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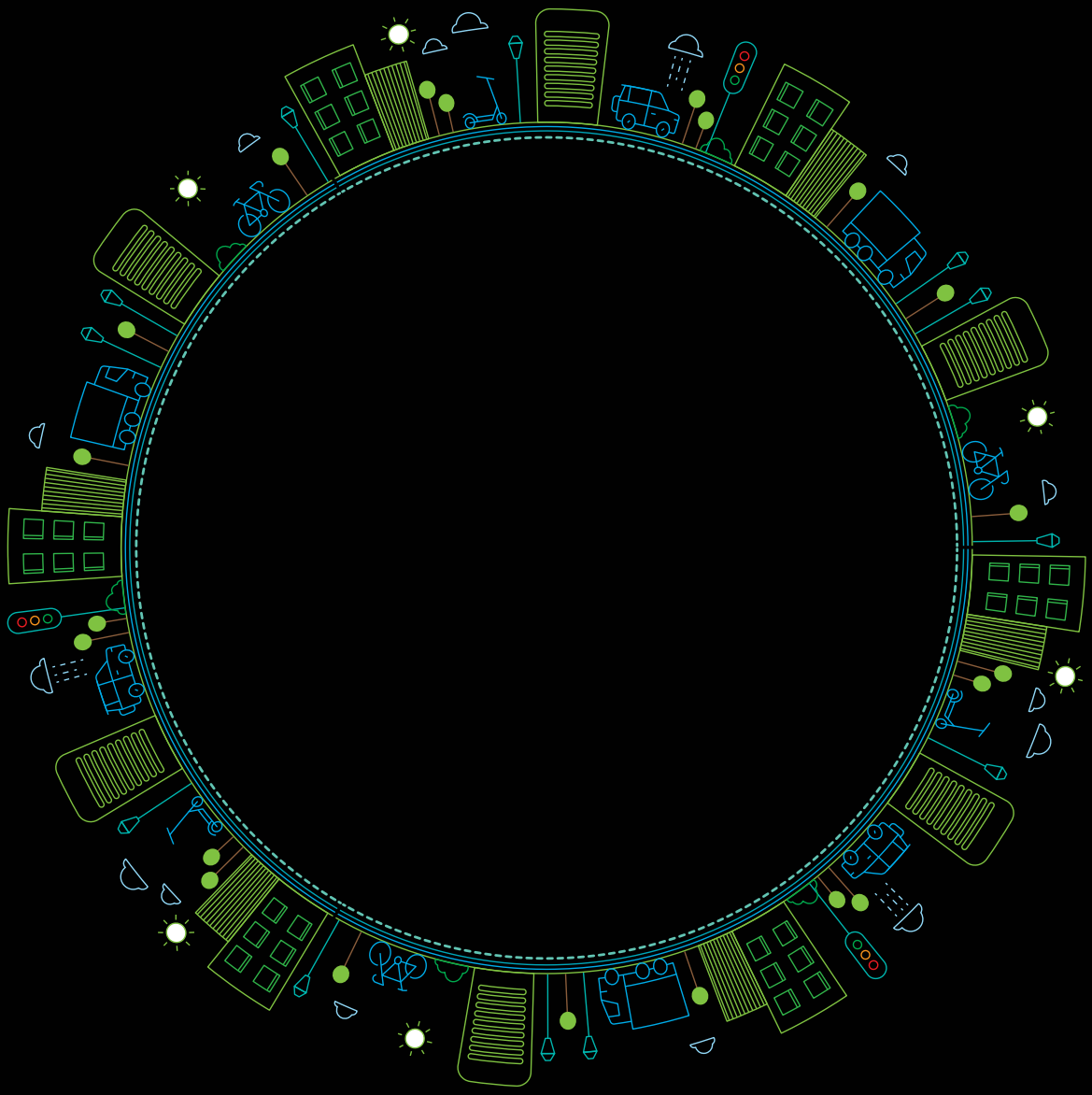

Digital transport reference model

Taking an outside-in approach that starts at the edge.

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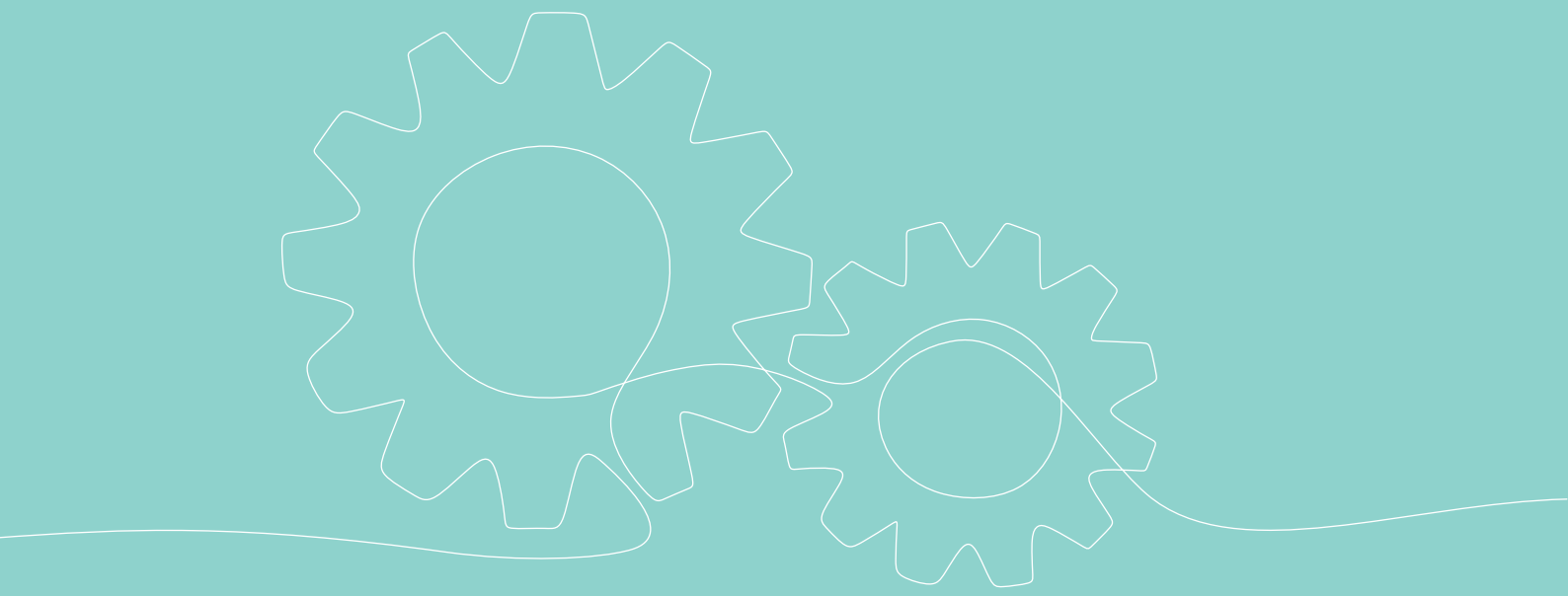


Abstract

The future of transport is many things but one thing is for sure—data will underpin everything. This paper outlines an approach and digital transport reference model for transport agencies to get started on a journey to harness the enormous value of their data.

Executive summary

To respond to increased congestion pressure, climate sustainability, and the evolving needs of our societies in a post COVID world transport agencies are making significant investments in both physical and technology infrastructure. These infrastructure investments are driving exponential growth in the amount of data that gets produced and the amount of data that is required to optimise performance and to support the needs of customers. To meet this challenge, transport agencies are focusing on transforming the core of many of their technology assets and enterprise systems which also carry high investment costs and implementation timeframes—this can be seen as an "inside-out" approach with respect to the core systems that manage processes and data in contrast with the technology in the transport network that generates and presents the data.

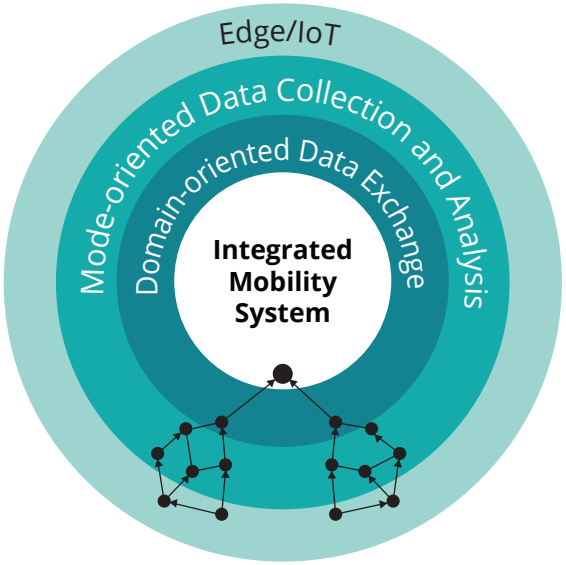
These core technology investments are in many cases necessary but will come under increased budget pressure going forward. At the same time, there are numerous opportunities to invest in technology out in the network where transport data is generated and distributed to customers—the "outside". Transport agencies have been running numerous trials which now need to be coordinated and harnessed to deliver sustainable value. These trials, ideas and opportunities require increased coordination to make the most out of the data that gets generated, unlock synergies, and to ultimately support the quality of data that is analysed and processed in the core systems.

