InfraTech Stock Take of Use Cases

Global Infrastructure Hub

G20 Infrastructure Working Group draft Reference Note

July 2020

1. Context and overview

1.1 Background

The G20 has highlighted the importance of infrastructure as a driver of economic prosperity and the basis for strong, sustainable, balanced and inclusive growth and development. However, a persistent and well-recognised infrastructure gap still remains. This has been addressed by the various G20 Presidencies – first in 2018 through the Roadmap to Infrastructure as an Asset Class and in 2019 through the Quality Infrastructure Investment (QII) Principles. In 2020, the G20 Presidency is developing an Agenda to accelerate the adoption of technology for infrastructure (InfraTech) that will help countries achieve better environmental, social and economic outcomes.

The need to close the infrastructure gap through the delivery of quality infrastructure and the implementation of InfraTech is greater now that it was before, as governments face increasing fiscal constraints due to the COVID-19 pandemic. While a global shift towards sustainable and resilient infrastructure was already in motion prior to COVID-19, it is now more crucial than ever that this is done (and done well) in light of new economic, social and political conditions.

1.2 Objective

InfraTech is defined by the G20's Infrastructure Working Group (IWG) as "*the integration of material, machine, and digital technologies across the infrastructure lifecycle*" and is supported by three reference notes produced in collaboration between the G20 IWG, the World Bank and the GI Hub: 1) The InfraTech Stock Take of Use Cases; 2) The Value Drivers for InfraTech; and 3) The InfraTech Policy Toolkit.

This paper serves as the reference note for the **Stock Take of Use Cases** and it supports the InfraTech Agenda by identifying InfraTech use cases in four quality infrastructure sectors (water, waste, energy and transport), identifying their benefits and how to use them. More specifically, the Stock Take identifies four key opportunities for InfraTech, which are:

1. Addressing the barriers to technology adoption
2. Engaging with the private sector
3. Supporting the advancement of Quality Infrastructure Investment (QII) principles
4. Supporting the government's response to COVID-19

These four areas are informed by the InfraTech Agenda's non-binding 'Elements' and other work streams delivered by the G20 IWG, MDBs and IOs over the last six months. Further details of how the Stock Take links with the 'Elements' and the above objectives are detailed in the following sections of this paper.

2. Addressing the barriers to technology adoption

2.1 The barriers to technology adoption

To support the development of the InfraTech Agenda and this Stock Take Reference Note, GIH undertook research in 2019 that investigated the levels of digital technology adoption in the infrastructure sector. The research showed that the uptake of digital technologies is relatively low in infrastructure compared with other sectors. This is illustrated by Figures 1 and 2 below.

Figure 1 shows that the construction sector, for example, has started on its digital journey but it is still well behind other industries.

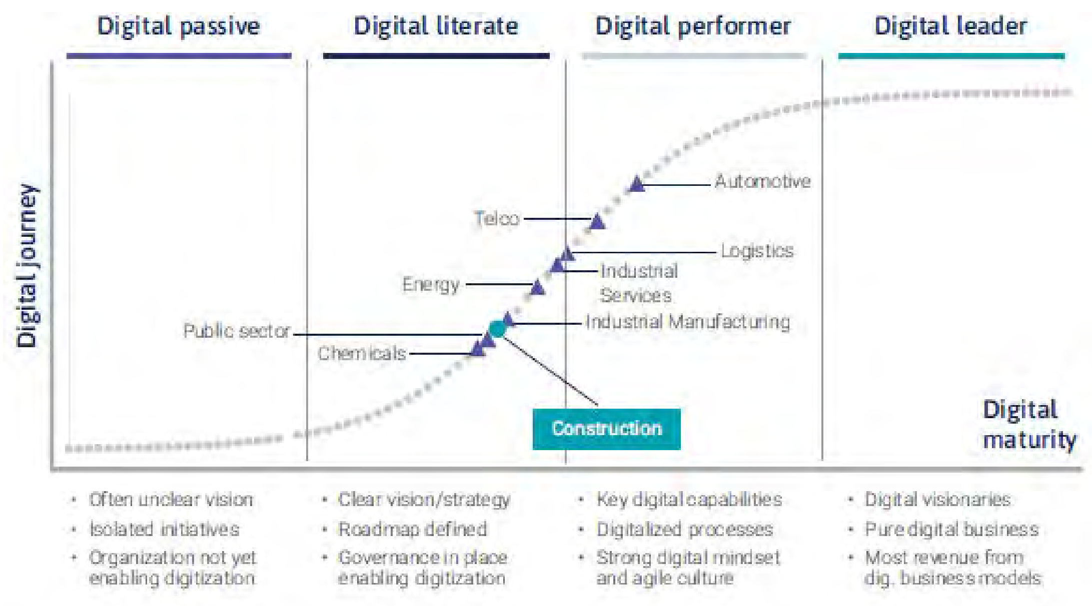


Figure 1: Digital maturity of the construction industry (GI Hub, 2019)

A similar situation exists with technology adoption across the infrastructure project lifecycle. Figure 2 below shows that the level of technology adoption across each infrastructure project stage is either ‘low’ or ‘very low’.

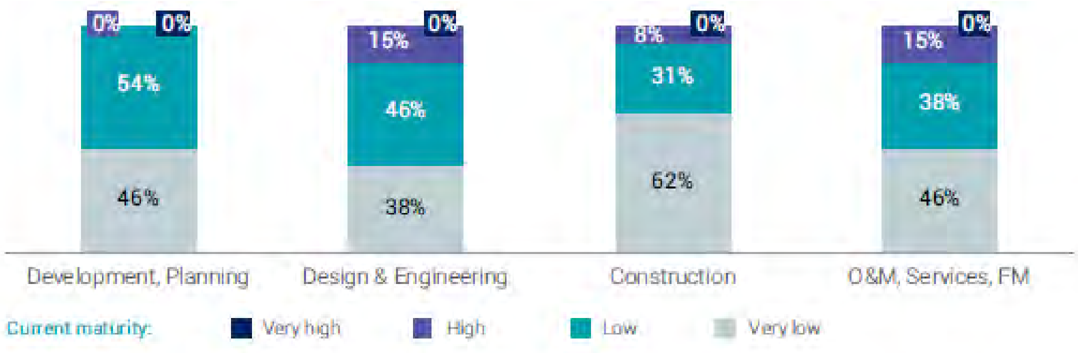


Figure 2: Digital adoption by stage of infrastructure lifecycle (GI Hub, 2019)

To shed some light on why these situations exist, a series of interviews were undertaken with representatives from governments, investors, contractors, operators, technology firms and advisors spread across the major global regions. Through these interviews, the GI Hub identified seven main causes of low technology adoption in infrastructure. These are outlined in Figure 3 below. One of the main causes is the education element – that is, a limited understanding of what's out there and what works.

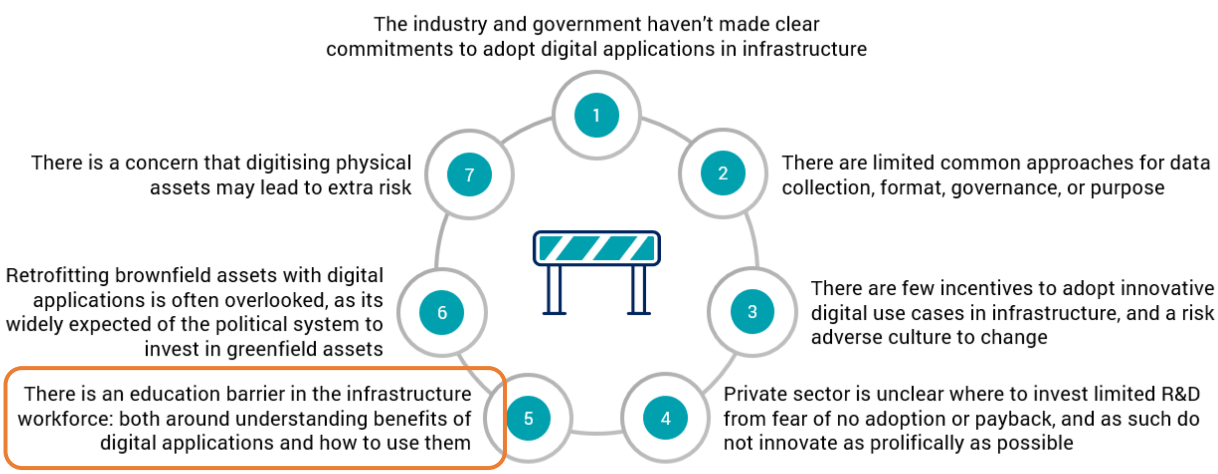


Figure 3: Seven key barriers to technology adoption (GI Hub, 2019)

2.2 Addressing the education barrier with a Stock Take of Digital Infrastructure Use Cases

The education barrier affects InfraTech adoption through a lack of knowledge around the technology landscape and the fear of being seen to be 'picking a winner'. This is not aided by the fact that digital technologies are rapidly evolving. Infrastructure is by nature long-term, therefore selecting technology is difficult. This already risky activity is made even riskier in the absence of skills and capabilities needed to evaluate, trial and implement technologies at scale. Consequently, public and private investors remain reluctant to adopt InfraTech. The content of the use cases can play a big part in addressing this education barrier and in bringing greater awareness of the risks and opportunities presented by InfraTech. The GI Hub intends the use case library to be a living resource, which can be continuously updated as technologies and their applications evolve.

3. Engaging with the private sector

In the context of a post-COVID world, the participation of the private sector in quality infrastructure investment is now more important than ever. A draft G20/OECD report1 released in April 2020 outlined seven key messages from the private sector to enable the environment for private investment. One of these is that technology and innovation can play an important role in encouraging private investment into infrastructure. That is, the adoption of new and disruptive technology (e.g. to improve infrastructure priority setting and optimise construction, operations and maintenance activities) can make infrastructure investment a more attractive proposition.

One example of a use case demonstrating these benefits is the *automatic pre-fabrication of stainless steel pipelines*. The case study was for the use of the disruptive K-TIG technology in Argentina. The adoption of the technology transformed the economics of the project by completing fabrication in 162 days instead of the original 720 days that would have been required if using traditional welding methods.

Other ways in which this Stock Take addresses the needs of the private sector are related to two technology-related recommendations made in the report, namely that the industry needs to:

- Respond in a proactive way to the shifting technological landscape, provide a vision for technology opportunities in infrastructure and develop long-term strategies to support the scaling up of opportunities and diffusion of knowledge
- Promote more broadly innovative firms and innovation ecosystems, cultivating creativity and knowledge to solve challenges in infrastructure systems[1]

In supporting the G20's InfraTech Agenda, the GI Hub's development and continuous update of the use case library will provide IWG members and the broader infrastructure community a 'go-to' resource for InfraTech trends and insights.

[1] 2020, G20/OECD, *A Report on the Collaboration with Institutional Investors and Asset Managers on Infrastructure*

4. Supporting the advancement of Quality Infrastructure Investment (QII) principles

Quality infrastructure and the efficiency of public spending has always played an important role in the infrastructure gap debate. InfraTech provides tremendous opportunities to facilitate the implementation of QII Principles by enabling cost-effective upgrades of existing infrastructure, extending asset life and deferring costly asset maintenance and renewals. Furthermore, quality infrastructure (and its enabling technology) can influence the outcome of crises such as the COVID-19 pandemic, which will be covered in the next section.

This Stock Take specifically helps to address QII Principle #2 - *Raising Economic Efficiency in View of Life-Cycle Cost*. It demonstrates how InfraTech can bring about efficiencies in life cycle costs for new and existing assets and identifies the relevant parts of the project life cycle that can bring about the most benefit if InfraTech is more broadly deployed. Furthermore, this Stock Take is focusing on the water, waste, energy and transport sectors – high impact sectors for the achievement of economic, social and environmental outcomes.

