Digital Systems: Transforming Rail Transport in Sydney with ETCSL2, TMS & ATO

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SUMMARY

Transport for NSW's Digital Systems Program is transforming the way the Sydney rail network is managed and operated. It will provide a 'step-change' introduction of a new traffic management system, radio-based cab signalling and automatic train operation to assist drivers, who will still remain in control. The first deployments will be at the two ends of one of Sydney's busiest suburban lines, allowing for the parallel development of two ETCS suppliers with interoperable solutions. Subsequent deployments of Digital Systems will be prioritised to increase capacity on the most constrained lines of the network first. An overarching program of rail upgrade projects, 'More Trains, More Services', has been formed to manage that prioritisation and bundle the Digital Systems rollout on any corridor with additional improvements and enabling activities required for higher service capacities, including traction power system upgrades.

A key challenge for introducing ETCS to a high-density brownfield operation near its capacity limits is the minimisation of service disruption combined with the transformative nature of Digital Systems. Learning from international best practice and the experiences of comparable projects, combined with effective knowledge transfer is vital for successful ETCS introduction far from Europe. Our paper will present and update the evolution of the transformative 'Digital Systems' program for the people of Sydney.

1 INTRODUCTION

Sydney is Australia's most populated city, housing over five million people. Increasing passenger demand is pressuring the existing transport infrastructure close to its capacity limits. Rail transport has become increasingly important for the 'heavy lifting' transit across Sydney in relation to other transport modes.

Transport for NSW (TfNSW) leads the development of safe, integrated and efficient transport systems for the people of NSW. This includes transport planning, strategy, policy, procurement and other non-service delivery functions across all modes of transport - roads, rail, ferries, light rail and point to point. TfNSW works hand-in-hand with its operating agencies, private operators and industry partners to deliver customer-focused services and projects.

Sydney Trains is the operator of rail services across the metropolitan Sydney area, bounded by Berowra, Emu Plains, Macarthur and Waterfall. It is also responsible for the maintenance of assets including tracks, trains, signals, overhead wiring, stations and facilities. Sydney Trains also maintains trains and a large proportion of the infrastructure used by NSW TrainLink.

NSW TrainLink provides services between Sydney and regions outside the metropolitan area including the Hunter, Central Coast, Blue Mountains, Southern Highlands and Illawarra and South Coast regions. NSW TrainLink brings together these services into an independent business focused on the specific needs of intercity and regional customers.

Significant investment has been made to introduce a new Sydney Metro system, featuring a dedicated rail network with CBTC driverless train operation, which commenced revenue operation in May 2019. While this novel service with its brand new stations and trains is an Australian first, the lion's share of rail transportation in Sydney is still carried by the existing metropolitan network operated and maintained by Sydney Trains. The busiest lines are expected to only get busier , presenting a compelling case for capacity upgrade driven by the economic and societal benefits of maintaining an effective rail network for the state.

Despite investment to maximise capacity of existing conventional signalling systems, they remain a constraint for further increase of train service frequency and capacity. Reliable operation of more than 18 trains per hour in Sydney, with the existing double-decked passenger rolling stock fleet, requires a transformational change in signalling technology. The European Train Control System (ETCS) has been selected as the preferred technology deployment for the Sydney suburban network.

2 INTRODUCING ETCSL2, ATO & TMS TO AN EXISTING RAIL NETWORK

2.1 Existing Signalling Technology Environment

The Sydney Trains network currently operates a conventional signalling system based on lineside signals, train detection, train safety information, and block interlocking. Existing trackside equipment comprises signals and trainstops to control train movements, track circuits to detect train locations (which also require insulated joints and impedance bonds), as well as point machines and associated assets such as cabling and location cases. Conventional signalling systems are costly to install and a constraint to capacity when compared with more modern technologies. In addition, the amount of equipment (there are over 6000 track circuits and 3000 signals on the network) makes the system unreliable and failure-prone.

TfNSW has recently commissioned a new Digital Train Radio System (DTRS), which implements GSM-R (Global System for Mobile communications – Railways) on all (non-Metro) rolling stock operating on the electrified rail network, along with the corresponding digital network infrastructure. The DTRS system was implemented in response to the 2003 Waterfall recommendations (Office of the National Rail Safety Regulator 2018) and ensures that train drivers, train controllers, signallers and train guards on the electrified rail network are able to communicate with each other using the same system with the same technology. However, the network has also been designed to support future mobile data communications and be reconfigurable to support the General Packet Radio Service (GPRS) protocol, while still maintaining support for voice communications. This capability within the DTRS network currently forms the basis of plans to support the introduction of ETCS L2.