This paper considers an "outside-in" approach to transport technology investment and coordination. It is about focusing on technology solutions across the network where transport data is originated and where data distribution occurs through to customers, the community, and transport ecosystem partners. This is not to suggest it is a replacement of more traditional investments in core technology and enterprise systems, but rather that there are opportunities for transport organisations to rapidly harness the value of their data whilst also contributing to the establishment of an enterprise-wide system-of-systems for transport data exchange that will be essential to deliver the future of mobility.

At its core, the outside-in approach is about:

- **Getting a bird's-eye view:** Creating a comprehensive view of all existing, planned, and potential "outside-in" transport network technology use cases to provide leaders with a birds-eye view of what is happening across the organisation. We have created the **digital transport reference architecture** to provide a "technology map" which will support plotting out what is happening across the organisation.
- **Defining a roadmap by linking use case chains:** With a comprehensive view and inventory of use cases and opportunities, the next step is to identify where there are opportunities to leverage data created by one solution or use case that can flow into another—building use case chains. For example, installing sensors on buses to support vehicle tracking and operational performance could deliver more value by installing multi-function devices which could not only track movement but also detect vibrations and as a result road condition to support asset management and reduce the need for costly road condition surveys. Beyond this, how could we leverage this data to support congestion information or enable more seamless customer journeys?

Use case chains



- **Establish, Enable, Extend:** To adopt the "outside-in" approach transport organisations should consider creating a matrix organisation that is initially formed across existing departments and organisational units but then expands to take on more formal roles, accountability and delivery ownership. We have outlined a three phase approach that can be used as a rough guide for the level of organisational commitment, investment, and governance required as the capability matures.

Transport organisations that adopt this approach should think of it as a journey. It is an iterative approach that is dependent not only on the right technology decisions but on the right people and leadership to drive its growth. The "outside-in" approach can only succeed if transport organisations are able to work outside of traditional departmental structures and build connections between people, functions, and problem areas. This is often challenging in large, complex organisations. It raises considerations around how to break down traditional barriers between IT and operational technology as well as customer service, operations, and asset maintenance. This has traditionally been a challenge for transport organisations which are by their very nature large, complex, and oriented around departments or business functions.

There is no simple solution to the organisational and technical challenges presented but the position of this paper is that the starting point is to get a common view across the enterprise of outside-in opportunities through development of the *digital transport reference model*. With a common view in place, to progress to creating use case chains that at a macro level are additive and contribute to a gradual uplift in our ability to access, leverage, and utilise the masses of data that are generated across operations and infrastructure investments. As the future of mobility becomes increasingly data rich and technology enabled this will be a critical piece to get right so that transport can meet the challenges of a more congested and mobile world whilst also driving opportunities to create a more environmentally sustainable and energy efficient transport network.

Introduction

In today's hyper-connected world, there is a need to integrate and optimise the passenger experience across transport modes –rail, road, or waterways. There is increased pressure for city leaders to better integrate existing disparate data sources across all modes of transport to drive a seamless customer experience. This white paper explores the challenges associated with harnessing data across the transport network and proposes an approach and reference architecture for building the underlying data ecosystem for transport.

Recent global trends in rising urbanisation, growth of the sharing economy and post-COVID impacts all highlight the urgency to deliver a more integrated, dynamic, tech-enabled future for transport. The need for seamless integrated mobility is apparent but there are some significant transport sector drivers that must be addressed:

- The proliferation of mobility operators and modes requiring connection. Ridesharing, on-demand travel and micro-mobility services, among others, have all emerged as a result of rising urbanisation and increasing demand for flexible and integrated mobility.
- The demand for more integrated journeys and mobility-as-a-service ecosystem is growing. The global MaaS market is expected to reach market capitalisation of ~US$9.5 trillion by 2030.[1]
- Policies need to evolve to support mobility transformation. Governments need to rapidly adapt policy to support, manage and enable mobility-related disruption.
- Constrained budgets mean governments need to do more with less. Given budget limitations, cities need to adopt innovative ways to increase the capacity of existing physical infrastructure, most of which are major legacy assets.

$16.5 billion

is the cost of congestion in Australia and without major policy changes, costs are predicted to reach up to $37.3 billion by 2030.[2]

To address these challenges, transport agencies need information. They need information to make operational decisions that aim to minimise the impact of incidents. They need information to help coordinate movement across modes and the broader network. They need information to better plan and manage critical infrastructure across its lifecycle. And above all, customers need information to simplify and streamline their journeys so they can rely on the transport network to get them where they need to go, on time, in comfort, and with minimal hassles.

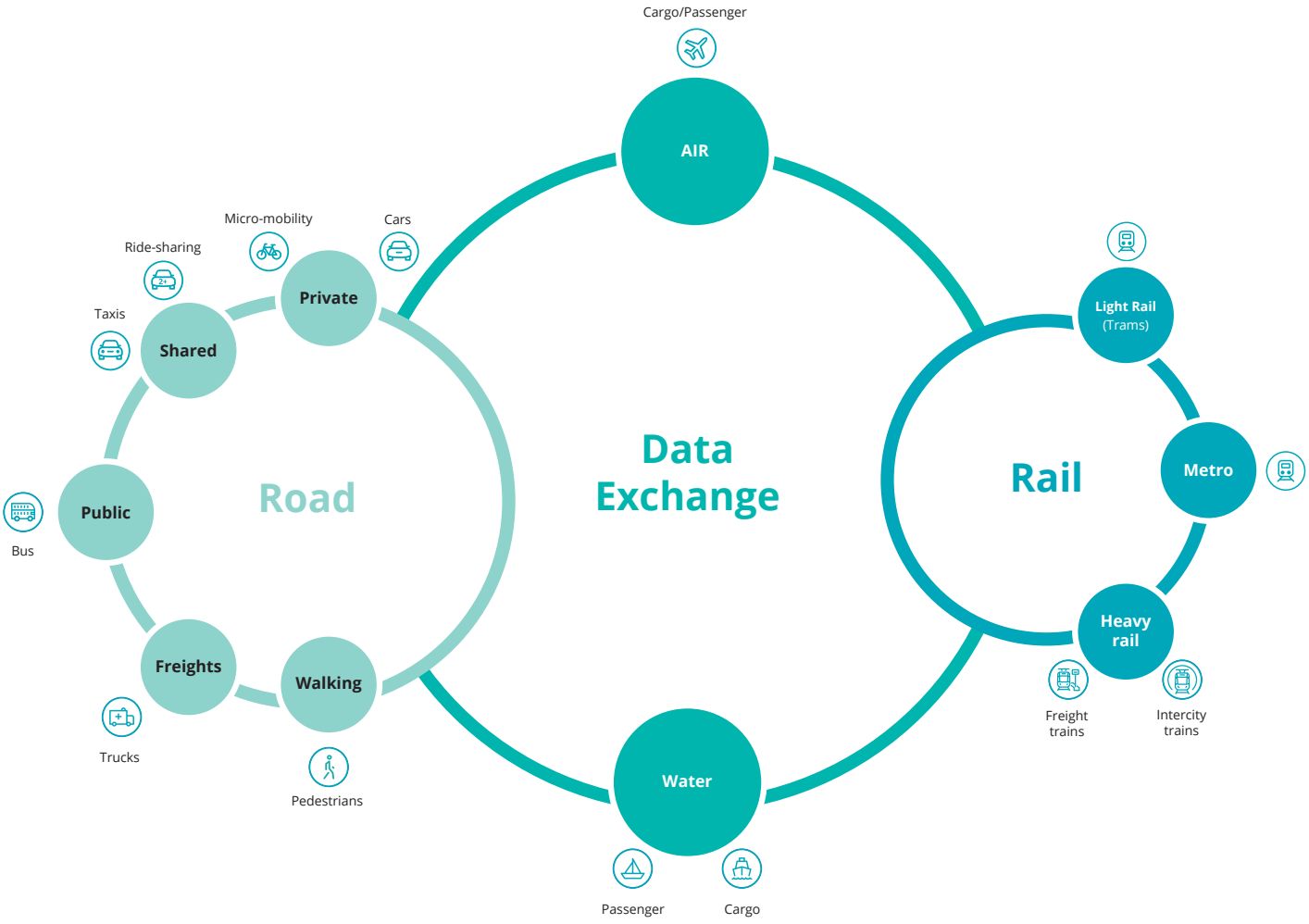
The data journey

Transport agencies around the world have recognised the opportunities and the challenges of harnessing the data produced across their operations to better manage the transport system to deliver seamless, reliable customer journeys. New technology offers the promise of a more data-rich and connected transport system.