An example of a use case that supports the advancement of QII Principles is the *intelligent process optimization for water treatment*. This use case leverages AI driven data analytics to treat water to a better standard while reducing operational costs by up to 10%.

5. Supporting government responses to COVID-19

The need to close the infrastructure gap through the implementation of quality infrastructure is greater now that it was before, as governments face increasing fiscal constraints due to the COVID-19 pandemic. The InfraTech Agenda recognises that technology plays a critical role in responding to the COVID-19 crisis and it enables infrastructure to become more resilient to future disasters and pandemics.

The purpose of InfraTech in pandemic response is **to ensure the continued operations of critical networks** – that is, ensuring that utilities, transport and telecommunications are resilient (and continue to operate) in the event of future disasters and pandemics.

InfraTech can be applied across three phases of a pandemic, including:

- **Alerting phase** – this is where technology can be used for early identification of unusual events and outbreaks. This includes combining sensors with AI technology to detect 'hotspots' for potential disease outbreaks (as per the example below).
- **Management phase** – this is where technology can be used to uphold pandemic management tactics and policies by enabling worker isolation and social distancing. For example, automated

manufacturing technologies reduces the need for workers to be physically present on site. Also, predictive maintenance of critical assets eliminates unnecessary site visits while still maintaining good levels of service (as per the example below).

- **Recovery phase** – this is where technology can be used to build resilience to future pandemics. For example, drones enable remote asset inspections and AI technology can be used to automate and optimise the operation of assets. These types of technologies reduce the need for human intervention in the event of future outbreaks and lockdowns.

11 out of the 41 use cases in this Stock Take are relevant to pandemic alerting, management and recovery as outlined above. Two examples of these use cases are as follows:

- *AI to slow the spread of disease outbreaks*: In this use case, AI is combined with temperature sensors to identify 'hotspots' for potential outbreaks. This technology can gauge the infection risk of an entire crowd within one minute without the need to make personal contact. This technology enables rapid 'testing' and assessment of infection risk while improving the safety of staff and ensuring that unaffected services continue to operate.

- *Predictive maintenance of physical assets*: This use case utilises sensors combined with advanced machine learning methods to predict when asset failures are likely to occur. Predictive maintenance technologies can benefit asset owners by preventing catastrophic failure of critical assets by giving an early warning of potential failure. They can eliminate unnecessary maintenance and inspection of assets while still maintaining good levels of service.

6. Coverage of the use case library

6.1 Defining a 'use case'

InfraTech use cases are enabled by digital technologies, but they are not the technologies themselves. The use cases show specific situations in which InfraTech products and services could potentially be used. Therefore, it is not just a list of technologies, but the combination of a technology and an application for which a value case or case study exists. For example, a use case for *last mile infrastructure for water provision in developing countries* will utilise smart water metering and billing technology to provide greater clean water access to low-income households while at the same time guarantee revenues to the water retailer.

Each use case includes the following information:

- The use case and its definition
- The infrastructure application
- The relevant stage in the project life cycle
- Case studies and value cases across a broad geographical spread
- The benefits achievable (in line with those identified in the InfraTech Agenda and Value Case report)

- The stage of development, from cutting-edge through to commercially available technology
- Identifying risks (in line with those identified in the InfraTech Agenda) and how they can be mitigated
- Impact on pandemic management, specifically in terms of safety and economic recovery
- Commentary on the pathway to successful government implementation
- The policy tools and levers that will enable a given use case

6.2 Breakdown of use cases

41 use cases have been developed by the GI Hub covering the transport, waste, water and energy sectors. Across these 41 use cases, over 100 technology-specific case studies were illustrated.

The use case library encompasses a broad range of use cases – including high and low-cost options and applications across both developed and developing countries – to ensure that it is relevant across all national circumstances.

The breakdown of the 41 use cases (and 100+ featured case studies) by geography, technology type, project stage and infrastructure sector are shown below.

Figure 4: Breakdown of case studies by geography

The geographic breakdown of case studies, as can be seen in Figure 4, maps the number of case studies identified in each region. It is important to note that one use case may feature several case studies (and will therefore be represented several times on the map above). This map only captures the current status of the use case library, but it is already able to demonstrate the relevance and potential viability of InfraTech across the globe. This picture will only become more compelling as the GI Hub continues to grow the use case library, adding to the greater pool of evidence in support of InfraTech adoption.

Figures 5 to 7 below show the breakdown in use cases by sector, technology type and project stage. Some observations from these graphs include:

- Figure 5 shows the prevalence of digital technology use cases in the water, transport and energy sectors. The use of digital technologies in the waste sector is less common than in others. This may present an opportunity for growth and development in the future.
- Figure 6 shows that there is roughly an even distribution of use cases in IoT, sensors and analytics. This is unsurprising given that these technologies are typically inter-dependent across the digital value chain.
- Figure 7 shows that more than half of all use cases fall within the operations and maintenance stage.

While the draft InfraTech Agenda 'Elements' for technology adoption were not specifically included in each of the use cases, it is also helpful to understand how the library of 41 use cases supports the delivery of the Agenda from this perspective. Figure 8 below shows the breakdown of uses cases by how they relate to the Agenda 'Elements'.

This library of 41 use cases provides an excellent foundation to build on over the coming months. In its current state, it is by no means exhaustive, however the GI Hub intends to continue efforts to build and maintain the library with the vision that this becomes the 'go-to' resource for InfraTech trends and insights.

The full list of 41 use cases is provided in the Annex to this document.

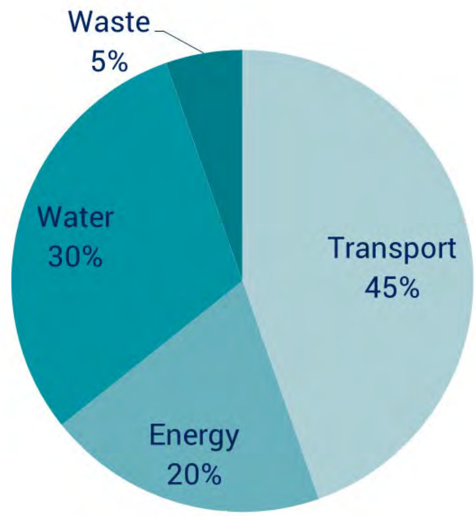


Figure 5: Breakdown of use cases by sector

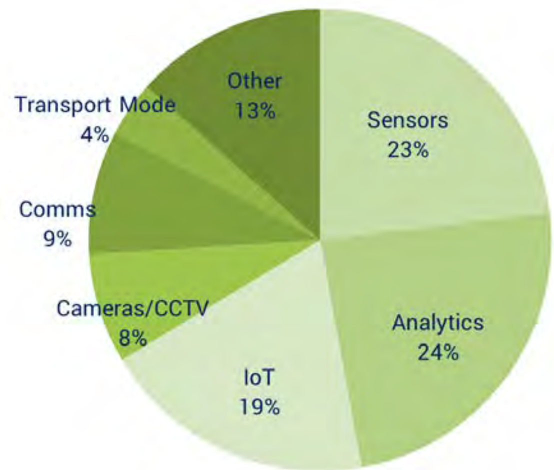


Figure 6: Breakdown of use cases by technology type

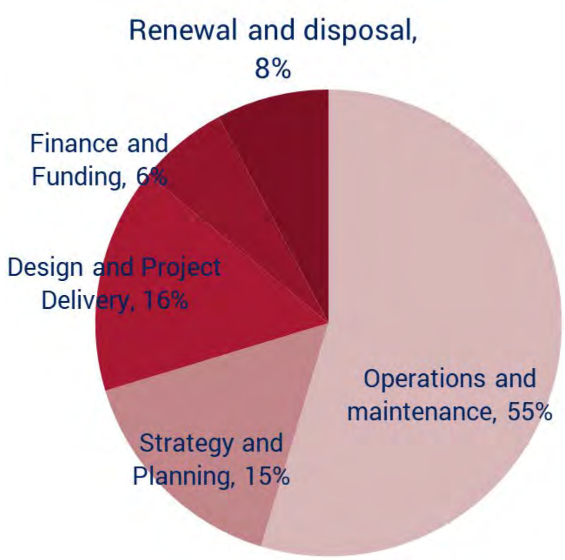


Figure 7: Breakdown of use cases by stage of project

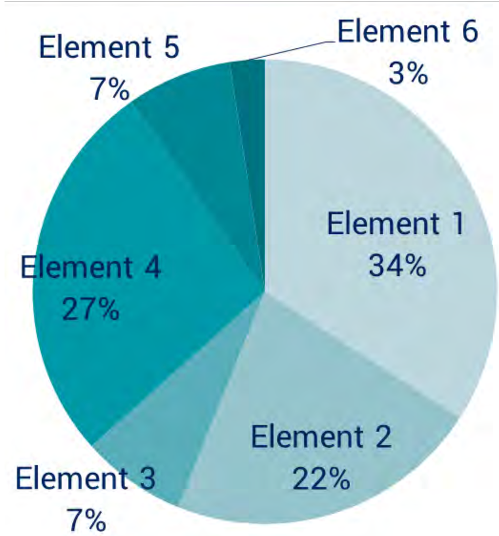


Figure 8: Breakdown of use cases by InfraTech Agenda Elements

6.3 Addressing InfraTech risks

The implementation of InfraTech is a complex undertaking and sometimes with uncertain outcomes that need to be managed through an adaptive approach. InfraTech can presents many benefits (as demonstrated by the use case library), but the risks of adopting InfraTech also need to be articulated.

The use case library outlines the various risks associated with adopting InfraTech. These risks are outlined below together with their definition as per the World Bank's Value Case Reference Note:

Implementation risk	• Uncertainty around the outcomes in InfraTech roll-out • Differences in delivery cycle times between infrastructure and technology • Technological obsolescence • InfraTech procurement capabilities and mechanisms • Public sector skills gap
Economic risk	• Impact of InfraTech on the job market and human capital (e.g. as with automation, sensors and AI) • Impact of InfraTech on ecosystems (e.g. as with sector disruption) • Loss of global competitiveness (e.g. as with countries at differing levels of technological maturity)
Social risk	• Widening the digital divide between different parts of society • Changing the nature of the social contract (e.g. as a result of access to data on people) • Addressing security and privacy risks through a combined approach of government policy, best practice operational procedures and technological solutions
Environmental risk	• Impact on energy cost and footprint due to more data being collected, processed and stored • Impact on mining of scarce resources (e.g. batteries requiring lithium) • Impact on pollution (e.g. in the case of ride sharing or e-waste production)

7. Conclusions and next steps

The adoption of InfraTech will not happen immediately, but instead will require the continued commitment of governments, private sector participants and the international community. This InfraTech Stock Take (and accompanying work undertaken by the G20 IWG and World Bank) is only the beginning of an ongoing journey and collaboration with the global infrastructure community to share insights and facilitate delivery of the InfraTech objectives.

The GI Hub interactive use case library – The InfraTech use case library is a living resource, and the GI Hub is committed to the ongoing collection and dissemination of InfraTech use cases. The GI Hub will produce an interactive, online tool that will be publicly available and hosted on the GI Hub's website. This tool will enable the infrastructure community to better understand digital use cases, the technology's benefits and create a bias towards action.

InfraTech beyond 2020 – The use case library will spark a discussion around use case prioritisation and begin the journey towards technology trials and full-scale adoption. The GI Hub will facilitate continued collaboration and engagement between countries, MDBs, private investors and industry to share knowledge and maximising the positive impacts of InfraTech investment according to country conditions.