TfNSW is also currently in the process of deploying an Automatic Train Protection (ATP) project across all of the Sydney electrified rail network in response to the Waterfall recommendations. The ATP project presents a clear migration pathway to the introduction of ETCS L2, because it uses the same underpinning technology base, being built around a limited supervision variant of ETCS Level 1. The ATP system communicates trackside data such as permitted line speed, signal aspect and approaching line speed. When travelling over a balise, the antenna on the underside of the train picks up these messages and uses them to update the on-board computer. The ATP project will install the on-board equipment required for ETCS L2 with only a small upgrade required, including support for the transition to Automatic Train Operation (ATO).

2.2 Preferred Technology Choice for Sydney

The selection of the most suitable signalling technology for the specific requirements of the Sydney suburban network included the following overarching requirements for the system:

- Provision of the identified target capacity of 24 trains per hour (requiring a design capacity of up to 30 trains per hour for short-term recovery from operational delays)
- Suitability for the wide range of different train types frequently operating on parts of the Sydney network, specifically including freight trains
- Ability to migrate from the existing signalling and telecommunications infrastructure
- Suitability for gradual implementation and ongoing improvements of the rail network layout.

These primary capacity requirements reduce the range of options to two international mainstream technologies:

1. Communications-Based Train Control (CBTC), which was the preferred signalling technology for Sydney Metro
2. ETCS Level 2 with specific enhancements for high capacity provision, sometimes referred to as ETCS Level 2+.

In Sydney's case, there were compelling reasons to select ETCS Level 2 over CBTC:

- ETCS Level 2 is compatible with recent investments in Sydney, namely ATP being rolled out in ETCS Level 1 technology and DTRS in ETCS-compatible GSM-R technology.

- The frequent mixed traffic between suburban, intercity and freight services in Sydney is better accommodated by ETCS than by CBTC which is optimised for consistent fleets of metro-style multiple units.
- ETCS was benchmarked as less expensive than CBTC, which is reinforced in Sydney by ETCS Level 2 re-using existing GSM-R radio with some upgrade – CBTC requires a dedicated new radio network.
- The size of the Sydney network justifies more than one supplier. However, due to the established operation of trains between lines, a solution that is interoperable between suppliers is required. ETCS was designed to provide such interoperability, while today's CBTC products are proprietary and hence incompatible with other suppliers' products.
- ETCS is more suitable to a staged rollout with gradual performance update than CBTC and is more forgiving to ongoing changes to track layouts that are anticipated in Sydney.

The key requirements for ETCS Level 2 application in Sydney, particularly regarding the specified capacity provision, warranted a solution which is at the leading edge of contemporary ETCS development. Since there is no precedence in Australia, the extensive monitoring of developments abroad, especially in Europe, has been of great importance. The Digital Systems Program is engaging internationally experienced specialists to be part of the client team in either a delivery or an advisory capacity. Timely updates on early implementations of the solution proposed for Digital Systems is a key benefit of that international benchmarking.

A significant reference project is the Digital Railway initiative in Great Britain and the implementation for the Thameslink project in London. This project features ETCS Level 2 with added ATO to provide operational capacity for 24 trains per hour in a densely trafficked city environment comparable to Sydney. Thameslink ETCS area is split into two sections. The Core (main route) was commissioned in December 2017. The latter section to London Bridge was commissioned (for ATO) in May 2018.

It is reassuring that Thameslink is not the only project where enhanced ETCS Level 2+ emerges. Backed up by European development initiatives, several countries are collaborating on applications of ETCS for higher capacity in dense traffic. In Australia, the Cross River Rail project in Brisbane has specified ETCS Level 2 with ATO, making this solution an alternative technology trend for signalling in Australian cities besides the CBTC applications chosen for Sydney Metro and the suburban networks in Melbourne and Perth.

2.3 Cab Signalling with ETCS Level 2

The economic analysis for ETCS in Great Britain was a signpost for operators worldwide. It confirmed that investment in network-wide rollout of ETCS (or any other ATP solution) cannot be economically justified on safety benefits alone, especially if the network already has a legacy ATP solution installed which makes the safety benefits from the new system even less compelling. Conversely, the Denmark Signalling program was justified based on the need to replace a substantial proportion of assets across the network, with a move to ETCS level 2 providing a more cost effective and higher performance alternative than replacing assets using conventional signalling.

The main drivers for the business case in Sydney are capacity increase, especially in comparison with the alternative building of new railway lines, and asset rationalisation with associated maintenance gains, particularly through the removal of lineside signals (Digital Systems Program Final Business Case 2018).

