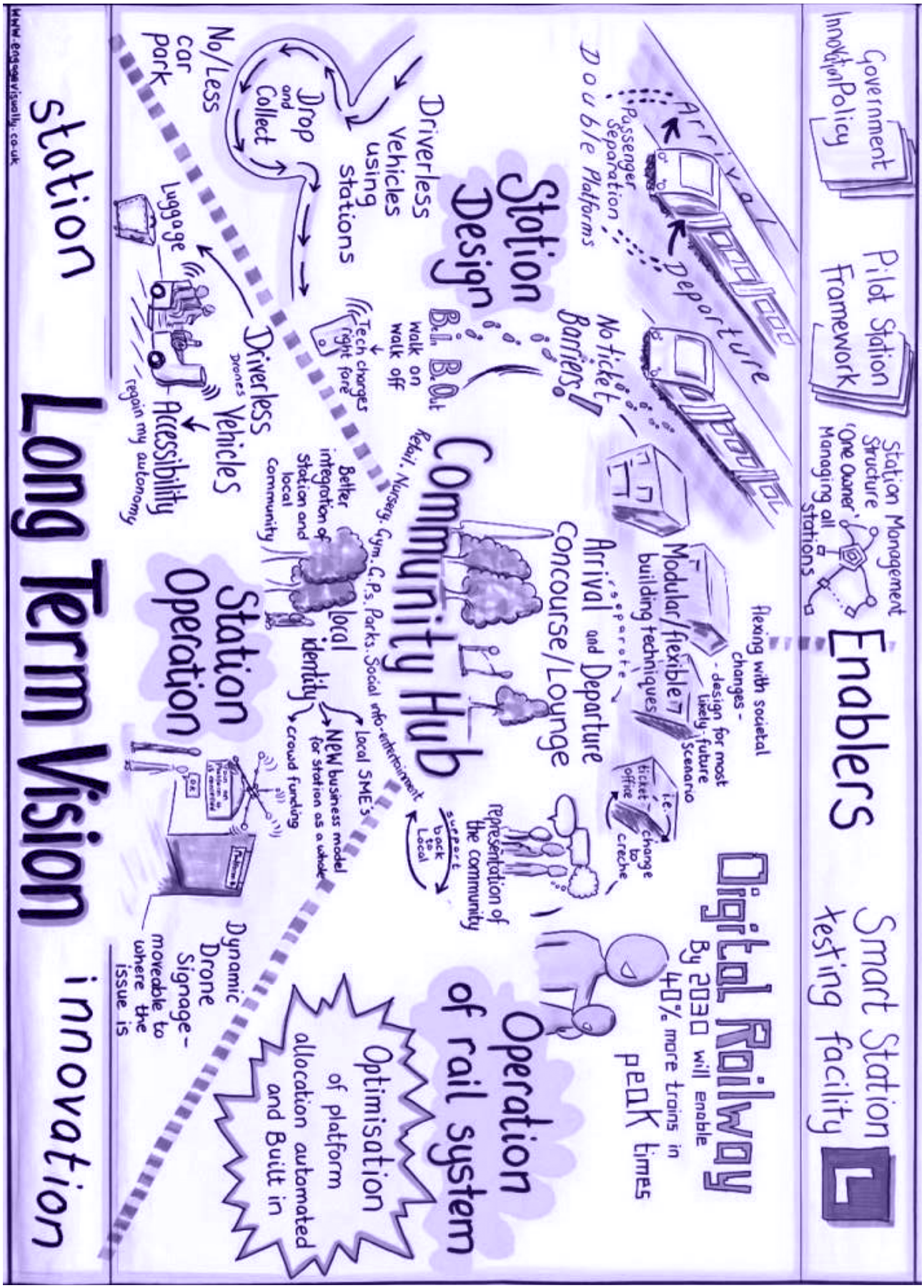


FIGURE29, Research concepts the longer term

LONGER TERM HORIZONS

139 Whilst the primary focus of this report is on short term innovations that could unlock latent passenger throughput capacity in UK railway stations, a number of longer term solutions also came out of stakeholder consultation and ideation. While some are being tested expansion of scope and combining the idea with other technology may yield further benefit.