8. Table of Use Cases

The following section provides an overview of each use case, categorised by sector, technology type and in line with the draft InfraTech Agenda's 'Elements' which are intended to be a non-binding guide to countries in the adoption of InfraTech. There are six Elements to adoption identified by the draft InfraTech Agenda:

- **Element 1**: Leverage InfraTech to enhance economic efficiencies and mobilize private sector investment to promote fiscal and debt sustainability
- **Element 2**: Promote technologies that foster inclusivity, sustainability, resilience and sound governance
- **Element 3**: Accelerate innovation and economic dynamism to support economic recovery and growth
- **Element 4**: Foster a robust in-country data ecosystem to improve resilience and better inform infrastructure planning, operation, maintenance, and investment decisions
- **Element 5**: Develop agile and flexible policy tools that promote potential growth, productivity and innovation while mitigating risks
- **Element 6**: Promote international cooperation in R&D and knowledge sharing

The 41 use cases are broken down below by Element. The full details of each use case are presented following the summary table.

Element 1: Leverage InfraTech to enhance economic efficiencies and mobilize private sector investment to promote fiscal and debt sustainability

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Intelligent process optimization for water treatment	AI driven data analytics to treat water to a better standard and reduce operational costs by up to 10%	Water	Analytics AI augmentation Digital twins	• Createch360 usage in Brembate wastewater treatment plant, Italy • Emagin HARVI usage in the City of Calgary in Canada	✓
Automated pre-fabrication of stainless steel pipelines	Automation of labor-intensive pre-fabrication processes to reduce time, costs, waste and enhance worker safety	Water	Construction automation	• K-TIG usage in The Acueducto Gran San Juan project, Argentina	✓
Automated robot cranes for Ports	Automation of crane operations in ports to reduce the operational costs and increase capacity while also providing a safer working environment	Transport	Sensors Cameras/CCTV IoT	• Automated Container Terminal in Shanghai, China • Automatic Stacking Cranes in Port of Brisbane, Australia • Neo-Panamax ship-to-shore cranes at the Victorian International Container Terminal in Melbourne, Australia	✓
Sensors and Robotics for Bridge Maintenance	Sensors, robotics and special dehumidifying system to reduce bridge maintenance costs and increase the asset life of bridges ** This use case is a contribution from the D20 Long Term Investors Club*	Transport	Sensors Analytics IoT Construction automation	• Genoa bridge over Polcevera river, Italy	
Electronic Tolling	Electronic tolling technologies to optimize transport efficiency and increase toll revenues ** This use case is a contribution from the D20 Long Term Investors Club*	Transport	Cameras/CCTV Analytics IoT	• DarsGo electronic tolling system, Republic of Slovenia	✓
Dynamic Road Pricing	Dynamic pricing to optimize traffic flows, enhance revenues and reduce congestion ** This use case is a contribution from the D20 Long Term Investors Club*	Transport	Cameras/CCTV Analytics IoT	• Dallas-Fort Worth region highways, North America • Stockholm Dynamic Congestion Zone, Sweden	
Satellite Based Navigation to Optimize Traffic Flows	The use of GPS and other technologies to track and guide public transport to enhance its safety and efficiency ** This use case is a contribution from the D20 Long Term Investors Club*	Transport	Communications Analytics	• RNIS real-time control system in the Moscow Region, Russia	
Predictive maintenance of physical assets	Sensors and data analytics to monitor assets and predict maintenance requirements, thereby reducing operational costs and extending the life of assets	All	Analytics	• Data61 pipe failure prediction in Sydney, Australia • Voda AI software for pipe monitoring in Florida, USA • Movus machine condition monitoring in Brisbane, Australia	✓
Knowledge access platforms for construction and maintenance	Digital knowledge platforms and devices to create a single 'source of truth' for construction data, thereby increasing efficiency, reducing costs, minimizing waste and providing safer working environments	All	Analytics Wearables Distributed ledgers	• Hindsite knowledge management platforms in Sydney and Melbourne, Australia • RedEyeDMS platform in Southern Nevada, USA	
Augmented and Virtual Reality for Training and Inspection	Utilizing the latest visualization technologies to enhance worker training and provide greater access to information on	All	Analytics IoT	• AR for safety inductions at the Sydney Metro, Australia	✓

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
	the job to enhance safety, increase productivity and reduce costs			• Headsets for bridge inspections in Cambridge, UK	
3D printing for Maintenance	On-site 3D printing facilities for rapid response to maintenance requirements at a reduced cost	All	IoT	• Stratasys' Rail Industry Solution • Deutsche Bahn, Germany • Chiltern Railways, UK	
Smart Cities-as-a-Service	Smart Cities-as-a-Service and Platform-as-a-Service models to replace traditional vertical chain models in favor of more efficient, scalable and interoperable architecture based on microservices to optimize and maximize the provision of existing public services and goods ** This use case is a contribution from the Government of Italy*	All	Sensors IoT Analytics Communications Distributed ledger	• Smart Ivrea Project for Agency for Digital Italy (AgID), Italy	
Heritage Recovery with 3D Printing	Using advanced 3D scanning and printing to totally or partially replicate heritage pieces ** This use case is a contribution from the Government of Spain*	All	Construction automation	• Replica of "The Bear & Strawberry Tree" in Madrid, Spain • Replica of Romanic Arc "Arco de San Pedro de Las Dueñas de Leon" in Madrid, Spain	
Used cooking oil and grease trap waste converted to biodiesel	Innovative grease trap collection technique to reduce build-up of fats, oils and grease in sewer networks and reduce maintenance costs, while providing alternative sources of fuel for renewable energy	Water, Energy	Treatment	• PumpFree Energy in Sydney, Australia • Argent Energy in Europe	

Element 2: Promote technologies that foster inclusivity, sustainability, resilience and sound governance

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Low greenhouse gas emission wastewater treatment	Monitoring technologies to better track and reduce greenhouse gas emissions, estimated to contribute 26% of the greenhouse gas emissions of the water supply chain	Water, Waste	Sensors IoT Analytics Treatment	• Cobalt Water N2O modelling in the Netherlands • Organics thermal ammonia stripping in Hong Kong SAR, China • Cranfield University nitrogen and carbon removal in the UK	
Last mile infrastructure for water provision in developing countries	Inexpensive decentralized digital water supply, metering and payment kiosks to deliver inclusive access to clean water	Water	Sensors	• UNTAPPED PAYG smart meters in Malindi, Kenya • CityTaps pre-paid water meters in Niger	
Water Height and Flood Management System	Real-time collection and analysis of flooding data to enable targeted responses and predict future conditions to support governments to build more resilient infrastructure	Water	Sensors Analytics IoT	• Maeslant Storm Surge Barrier, the Netherlands • WaterNSW Water Monitoring Network, Australia • Oxford Flood Network, UK	✓
Smart AI-based waste management in stations	Robots embedded with AI to collect rubbish and clean transport hubs, including by spraying vaporized Hydrogen Peroxide to improve train hygiene standards during pandemics	Waste	Cameras/CCTV	• Whiz Cleaning Robot, Japan • 'BARYL' Smart Waste Bin, SNCF, France • Deep Cleaning Robots, Hong Kong SAR, China • Neo Floor Cleaning Robot, Canada	✓
Demand Responsive Transport	Public transport options which respond to the specific needs of users to enhance service delivery	Transport	IoT Transport mode	• MOIA Hamburg • Kutsuplus, Helsinki • Beeline Singapore	

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
AI for Disease Outbreak and Pandemic	AI and thermal cameras to more efficiently and safely detect people displaying symptoms of illness to enable a tailored response to pandemics to minimize community and economic disruption	Transport	Cameras/CCTV Analytics	• Baidu's AI Tool, China • DJI Temperature Screening Drone • iThermo Tool, Singapore	✓
Smart Street Lighting	Sensor technologies to adjust lighting to respond to public needs, optimize energy usage, reduce traffic accidents and create a safer environment for pedestrians	Transport	Sensors Cameras/CCTV IoT	• Barcelona Lighting Masterplan, Spain • Shanghai Smart Lighting, China • Tilburg Smart Philips Streetlights, Various Countries	
Drone for Monitoring, Surveillance & Inspection	Pilot driven and autonomous drones to undertake otherwise dangerous and time-consuming tasks, such as inspecting operational network assets, to reduce costs and keep workers out of harm's way, particularly during times of pandemic	All	Sensors IoT	• Pedestrian Monitoring Trial, Yarra Trams, Australia • Dedicated Freight Corridor (DFC), India • Network Performance Improvements, SNCF, France	✓
Augmented and Virtual Reality for Planning and Design	Utilizing the latest visualization technologies to enable members of the community to experience a proposed design or concept in a real-life environment to help to garner feedback and shape ongoing policy and planning agendas	All	Analytics IoT	• Cross River Rail (CRR) Experience Centre, Australia • Sydney Metro, Australia • Uppsala Virtual City, Sweden	

Element 3: Accelerate innovation and economic dynamism to support economic recovery and growth

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Transition to Electric Vehicle Transport Networks	Governments transitioning to electric vehicles fleets to advance the technology, reduce greenhouse gas emissions from cars and provide cleaner more livable cities	Transport	Transport mode IoT	• Quebec Public Transit Electrification, Canada • Paris RATP And IDFM Electric Bus Plan, France • Heliox Fast Charging Stations, Luxembourg	
Hyperloop	Development of hyperloop technology to with the aim to provide a fast and affordable form of ground transport between city centers	Transport	Transport mode IoT	• Virgin Hyperloop One, Various Countries • Hyperloop Transportation Technologies, India • Hyperloop Alpha, USA	
Unmanned Aerial Vehicles for Passenger Travel	Development of unmanned aerial vehicle technology aimed at providing alternative transport modes, reduce travel times and reduce road congestion	Transport	Sensors Cameras/CCTV Transport mode	• CityAirbus, Various Countries • Volocopter in Germany and Dubai • Ehang 184 in China	

Element 4: Foster a robust in-country data ecosystem to improve resilience and better inform infrastructure planning, operation, maintenance, and investment decisions

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Smart Metering	Real-time monitoring of water usage to reduce water loss and enhance operator revenue sources, as well as better utilize scarce water resources	Water	Sensors Analytics	• Suez smart metering, Singapore	