For rail, the proliferation of sensor data built into new rolling stock fleets across the nation is enormous. Rail infrastructure investments, including deployment of remote condition monitoring and ETCS Level 2 into critical rail lines, are creating rich new data sets of operational information. The challenge is not a lack of data but rather how to consume, analyse, and drive insights from it.

Roads are being transformed through investment in smart motorway technology including video analytics and wireless sensors. Traffic signalling systems will see significant change as investments in adaptive traffic control systems to improve options for data collection and network management will offer enhanced intelligence at intersections across our nation. Buses, cars, and freight vehicles are increasingly being deployed with technology that connects to the transport network and roadside infrastructure.

Ecosystem of mobility | The universe of public transport



At the same time, integrated mode operations are also a focus of transport agencies. With continued trends to outsource mode-specific operations and increased recognition of the need to solve the "customer journey problem", transport agencies are investing in technology that brings together modal operations and aims to rapidly respond, predict, and optimise the network's ability to manage planned and unplanned disruptions.

Transport agencies are also seeking to shift their focus from managing the "supply" of the transport systems in terms of road capacity, routing, and more public transport services to managing demand for services by developing tailored information channels and travel incentives to influence customer behaviour around how and when they use the transport network.

In parallel, changes in how we use transport as a society and new transport options including micromobility, autonomous, shared, and electric vehicles are driving changes in the regulatory space which is increasingly becoming dependent on data to support its evolution in keeping pace with industry changes.

All these changes will require transport agencies to better understand the data that is produced across their networks. This is well known and recognised across the industry. There is an emerging need to drive the development of a "system-of-systems" that is able to bring together the data from across the operational network and ensure that it is accessible, can be interpreted, and accessed and used by enterprise systems and ecosystem partners to drive integrated decision making across modes, services, and operations. This vision for a "system-of-systems" for transport data can be seen as a "mobility operating system".

To varying degrees, transport organisations have been working towards this vision, but the results have been somewhat more elusive. There is clearly a technical challenge to deliver connected and integrated data across the network but in many cases, it starts with a broader investment and funding challenge. While we are in the midst of a generational period of investment in transport infrastructure it is difficult to put forward the case for investment in something that doesn't deliver an immediate and tangible result. At the same time, with transport decision making centred on specific jurisdictions or modes, it is often hard to find a natural owner at an executive level who is able to sponsor investment in a platform that sits across the enterprise.

Transport agencies have also focused on initiatives to build common data exchanges, but many are still at the strategy phase or focused internally rather than with external parties in the ecosystem, which is where the value lies. In the absence of any real success stories for a transport data exchange the data keeps on growing. There are plenty of specific challenges and opportunities that are being solved with technology solutions. Vehicles are increasingly being tracked, traffic signals are getting enhanced information feeds, rail networks are being digitised, and sensors are getting built into roadside infrastructure. Unfortunately, many of these solutions are built in isolation. They solve each specific use case, but are often built on closed system architecture and lack the vision and architectural considerations for how each individual use case, and the data it produces, contributes to a bigger picture across infrastructure, operations, and customer data. With each new transport solution, the challenge of harnessing all the data is becoming more difficult.

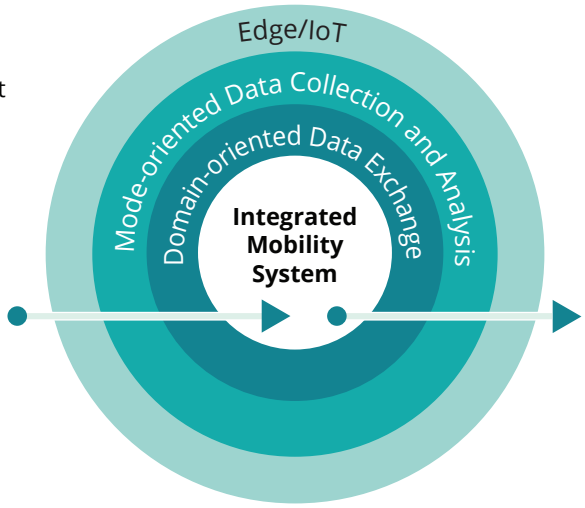
Outside-in vs inside-out

To address this challenge, we believe that transport agencies should articulate a digital transport reference architecture that provides a common vision for how the millions of data end-points across infrastructure, customers, and operations can be structured to contribute to the development of a system-of-systems for transport data, or a mobility operating system. With this in mind, transport agencies should focus their efforts on generating quality information at the edge. We see this as an "outside-in" approach which is about focusing on getting the best data first, and incrementally driving towards integrating the data sources and structures through a transport data exchange. Solving relevant, right now problems with an aim to architecting them as building blocks for a long-term vision is an effective way of delivering a future transport solution that is both commercially viable and fit-for-purpose.

This contrasts with the more traditional "inside-out" approach which focuses on building a centralised data platform first and gradually hooking in information sources from across transport customers, operations, and infrastructure. The inside-out approach has been the natural focus for transport agencies, but it has been an elusive target.

Outside-In

- Solve relevant, right now problems that are able to attract funding
- Focus on data generation and data quality
- Point solutions that are architected with a bigger vision in mind
- Build critical mass of data
- Focus on platforms, component architecture – avoid vertically integrated solutions



Inside-Out

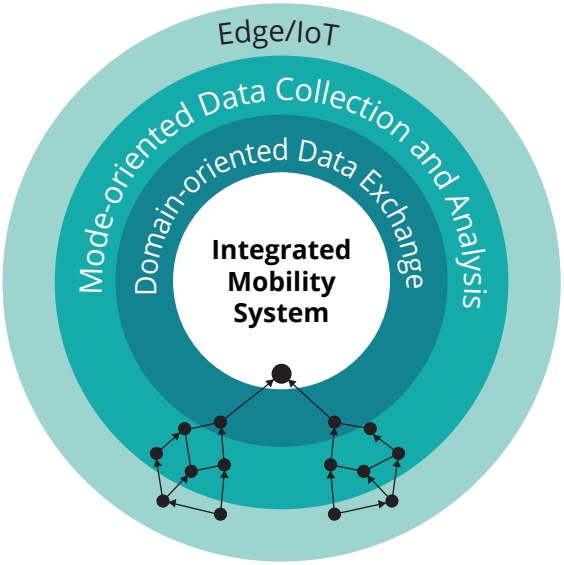
- Focus on building the central data repository and exchange
- Focus on standards
- Focus on building data management and interoperability layers
- Often starts at domain-oriented data exchange level (e.g. OT)
- Often aligned to MaaS initiatives

This contrasts with the more traditional "inside-out" approach which focuses on building the central data exchange first and gradually hooking in information sources from across transport customers, operations, and infrastructure. The inside-out approach has been the natural focus for transport agencies, but it has been an elusive target.