140 **Real-time Passenger Flow Optimised Timetable and Platform Allocation** (with systems embedded) This solution is a more enhanced version of the optimised decision support tools and would be fully integrated into Network Rail's digital signalling and control systems and with increased automation. The timetable would be adjusted in real-time to optimise passenger throughput capacity at each station and respond to customer demand. This solution could be incorporated in the Digital Railway programme and align some aims of this project to the Digital Railways work. A similar vision is already highlighted in Network Rail 's Technical Strategy where NR aspires to a vision where "Our network will operate on an increasingly optimised basis, balancing the needs of passengers and freight and progressing towards real-time optimisation of the rail timetable linked to customer demand"[xxxiii]

141 **Removal of Ticket Barriers.** With a high level of urban ticket barriers focused on revenue protection they have the adverse effect of restricting flow in overcrowded stations. RSSB is trialling three different 'Be in Be Out' (BiBO) fare collection technologies through their £2m Future Ticket Detection competition[xxxiv]. The projects will be complete by 2020.

142 **Temporary Drone Signage**. A configurable LED display mounted to a drone could be used to hover above the desired location to deliver information to passengers. This would have the advantage of not taking up valuable floor space and be more efficient than having many permanent ceiling mounted displays installed. Trials for roads and shopping areas are already underway.

FIGURE 30, Superflux Drone aviary example

143 **Separate Arriving and Departing Passengers** In future station improvements or new stations, arrival and departure concourses should be established with dedicated convenient paths from arrivals to departures for connecting passengers..

144 **Digital Railway and High Capacity Trains** Overcrowding at stations is linked to the capacity constraint on the rail network. Without unlocking extra capacity in both, isolated measures will be largely futile. Network Rail's Digital Railway initiative will deliver the digital enablement of the railway through digital signalling and train control. It will enable a 40% increase in train services potentially from 2024 onwards as each line is upgraded with next generation technology.[xxxv] Network Rail are also working to unlock capacity in the short term. Alongside Station Innovation, Transport Systems Catapult (TSC) were also sponsored by the DfT to investigate innovations in high capacity train design and a range of options has been developed in other RSSB competitions. The effort put into high capacity trains needs reinforcement.

145 **Virtual Station infrastructure**. A common data and systems platform within stations which would integrate all digital infrastructure and communications is essential to reduce cost, enable the Internet of Things and improve customer experience through provision of highly accurate real-time information. A similar idea has been transforming the operation of highway and public transport in local authorities over the past 10-15 years. All systems that provide live highway information have been consolidated on Urban Traffic Management and Control (UTMC) common databases including traffic signal, CCTV, ANPR and bus RTIP. Data exchange is standardised so that the system can be managed from the one interface. The Innovate UK consortium behind Stations as a Service (StaaS)[xxxvi] built a prototype IT platform and trialled it at Gloucester station. The platform allows for scalability and provides a greater capability to rapidly deploy new technology. This work should be built upon and platforms installed alongside existing digital infrastructure for migration.

146 **Post Opening Project Evaluation (POPE)** Once improvement schemes and new stations are built and opened to the public passenger flow data should be collected regularly and compared with forecasts from modelling work that were used to assist the design. The comparisons should be made freely available to the modelling industry so that areas for improvement can be identified and addressed. This practice would also improve transparency. Highways England has been producing POPEs for major and minor schemes for several years[xxxvii]. Evaluations are carried out one and five years after opening.

Community Hub. Making the railway station the centre of the community is an idea that has gained considerable recent backing. People use Kings Cross, St Pancras and Birmingham New Street as a destination in itself. A 'Station City' that incorporates shops, restaurants, pubs, GPs, dentists, business meeting areas, nurseries, music venues, theatres, sleeping pods, faith spaces along with many other facilities should be the aim of future developments. The idea has also been embraced in other countries. Tokyo station, one of the largest stations in the world by passengers, has achieved this vision. There is no delineation between the station, facilities and amenities, they are one. The sprawling expanse of shops, restaurants, banks and nurseries has train related wayfinding and real-time passenger information throughout. It is also large enough and designed to cope with both the train passengers passing through and the customers for other facilities. Station Cities are built around the stations –shops, restaurants, offices, hotels, medical centres, nurseries. When building new stations rail companies use the commercial development to fund the railways (nearly 30% of an operators income is from stations) Stations are integrated with the communities and other services providing direct access to office buildings and other amenities close to the station with a large number of entry and exit points.