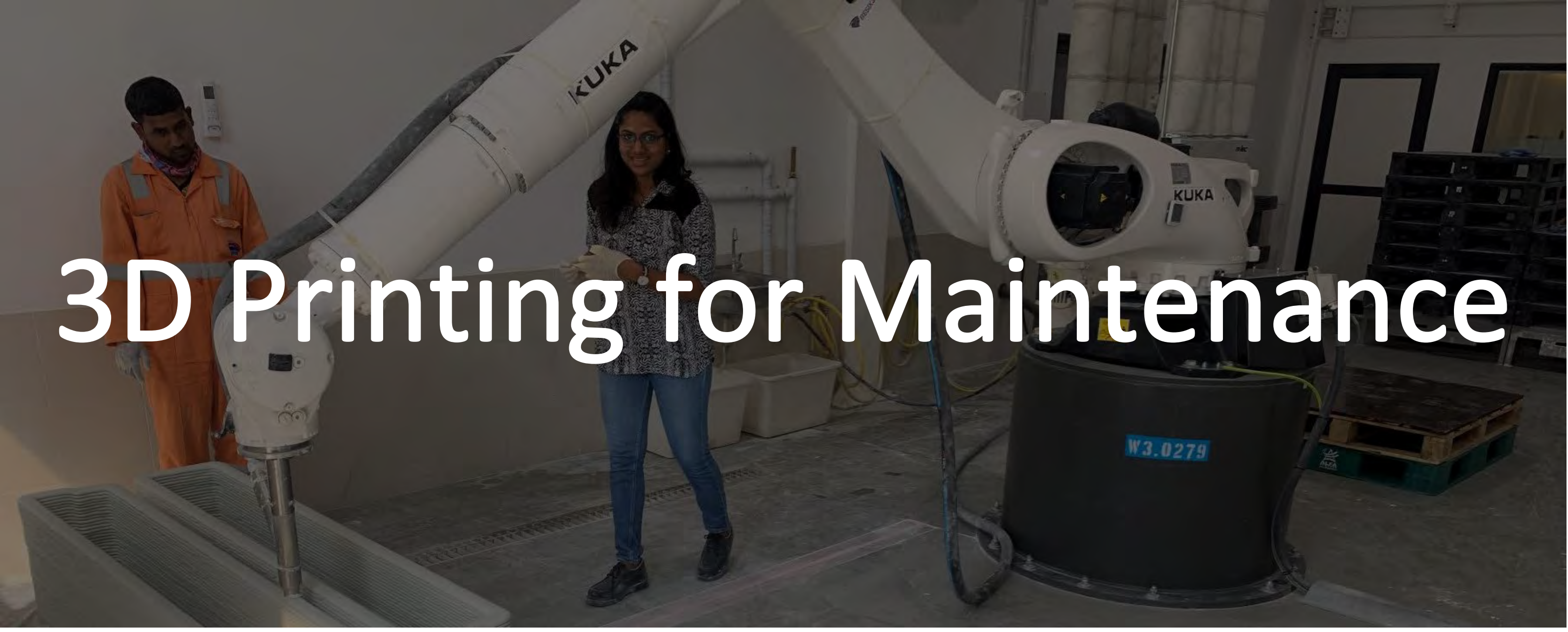
Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Remote monitoring for algae risk in water bodies	Drones and satellite technology with advanced risk modelling techniques to better manage algae risk in water, reduce water treatment costs and enhance water quality	Water	Analytics	• Cyanolakes EONEMP project in South Africa • NASA early warning system, USA	✓
Smart Parking Infrastructure	Sensors and communications devices to better utilize parking spaces and support drivers to leave roadways faster, reducing up to 30% of traffic volume, to reduce congestion	Transport	Sensors Cameras/CCTV Analytics IoT	• SFpark Smart Parking Pilot, USA • Intelligent Search for Parking Spaces Pilot, Germany • AppyWay Smart-Parking Scheme, UK	
Real-time Traffic Management	Sensors, connectivity technologies and data analytics to better manage traffic flows to optimize road assets and reduce congestion	Transport	Sensors Cameras/CCTV Communications	• Active Traffic Management Approach, UK • LTA Intelligent Transport Systems, Singapore • The Urban Lab Dynamic Traffic Forecasting, Spain	
Weather and Pedestrian Sensors	Sensor technologies to better track movement of pedestrians and real-time weather conditions to reduce accidents and optimize traffic flows	Transport	Sensors Cameras/CCTV Analytics	• Smart Crossing Trial, Australia • Pedestrian Recognition IoT, Finland • Starling Crossing, South London, UK	
Electric Vehicle Charging Cloud Platform	A cloud platform for scaling up of EV charging operations and managing wide charging networks more efficiently to lower costs and improves operational efficiency ** This use case is a contribution from the D20 Long Term Investors Club*	Transport	Sensors Communications Analytics IoT	• Allego system, Netherlands	
AI-enhanced Digital Maritime Logistics Platform	Advanced digital platforms to improve data flows between stakeholders to optimize port assets and increase speed and reliability of delivery of goods ** This use case is a contribution from the D20 Long Term Investors Club*	Transport	Sensors Communications Analytics IoT	• Calista supply chain platform, Singapore and Belgium	
Digital Service Platform for Transportation Hubs	Connectivity technologies, cloud computing and data analytics to create operational efficiencies in transport hubs. ** This use case is a contribution from the Government of China*	Transport	Communications Analytics	• Beijing Daxing International Airport, China	
Digital Twins	The integration of data including real-time sensor data to better visualize and optimize assets, ensure continuity of services and make well-informed new investment decisions	All	Digital twins	• SNCF Digital Twin, France • Tamba City, Hyogo Pulp factory, Japan • Singapore Digital Twin, Singapore	
Smart Sensing System for Water Service and Urban Mobility	A data collection system to provide decision makers with key data, such as flow of people and water consumption and quality to improve government planning and management capabilities ** This use case is a contribution from the Government of Italy*	All	Communications IoT Distributed Ledger Analytics	• Smart, Secure, Reliable and Distributed Monitoring through 5G, University of Cagliari, Italy	
Digitizing water access data for regulatory use	The collection of water access data for regulation (i.e. compliance and enforcement) can be kept cybersecure through a system that is designed with security from end to end. The solution includes metering, logging, transfer of data, collection and ingestion in data storage and visualization of the data. All these components require cybersecurity elements to minimize risk at vulnerable locations and ensure the system works as intended.	Water	Sensors Communications Analytics IoT	• NSW Dept of Planning Industry and Environment, Australia	

Element 5: Develop agile and flexible policy tools that promote potential growth, productivity and innovation while mitigating risks

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Mobility as a Service	Digital platforms which integrates end-to-end trip planning across transport modes with payment methods to provide an enhanced service to users and improve transport access	Transport	Sensors Communications Analytics IoT	• Whim, Finland • MinRejseplan, Denmark • NaviGoGo, Scotland	
Smart Containers	Containers enabled with sensors to track shipping deliveries and ensure goods can be quickly processed through ports with fewer losses of cargo and the containers can be updated as the technology develops	Transport	Sensors IoT	• Silk Road Intelligent Shipping Containers • Port of Rotterdam Pilot, Netherlands • Mediterranean Shipping Co.	
Decentralized Microgrids and Peer-to-Peer Energy Transactions	Distributed ledger technologies to enable peer to peer electricity transactions, reduce transmission and distribution costs and create greater reliability of electricity networks	Energy	Analytics	• Brooklyn Microgrid, USA • Bangkok T77 Precinct, Thailand • Hackney, Banister House Estate, UK	

Element 6: Promote international cooperation in R&D and knowledge sharing

Use Case	Description	Sector	Technology Type	Case Studies and Locations	Relevant to COVID-19 Response?
Vehicle to Vehicle (V2V) Connectivity	Utilization of data and connectivity between vehicles to avoid accidents and optimize traffic flows, where common standards for interoperability is essential	Transport	Sensors Communications IoT	• Queensland CAVI Program, Australia • CETRAN Singapore • Nevada trials, USA	



3D Printing for Maintenance

DETAILS

SECTOR | Transport, Energy, Water and Waste

STAGE | Project Design and Construction; Operations and Maintenance

TECHNOLOGIES | 3D Printer, 3D Scanner, Material Technology

SUMMARY

A 3D printer is a machine that can create a physical three-dimension object based on a computer-aided design (CAD) model. The process is usually done by extruding material (in molten form) through a nozzle that moves around precisely under computer control. The material is added layer by layer until completion. 3D printing was first developed in the 1980s as a cost-effective method of creating prototypes for product development. From the mid-2000s, 3D printers began to diversify, with new uses geared towards part production for high value, highly engineered, and complex parts.

3D printing can be used in many sectors. It can enable the creation of entire pieces of infrastructure, such as the MX3D Bridge in Amsterdam, or printers in factories can enable pieces of infrastructure to be prefabricated off site and transported to the construction site for modular construction (*see also the Prefabrication and Modular Construction use case*). However, the relative immaturity of the technology today means that 3D printing in the short term is more frequently used to assist in manufacturing specialist components than completely replace traditional construction techniques.

Where limitations in the complexity of traditional infrastructure design and construction exist, 3D printing has the potential to enable more design freedom and rapid and cost-effective formulation of parts. 3D printed components can also improve construction safety by minimising worker participation in the manufacturing of components.

The main focus of this use case is on using 3D printers to produce individual components on-site to allow for a fast response to maintenance requirements. For example, on-site printers in railway maintenance facilities can enable the rapid production of parts (e.g. chair armrests for trains) to replace faulty parts and allow a train to re-enter service. This on-demand 3D printing style is increasingly being adopted in public transport maintenance facilities, such as those operated by Bombardier, Siemens Mobility and Deutsche Bahn.

It has been estimated that on-site 3D printing can reduce the manufacturing time of spare parts by up to 95%[1] compared to traditional external part sourcing and manufacturing methods[2]. It provides a level of flexibility to operators, who can create and replace parts on-demand without relying on delivery from external suppliers and minimizes the need for operators to keep spare parts in a stockpile. Instead a digital inventory can be created that will reduce costs associated with holding physical parts (e.g. storage space and the high prices of spare

[1] "Application Spotlight: 3D Printing in the Rail Industry", AFMG, Accessed 20 May 2020.

[2] "3D Printers", Chris Woodford, Accessed 8 May 2020.

parts) and delays associated with long lead times. Thus, a more agile supply chain is created. 3D printing could also enable obsolete or discontinued parts to continue to be produced, potentially extending asset life spans.

With improved precision and quality, 3D printing can minimise the cost associated with human errors. Errors can be identified and corrected within the CAD model prior to printing. It is estimated that 3D printing can reduce the price of objects by 20% to 25%, the cost of materials by 25% to 30%, and the labour required by 45% to 55%[3].

The use of 3D printing in the infrastructure sector is expected to mature further through ongoing research and development. For example, in Dubai the market for 3D printing is expected to be USD $300 billion by 2025 with 25% of Dubai's buildings to be 3D printed by 2030[4]. Furthermore, by combining 3D printing technology with artificial intelligence and autonomous robots, printing can occur with minimal human interaction.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce the time required to obtain spare parts by up to 95%[5] and enable vehicles/machines to return to service faster thereby reducing the cost associated with their downtime.
- Reduce cost to produce spare parts by decreasing the costs associated with materials and labour.
- Eliminate the need for a physical stockpile of spare parts by building a virtual inventory thereby enabling the repurposing of stockroom space and reducing the cost associated with purchasing spare parts in advance due to long lead times.

Enhancing economic, social and environmental value:

- Improve the precision and quality of components, ensuring parts are produced identically each time and improve the standardization of component production, including time to produce, therefore enabling better maintenance planning and scheduling.
- Improve safety by enabling the remote control of printers thereby eliminating worker handling of components during formulation and decrease material waste by minimizing errors.
- Enable flexibility in design especially in the use of spheroid or hyperbolic shapes.

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments should develop regulations for 3D printing that outline the minimum standards for operation and quality, testing and maintenance of equipment and product testing to ensure safe use.

Transition of workforce capabilities: For transport operators 3D printer terminals are best placed on-site at maintenance facilities. This will enable rapid on-demand production of components in response to the malfunction or failure of parts. Therefore, on-site staff will need to be trained on the use and upkeep of the equipment.

Funding and financing: Most implementations of 3D printing are taking place in the private sector, however there are clear uses for it in the public sector, such as for public transport operators. Funding can therefore be public or private.

Procurement and contract management: Any contract with the transport operator should identify the requirements around 3D printer equipment testing, to ensure ongoing performance. It should also include testing of parts produced to ensure they meet a quality standard and are safe for use.

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[3] "Contour Crafting: Automated Construction", TEDxOjai, Behrokh Khoshnevis, Accessed 10 May 2020.
[4] "Dubai 3D Printing Strategy", Dubai Future Foundation, Accessed 8 May 2020.
[5] "Application Spotlight: 3D Printing in the Rail Industry", AFMG, Accessed 20 May 2020.