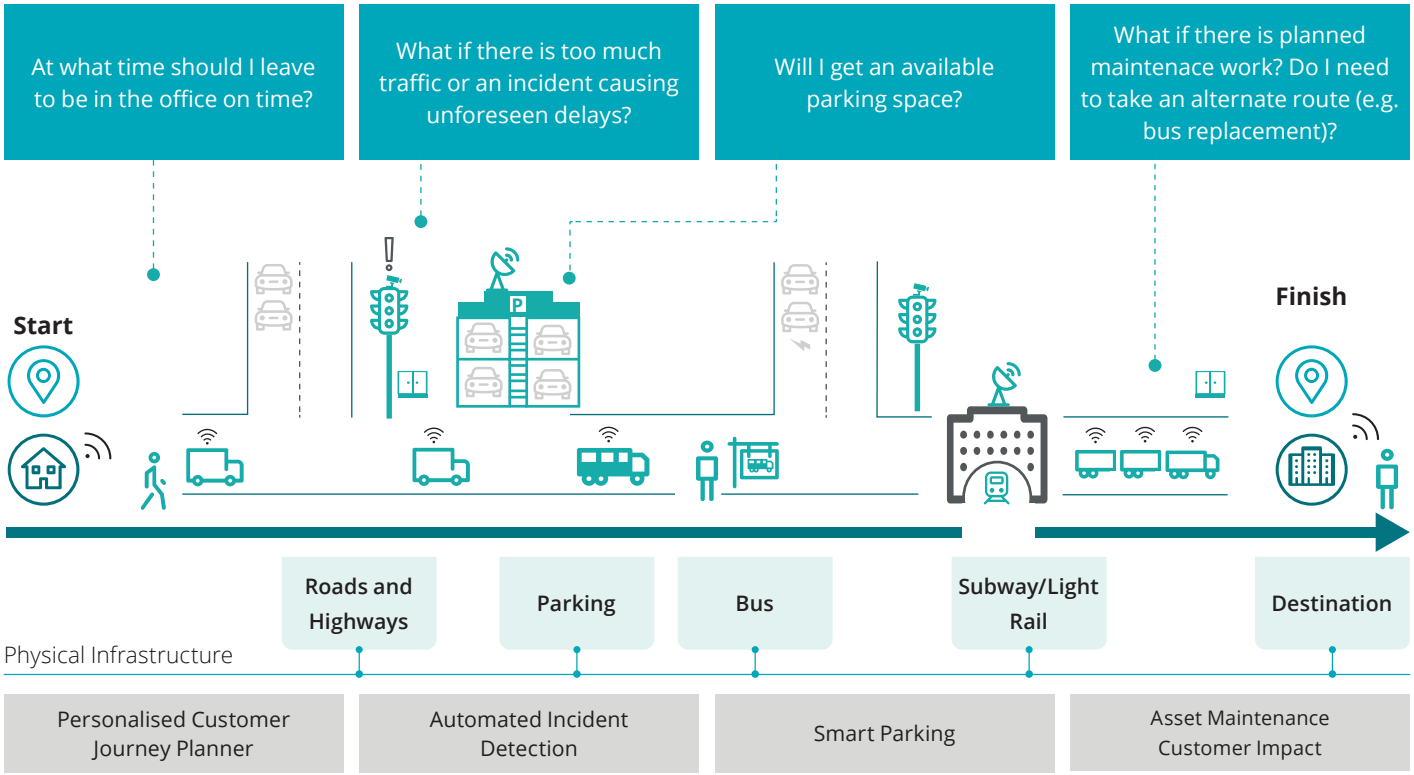
Outside-in: building use case chains

There is a shift required in the way transport agencies tackle some of the challenges the transport sector faces. Transport agencies need to foster an environment that supports the development of solutions to real-world problems through individual use cases. They should also ensure that a broader strategy and reference architecture is in place to link individual use cases as building blocks towards a broader, integrated data ecosystem. This is about seeing individual solutions and the data they produce as links in a chain that support a common strategy for an integrated data ecosystem across transport. This approach embodies several key characteristics:

- Solutions to specific use cases that address real-world challenges should not be postponed for the sake of enterprise investments in data platforms.
- Solutions to specific use cases should not be done in isolation. The right level of governance will ensure that the solution design enables future integration and flexibility to support future use case chains.
- The solution design should support open standards, avoiding proprietary solutions that could be translated into a specific vendor dependency and limit future evolution and scalability.
- The solution design should avoid vertical integration of data collection, analysis, and decision making. Interoperability and ease of integration between systems is key.
- Solutions to specific use cases should be tracked in a transport-wide inventory and be available to people designing new data solutions.
- With an inventory in place, a use case chain roadmap should be developed to illustrate how the current and future portfolio of use case solutions will combine to support an integrated data ecosystem. The roadmap is not a one off—it will evolve. It should also be available to the transport community.
- Transport problems and opportunities should be framed around user groups to drive more lateral thinking about use cases rather than being constrained by current data silos. This could emerge as building use-case chains around customer journeys, operations management, strategic planning, and capital investment to bridge the gaps and hone in on real world challenges.



To illustrate the concept of use-case chains across infrastructure, operations, and customers it is useful to consider a day in a commuter's life.



A day in a commuter's life

While there are many use cases associated with the customer's journey this example illustrates the need for four key use cases to work together in a "use case chain" to improve journey reliability.

The four use cases are:

1. Personalised customer journey planner—mobile app integrated to transport data feeds to deliver real-time journey planning.
2. Automated incident detection—embedded infrastructure sensors combined with data analytics to detect abnormal congestion patterns.
3. Smart parking—embedded infrastructure sensors to show transport exchange parking availability.
4. Customer impact of asset maintenance—network-wide awareness of planned asset maintenance and interpretation of maintenance activities into network and customer impact.

Transport agencies are already using innovative technology to deliver solutions to each of these use cases. The value is enhanced, however, when the use cases are integrated to provide a use case chain that helps to solve challenges around reliability of transport.

Personalised customer journey planner

Most transport agencies are already leveraging mobile apps supported by real-time data feeds to transport operations to enable customers to manage their travel conveniently through their personal mobile device. Mobile app solutions are trending towards driving more personalisation. Customer journey patterns can be logged to create a travel profile that provides more personalised information to customers—for instance as an alert if abnormal congestion is causing service delays on the customer's regular bus service. The combination of awareness of personal travel preferences with real-time situational awareness of transport operations will deliver significant benefits to customers by ensuring reliable transport. It is worth pointing out that this use case can also evolve into "demand management" of transport as proactive, personalised "nudges" can be generated to change how and when customers use the transport network, which can help to minimise the impact of congestion, particularly during peak hours.

Automated incident detection

Transport operational control centres are typically fairly reactive. Detection of incidents often comes through alerts from the public or emergency services. CCTV monitoring does help but there is a limit on how much coverage humans can deliver through monitoring of CCTV feeds. Transport agencies are increasingly seeking to leverage video analytics and other embedded AI/IoT solutions to detect abnormal congestion patterns to speed up detection and response by transport operators. This information can also be fed to key stakeholders across emergency services and freight but also critically, to the end customer to avoid increased congestion build up and alternate route planning.

Smart parking (Network usage)

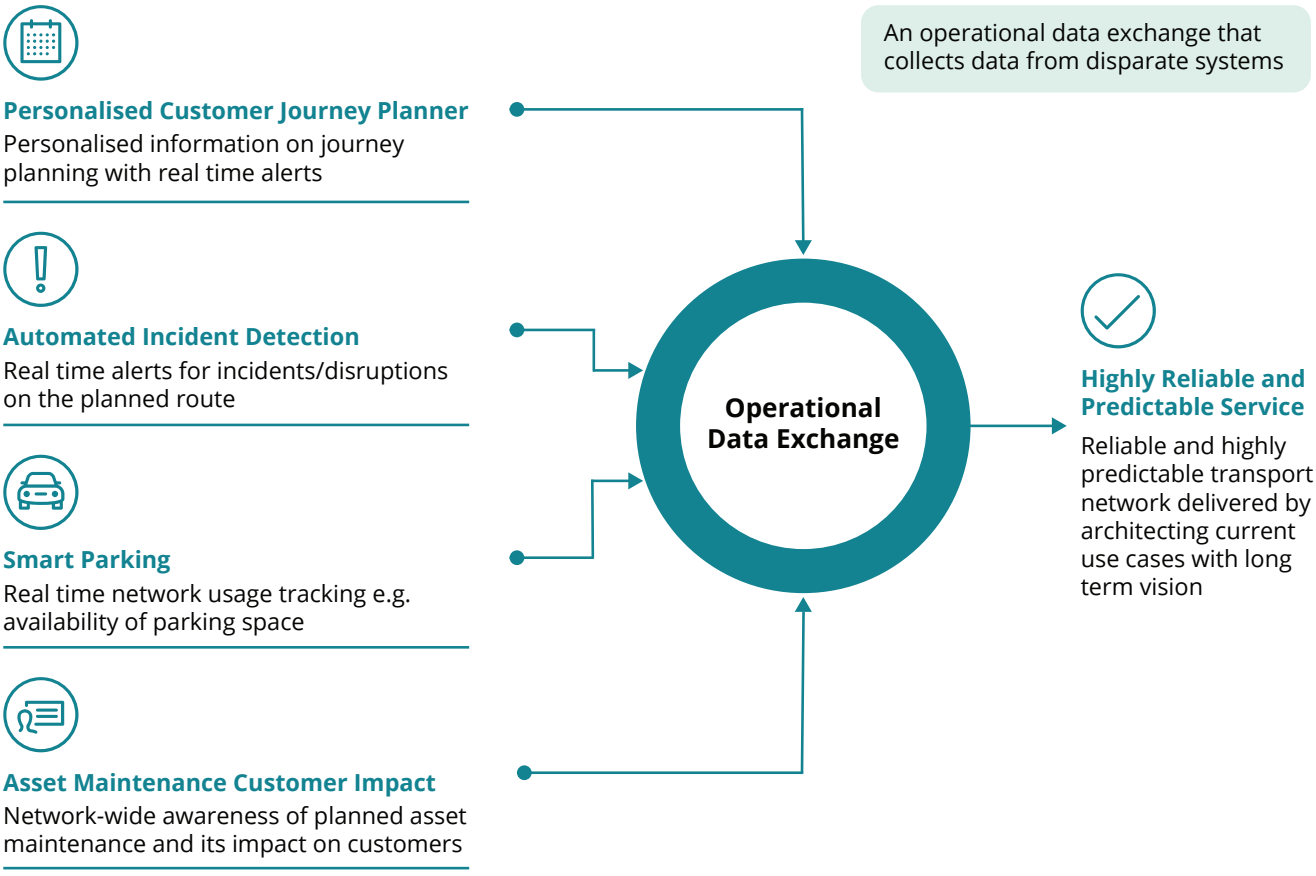
Public parking facilities at major transport interchanges are central to solving the first mile/last mile problem to incentivise people to use public transport. Their effectiveness is diminished if customers are not able to rely on parking availability which encourages people to stay in their cars for the whole journey. Already, advances in vehicle connectivity, smart infrastructure, and IoT applications are creating new opportunities for smart parking solutions. Sensor-equipped parking facilities and street meters combined with license-plate recognition and connected payment platforms can generate the information needed to help customers access parking that suits their schedule. They can help to enable seamless interchanges with reduced search time and increased confidence in journey reliability. Smart parking information can help operators to maximise asset utilisation, tap into new revenue streams, and improve planning of future interchange infrastructure.