CONCLUSIONS AND SUMMARY OF RECOMMENDATIONS

KEY MESSAGES

147 **The increase in demand for rail travel, coupled with the rapid urbanisation and concentration of the population in cities represents a huge challenge to industry. Failing to meet passenger needs and the ability to provide increased throughput at stations may inhibit economic growth, increase safety risk and significantly damage the reputation of the industry.**

148 Major investment in new major station facilities will not address the needs in the short term and industry cannot wait for these big step changes to deliver salvation. Industry is facing a significant challenge from innovations in other sectors through the unrelenting rise of the digital and shared economy. Speed and a 'can do' attitude are needed. This study has found a range of simple and also innovative ideas that might help reduce the impact of overcrowding and there is much more experimentation and insight to be obtained. It's time to act now, time to take risks, time to innovate.

> If the rate of change on the outside exceeds the rate of change on the inside, the end is near
>
> Jack Welch, former CEO GE

RECOMMENDATIONS FOR ACTION – SUPPORTING INDUSTRY ACTION

149 **A number of recommendations have been identified throughout this report and the main critical areas for action recommended are;**

- A number a of carefully selected but high tempo trials need to be started, focused on the short term solutions identified, using stations identified in Network Rail's priority list and from franchise priorities;
- Support needs to be provided to the development of a 'Pilot Station Framework' concept, and used as a rapid deployment technique for the pilot programme. The insights from this work ought to help develop a new measurement and information approach for assessing station success that is more holistic and balanced against the varying purposes of stations;
- Use the leverage of the franchising programme to encourage significant station demonstrators requiring new innovations to be developed at selected locations in the next franchise competitions, and reduce penalties or other inhibitors at those stations to encourage entrepreneurship;
- Align and focus the use of existing financial innovation resources including the innovation funds from the trial innovation fund franchises, residual value mechanism to inject the financial resources into action;
- Work with train operating companies to make service level loading data open so that the plethora of travel apps can deliver this to the passenger. An open data pilot needs to be sanctioned and enabled around the demonstrator stations;
- Encourage InnovateUK and the RSSB to develop specific competitions around increasing passenger throughput capacity in stations in the short term;
- Commission further deeper modelling of the benefits of proposed solutions and combine this with an open data strategy to ensure that as many possible sources' of data can be used to create new value and reduce cost;
- Ensure that the medium and long term solutions identified, are expanded and evaluated as part of the design process for station improvements or new station construction;

- Investigate and the options for extending research and development facilities to enable a SMART stations facility to be established to enable rapid trials and proof of concepts to be tested to facilitate new innovations being brought to the market. Its potential location and modus operandi should be developed by a cross industry team from DfT, RDG, NR, RSSB (as a minimum);
- Explore the management options for stations and consider putting management and/or ownership of all stations in Great Britain under one organisation that would be able to create and deliver a strategic vision for stations. This could be through removing stations from current route franchises and creating one long term franchise for stations.

POTENTIAL SHORT TERM SOLUTIONS

150 This initial research served as an exploratory analysis of potential solutions with the aim of resolving customer challenges around overcrowding and improving passenger throughput capacity at stations. Subject to a review of learning from phase one, the second phase will explore and deliver:

- The establishment of potential pilot stations to identify frameworks required for rapid installation of technologies and testing of operational ideas;
- A pedestrian tracking technology trial could be conducted after deploying sensors in TSC office to test and validate technology. The findings should be reviewed with stakeholders and then sensors implemented in showcase stations for a trial period, with data collection and review;
- Facilitate workshops with stakeholders including tech providers, legal experts and academia to agree outputs and aims of trials and develop data in 2D, 3D, Augmented Reality (AR) and Virtual Reality (VR) formats with a link to pedestrian simulation software;
- Horizon scan for new technologies and develop a proof of concept app to be used at each station Carriage Occupancy Technology Trial, building or adapting learning from C2C trial;
- Create a prototype schedule real-time platform allocation optimisation algorithm decision support tool for signal box operation to increase passenger throughput capacity and robustness and conduct a small trial;
- Conduct operational trails and develop customer experience focused innovations for low cost trials;
- Explore the integration of Autonomous and Connected Vehicles (CAV) and their impact on stations
- Produce an industry launch report with visualisations, data and provide materials for wider use by the industry

Further details are available from the TSC who welcome the engagement of industry and innovators to help reinvent the future of intelligent mobility.

Facilitate workshops with stakeholders agree outputs and aims of trials and develop data in

2D, 3D

Augmented Reality and Virtual Reality

APPENDIX A - STAKEHOLDERS AND PARTICIPANTS

STAKEHOLDER INPUT : Throughout the project valuable input through idea-shops and interviews was provided by the following stakeholders. We would like to thank all of them for their efforts and willingness to contribute.