IMPLEMENTATION

Ease of Implementation 	To implement this method of manufacturing, operators would need to select a 3D printer supplier and set up a new supply chain for materials. A digital inventory of parts would need to be developed based on existing designs. In-house staff would require training to operate the machine and new operations processes would need to be defined. Maintenance of the machine would be performed by the supplier, enabling updates of the technology as its advances. Testing of the new parts should ensure their quality and safety for the specific purpose.
Cost 	3D printers can be purchased outright or leased from suppliers. The initial investment to purchase printers is relatively high, with printers ranging from USD 6,000 to USD 200,000 depending on size and functionality. 3D printers are decreasing in cost as they continue to be developed. To roll them out across multiple sites would require significant investment. However, 3D printers can reduce the operational cost of maintaining assets, through reducing the cost of materials and labour, and reducing the time to produce and therefore replace a part, enabling an asset to return to service faster.
Country Readiness 	Today, 3D printing is used by many transport operators in developed countries including Bombardier Siemens Mobility and Deutsche Bahn. It is increasing in popularity due to its demonstrated time and cost savings, and as assets get older it becomes increasing difficult and expensive to source replacement parts from suppliers. For developing countries, the cost to procure 3D printers may be disproportionate to the cost of having assets out of service, or too costly. Collaborations with researchers and technology suppliers could be investigated to determine a suitable leasing style model.
Technological Maturity 	While there are some 3D infrastructure printing projects that have been done around the world (Amsterdam, Dubai), the technology is not mature enough yet for them to be widely used to produce entire assets. Further research and development are needed. However, to produce components, the technology has been readily tested.

RISKS AND MITIGATIONS

Implementation risk

Risk: 3D printers require high amounts of energy, which will increase demand on the energy grid and potentially increase energy costs for the operator. Additionally, the types of materials that can be used in 3D printing are limited, thereby limiting the choices of materials that can be used. In some circumstances, 3D printing would not be suitable.

Mitigation: 3D printing technology is continuously advancing, and new materials can be used such as metals. Similarly, energy consumption is being reduced. To cope with the increased energy demand, operators should develop a sustainability plan that outlines their solutions to minimise energy consumption and managing demand. For example, a dedicated energy source (e.g. solar) could be implemented to power the 3D printer and reduce its effect on the energy grid.

Social risk

Risk: By introducing 3D printing, the technology will minimize the need for workers to produce components. This could lead to a need to transition workers to complete different tasks.

Mitigation: Employees should be retrained to work with the 3D printer and perform services/maintenance on the equipment or redeployed to other activities. Improved production capacity from 3D printing can be used to increase output.

Safety and (Cyber)security risk

Risk: 3D printing is based on a computer-based system. There is, therefore, a risk that data could be hacked as a result of cybercrime or sabotage. Designs could be altered which would present a risk if undiscovered, as the parts could be installed into an asset and potentially cause accident or injury.

Mitigation: Organizations must ensure their systems are robust to eliminate the threat of cybersecurity. Furthermore, governments should set legislative frameworks to outline the requirements of these systems to repel cybersecurity attacks and protect data.

Environmental risk

Risk: 3D printers consume large amount of energy when melting plastic or other materials with heat or lasers. They can potentially generate toxic emissions and carcinogenic particles according to research at the Illinois Institute of Technology[6]. This could pose a risk to workers and the surrounding community and environment.

Mitigation: Appropriate measures should be taken to protect workers from these fumes, and ensure they are not allowed to be released into the environment. 3D printing should be performed in a dedicated on-site location, with ventilation and air purifying systems installed. Workers should be required to wear appropriate personal protective equipment to reduce their risk.

[6] "Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments", Illinois Institute of Technology, Accessed 8 May 2020

EXAMPLES

Example	Implementation	Cost	Timeframe
Stratasys' Rail Industry Solution	3D printers used to produce spare parts for trains. The company has established partnerships with Angel Trains, Bombardier Transportation, Chiltern Railways, Siemens Mobility and DB ESG, who have found additive manufacturing to be an ideal solution for producing spare parts for trains on demand.	According to Stratasys an operator can spend €18,000 every day a train is out of service. Often, it is a part worth less than €100 that is the cause of disruptions. 3D on-demand printing can minimize the time that train is out of service.	3D printing can reduce the time to obtain a spare part by up to 95%.
Deutsche Bahn	Deutsche Bahn (DB) is primarily using 3D printing for maintenance purposes and has printed more than 6,000 parts covering 110 different use functions for its range of high-speed trains.	In one example, DB printed replacement tube fixtures for display lights used in the train's electronic onboard information system. The project took one month with total manufacturing costs 80% lower than traditional injection moulding.	In September 2016 the company founded the Mobility goes Additive network to facilitate collaboration between companies, institutions, and researchers involved in the 3D printing and mobility space.
Chiltern Railways	The cross-industry collaboration between Angel Trains, DB ESG and Stratasys who have partnered to 3D print replacement parts for trains.	The lead time for armrests using conventional manufacturing methods is four months. Using 3D printing, the armrest can be manufactured within a week, decreasing the lead time by 94%, with possible savings of up to 50% per part.	First announced in December 2018. Trials began in September 2019.

AI for Disease Outbreak and Pandemics

DETAILS

SECTOR | Transport
STAGE | Operations and Maintenance
TECHNOLOGIES | Artificial Intelligence, Thermal Camera, CCTV

SUMMARY

Artificial Intelligence (AI) is technology that powers machines using human-like intelligence. AI-enabled machines can mimic humans, automate manual tasks and learn like humans. These machines are increasingly being used alongside biometrics. Together these systems are being used during disease outbreaks and pandemics to detect people displaying specific attributes, such as high temperatures to indicate fever. These systems can be used at a multitude of places where people congregate – including railway stations, hospitals and municipal buildings.

These systems scan about 200 people per minute, calculating their forehead temperature from up to three metres away. They can accurately detect temperature even when people are wearing masks, hats, or covering their faces. The system will generate an alert when it detects a high temperature that will prompt staff to carry out secondary checks.

Biometric technologies of today are typically used to authenticate and identify individuals (e.g. the passenger screening process at an airport or the fingerprint-scanning button of a smartphone). Now, in response to major country-wide or global disease pandemics such as Coronavirus (COVID-19), governments are deploying such technologies to identify infected persons and curtail the spread of disease. Several devices have been trialled across China and Singapore, targeting built up areas including public transport, in response to COVID-19.

With the global outbreak of COVID-19, countries are looking for unique ways to utilise technology to minimise the spread of the disease. To avoid enforcing mass quarantine on their citizens, governments are seeking ways to enable their citizens to continue moving around their regions to maintain as much normality to life as possible.

The initial means of achieving this was to implement manual thermometer testing in common areas for mass congregation of people, such as railway stations. This led to major queues in accessing these areas due to the time-consuming nature of the process. Such devices can only measure two to three people per minute and put front-line testers at risk of contracting the disease.

Alongside the increasing movement to automation and the growing sophistication of AI human intelligence, repetitive and time-consuming tasks will increasingly be undertaken by AI. What's more, AI-powered systems exhibit human intelligence and learn with time, which indicates that these machines can eventually carry out critical-thinking jobs and take decisions by themselves. For example, Baidu Maps is providing information on infected cases through data to track population migration and predict the spread of the pandemic in China.

VALUE CREATED

Improving efficiency and reducing costs:

- Enable the targeted identification of health issues and a tailored response to minimise community and economic disruption
- Increase testing rate as traditional forehead thermometers can only measure two to three people per minute, while AI devices can measure hundreds of people per minute
- Cheaper and more portable than high-end screeners deployed at airports
- Reduces number of on-site monitoring and testing staff thereby freeing up skilled resources to work elsewhere

Enhancing economic, social and environmental value:

- Improve identification of infected persons, enabling reduction in spread of the virus or disease
- Reduce disruption to the local economy by enabling, for example, the continuation of infrastructure usage and infrastructure projects
- Improve safety for staff where devices are deployed as they are only required to perform secondary testing and have less and shorter contact with the public
- Minimise anxiety and disruption brought about from long testing queues at busy locations
- Proactivity and reliability in the tools and modelling behaviours, as the situation evolves it is key to prevent social anxiety

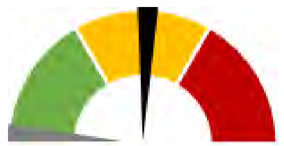
POLICY TOOLS AND LEVERS

Legislation and regulation: Local authorities and transport agencies should develop a response plan for secondary testing and the subsequent processes to be followed when an alarm is triggered. These processes should reduce the potential for spread to passers-by and staff and should minimise anxiety. Data privacy legislation will need to be considered, which will vary by country. It is key that governments communicate with their citizens to explain these technologies and their benefits.

Effective institutions: Safety education should be developed. This should establish self-protection guidelines and increase awareness of risk prevention. Authorities should consult with health partners and scientists about evidence-based support and required outcomes and conditions to meet for prevention of infection in public places. These outcomes will thus generate the right objectives and can then be translated into performance specifications for the AI solution’s development.

Transition of workforce capabilities: To effectively develop and implement these solutions, authorities will need to add pandemic requirements to their business case framework as well as digital programming and engineering support to translate those pandemic requirements into solution specifications. This will require inputs from health specialists and researchers.

IMPLEMENTATION

Ease of Implementation 	During the COVID-19 pandemic, many countries were able to innovate quickly to develop or adapt technologies to fight the spread of the disease. Governments should position themselves to act quickly to enable technologies (temperature screening, drones, robots, AI) to be implemented in new ways. Going forward, there are opportunities to integrate these same technologies into existing and developing infrastructure so that they can be immediately utilized when similar public health emergencies occur.
Cost 	The costs of development, implementation and operations of such AI solutions is low but relies on the availability and level of accuracy of the relevant data captured by technologies implemented on the network.
Country Readiness 	More developed countries will be able to implement these technologies quickly in response to such emergent situations. Existing data and communications infrastructure will readily enable the collection and analysis of data. Mature health care systems and researches will provide support to technology developers to ensure solutions are robust and accurate.
Technological Maturity 	CCTV and temperature screening technologies are today mature. However, the algorithms used in AI to calculate the level of heat would need to be adapted according to the specific country and disease requirements. There is no significant difference between the accuracy of temperature measured by iThermo tool and clinical forehead thermometers, with respective margins of error within 0.3 degrees Celsius / 0.05 degrees Celsius.

RISKS AND MITIGATIONS

Implementation risk

Risk: One of the biggest problems with scanning for temperature or fever conditions is how far away people are from the device. Taking ambient temperature into account is also necessary to avoid faulting the detection. If people come from outside, they will appear hotter.

Mitigation: Further modification of the software could be required to enable it to consider changes in temperature based on distance. The AI system can learn what the compensation should be as the person approaches nearer and nearer and how to measure ambient temperature and take that into consideration.

Social risk

Risk: Due to the growing complexity of machine learning, and the potential for human biases to influence the system, it can be difficult to understand how AI systems produce their results. It can be difficult to determine who is held responsible for when the system outputs go wrong: Is it the responsibility of the developer, tester or product manager?

Mitigation: Organizations must include internal and external checks to ensure equitable application across all participants and ensure that data and algorithms minimize discriminatory bias and avoid pitfalls introduced by humans during the coding process, to ensure there are no unintended or unfair consequences for users. Organizations should also make algorithms, attributes and correlations open to inspection so that participants can understand how their data is being used and how decisions are made.

Safety and (Cyber)security risk

Risk: There is a risk that users will reject the technology due to perceived or real threat that that data will be used for other purposes, or that there is a cybersecurity risk. People are particularly reluctant to share their health-related information.

Mitigation: Data privacy and cybersecurity considerations vary from country to country. This technology is designed to log the volume of traffic, timestamps, and temperatures and send these to a cloud-based system that can report the rate of traffic and number of fevers detected. The use case is not designed to capture other specific personal data and the relevance of the movements' analysis and the protection of people's identity should not be compromised by its processing in the application. The application should also be protected using the same proven and robust techniques and technologies commonly employed by high traffic commercial websites and includes data encryption, specific workflow to process and validate the data integrity and restricted user access.

Governments can also educate their citizens on the use of the data and prove that it will not be used to track citizens beyond the specific use case.