ETCS Level 2 is a continuous ATP system where trains receive updates of their movement authorities at all times. The train driver can see the movement authority for their train on a display on the driver's desk, no longer requiring signals at the side of the track. This enables asset management savings from the removal of signals and can also lead to some capacity and speed benefits as the practical constraints with drivers seeing and responding to optical signals are no longer present, and, the safety controls of ATP permit trains to operate without the extensive margins allowed for manual driving without such protection.

The removal, or reduction as far as practicable, of trackside signals is but one of the simplifications to existing signalling infrastructure. The legacy signalling system in Sydney, together with the currently implemented ATP system in ETCS Level 1 technology, requires various trackside signalling components which would no longer be needed under ETCS Level 2 cab signalling. For example, further infrastructure simplifications include:

- Signals are replaced by cab displays on the train driver's desk
- The ATP provision of ETCS allows for the removal of the legacy train stops
- Track circuits and associated impedance bonds can be replaced by axle counters at optimised locations
- In areas where all trains operate under ETCS Level 2, most of the trackside equipment needed for the current ATP becomes redundant, such as Lineside Electronic Units and active balises connected to them.

2.4 Automatic Train Operation (ATO)

Previous studies undertaken in Sydney concluded that cab signalling with ETCS Level 2 can improve train operations in Sydney for reliable capacity of up to 20 trains per hour. This may be enough for most parts of the Sydney network, particularly in the early years of rolling out Digital Systems, but the longer term capacity demand identified for the busiest corridors of the Sydney network is 24 trains per hour, requiring another 20 per cent increase from what is achievable with standard ETCS Level 2.

Modelling in Sydney has shown that the headway benefits of ETCS Level 2 begin to plateau when operating more than 20 trains per hour because variability in driver behaviour becomes the main operational constraint. Therefore, the key justification for the addition of ATO to ETCS in Sydney is to support higher train frequencies (i.e. 24 trains per hour). The benefits of ATO have been demonstrated by the Thameslink project in London and other Digital Systems Program reference projects.

Another benefit of ATO is the possible decrease in journey time as the system is able to drive the train closer to its brake intervention curve than possible with manual train driving.

It is expected that the addition of ATO to ETCS Level 2 can provide reliable operational capacity of 24 trains per hour. This would include a capacity margin of 20 per cent for timetable recovery after service disruptions, where trains could follow each other at headways of as low as two minutes for short periods, being equivalent to a design capacity of 30 trains per hour.

There are four different levels of ATO known as Grades of Automation (GoA) defined in IEC 62290. ETCS Level 1 is currently being deployed and reflects GoA1, meaning the train driver still controls the trains in response to lineside signals. Moving one grade higher to GoA2 provides ATO but retains a driver to supervise the corridor, manage station departures, and manage degraded options.

Figure 1 provides an overview of the various levels of GoA, and the preferred solution for the Sydney suburban network based around ETCS L2 in combination with ATO at GoA2.

Figure 1 ATO Grades of Automation (IEC 62290)

Grade of Automation	Sets train in motion	Stopping train	Door closure	Operation in event of disruption	Type of train operation	**ETCS fitted**	**ATMS inter-operability**	**Portable units**
GoA0 MANUAL	Driver	Driver	Driver	Driver	Manual operation no ATP	—	—	✔
GoA1 PROTECTED	Driver	Driver	Driver	Driver	ETCS L2 with driver	✔	✔	✘
GoA2 AUTOMATIC	Automatic	Automatic	Driver	Driver	ETCS L2 & ATO with driver	✔	✘	✘
GoA3 DRIVERLESS	Automatic	Automatic	Train attendant	Train attendant	Driverless	Potential future states		
GoA4 UNATTENDED	Automatic	Automatic	Automatic	Automatic	Unattended train operation	Potential future states		

LEGEND:
- — Not permitted
- ✔ Delivered by Digital Systems Program
- ✘ Not available for this traffic type

The use of ETCS Level 2 with ATO (GoA2) enables the Sydney network to achieve the capacity benefits associated with greater levels of automation, without incurring the increased cost and disruption to the network that the deployment of a higher grade of automation would necessitate, such as safe corridor segregation and a more refined platform<->train interface (typically incorporating platform-edge doors). GoA2 also avoids the practical implications directly related to having driverless trains (i.e. passenger trains) as well as driver-operated locomotives (i.e. freight and interstate trains) using the same corridors.