Asset maintenance customer impact

While asset maintenance information is already captured and managed in the transport operator's asset management systems, there has been significant interest in gaining insight into the customer impact of planned service disruptions. AI-based simulation technology has already been trialled to simulate, predict, and quantify the impact on customers from service disruptions to provide insights into maintenance planning. A natural extension of this technology is to link service impact information to personalised customer journey profiles, which can be made available through mobile apps to minimise disruption to customer journeys. If customers can plan their journeys around disruptions, they can re-plan their travel, which reduces the impact of disruptions on the network.

Building the use case chain

Reliability of the public transport network has always been at the core of customer experience. This will become more pronounced, as cities witness large scale urbanisation, and more and more people are incentivised to use public transport. The outside-in approach can deliver the much-required use cases that when integrated can contribute to building a highly **reliable and predictable public transport network.**



This can be achieved by designing use cases that are easy to scale and that are architected with a broader objective in mind. This will enable new opportunities to solve transport challenges by combining pre-existing solutions (use cases). By connecting use cases (use case chains) and delivering them with an integrated architecture, the goal of building an integrated mobility operating system will emerge, one use case at a time.

More sophisticated use of data from "smart parking" solutions could deliver personalised parking availability alerts to commuters via mobility apps based on the history of frequently visited parking locations. Operators can also tap into data generated by personalised customer journey planner collected from customer journey profiles (assuming there is a resolution to associated privacy considerations) to provide insights into preferred daily route and modes of transport. With planned maintenance data, real-time disruptions/incidents identified through automated incident detection solutions from roadside devices, and traffic monitoring systems, customers can benefit from personalised journey planning with in-built real-time situational awareness to help ensure they get to their destination on time or find alternative times to travel.

These examples illustrate how multiple use cases that each solve a unique problem can be integrated to support more strategic transport objectives, in this case reliable transport and seamless integrated customer experience. Each of the use cases have natural extensions (e.g. influencing customer demand through "nudges") that can enhance strategic transport objectives. If transport agencies can harness the power of individual use case solutions there is an opportunity to deliver a more reliable, dynamic transport network that will help manage the growing challenge of congestion and liveability in our cities and connectivity to our regional and rural areas.

The digital transport reference model

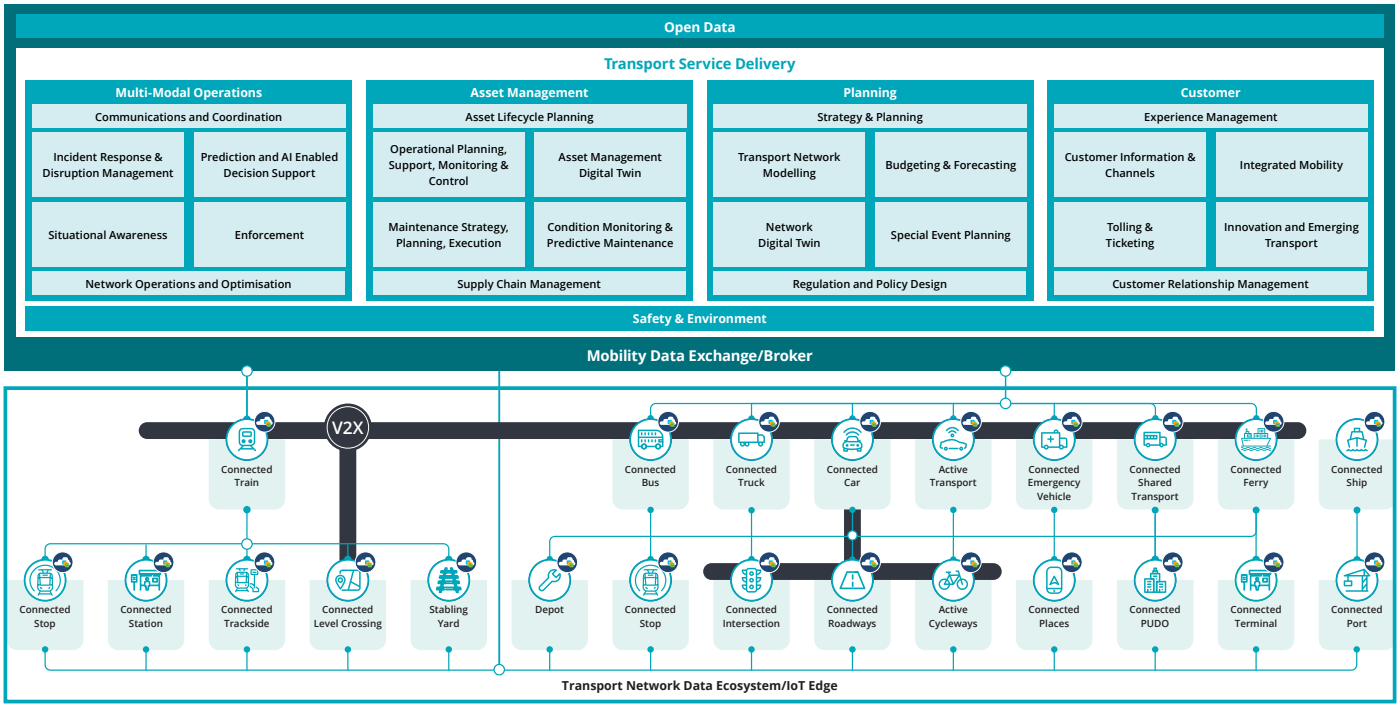
To support the "outside-in" approach to establishing a mobility operating system, transport agencies need a common view of how each point solution contributes to the achievement of an integrated system. To support this, Deloitte and Cisco have developed a digital transport reference model that illustrates an overarching picture of an integrated technology architecture. The model is built on a range of data points and devices in the transport network that are collectively harnessed through a centralised mobility data exchange.

Digital transport reference model

The digital transport reference model defines a common architecture that creates a bird's-eye view of the integrated system that each use case chain serves to develop. As described under the "outside-in" approach, the digital transport reference architecture is not built with a focus on establishing a centralised data platform up-front, instead it relies on individual use cases, built with a common reference architecture to incrementally contribute to the establishment of a mobility data exchange.

This model represents what should be achieved if transport agencies take a coordinated approach to building out their transport data use cases. It can be used to establish a common view of what the bigger vision is for each technology use case. It can also be used to map out which parts of the architecture have been built, which still remain, and how individual use case solutions can play out within the broader digital transport reference architecture.

Customers	Transport Market Participants	Government & Community
Journey Planning, Management and Alerts	Route Planning	Placemaking & Smart Cities
Multi-modal Service Integration	Demand Management & Incentives	Planning & Investments
In Journey Experience	Service Integration	Policy Coordination
Payments	Service & Performance Management	Community Services
Customer Information	Policy Management & Coordination	Incident Response and Coordination



Key components:

Transport customers, community and market participants:
Each transport use case has to have a customer. There are the obvious customers—the users of public transport—but transport's perspective is much broader. The broader community is also important as transport services play a greater role in shaping our cities and our regional areas. Transport also plays a major role in adjacent government services such as emergency services or broader infrastructure planning. It is also worth considering broader transport market participants who are at the forefront of innovation and service delivery with new transport service offerings from ride-sharing to new mobile apps that change the way transport is consumed.

Mobility data exchange/broker:
A mobility data exchange will enable the development of a more dynamic, integrated transport system for customers and the community. It is a challenging technical feat to put in place and requires significant organisational alignment, funding and commitment to achieve. As such, we see organisations gradually putting this technology in place through an incremental method we have referred to as "outside-in". The vision for this is not just a central platform that enables integration and translation of data (transport data technology layer). It also includes capabilities to drive data analytics, manage guidelines and policies for interoperability, and provide an interface for the bi-directional exchange of data with external parties (business of transport data layer). More advanced versions will include components to support market making across all public and privately owned public transport services.