EXAMPLES

Example	Implementation	Cost	Timeframe
Baidu's AI Tool, China	Baidu introduced their systems at transport hubs in response to a call to improve temperature monitoring in the city in response to COVID-19. Baidu's system can detect the temperature of moving masked people with a margin of error of 0.05°C.		The tool was developed from an existing Baidu tool and therefore was able to be developed quickly in response to the pandemic.
DJI Temperature Screening Drone	DJI adapted their existing drones, designed to monitor temperature fluctuation in industrial environments, to accurately measure fever in humans remotely. The drone is fitted with a FLIR Lepton thermal micro camera. A cotton swab was used to improve the cameras accuracy for human use. The drones were also used to spray disinfectant on to infrastructure (e.g. roads).	DJI pledged USD 1.5 million in aid to help contain the COVID-19 outbreak.	Minimal time required to develop, as DJI repurposed their existing drones to meet the public health requirements of the pandemic e.g. the existing Agras series of agricultural spraying drones was adapted to spray disinfectant in potentially affected areas.
iThermo Tool, Singapore	The Integrated Health Information Systems (IHiS), partnered with local healthcare AI startup KroniKare to pilot iThermo: an AI-powered temperature screening tool used to identify people showing symptoms of fever, in response to COVID-19.		KroniKare ramped up production to ensure 100 units of the device would be developed within a month of the pilot being agreed (February 2020).

AI-enhanced Digital Maritime Logistics Platform

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Global supply chain digital platform to enhance maritime logistics

SUMMARY

In today's complex global supply chain, a number of inefficiencies constrains the physical flow of goods due to asymmetrical or erroneous information flow, compliance and regulatory issues, lack of data standardisation as well as financial risks. Port operators stand in the middle of a highly fragmented maritime supply chain including factories, warehouses, logistics service providers, freight forwarders and customs.

Digital platforms are developed to facilitate trade and help shippers to better manage the physical movement of goods, trade financing and compliance. Taking advantage of advanced digital technologies, these platforms aim at reducing inefficiencies for the global supply chain by interacting with systems and applications (existing and new) of various stakeholders. They help streamline processes, documents and data in the flow of goods within and across countries and regions. Stakeholders benefit from the reduction of data duplication, automated handshakes across nodes, improved authenticity of data flow and access to accurate and up-to-date status visibility.

These digital platforms can also be powered by Artificial Intelligence, hence adding a number of services in terms of supply chain orchestration including providing users with insights on route options, free trade agreements, import, export formalities and other value-added services. By collating and analysing real-time data to devise the ideal trading strategy, these features broaden the platform's benefits for the clients, as well as for the terminal operator. They provide to the clients optimised freight options based on budget, preferred timeline and modalities, while also providing updates of cargo status and movement. They provide to the terminal operator increased fluidity in the management of its complex yard operations.

VALUE CREATED

Improving efficiency and reducing costs:

- Optimize use of ports' and associated logistics stakeholders' assets by optimizing cargo routes
- Boost supply chain efficiencies by better matching supply and demand, improve tracking and streamline transactions
- Provide operational data, valuable analytics for business and operational insights
- Increase speed and reliability of delivery of goods (current average schedule reliability of ocean carriers below 75%)
- Customer satisfaction (82% feel the level of connectedness and visibility needs to be improved)

This use case is a contribution from the D20-LTIC (Long Term Investors Club) together with the LTIIA (Long Term Infrastructure Investors Association) , with some adaptations from the Global Infrastructure Hub.

Enhancing economic, social and environmental value:

- Optimization of utilization of heavy and energy-intensive assets
- Enhancement of multimodal supply chain, reducing trucks usage
- Environmental criteria included in AI engine for optimal supply chain strategy, reducing human bias
- Decrease of logistics and inventory buffers
- Limit loss or waste of food (USD 460Bn worth of food value lost through logistics inefficiencies per year globally)

POLICY TOOLS AND LEVERS

Legislation and regulation

Ports are pivotal parts of multi-modal supply chains which cannot be designed in isolation, and not without factoring in a country's overall supply chain and logistics system and the links with its trading partners. This requires governments to develop and implement national digital vision within the global digital trade context and help their ports to get equipped to implement them. It requires ports to enhance the "traditional" thinking and prepare to attract digital talent

Singapore is a leading example of such government support to build a digital roadmap for the maritime sector:

- In April 2018, the Maritime and Port Authority of Singapore (MPA) announced a strategy to set the port on a digital path.
- Dr Lam Pin Min, Senior Minister of State, Ministry of Transport & Ministry of Health announced in April 2019 that the Singapore Maritime Institute (SMI) will prepare "the Singapore Maritime R&D Roadmap 2030 to optimize R&D efforts and resources for greater value co-creation within the maritime industry".

Effective institutions

Such digital platforms require the alignment of a number of stakeholders around on technical solution to ensure end-to-end efficiency and reliability. This includes private stakeholders such as freight carriers, terminal operators, market places and financial institutions, as well as public stakeholders such as governments and regional agencies, including customs agencies.

A future-enabled workforce

In many countries, the logistics industry, including the ports struggle to attract digital professionals and talent. Public support should include the development of a strong pool of digital talents specifically for the logistics industry (systems implementation and integration; maintenance and continuous development of the systems and tools).

EXAMPLE

Calista: PSA International Pte Ltd ("PSA") is partnering Global eTrade Services ("GeTS") Asia Pte Ltd, a fully-owned subsidiary of CrimsonLogic Pte Ltd ("CrimsonLogic"), in the development of a global common trade and supply chain platform called "CALISTA™" – an initialism for CArgo Logistics, Inventory Streamlining & Trade Aggregation – to facilitate trade and help shippers to better manage the physical movement of goods, trade financing and compliance. The system is operational in PSA"s flagship terminals of Singapore and Antwerp.

https://calista.globaletrade.services

This use case is a contribution from the D20-LTIC (Long Term Investors Club) together with the LTIIA (Long Term Infrastructure Investors Association) , with some adaptations from the Global Infrastructure Hub.

Automated Pre-fabrication

DETAILS

SECTOR | Water

STAGE | Project Delivery

TECHNOLOGIES | Robotics, Auto Cognitive, Modular Construction

SUMMARY

Novel welding processes and automated welding technologies are used in the pre-fabrication and construction phase of infrastructure projects. These technologies increase productivity and decrease production time by automating repetitive welding tasks, improving welding quality and consistency, and augmenting the skills of welders. New business models such as 'Weld-as-a-Service' are assisting in mitigating the high capital cost associated with automated welding technologies. Though this technology can be used in many infrastructure sectors, this use case explores its use in water related infrastructure such as pipes, tanks and treatment plants.

Typically, automated welding technologies are only used for sophisticated high throughput production facilities due to the high capital requirement. As costs for automation decrease and welding technology becomes more advanced, there are new opportunities to use automated welding in small and medium sized fabricators and production runs. Welding robots may be pre-programmed, guided by machine learning technology, or by a combination of the two methods.

In 2020, it is forecast that USD $70 billion will be spent on new pipes and USD $118 billion on construction and fabrication of water and wastewater infrastructure globally[1]. There is a large opportunity to reduce infrastructure costs through pre-fabrication from automated welding. Welding and fabrication are labour intensive industries in both developed and developing markets. Reliance on manual human welders can dramatically increase a fabricator's labour costs. This can have a negative impact on production costs for infrastructure projects. As with many skilled trades, there is a shortage of skilled and experienced welding operators in many markets. Automation can therefore fill the labour gap.

Automation saves time and costs on repetitive welds, increasing production efficiency. Robotic welding devices provide increased accuracy, repeatability, and throughput for fabricators with high volume applications enabling welders to concentrate on more complicated tasks. Lower costs can also assist to keep local and smaller small and medium enterprise fabricators competitive with larger fabrication companies.

Innovation with more complicated welds can enable prefabrication of more types of parts and further increase cost and labour savings. As the technology develops, the cost of automated welding will decrease even further which will continue to make it more accessible.

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[1] Global water market: breakdown by products Global Water Intelligence: Water Data. Accessed 25 April 2020

VALUE CREATED

Improving efficiency and reducing costs:

- Decreased labour costs and time of production while increasing output
- Increased quality of final product through increased quality, accuracy and consistency on repetitive and critical welds
- Improved welding efficiency results in less scrap metal and consumable gas and filler metal usage

Enhancing economic, social and environmental value:

- Assist onshore fabrication industries to be competitive with offshore fabricators
- Assist Small and Medium Enterprises (SMEs) to stay cost competitive with larger companies
- Decrease safety risks for workforce

POLICY TOOLS AND LEVERS

Legislation and regulation: Legislation to incentivise onshore fabrication of infrastructure can be considered to keep industries from going to offshore manufacturers. Ensure relevant design and construction standards are updated to reflect use of automated welding.

Transition of workforce capabilities: With automation being able to complete simple and repetitive welding tasks with high quality and consistency, skills will need to shift to operating, maintaining and overseeing automated systems and focus on more complex value-add welding products. Trade schools and training organisations will need to adjust their courses and offer more automation-centric education.

Procurement and contract management: Contracts should include flexibility to allow for use of automated welding alongside traditional manual welding. This might include both the requirements of the welding activity and the inspection program.

Funding and financing: Assisting local and small and medium sized enterprises in funding for new technologies can help to create a level playing field.

IMPLEMENTATION

Ease of Implementation

Automated welding robots are already used in multiple industries and there are many sources of best practice in technology and workforce implementation and transition. Proper training will be needed to ensure machines are operated in a safe and efficient manner. Considerable trialling should be undertaken to guarantee the fabrication outputs meet end user specifications.

Cost

Currently automated or robotic welding machines have high capital costs and are only suitable with high volume production facilities. Weld-as-a-Service models are available to avoid capital spend.

Country Readiness

Currently, labour costs in developing countries are low and high capital investment of automated welding systems are less cost effective in these markets. Developed markets have well established fabrication industries and high levels of technical literacy to be able to oversee operations. Potential time and cost savings will be big drivers to shift to more automated methods.

Technological Maturity

Automated welding for fabrication is well established and used. Innovation will decrease costs and enable it to be used in smaller production projects.

RISKS AND MITIGATIONS

Implementation risk

Risk: There are different levels of automation that companies can achieve. Issues can arise when trying to shift to a high level of automation too quickly. Transition projects that do not have realistic scopes or initially automate too many processes will find that projects that cost too much, take too long to implement, and fail to deliver cost and efficiency targets.

Mitigation: Successful automation strategies must align with business and operations strategies. Companies must have clear and deep understanding of fabrication processes and costs to choose the right level of complexity to meet their needs and have a solid return on investment.

Social risk

Risk: Automation can create the need for re-training of workers to operate, maintain and oversee automated systems and focus on more complex value-add welding products.

Mitigation: Government and industry can assist through training and up-skilling programs to help mitigate these issues.

Safety risk

Risk: Safety risks such as increased crush risks and electrical or mechanical faults causing machine malfunction can put operators at risk.

Mitigation: These risks can be managed through the implementation of safety precautions including physical barriers and sensors to keep workers at a safe distance and automatically shut it down when people are too close.

EXAMPLES

Example	Implementation	Cost	Timeframe
K-TIG	The Acueducto Gran San Juan project in Argentina consists of the installation of a new drinking water system to transport water from wells located approximately 25km west of the city of San Juan to complement the existing water system. 15km of this pipe was fabricated from stainless steel and welded using the automated K-TIG technology[2].	The project is being jointly funded by the Kuwait Fund For Arabic Economic Development (US$51 million), and the Argentinean Government (US$127.6 million).	The use of K-TIG transformed the economics of the project and the fabircation was completed in 162 days. The orginal timeline was 720 days with traditional welding methods.

[2] K-TIG's Role in the Construction of the Acueducto Gran San Juan Water Pipeline. K-TIG. Accessed 7 May 2020.