2.5 Traffic Management System

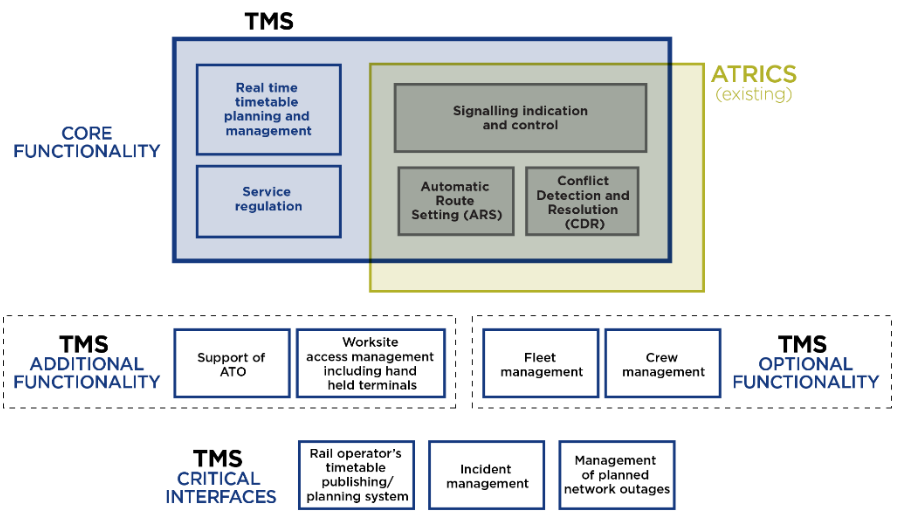
Sydney Trains has recently implemented a project to combine centralised signalling control with its rail traffic management centre in a new purpose-built Rail Operations Centre (ROC). The scope of the ROC includes systems that minimise delays and ensure customers receive better and faster information when incidents occur on the Sydney Trains rail network. The ROC modernises how Sydney's rail network is controlled by consolidating dozens of different systems into a single location and changing the approach to managing trains.

The introduction of the ROC provides the perfect platform for the introduction of a Digital Systems Traffic Management System (TMS), which would provide the following key functionality:

- Operation of signal controls to execute the train timetable, including commanding the signalling infrastructure, resolving train conflicts and setting routes;
- Dynamic planning and re-planning of timetables in response to 'day-of-operation' incidents and other types of delays, reducing secondary delays and allowing faster service restoration; and
- Optimisation of ATO train movements to achieve arrival/departure times accurately (providing greater consistency in overall train performance and on-time-running), while capturing energy efficiencies as a secondary benefit.

Currently Sydney Trains has its own in-house Train Control System, (Advanced Train Running Information and Control System, or ATRICS), deployed across the network. Figure 2 provides an overview of the TMS functions that are also provided by ATRICS (in green), and the functions (in blue) that are specific to the implementation of a TMS.

Figure 2 Overview of Digital Systems TMS functions



Inclusion of a TMS as part of the Digital Systems solution aims to replicate the benefits of CBTC-ATS for an ETCS-base systems solution. In CBTC, the Automatic Train Supervision (ATS) is an integrated part of the overall solution.

The ATS ability to regulate the movements of multiple ATO operated trains is one of the key benefits for avoiding conflicts of train movements and hence improving train service reliability.

While a TMS implementation is pivotal to the introduction of ATO, the key functions of 'conflict resolution' and 'dynamic timetable management' are also critical to unlocking additional network capacity and more dynamically managing and regulating the network in the event of any incidents. In the UK, the Network Rail Digital Railway program has recently estimated that the introduction of a TMS could "cut reactionary delays by 15%". (Network Rail Digital Rail Strategy 2018)

2.6 Data Communications

The Digital Systems Program solution will also require some upgrade of the existing DTRS. The DTRS was specified from the outset to be able to support ETCS Level 2. However, detailed studies for coverage and Quality of Service (QoS) will be necessary together with the selected suppliers for the ETCS trackside subsystem to determine which levels of infill or other improvements to the DTRS will be required to accommodate the application of Digital Systems on a specific corridor.

One improvement to the DTRS has already been identified to overcome the capacity limitations of the GSM-R technology used for the DTRS. GSM-R is a circuit-switched radio solution which uses dedicated channels for both directions of the ETCS communication with every train in the radio cell. If the number of ETCS controlled trains in one radio cell is higher than the available number of channels, some trains would no longer be able to communicate with the Radio Block Centre (RBC) of ETCS, resulting in service disruptions from those non-communicating trains being stopped.

The solution which was ratified in the latest release of the ETCS standards is to overlay GSM-R with the General Packet Switched Services (GPRS), transforming the circuit-switched GSM-R communication to a packet-based communication. This allows much more efficient use of the available radio bandwidth and enables nearly ten times the number of trains per radio cell under GPRS, compared to pure GSM-R.