Transport service delivery—enterprise systems:
Not technically a component of the digital transport reference architecture, it is included to highlight the broad spectrum of transport technology systems that are used to drive service delivery and that will consume and process data captured across the transport network. Key systems that relate to transport service delivery are included for contextual reference. Many of these systems will already be in place across IT (Information Technology) and OT (Operational Technology) functions in transport.

Transport network data ecosystem:
This is where it all begins—it is also where future obstacles and challenges are created when use cases are implemented without the bigger picture in mind. This is the collective set of technology that supports collection and distribution of data from and to the transport network. It is the natural home of IoT and Edge computing investment. It is important to ensure each data component or device is architected to integrate into a common mobility data exchange and to consider how each device could be extended and/or leveraged into other parallel use cases—for example, a sensor on a bus that initially provides tracking information could also be used to measure road vibrations, which could support condition monitoring of urban routes and arterials.

Design principles

The outside-in approach starts with a focus on the edge layer of the reference architecture. For it to successfully support expansion into the higher-order functions of the model it is critical that the edge solutions are designed with interconnectivity and the bigger picture in mind. There are key design principles that should be considered when applying the model:

- **Interoperability:** Edge technology, communication protocols, and data standards should aim for interoperability to facilitate data ingestion and analysis across a wide range of data sources.
- **Scalability:** Use case solution design should consider scalability of the design as a priority to support the inevitable growth in emerging data volumes and data sources.
- **Extensibility:** Solutions should work within and alongside the current landscape and build on top of them.
- **Manageability:** IoT solutions are multi-domain in nature, and depend on many different functional layers. Operations requires the information to understand the causes of issues to respond quickly and efficiently. Visibility and control of each of these layers must be provided across appropriate transport management domains.
- **Component architecture:** Avoid developing overly complex, vertically integrated solutions that create future challenges with vendor lock-in and flexibility. Use cases should be designed as a set of interconnected modules that build off a common mobility data exchange platform.
- **Security:** Cyber Risk is unavoidable. The attack surface is growing along with the dispersion of technology across the transport network. Data security also plays a significant role with privacy and system assurance concerns, ensuring security must be considered holistically across all components and layers of the solution.
- **Reliability:** Technology that produces critical operational data needs to be reliable. It needs to perform consistently at high levels of accuracy day in and day out.
- **Sustainability:** Technology solutions need to consider future support and sustainability of the technology assets. As such, alignment to broader technology ecosystems, availability of talent, future product investment, and ease of support are key considerations.

These foundational principles provide guidance when designing a future proof and sustainable digital transport architecture. An open, secure, scalable and flexible model that will not just address today's transport agencies challenges but will also easily incorporate future solutions that will respond to the evolving needs of the sector.

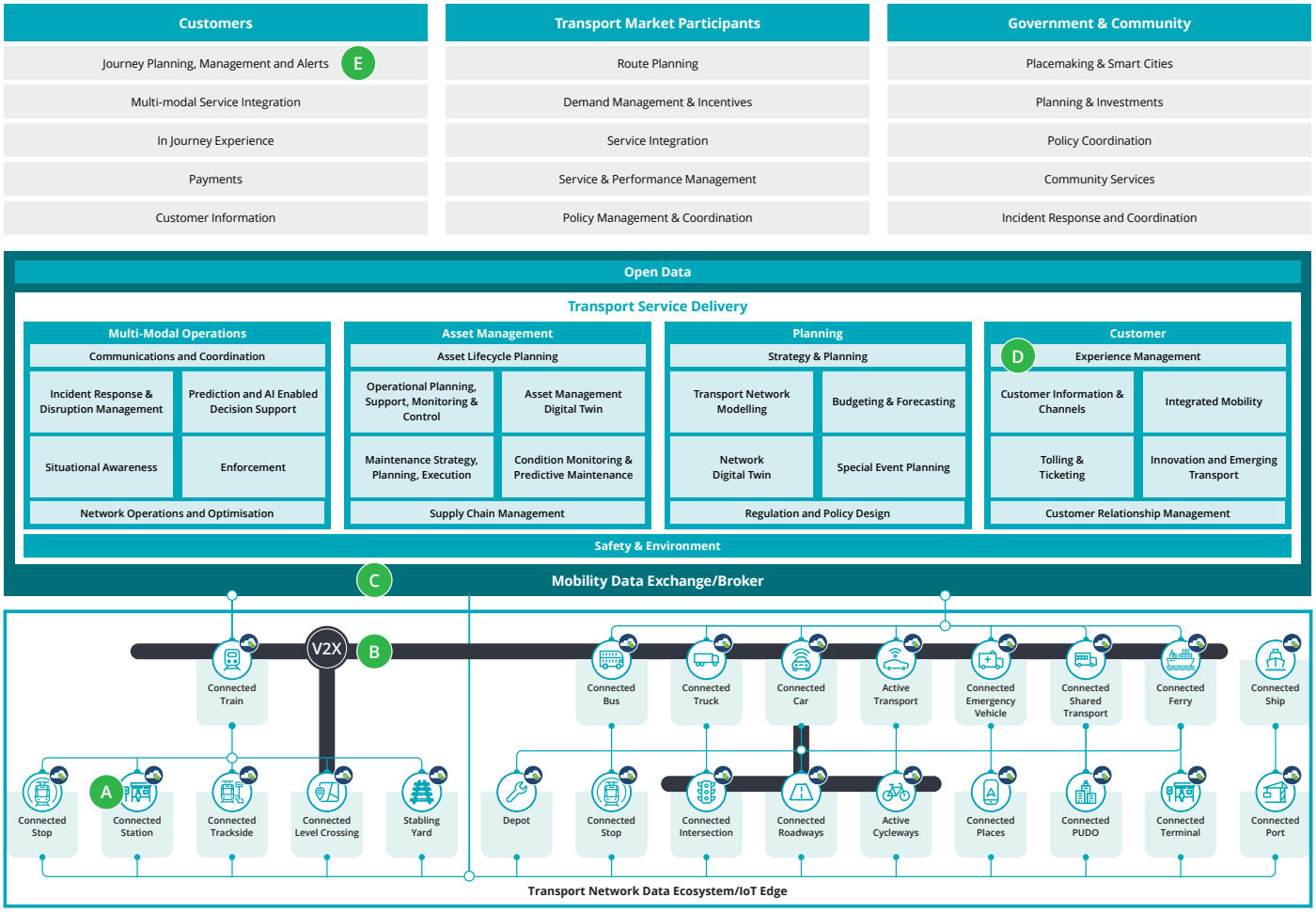
Applying the digital transport reference model—a use case chain for train station crowd monitoring

To illustrate the concept of "outside-in" and "use case chains" framed around the digital transport reference architecture we have played out an example of a transport agency considering implementing train station platform monitoring equipment.

First use case—station platform crowd monitoring

The initial use case for consideration is to provide platform crowding information, which can advise customers pre-journey if crowds are significant and suggest journey options if there is a major disruption or to advise other entry points or waiting areas. This use case is particularly relevant for periods of high use such as major events.

As referenced in the digital transport reference model the first part of the story reflects on the need to implement an IoT device on a station platform which should support the design principles previously mentioned so the data can be seamlessly ingested through the mobility data exchange (A, B, and C).