Automated Robot Cranes for Ports

DETAILS

SECTOR | Transport and Energy

STAGE | Operations and Maintenance

TECHNOLOGIES | Artificial Intelligence, Sensors, Cameras

SUMMARY

Automated Robot Cranes (ARC) are cranes that are integrated with Artificial Intelligence (AI) technology. The ARC can perform tasks autonomously or be controlled remotely by humans. ARC have object detection capabilities which enable them to identify workers or objects nearby in order to avoid collisions, accidents and delays during operations. The popularity of ARC is growing, particularly in the freight and logistics industry. ARC can be installed at shipping ports and container terminals to replace traditional driver operated cranes. To transition to ARC, operators need to undertake multiple changes in the existing infrastructure (including the control centre, maintenance facilities and communication system upgrades).

An efficient and affordable freight industry is important to enable world trade. About 90% of the world's commodities are transported by the international shipping industry[1]. The numbers of shipping containers that are transported between ports around the world is increasing as economies grow. As this demand increases, port operators need to improve their operations efficiency to meet this demand.

Traditional cranes perform repetitive and routine tasks and require skilled workers to operate them. These tasks can require considerable operation time, and are susceptible to human error, which can result in damage to equipment or freight, accidents and delays. Human error can also result in mistakes being made, such as the movement of the wrong container. Thus, wasting time to correct the error and causing delays to cargo, which will result in knock-on effects further down the supply chain.

By merging AI technology with crane machinery, ARC can optimize the performance of these tasks whilst reducing the risk of mistakes, accidents, injury and delay. Through this optimization, cost savings can be made for the operator associated with the reduction in time taken to perform tasks, reduction in damage to equipment and cargo, reduction in workforce injuries and enhanced asset capacity, which can enable cost savings at every level of the supply chain.

Future trends are moving toward fully autonomous shipping ports and freight facilities (*see also the Autonomous Shipping Ports use case)*. Autonomous ships and Smart Shipping Containers (*see also the Smart Containers use case*) are being developed and implemented around the world (e.g. China and the Netherlands). In the near future, it is expected that the freight shipping network will become fully automated where Smart Containers and Autonomous Ships will be able to communicate with ARCs throughout operations.

[1] "The Port of the Future", Future Platform, Accessed 5 May 2020.

VALUE CREATED

Improving efficiency and reducing costs:

- Accelerate the time to complete tasks by optimizing operations using artificial intelligence and therefore increasing productivity.
- Improve asset capacity enabling more freight to be processed.
- Reduce costs associated with delays to cargo and worker injuries by minimizing human errors.

Enhancing economic, social and environmental value:

- Improve worker safety by utilizing automated machinery that will perform dangerous tasks without human intervention and can detect potential hazards thereby avoiding accidents.
- Improve freight service for customers by minimizing delays and improving accuracy of operations.
- Enhance trade by improving port operations for more efficient and accurate cargo transfer.

POLICY TOOLS AND LEVERS

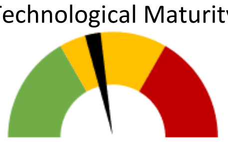
Legislation and regulation: Governments must develop regulations that outline the standards for ARC operations and maintenance and the requirements and testing they must undergo to be considered safe (e.g. load capability, detector system reliability).

Effective institutions: Collaboration between freight companies and crane suppliers is critical to ensure the ARCs are fit for purpose. Once installed, continued collaboration is required to enable further updates and maintenance of the machinery and systems.

Transition of workforce capabilities: A shift to ARCs will create a need for technically skilled workers to oversee crane operations, detect issues, perform services and maintenance of hardware and software. Several capabilities in areas such as technical engineering, software engineering and system integration are required. Where possible, these skills should be brought in house to enable workers displaced by the machinery to fill another role and enable prompt issues identification and corrective actions.

Funding and financing: Many implementations of ARC technology to date have been undertaken by private freight operators. However, the Port of Rotterdam (managed by the public entity the Port of Rotterdam Authority) is undertaking (from 2019) a project to make its operations autonomous, including the installation of ARCs. There are several private funds for ARCs projects around the world. For example, a private company (DP World) invested in the upgrade of Port of Brisbane, Australia. Several private companies have partnered to transition the Port of Caofeidian in China to a fully autonomous port.

IMPLEMENTATION

Ease of Implementation 	Many companies are already making the transition to using ARC. The AI technology has been implemented in different sectors and industries to ensure its capability in task performance. The transition to ARC will result in the change in crane operation processes, machinery maintenance requirements and human resources. The operation around ARC should be strategically designed to ensure a seamless transition to the ARC, including appropriate training of employees and updated safety procedures. Each port operator will have specific requirements for ARCs, such as the size of the ARC, the loading capability and power supply, etc. Operators must select a supplier that can meet their requirements. An operator can calculate the numbers of ARCs it would need by calculating how many containers one ARC can process per day and also needs to make sure there is enough space at the port to accommodate the required number of ARCs, which will likely result in some reconfiguration of facilities. Once operational, the AI component will need to be updated regularly to ensure it is learning and no errors or biases have been programmed.
Cost 	The capital expenditure associated with ARCs is higher than that of a traditional crane. However, the operational cost of ARCs is lower due in part to the reduction in labour cost. ARC can also eliminate possible human errors that could lead to accidents and cargo errors thereby reducing the cost associated with damage and delays and improve operational productivity.
Country Readiness 	ARCs have been installed at port facilities in several parts of the world including Europe, Asia and Australia. A key requirement to implement this technology is a reliable energy network to power the automated cranes. Electricity regeneration technologies can be deployed to capture heat energy and put it back into the network. Physical and virtual fencing can be implemented to ensure automated operations stop when people come into proximity with the cranes. Therefore, a reliable GPS, WiFi or cellular network is required.
Technological Maturity 	ARC technology is stable and mature enough to meet the existing operational and service demands. Many shipping ports around the world (e.g. Port of Shanghai, Port of Caofeidian, Port of Brisbane) have already implemented ARCs partially or fully in their operations. Additionally, AI required to optimize operations are mature and are being utilized in multiple sectors to enable improved performance and demand forecasting. Key equipment control systems are needed to oversee the movements of the automated cranes, but currently there is no standardization of these controls.

RISKS AND MITIGATIONS

Implementation risk

Risk: ARCs are designed to perform repetitive tasks without human interference. In the case that an unprecedented event occurs during operation the AI may be limited in being able to respond to it. This may result in the crane operations ceasing, thereby causing a delay, or may result in unintentional harm.

Mitigation: Until further development of AI technology can enable these machines to deal with unexpected incidents, the ARCs should remain under supervision by human operators. These specialist workers should be poised to step in if an unforeseen issue arises.

Social risk

Risk: ARCs will replace human employees who previously performed these tasks. This could result in the need to transition staff to alternative tasks.

Mitigation: Employers should develop a strategy to minimize the number of staff made redundant. Existing staff can be trained to perform more technical roles in supervising and maintaining the machinery.

Safety and (Cyber)security risk

Risk: The ARC operation is based on a computer network or internet-based system. Therefore, there is a risk that the system would be hacked due to cybercrime or sabotage. For example, in some cases, gaming bots powered by machine learning were able to hack the simulations they were being tested in.

Mitigation: Organizations should ensure their systems are robust to eliminate the risk of a cybersecurity breach. Furthermore, governments should set legislative frameworks to outline the requirements of these systems to repel cybersecurity attacks.

Environmental risk

Risk: A transition to ARC will result in the need to dispose of existing traditional cranes, which could result in considerable industrial waste if the cranes are not recycled or reused.

Mitigation: Companies should develop sustainable waste and disposal strategies, whereby machinery that is no longer required but remains within its asset life can be sold on for continued use or the components broken up for recycling or reuse.

EXAMPLES

Example	Implementation	Cost	Timeframe
Automated Container Terminal, Shanghai	The terminal is operated by 26 bridge cranes, 130 autonomous vehicles and 120 rail-mounted gantry cranes which are remotely controlled.	The development cost USD 2.15 billion. The operator hopes to save up to USD 80,000 in terminal operation costs per vessel via a 70% reduction in labour costs and a 50% increase in handling efficiency. Carbon emissions are also expected to decrease by 10%.	The automated container terminal started its operation in late 2018.
Port of Brisbane	The Brisbane port operator added two new automatic stacking cranes to its operation.	The port of Brisbane invested AUD $250 million to upgrade the port to semi-autonomous operation in 2014.	The port operator placed an order for the two new cranes, the cranes were delivered in 2016 and became operational in early 2017.
Victorian International Container Terminal	The new Melbourne facility includes five Neo-Panamax ship-to-shore cranes designed to lift loads of up to 65t and 20 automatic stacking cranes, which handle the interchanges between trucks and the container stacking blocks.	The facility cost AUD 650 million to develop. It provides an additional 33% capacity to the Port of Melbourne.	The container terminal became operational in January 2017.

Demand Responsive Transport

DETAILS

SECTOR | Transport and Energy

STAGE | Operations and Maintenance

TECHNOLOGIES | Passenger and Routing Platforms and Applications, New Vehicles (AV, EV, Shuttles)

SUMMARY

Demand Responsive Transport (DRT) are a flexible form of shared transport and infrastructure where the day-to-day service provision is shaped by the demand of the users. DRT does not follow a fixed timetable or route. Instead the most efficient route is calculated in response to user requests. DRT has characteristics of both buses and taxis but can take the form of a broad range of vehicular transport solutions; from familiar 'dial-a-ride' services typically booked by phone, to more recent dynamic applications that allow journeys to be booked through an application, adjusting the route to accommodate new pickup requests in almost real-time.

DRT is not a new concept. In developing countries, informal 'paratransit' systems are a significant form of urban transport. In developed countries, DRT had previously been employed as a rural community transport solution, used where conventional services do not exist, often due to their financial instability and requirement for heavy subsidisation. In response to the massive uptake of phone-based demand responsive solutions (e.g. Uber, Lyft, DiDi), cities are beginning to investigate how they can utilize DRT to improve shared use of public infrastructure, and the attractiveness and cost-efficiency of their public transport services.

Low frequency, low patronage transport services, which generally occur in sparsely populated areas or are due to under-developed transport service networks, must be heavily subsidised to maintain their service. These characteristics serve to encourage uptake of privately-owned cars for journeys. Due to the financial burden on local authorities, these services are at risk of being withdrawn. This would exacerbate the lack of accessibility to these areas with only those who can use privately-owned cars able to access the area, and in-turn increasing the physical road infrastructure load.

DRT can be used to solve an array of mobility related issues. They can act as first- and last-mile passenger and freight solutions particularly when combined with electrical infrastructure, as electric vehicles are suitable for short routes (*see also the Transition to Electric Vehicle Transport Networks and Electric Charging infrastructure use cases*). They can replace poor performing low frequency, low patronage services by shuttling users to the wider public transport network.

One prospective technological advance that is expected to greatly impact DRT are autonomous vehicles (AVs). With the introduction of AVs, user fares are anticipated to sharply decline as driver costs currently make up approximately 50% of DRT operational expenditure[1].

[1] "Going the Distance: Integrated Demand Responsive Transport in Cities", Arup, Accessed 15 May 2020.

VALUE CREATED

Improving efficiency and reducing costs:

- Replace low patronage routes with a dynamic service that responds to demand, which can reduce the overall costs of service delivery
- Reduce road deterioration and maintenance costs by increasing the number of economical vehicles on the road in place of heavier low patronage vehicles
- Reduce need for additional capital investment as use of existing road infrastructure can be optimized

Enhancing economic, social and environmental value:

- Reduce emissions by replacing inefficient fixed services with flexible, adaptable services that optimize service use
- Encourage mode shift from private car usage with convenient shared mobility options that are tailored to the user's specific needs

POLICY TOOLS AND LEVERS

Legislation and regulation: Strategic planning must be undertaken to decide on the provision of projects that will solve infrastructure gaps and future development requirements (modifying the use of parking, stops, stations, grid; monetising public infrastructure usage for private providers). Implement outcome-based regulation for the delivery of DRT services with a view to serve the integration policy and development/optimisation of mass transit infrastructure.