Some upgrades are also expected to be required for the existing Fixed Telecommunications Network (FTN) in Sydney. Some of those upgrades will be related to DTRS changes, and some others may be necessary to accommodate communication between interlockings and trackside controllers for signalling equipment.

2.7 Accommodating Various Train Types

A specific challenge in Sydney is that the network functions as both a main line railway and as an urban network. This means that there are a wide range of different train types, mainly freight trains, which frequently operate on parts of the network. The aspiration of removing lineside signals when introducing Digital Systems requires some form of cab signalling solution for every vehicle operating on a line where Digital Systems has been implemented. For the electrical fleet operated by Sydney Trains (and other trains that only operate on the Sydney network), the obvious solution is the fitment of all trains operating on a Digital Systems corridor with ETCS Level 2 onboard equipment, with or without ATO. For trains which are not necessarily contained to the Sydney network, the Digital Systems Program proposes two additional solutions.

Trains which operate mainly on the Australian Rail Track Corporation (ARTC) interstate network, including the diesel train fleet operated by NSW TrainLink, are all expected to be fitted with ARTC's newly developed Advanced Train Management System (ATMS). For those trains, the Digital Systems Program is working with ARTC to develop an interoperability solution. One concept for this would be for the Digital Systems solution to communicate routes for ATMS trains to the ATMS Authority Management Server, which would then generate and transmit movement authorities to the train and return confirmation to Digital Systems. Such an interoperability solution could become the blueprint for the handling of ATMS-fitted trains entering urban networks with reduced or no lineside signals in other Australian cities. It should be noted that such a solution would also increase the safety of freight train operations in city areas due to the inherent addition of ATP. This safety enhancement is not available if optical signals are retained for the operation of freight trains.

A different but equally challenging solution is needed for occasional network users, for example maintenance vehicles or heritage trains. Maintenance vehicles solely operating on the Sydney network will be considered for fitment with ETCS. However, heritage vehicles such as steam locomotives operate too infrequently to justify full fitment of ETCS, nor would that be possible in some cases due to practical constraints. For these cases, the Digital Systems solution envisages a portable device which can at least transmit the train's movement authority into the driver's cab. This solution would not provide ATP, but those trains have never operated with such protection anyway. To compensate, some operational restrictions are likely on the use of the portable solution, meaning that it will likely only be a viable option for occasional users in off-peak times.

The utilisation of a portable device will also improve the safety of maintenance staff in the field who will be equipped with handheld devices that communicate with the RBC of ETCS to reserve sections of track just like a train does.

2.8 Business transformation – bringing the Operator/Maintainer on the journey

The careful and effective development and implementation of the new systems is crucial, as it will drive the management of risks, costs, and ultimately the realisation of customer and operational benefits. Implementation will result in significant changes to how the network is planned and operated in the areas directly affected, but also more broadly to the wider TfNSW organisation. The changes related to deployment can be classified in three broad categories that interface with each other: Technical integration, Business change, and Transformational change.

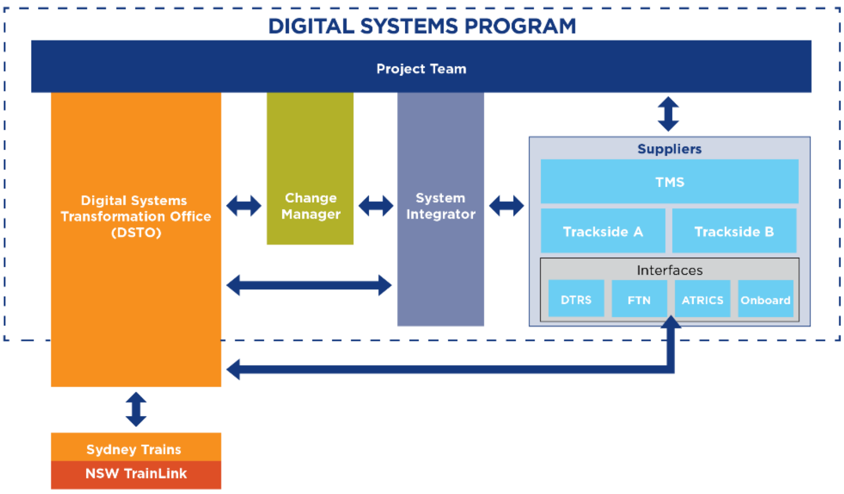
- Technical integration: changes arising from the phasing out of conventional signalling and train control technologies as the new systems are rolled out.
- Business change: changes required to current methods of operation due to the implementation of ETCS L2, TMS and ATO, such as to existing Network Rules.
- Transformational change: opportunities that are created by the deployment of the new systems that are not essential to the system introduction, but would enable Sydney Trains, NSW TrainLink and TfNSW to leverage the full benefits available.