NAME	ORGANISATION	NAME	ORGANISATION
Neil Buxton	AcoRP	**Sophie Harper**	Priestman Goode
Simone Bailey	Abellio Greater Anglia	**David Sturdy**	PFM Footfall Intelligence
Panagiotis Petridis	Aston Business School	**Jennifer Scattergood**	Rail Delivery Group (RDG)
David Mapp	Association of Train Operating Companies (ATOC)	**Trevor Bradbury**	Rail Safety and Standards Board (RSSB)
Ersel Oymak	Cisco	**Peter Ainsworth**	Rail Safety and Standards Board (RSSB)
William Reddaway	Crossrail	**Colin Tiller**	Siemens
Maggie Brown Batten	Crossrail	**Geert Vanbeveren**	Siemens AG
Peter Batten	Department for Transport (DfT)	**Jan Helebrant**	Siemens AG
Johannah Randall	Department for Transport (DfT)	**Richard Crappsley**	Steer Davies Gleave
Colin Ledwith	Futurecity	**Fred Gangemi**	Steer Davies Gleave
Katerina Examiliotou	Grimshaw Architects	**Mark Rose**	Stationguru
Catherine Howe	Grimshaw Architects	**Jason DaPonte**	Transport for London (TfL)
Alex Tucker	Grimshaw Architects	**Dr Robin Hickman**	Bartlett School of Planning/UCL
Martin Phillips	High Speed Two (HS2)	**Jonathan Bray**	Urban Transport Group
Julian Maynard	Maynard-Design	**Pedro Abrantes**	Urban Transport Group
Kevin Siddell	Network Rail	**Mark Pettman**	Virgin Trains East Coast
Andrew MacKinnon	Network Rail	**Chris Beattie**	Wegocouriers
Mervyn Pierce	Network Rail	**Paul Corney**	Virgin Trains
Craig Stenning	Network Rail		
Malcolm Pitt	Network Rail		

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JAPAN RAIL EAST	JAPAN RAIL CENTRAL	MINISTRY OF LAND, INFRASTRUCTURE, TRANSPORT AND TOURISM	JAPAN RAILWAY TRANSPORT AND TECHNOLOGY
Yasunari Nakajima	Yoshinori Hatta	Youichi Shimotashiro	Yas Morita
Satoshi Kuji	Shogo Okurano	Hiroshi Mizusaki	
Soichi Shibuya	Seigo Tsuboi		
Akihito Someno			
Jun Kobayashi			

The report authors were Charles Carter, Nicholas Stafford, Nicolas Le Glatin, Christos Tsotkas and Andrew Payne from Transport Systems Catapult.

APPENDIX B – IDEAS WORKSHOPS

In order to generate the seeds of change, challenge the station status quo and generate ideas for addressing the challenges, a wide range of stakeholders worked through a series of Idea-shops. Colleagues from inside and outside the rail industry, from companies, government and academia, in a specially designed, fun, creative environment provided at the TSC Ideas Lab to develop fresh thinking. The summary approach used is in figure 34. Lego was used to unlock options and map out options while architects, transport planners, gamification and human factors experts came up with ideas for increasing throughput capacity, improving customer experience and explored the station of tomorrow.

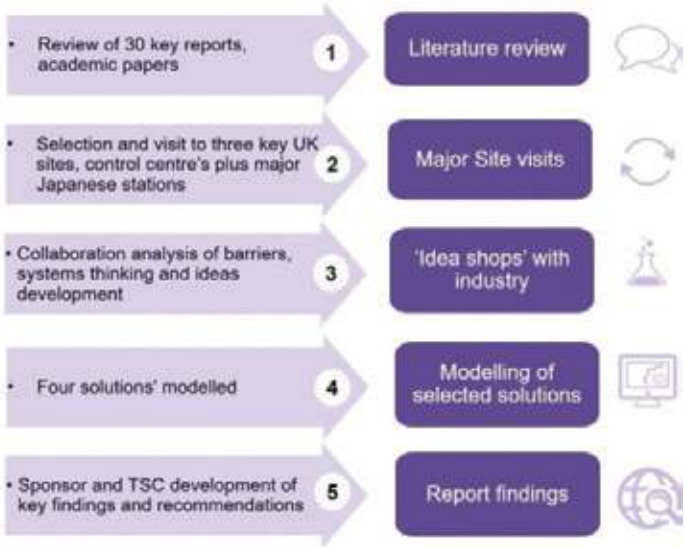

FIGURE 31, Indeation workplace process

OUTPUT EXAMPLES

The key ideas resulting from the idea-shops are developed within the main report. The main report focuses on those ideas linked directly to easing overcrowding and this section includes a summary of inputs.