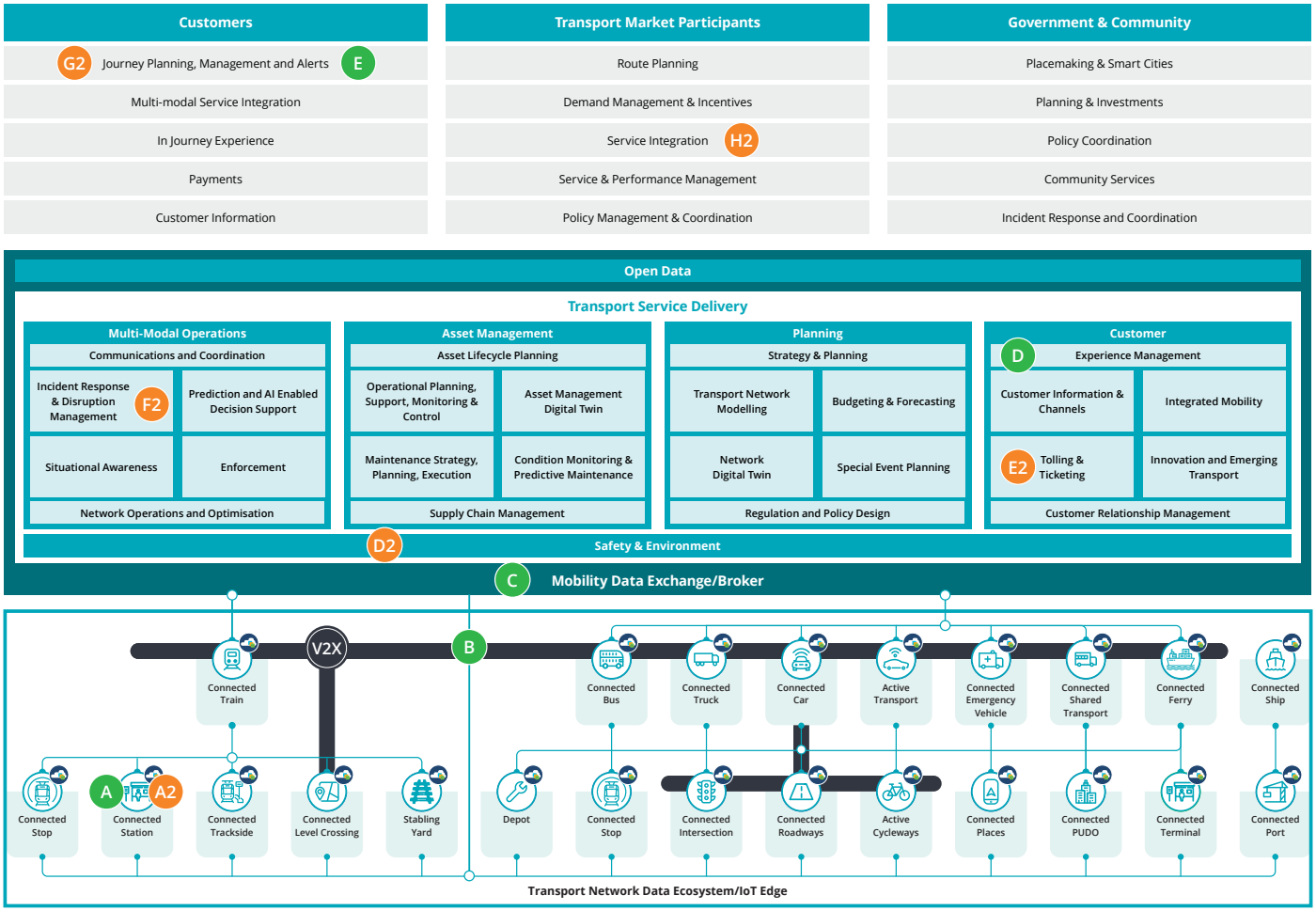


The data will then be consumed by an internal transport service delivery system, in this case experience management and customer information channels (D) to provide suggestions to the customer via journey planning mobile apps (E). As the mobile app is not a specific transport agency supplied app it will access this data via the open data portal established by the transport agency as part of its mobility data exchange.

Use case chain extension –enabling demand/supply matching and replacement bus services with crowding information

The second use case is a natural extension of the first use case. Where people crowding information is already being collected it can also be used to more accurately predict the number of replacement buses required to move people from a station that has been impacted by a significant service disruption.

If the design of the first use case has selected a device that outputs data that can be transformed and interpreted by down-stream analytics, the same underlying infrastructure can be leveraged to support this use case (A,B,C)



With the data ingested into the mobility data exchange there are numerous possibilities for extension use cases. In this case we are considering extending the capability to support current challenges with identifying the number of replacement buses required when train services are impeded through either planned or unplanned events.

In this case, the underlying crowding data will be submitted to a transport service delivery system for incident response and disruption management and estimates of people numbers will be consolidated (F2). This may also include using data from ticketing information (A2), which is also captured within the mobility data exchange and ingested by transport service delivery technology for tolling & ticketing (E2). This data can then be merged with the station platform crowding information to provide a more accurate picture of crowding, and predicted crowding as the event continues (F2).

The same information could be made available to safety & environment service delivery technology (D2) to support other safety concerns or management processes.

With a more accurate picture of customer demand in place, transport service delivery technology can then route bus-load requirement information via the open data portal to third-party bus contractors to meet the station offloading demand (H2).

To close the loop, information can then be broadcast to customers to provide warnings and alerts but also to provide localised information to people involved in the incident for wayfinding and route change information via their own journey planning mobile apps (G2).

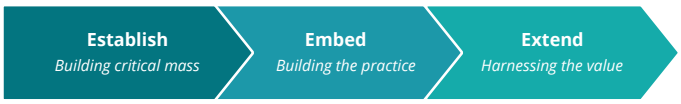
Other options might include creating push notifications on the station platform, which could be facilitated by the original device that manages the crowd counting, if it was implemented with multi-function capability (A).

What's important to note in this example is that by thinking about individual use cases in the context of a broader transport architecture and considering some of the use case extensions we understand the requirements that should be considered when designing the station-based or end point infrastructure. It is important to consider some of the parallel use cases that could be delivered and design specific solutions to fit in and contribute to the development of a more dynamic and integrated transport system.

Three phases of outside-in

The concept of an outside-in approach is a great way to get started, leveraging a more organic approach to the development of a transport data exchange. It can, however, result in chaos if not properly managed. There are many examples across the industry of initiatives that were built on good ideas but struggled to become sustainable and keep up with industry and technology change.

To ensure the outside-in approach delivers a sustainable and value-driven data ecosystem it is useful to think of its evolution across three phases: establish, embed, and extend.



Establish

Key characteristics: Organisations will typically be faced with many disconnected use cases from previous projects. Often, many solutions are not visible across the organisation—functionality is often duplicated across business units. Many of the solutions will have been built using proprietary solutions that have limited ability to integrate and/or the flexibility to adopt open standards. The effort to connect varying data sources across multiple formats and proprietary walls seems daunting and insurmountable.

Goal: The primary goal is to build critical mass. The organisation will need to work with what it has, focusing on leveraging existing solutions that are easier to connect to and combine while also developing new initiatives that align to common standards and design principles.

Governance: Governance is important but at this stage it should be relatively light-touch. Governance should be about helping to drive an enterprise view of what is happening, reduce duplication, and connect opportunities. Its less about control and more about connections and coordination. Delivery decisions will reside within the business units and as such are not centralised. Architecture should be focused on providing guidance to support decisions and to influence more open thinking in solution design. Success will depend upon the right level of executive sponsorship to drive customer/operations improvement across multiple modes.

Recommendations:

- Establish a common view of transport use cases that are in place and future opportunities that have been identified. Seek to break-down silos. Work across the organisation and build an enterprise-wide view.
- Create an inventory of use cases delivered and future opportunities.
- Map these use cases to the digital transport reference architecture and consider new opportunities to build use-case chains.
- Set up a practice (through a matrix structure rather than formal reporting lines) to look for opportunities to connect use cases to deliver better outcomes and insights.
- Leverage the "new practice" to build a roadmap of use cases and how they interact into use case chains.
- Leverage what's already out there. Work with use case/solutions that have a degree of openness and find opportunities to make new connections. Avoid getting trapped into building connections or unifying everything that is out there—if it's too hard, leave it.
- Work with architecture teams to establish a broader view across the enterprise. Establish standards and design guidelines but don't make them a prerequisite for progress.
- Don't try to establish a build team too early. Let delivery happen organically through business unit priorities and real-world problems.

Funding: At this stage, it is likely that funding will be minimal or non-existent. As such, business units will fund their own initiatives. If there is enough support at the executive level it may be possible to establish a small seed fund to co-fund delivery with business units but it should not be seen as a pre-requisite to building momentum.

Embed

Key characteristics: With support from the virtual team established, there will be an emerging critical mass of use cases and connected solutions in place. New opportunities to connect data sources and deliver higher value solutions will emerge. With increased alignment to design standards the incremental cost of connecting data drops, enabling increased acceleration of delivery and viability of experimentation. It will be easier to mount a case for investment in more centralised technology platforms (e.g. data, Edge/IoT, integration, API management) to lower deployment costs and increase sustainability.

Goal: The goal is to formalise a team that can work across the enterprise to manage data-driven use case development and to embed a platform that supports Edge/IoT as well as some of the transport data exchange components. This centralised team should increasingly target understanding the current and future value of the data. Getting early visibility of commercialisation opportunities and new revenue streams should be a focus.

Governance: Increasingly, delivery decisions will be made from the centre as they provide multi-modal, enterprise wide benefits. It is likely that most use case/solutions are driven through business unit priorities. Architecture standards and guidelines are in place and are more frequently adhered to. Build decisions need to ensure future sustainability and support has been considered—if underlying platform architecture is in place it will help to encourage use of the platform as sustainability costs should be lower.