Responsibilities to manage the change will be shared between TfNSW, Sydney Trains and NSW TrainLink. Implementation of the new systems will require changes within the current operating agencies, as well as new operational standards and amendments to existing ones. The development of rules will be undertaken in a collaborative way with the operating agencies and the regulator, to deliver a broader set of opportunities to transform the way the operating agencies work and deliver services.

The management of technical integration changes will be led by TfNSW, with support from Sydney Trains and NSW Trains as required, whereas the management of business change will be a shared responsibility between TfNSW and Sydney Trains/NSW TrainLink.

Sydney Trains and NSW TrainLink will be responsible for leading the management of their own transformational change with TfNSW supporting as required. Figure 3 shows the proposed responsibilities to manage these changes, as well as other key Program relationships.

Figure 3 Digital Systems Program responsibilities and relationships



For the change management associated with the introduction of ETCS L2 in Sydney, the key underpinning principle is that there is shared ownership to facilitate effective collaboration between any project team associated with the implementation of ETCS L2 and the impacted business units.

This collaboration process will directly involve impacted staff in system design and implementation planning wherever possible, as this will not only lead to an improved solution but also to an increase in the levels of internal change advocacy. Given that a diverse and predominantly operational workforce will be involved, the change program has also been designed to allow staff to 'experience' ETCS L2 in the lead up to implementation (rather than simply focus on words).

To deliver this 'experience' of ETCS L2 and achieve optimum success, the change effort will target interventions at the best leverage point in its wide sphere of influence: from simulator training to peer-to-peer mentorship; from process re-design to new recognition metrics; and from experiential prototypes to best-practice communication campaigns.

A collaborative approach will be used to achieve this culture change, and an embedded change model is planned whereby change managers work within the key business areas alongside the management team and SMEs to undertake the necessary analysis and business readiness activities that will be required leading up to implementation.

Whilst the direct changes that arise from the implementation of the new systems will be managed as part of the project scope, the technology will deliver a broader set of opportunities to transform the way the operating agencies work and deliver services. It will be up to the operating agencies and the wider Transport cluster to seize these opportunities.

In addition, given the breadth of impact across the Transport for NSW cluster of agencies, the Digital Systems Program plans to hook into existing staff networks, leverage the trusted relationships already in place and tap into existing social structures, with the project related messaging focusing on the benefits of the Program in shaping the future of the railway.

From an asset management perspective, there are opportunities to develop and implement improved predictive tools for network planning and maintenance in order to increase availability of the network for operation and to meet customer needs. An opportunity also exists to re-visit asset management strategies more generally.

More fundamentally, modern technologies such as ETCS L2 present further opportunities to investigate alternative lifecycle management approaches, such as the provision of systems as a 'service' rather than an 'asset', which may prove more cost-effective in the long-term.

2.9 Summary of Program benefits

Increasing the capacity of the Sydney rail network is an important benefit of Digital Systems but only in as much as the Program's implementation also enhances the network's safety, resilience and ability to recover from incidents. These enhancements must be delivered sustainably with consideration to whole of life systems thinking and asset management, and deployment without network disruption.

The Digital Systems Program will address challenges facing the Sydney rail network by:

- supporting more reliable capacity by removing signalling technology constraints and optimising train running to decongest Sydney's train network
- enabling future capacity to meet forecast growth by implementing Automatic Train Operation to help drivers, who will still remain in control
- operating more resilient and reliable train services enabled by dynamic systems and reduced trackside infrastructure
- enabling more efficient network operations from lower asset replacement and lifecycle costs, improved safety for trackside maintenance, as well as fewer network disruptions.

The Program's key benefits can be summarised as follows:

- higher capacity for current and future demand
- better customer information
- more reliable services
- reduced journey times
- safer and more efficient operation and maintenance
- lower capital (capex) and operating (opex) costs
- lower energy consumption.