KEY IDEA-SHOP 1 OUTPUTS

The principal and reoccurring concepts and directions from the idea-shop were as follows:

- The separation of arriving and departing passengers to remove conflicting flows which cause congestion.
- Creation of a more personal and human centred infrastructure – using real-time data, personal devices and smart wayfinding to better inform and guide passengers, to help enable the connected passenger.
- Reassess the balance and location of retail space v passenger space, to consider the possible opportunities for digital/ e-commerce retail.
- Simplify the ticketing process, a new approach is needed.
- Thinking beyond the station perimeters, the relationship the station has to its wider surroundings but also the end-to-end journey of passengers.
- Encourage an entrepreneurial spirit, how to embrace new SME business opportunities
- Better integration of stations into the local community to give them a stronger identity, sense of pride and social role, to support the station as a community hub.

KEY IDEA-SHOP 2 OUTPUTS

The principal concepts and directions from the second idea-shop included:

- Separation of arriving & departing passengers
- Spatial planning to suggest fast-track and dwell areas
- Creation of a virtual infrastructure combining different agencies to control and monitor flow
- Changing passenger behaviour to travel at different times
- Stations as community hubs
- Improve the sense of safety and security at smaller regional stations by greater community involvement
- Utilising unused space by introducing new services and facilities
- Overriding aim is to make regional stations more appealing destinations
- The use of drones, robots & autonomous systems (such as drones to move information boards)
- Use technology to improve operations efficiency through better environment monitoring
- Safety and security, the use technology to remove human error
- Use technology to improve the experience for vulnerable users
- Policy, business model, franchise and funding
- Devolving stations to regional areas – to have them run by local authorities or local station boards
- Moving to a bare minimum infrastructure provided by the station franchise operator or Network Rail, with everything else bid and managed by investors and entrepreneurs
- Enabling a sponsorship approach to stations to attract new investment
- Retailers taking on a greater management of stations

FIGURE 32, Visualising options using Lego

APPENDIX C – RAIL DELIVERY GROUP NINE PRINCIPLES FOR STATIONS

These core principles to station design underpin the RDG vision for stations.

P1: CUSTOMER FOCUSSED

There has been significant investment in stations but Rail Delivery Group Vision aims to build on this.

P2: INTELLIGENT USE OF TECHNOLOGY

The latest information and ticketing technologies are fully utilised to support and enhance the experience at stations.

P3: SEAMLESS JOURNEY EXPERIENCE

Ensure stations are fully integrated with rail services and onward travel modes (including walk, cycle, bus, car, tube, transit, metro, air, ferry or ship).

P4: REFLECT LOCAL NEEDS AND OPPORTUNITIES

Tailor stations to reflect local needs and characteristics while still being part of a recognisable national network.

P5: SAFE AND SECURE ENVIRONMENT

Ensure all stations and their localities are places where users can feel safe and secure.

P6: ENTREPRENEURIAL SPIRIT

View stations as potential catalysts for innovation and entrepreneurship, and thereby enhancing the railway and local economies.

P7: FLEXIBLE AND LONG-TERM STEWARDSHIP

Plan and operate stations for the long term, with built in flexibility to adapt to change.

P8: SHARED INDUSTRY KNOW-HOW

Share knowledge and experience of what works best at stations in meeting passengers' diverse needs in the most efficient and effective manner.

P9: OPTIMISED NETWORK

Realise the full value of every station while minimising inefficiencies through investment and operation based on objective and informed decision making.

APPENDIX D – REFERENCES AND SELECTED LITERATURE RESEARCH

Alongside legislation, standards and guidance detailed in Appendix B of Station Design Principles for Network Rail, selected key literature that supported Station Innovation is listed below.

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Rail passengers' experiences and expectations of the East Anglia franchise – Transport Focus (2015)
Station Design Principles for Network Rail – Network Rail (2015)
Passenger Flows in Underground Railway Stations and Platforms – Mineta Transportation Institute (2015)
Vision for Stations – Rail Delivery Group (2015)
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STATION INNOVATION

OVERCROWDING AND INCREASING PASSENGER THROUGHPUT AT STATIONS

April 2016

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