Recommendations:

- With critical mass in place and emerging investments in centralised technology platforms there will be a clear justification to formalise the central team rather than relying on a virtual matrix structure.
- Team capabilities will need to expand to include specialist data skills (e.g. data scientist, data engineers).
- This team should work alongside any pre-existing data analytics teams that perform a central function across IT, operations, and customer information.
- Investment and implementation of centralised technology platform infrastructure should be in progress at this stage. Key components should include Edge/IoT, data ingestion, analytics, integration, API management, and external partner collaboration/management.
- Expand scope of analysis to include possibilities that might emerge through external partner data exchange (e.g. on demand, freight, shared mobility).
- Investments should include sustainability costs of future solutions, which should be included in decision making.
- The centralised team should focus on assessing the value of the data and identifying future value capture. The team should also explore opportunities for industry partnerships as new opportunities emerge with external data exchange/partnering.
- A more formalised and dedicated technology support function should be put in place and embedded in the team—this may leverage existing IT capability and/or technology vendor relationships.

Funding: With a critical mass of use cases and working proof points of successful delivery, there should be a stronger case for increased funding and investment in transport data exchange technology. Increased budget allocation for delivery/investments in strategic solutions should be outlined and allocated as the organisation will increasingly rely on the new central function for delivery. In some cases where priorities differ, business units will still fund delivery of their own solutions. However, they will increasingly rely on the centralised team for delivery.

Extend

Key characteristics: At this stage the centralised data ecosystem is in place. With critical mass of use case/solutions in place built from a common technology platform, there may be some remaining investment required in platform/data management. Now that there is a central place to access data across operations and customer demand new "big picture" opportunities will emerge around transport market management—transport agencies will now have a tool that can be used to influence supply/demand forces across the network. Opportunities for value capture will be apparent and the technology and data focus will increasingly shift to a commercial/collaboration/market focus.

Goal: The goal is to start harnessing the value of the data within the platform. There will be opportunities to self-fund the technology and operations that may emerge into new transport revenue/funding models. Partnerships with industry will be identified and formalised and should be built on mutual exchange of value to create incentives for participation.

Governance: With a transport data exchange in place and associated IoT/Edge platforms established, delivery decisions will be more centralised and set up as a service to business units. Some solutions will involve industry participation and as such governance needs to include commercial management considerations.

Recommendations:

- The value of the use case/solutions and underlying data should be understood and as such there is increased focus on commercial opportunities which in some cases may fund the platform but in other cases may support industry engagement to enrich the value of the platform and support broader transport/community objectives.
- Establish a commercial function to drive and manage industry partnerships within transport but also with associated technology providers.
- The data ecosystem should include technology components to facilitate external industry/partner collaboration and data exchange.
- Some use case/solutions will begin to be superseded at this stage. There will be a need to clean up, decommission, and consolidate what has been built previously.

Funding: If value capture opportunities are recognised and managed, there is potential for the technology platform and operating unit to be self-funding—opportunities may exist beyond this as well. Funding for new initiatives should be established in a central pool. Business units may still fund their own use cases but will leverage the central technology platform for delivery—this should also be a natural path due to the low cost and practicality of leveraging the central platform as opposed to something that needs to be mandated.

Key takeaways

The key recommendation is for transport organisations to take an iterative but coordinated approach to building a central data exchange across transport operations. These takeaways are essential for success:

1. **Articulate user-oriented problem spaces:** Articulate and define key problem/opportunity spaces that are built around user groups (e.g. customer journeys, operations management etc.). Ensure that all point solutions/use cases are aligned to one of the problem/opportunity spaces and that there is a clearly articulated path as to how it will contribute to a solution (in full or in part).
2. **Build a team that can integrate:** Transport organisations are large and often compartmentalised. Key to the success of this approach will be to establish horizontal relationships across the organisation and to build a support organisation that can operate in a matrix fashion across the enterprise. Building a team who can integrate and collaborate will be essential for success.
3. **Ambitious goals, pragmatic delivery:** A key principle that should be adopted is to set ambitious goals that really stretch current capability and use these to guide solution delivery. What is delivered should deliver tangible results in the current environment. What is key is that there is a clear link built into the design of each solution between the current needs of the organisation and the ambitious goal of the problem/opportunity space.
4. **Build a common frame of reference:** To facilitate collaboration and integration across the enterprise there will be a need for a common way to articulate and frame each use case/solution in the context of the bigger picture of how all the digital components fit together. This is the purpose of the proposed digital transport reference model. Transport organisations can use the example provided in this paper as a starting point or adopt their own frameworks/architecture to enable teams to collaborate and articulate what they are aiming to achieve and how it aligns to the broader vision for a mobility data exchange.

Conclusion

Transport is going through rapid transformation across the globe. Many countries we are witnessing a generational investment in transport infrastructure across urban centres as well as a growing focus on connecting rural and regional areas. These investments increasingly embed technology into their delivery and with technology comes data.

At the same time there is speculation in the industry about some of the emerging trends, debate about the prime time of autonomous vehicles, and the critical mass of EVs. Speculation on when we may build the next hyperloop or drone taxi. There are sceptics and futurists with differing views on whether this is all fact or fiction but irrespective of the arrival of our "Jetsonesque" future one fact is inevitable—for transport, connectivity and data is the future.

Observations from industry point to a current state that is a bubbling mixture of good ideas, successful point solutions, and some failed projects. It's a chaotic soup where the exponential rise of data volumes is keeping the heat on max. What is needed is an approach that starts at the source—the data. We take the position that big centralised approaches are unlikely to succeed in what is now a time of disruption. Instead, the outside-in approach is about fostering organic development and starting at the edge through use cases and development of use case chains. It's a bit like herding cattle as opposed to walking your dog. Over time, the centralised platform approach will take shape but it will emerge through natural forces that build up justification to centralise and consolidate rather than imposing a structure on something that is still fluid.

There are differing opinions on which approach works best. Our view is that transport agencies need to get started. There are many paths to achieve a transport data ecosystem. Irrespective of the journey, the starting point should begin with focusing on the data at the edge.

Endnotes

1 Burgueño Salas, Erick., *Mobility-as-a-Service—statistics & facts*, 2022. <https://www.statista.com/topics/4664/mobility-as-a-service/>

2 Department of Infrastructure and Regional Development, *Traffic and congestion cost trends for Australian capital cities*, 2015.

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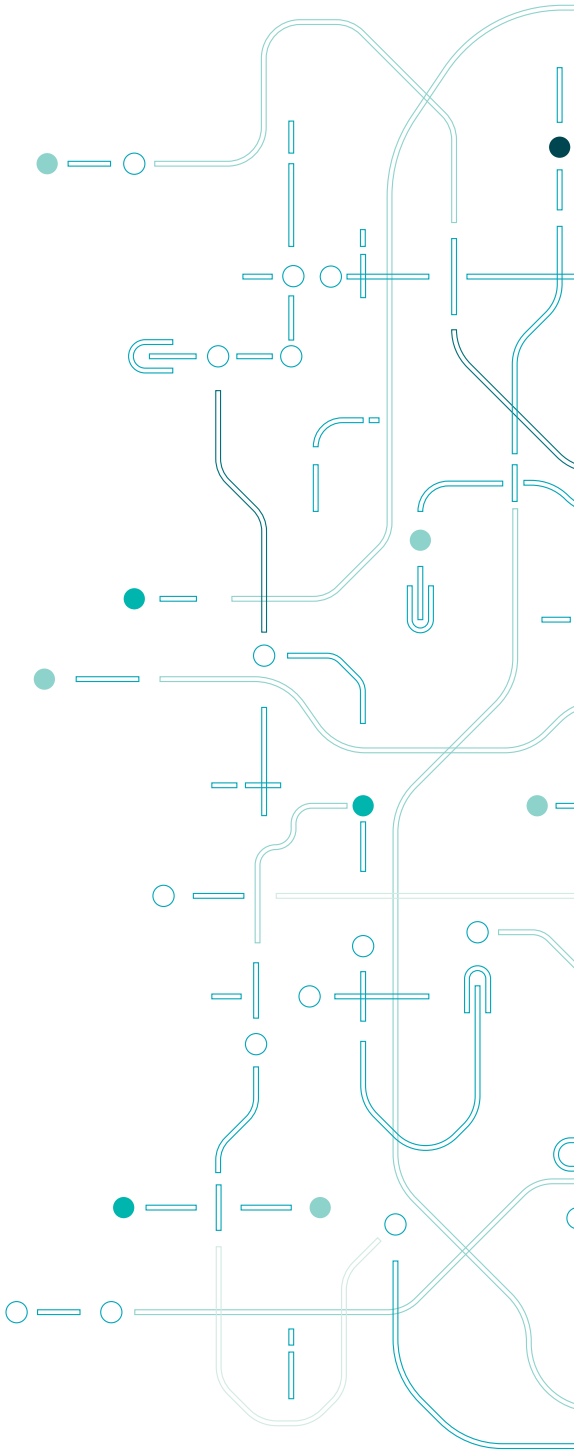

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