3 REFERENCE PROJECTS, LESSONS LEARNED AND PROGRAM PRINCIPLES

3.1 Identifying key reference projects

Understanding potential delivery innovations and pitfalls from similar complex, transformational brownfield projects has been and will continue to be valuable in shaping the future success of the Digital Systems Program. The Program has therefore considered and incorporated lessons learned from many comparable international and Australian reference projects. This paper has already referred to the Program's learnings from significant reference projects such as Digital Railway UK, Thameslink, Brisbane Cross River Rail, and ETCS National Rollout Denmark. Other Digital Systems reference projects include but are not limited to:

- Melbourne Metro Tunnel Project
- Perth Automatic Train Control
- Brisbane ETCS Level 2 Inner City
- London Crossrail
- ETCS National Rollout Sweden
- ETCS National Rollout Norway
- Madrid Cercanias
- ETCS National Rollout Netherlands
- Smartrail 4.0 Switzerland.

3.2 Managing Lessons Learned

In addition to observations from reference projects, lessons learned are derived from a variety of other sources including studies and white papers from industry bodies and specialist consulting firms, conference presentations, industry journal and magazine articles, post-mortem project analyses, notes and reports from interviews, meetings and audits, and lessons learned workshops.

An International Independent Peer Review Group (I^{2}PRG) has been established to support the Digital Systems Program. The I2PRG provides expert advice on current technology developments and ensures best practice from local and overseas projects is available to the Digital Systems project team and applied to the Program. The I^{2}PRG continuously updates and prioritises items in the Reference Projects and Lessons Learned registers, ensuring they are up to date and remain reflective of world's best practice.

In addition to updating these registers, the primary objectives of the I^{2}PRG are to provide the Senior Leadership Team and Executive with independent assessments to support informed decision-making, and identify potential issues and risks for delivering the Digital Systems Program.

The Digital Systems lessons learned process is documented through two main registers:

- The Reference Projects Register lists the technical pitfalls and successful outcomes of each transformational project, synthesised and grouped by key topics and themes.
- The Lessons Learned Register lists the relevant lessons learned from selected projects and links those lessons to the work breakdown structure of the Digital Systems Program, showing clear accountability for implementing the respective learnings.

3.3 DIGITAL SYSTEMS PROGRAM PRINCIPLES

Digital Systems has distilled the top lessons learned into seven key Program Principles with associated definitions. This ensures that the knowledge and experience gained from comparable local and international projects consistently informs the Program so that it is delivered in the best way possible. These principles guide delivery, decision-making and behaviour, and help ensure collaboration with internal stakeholders and industry.

3.3.1 A Learning and Growth Culture

"We're focused on creating a learning and growth culture, implementing global lessons learned to continually improve the Program and develop a sustainable workforce. We don't just 'set and forget'. Rather, we 'set and refresh'. We continuously update our Lessons Learned register to inform our Program while we live and breathe our principles."

It is important to look for lessons learned from a variety of worldwide sources and projects at the beginning of a new project, such as the business case phase, but in a lengthy program it is also absolutely critical that these lessons are kept up-to-date, refreshed, and actively managed throughout the delivery of the project.

The use of a formal register with detailed references to published reports and documents helps to provide a formal, evidence-based process to support decision-making within the project, avoiding the risks associated with unreliable anecdotal evidence or hearsay.

The Digital Systems Program's commitment to learning and growth, includes ensuring that knowledge, experience and lessons learned are transferred into the organisation in support of future deployment and projects, as well as in developing a sustainable and capable workforce for the delivery of projects, and the operation and maintenance of the outcomes delivered by those projects.

3.3.2 Early Wins for Customers

"Digital Systems provides a step-change in improvement of system reliability, availability and maintainability, and a pathway to further improvement. Realising early project benefits for customers will help reinforce our stakeholders' motivation and buy-in."

Often teams focused on and invested in the delivery of a project can get fixated on delivering a perfect or best-possible outcome, and lose sight of the benefits to customers that come with a 'suitable and fit-for-purpose' outcome, that are being delayed in the meantime.

There are significant benefits to the deployment of Digital Systems, and the Program team is committed to ensuring that front-line customers experience the outcomes from these benefits as early as possible.

3.3.3 New Systems, New Ways of Working

"To fully realise the benefits of the new systems and technologies, we will develop new rules, principles, procedures and competencies. Our new ways of working will support a sustainable future for our customers."

Though Digital Systems utilises world class technology, it is very much about people and process. The Program will transform the way Sydney Trains and NSW TrainLink operate and have an impact on their operational structures and organisational strategy. It is important to understand the complexities and critical interdependencies associated with the balance of people, process and technology, as trying to incorporate the new technologies into existing ways of working has been shown repeatedly and consistently to dramatically increase the costs and risks associated with project delivery, whilst also significantly reducing the benefits delivered.

3.3.4 Whole-Of-Life Thinking

“Digital Systems will embrace ‘whole of life’ systems thinking and asset management to optimise future operations and maintenance efficiency. We will not sacrifice long-term Program benefits to achieve short-term gains.”

The Program will demonstrably consider the whole of life of the asset at all times in all design, development and implementation activities. The Program's asset management strategies take into account asset recovery, reconfiguration and decommissioning as well as the implementation of new technologies and systems. Consideration will be given to creating and maintaining the environment and capabilities to enable effective asset stewardship and benefits realisation at all times.

TfNSW has introduced a contemporary, common transport Asset Life Cycle model that identifies the life cycle stages as demand/need, plan, acquire, operate/maintain and dispose. Within each stage there is a further level of detail describing life cycle activities. Aligning Program thinking and processes against this model will promote integration and collaboration in the approach to managing TfNSW's assets. This will ensure the Program consistently adopts effective asset strategies that support the sustainable and efficient delivery of Digital Systems into the Sydney railway network.

3.3.5 Configure Not Customise

“Digital Systems will adopt standard equipment and systems, taking off-the-shelf solutions and configuring them for the Sydney network. This approach will allow us to benefit from future developments and innovation as part of global technology roadmaps.”

In order to leverage and benefit from many years of extensive development and operational experience associated with ETCS Level 2, TMS and, more recently, ATO, a critical aspect of the Digital Systems Program is to ensure that we do not introduce bespoke arrangements or customisations. With the increasing complexity of the technologies and systems, along with the interdependent people and process issues, the knock-on effects of even seemingly small customisations can be significant and cascade into multiple systems and subsystems, dramatically increasing the costs and risks associated with project delivery.

Internationally standardised technologies also allow for greater competition in future deployment and more efficient through life support. The long-term benefits from innovations and improvements in supplier systems are largely dependent on being part of an international community of clients and system operators/maintainers that have standardised system applications.

3.3.6 No Network Disruptions

“We’re determined that the implementation of Digital Systems will not disrupt services for customers. Innovative tools and methodologies will allow us to deploy and test new systems while minimising the need for network access.”

Deployment of Digital Systems technology has been planned recognising that the network has to remain operational at all times, considering mixed traffic (passenger and freight) requirements, as well as careful consideration of staff and fleet impacts and safety.

With other significant project work occurring across the rail network in the coming years, a core theme for the Digital Systems Program has been to engage with industry to discuss innovative approaches to installation and testing that do not necessitate extensive shutdowns, and wherever possible, to coordinate rail corridor works with other projects and programs.

3.3.7 An Integrated and Collaborative Approach

“International experience has consistently demonstrated the need for meaningful collaboration between clients and suppliers, moving away from adversarial client/contractor relationships. The Digital Systems Program will also integrate this collaborative approach with the operator/maintainer, ensuring engagement and meaningful consultation with frontline employees as end-users.”

Digital Systems is a complex, transformational Program with multiple interfaces between new and existing systems, requiring numerous packages of work and specialist suppliers. In addition to working closely with the Operator/Maintainer organisations through the Digital Systems Transformation Office (DSTO), the Digital Systems Program delivery model includes early industry engagement and meaningful collaboration. This is an approach that is now standard in TfNSW and across NSW government.

A more collaborative delivery model allows all parties to better understand and align on issues related to the operating environment, scope, pricing, interfaces and associated requirements, leading to reduced risks and optimised Program outcomes and customer benefits.

4 CONCLUSION

Growing public transport demand has resulted in a critical need to increase the capacity of the existing Sydney rail network. To provide this increased capacity and other benefits including enhanced network safety, reliability and recoverability, the Digital Systems Program will deliver a 'step-change' introduction of a new TMS, radio-based cab signalling and ATO to assist drivers, who will still remain in control. The Program has selected ETCS Level 2 as the preferred technology for reasons including its compatibility with recent Sydney network technology investments, its ability to meet mixed-traffic, interoperability and network size requirements, and its suitability to staged deployment.

The modern technology that the Program is delivering in Sydney is already proven in many cities around the world. The Program is engaging local and international expertise to be part of the client team in either a delivery or an advisory capacity. However, inherent challenges and corresponding risks still remain in the Program's transformational implementation into a complex brownfield environment. Understanding lessons learned from comparable transformational projects is an important component for the Program's successful implementation.

The Digital Systems Program maintains formal registers of key reference projects and lessons learned. The top lessons learned have been distilled into seven key Program Principles, which guide delivery, decision-making and behaviour, and help ensure collaboration with internal stakeholders and industry.

The ongoing lessons learned process and adhering to the Program Principles will be vital in overcoming the enormous transformational challenge that is crucial to the Digital Systems Program's success.

5 REFERENCES

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