Effective institutions: Providers of DRT platforms and operators need to develop their solutions by taking a holistic view of the mobility ecosystem including network planning capabilities to improve machine learning and DRT dispatching algorithms. They must capture user expectations and utility preferences (as for Mobility as a Service (MaaS) – *see also the Mobility as a Service Use Case*) into their grouping algorithms.

Transition of workforce capabilities: Governments need strategic network planning, commercial and project management capabilities to understand and address the infrastructure gaps (physical, electrical and digital) to integrate such solutions with the provision of existing transport and energy services and develop the commercial framework to support the transition to outcomes-based delivery.

IMPLEMENTATION

Ease of Implementation

Local transport operators should make their data open source to enable innovation in this space. Without this data to draw upon, developing a service offering, including pinpointing areas of service and operations hours, will be unfeasible. As demonstrated in London, Citymapper's Smart Bus experienced several regulative hurdles that impeded the roll out and subsequent adaptation of their service offering. Regulations can act as a significant barrier to innovation and therefore local authorities should work in partnership with DRT operators to support new modes and operating models. The most successful rollouts to date have been well integrated into wider transport networks and provide first-and-last mile connections to train, metro and fixed bus lines.

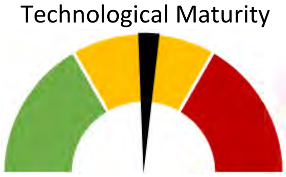
Cost

Fundamentally the DRT business model relies on maximising vehicle occupancy. Many techniques to achieve this have been applied to ride-hailing fleets to increase the number of riders served by a given vehicle, such as operating during limited hours and locations during peak periods. Vehicle size and staffing are also key decisions, with driver pay making up 50% of the total DRT operations cost[2]. There are many opportunities for an established DRT service to capitalise on economies of scope, expanding to new customer segments.

Country Readiness

Demand responsive transport planning requires an understanding of the passenger demand and a viable solution on how the demand responsive services could respond to a dynamic demand. The more data there is about the demand, the easier it will be to plan the corresponding demand. Curbside/temporary parking drop-off-pick up demand and management should also be taken into whole of infrastructure strategic planning (this is not the case today and DRT services in some places cause major traffic disruptions).

Technological Maturity



Much of the technological elements of DRT already exist. The necessary algorithms to optimise routes based on user requests are already being employed by private mobility providers like Uber and DiDi, however they need to improve with machine learning to group more users. One prospective technological advance that is expected to greatly impact DRT is the autonomous vehicle (AV). With the introduction of AVs, user fares are anticipated to sharply decline as driver costs currently make up approximately 50% of DRT cost[3].

RISKS AND MITIGATIONS

Implementation risk

Risk: To ensure its viability, a DRT service must maintain its market penetration to be seen by the user as a 'go to' option instead of a temporary service. The user must be able to rely on the service. Long wait times or periods without service can lead users to favour alternate services.

Mitigation: To mitigate, the service offering should be flexible enough to be scaled up in response to growth in demand and to avoid spreading the fleet too thinly over a geographical area. The scaling up of the fleet will enable better optimization of vehicles, enabling users travelling the same direction to be allocated to a single vehicle. This will enable the high vehicle occupancy necessary to make the service cost effective.

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[2] "Going the Distance: Integrated Demand Responsive Transport in Cities", Arup, Accessed 15 May 2020.

[3] "Going the Distance: Integrated Demand Responsive Transport in Cities", Arup, Accessed 15 May 2020.

Social risk

Risk: The public understanding of DRT is currently limited. Users have different expectations of the service or no knowledge at all. Current examples of DRT are typically implemented as niche services. They do not take into consideration integration with other modes in the wider transport network.

Mitigation: This integration with other modes creates a unique value offering for public and private stakeholders. Therefore, is it important that legislation does not hinder growth for innovations in this space. Governments should lead conversations with stakeholders to encourage collaboration for the public good. Communication and consultation with the public about the service and its role for the community can be an effective way of capturing user expectations and encouraging uptake.

Safety and (Cyber)security risk

Risk: Dynamic demand management relies on connected technologies to capture the relevant demand data. Therefore, risks related to data privacy and data sharing exist.

Mitigation: Those risks can be addressed through appropriate regulations on data privacy which ensure a secure system that protects user data privacy.

EXAMPLES

Example	Implementation	Cost	Timeframe
MOIA Hamburg	A co-operation between the city of Hamburg and Volkswagen, which now has a fleet of 450 EVs and approximately 7,000 stopping points. MOIA now also operates in Hanover.	An average ride costs between €6 and €7 per person.	The service has been operating since 2018. A major extension of the operating area and fleet was announced for March 2020.
Kutsuplus, Helsinki	Research started at Aalto University led to a pilot project that started in 2012. Helsinki Regional Transport Authority paid the drivers and operated the buses, which eventually grew to a fleet of 15. The project had two main objectives: to assess technological feasibility and user acceptance.	Kutsuplus was working towards being an economically feasible service. The average fare was €5 (~US$5.50) with an estimated two-thirds of their costs related to drivers' wages. Despite positive developments the small-scale operation needed substantial subsidies.	Launched in October 2012, Katsuplus ultimately ceased operations at the end of 2015, as it was deemed the cost to taxpayers was too high. The popular service was hindered by the investment cost required to scale up operations in order to optimize trips across the fleet.
Beeline, Singapore	Beeline was developed by the Infocomm Development Authority and Land Transport Authority. It was an application that enabled users to pre-book rides on express routes operated by private bus operators. The project aimed to explore how transport networks could be made to adapt to changing commuter demand.	The average fee per ride is between S$5 and S$6. Driver costs account for a significant amount of the operational costs.	Launched in 2015, with operations ultimately ceasing in January 2020. Like with the above examples, achieving the required fleet optimization requires a significant scale up in fleet size and geographical service offering. The LTA instead decided to redirect resources to their core transport offering in 2020, citing the high technology costs associated with the Beeline service.

Digital Service Platform for Transportation Hubs

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Digital technologies, 5G

SUMMARY

Digital service platform integrating the latest digital and communication technologies such as cloud computing, 5G, big data and the Internet of Things can effectively improve the operation and management efficiency of transport hubs such as airports, harness economic, social and governance (ESG) benefits, and enhance the security and quality of services. The digital service platform can be established on the basis of cloud computing platform, featuring high efficiency of computing resources utilization, dynamic response and flexible configuration. 5G mobile communication is featured by low latency, good security and large device connection capacity, which can improve communication efficiency and reduce costs. Indoor positioning technology can identify the floor and area where the user is standing, and provide real-time and accurate indoor positioning services by integrating indoor navigation map into mobile devices and on-site service equipment. Virtual reality technology can give full play to the terminal performance ability of augmented reality and realize user interaction experience. The digital service platform based on the above technology can realize the "One ID" service mode advocated by the International Air Transport Association (IATA) through connection with various functional systems including the departure information system, security check information system, flight integration system, information acquisition equipment and display screen in the transportation hub and other systems, as well as the connection with the user mobile terminal. With pre-authorization authentication and use of biometrics, passengers can realize paperless customs clearance, and have access to diversified services like real-time transportation information around a transportation hub, boarding, navigation services, translation services, business, marketing etc., significantly improving travel efficiency and experience. At the same time, the digital service platform can monitor the operation of key service nodes through the information acquisition equipment in the field, thus effectively improving the management level and security of traffic hubs. Through the establishment of digital service platform, Beijing Daxing International Airport has achieved positive results in improving airport management and service.

VALUE CREATED

Improving efficiency and reducing costs:

- Micro-service architecture built on cloud platform can realize virtual dynamic allocation of underlying computing resources and high-availability mode of operation, which can effectively reduce the construction and operation cost of fixed servers.
- Mobile-assisted Apps enable online ticket purchase, check-in, seat assignment and custom procedures. Automation and digitalization increases access to self-service. According to the data by the Shenzhen

This use case is a contribution from the Government of China, with some adaptations from the Global Infrastructure Hub.

Airport, check-in waiting time was reduced by 15% and self-serviced baggage check-in increased by 30%.

- Digital platforms can help improve security check and enhance security assurance, over 30% of passenger risks can be identified by digital platforms.
- Radio Frequency Identification (RFID) technology enables travellers to track real-time baggage location through mobile Apps. The RFID boasts a baggage identification accuracy of 99.5%, according to user data recorded by the Beijing Daxing International Airport.
- One ID model can recognize and verify users' identities through data matching process. According to statistics of the Beijing Daxing International Airport, this technology helps significantly expedite screening at the security gates, with each processing device handling 260 people per hour.
- Indoor positioning technology is deployed to fast-track travelling, improve commercial resources allocation, save labour costs, improve service assurance and commercial operation efficiency. Real-time positioning can also provide smart parking, real-time parking lot inquiry, among other value-added services.

Enhancing economic, social and environmental value:

- Online self-service and electronic boarding card provides paperless service to passengers and increases their green awareness.
- Passengers can enjoy seamless service in their traveling and be spared of repeated ID recognition. They can use Apps to check in, which reduces queuing time and allows spare time and improve overall travel experience.
- Automation can increase efficiency and save labors in identity certificate processing, provide customized service, optimize airport space utilization efficiency and improve its operation capacity and financial revenues.
- Information digitalization improves security at transportation infrastructure. Enhanced data connectivity and robust identity check prevent cross-border travel with false identity, and will help reduce cross-border criminal activities.
- Internet-enabled service is easier to be supervised by the public and delivers better service quality.

POLICY TOOLS AND LEVERS

Building institutions:

Guidelines on Application of New Technologies for Airport was released by the Civil Aircraft Agency of China in August 2018, where 25 new technologies under 5 categories are featured as new technologies and will be rolled out across airports of different sizes in a phased and orderly manner, so as to improve construction, management, security and service delivery of airports across China. A "trial and error" mechanism is in place to encourage proactive uptake of new technologies in airport construction, operation and management

Legislation and regulation:

Privacy protection legislation. In China's newly enacted Civil Code in May 2020, individuals' rights to privacy and personal data protection was clearly enshrined. It is provided that data collectors have the obligation to protect an individual's personal information and cannot obtain, disclose or conduct transactions of such data without consent.

Future enabled workforce:

Staff training must keep abreast of technology advancement and function upgrade. According to the Beijing Daxing International Airport, it hosts over 100,000 hours of on-the-job training for its staff, covering vocational training and management training.

This use case is a contribution from the Government of China, with some adaptations from the Global Infrastructure Hub.

RISKS AND MITIGATIONS

Technology Maturity

Customized service requires advanced data sorting and algorithms. As airports at different countries and cities differ in terms of design, passengers diversify in travelling pattern. More data analysis is needed to work out viable solutions. Hence, it is important to embed data-based service capacity at the outset of service ecosystem development, and ensure that data is constantly enriched and updated throughout the course of operation and management while improving data analysis capacity.

Privacy Protection

Digital platform needs access to user identity and biometric information. It is therefore important to ensure users are fully aware of their information to be provided. Hence, before services are provided, questions like how the personal data will be used and its storage duration must be fully explained to users, and explicit expression of consent by users should be obtained. To this end, legislation and legal guarantee must be in place to protect personal information is only used when necessary and with approval, and prevent any leakage or abuse of such information.

EXAMPLES

One ID scheme, Beijing Daxing International Airport, weblink:
https://daxing-pkx-airport.com

5G application, Shen Zhen International Airport, weblink: http://www.szairport.com/szairportyw/

This use case is a contribution from the Government of China, with some adaptations from the Global Infrastructure Hub.

Digital Twins

DETAILS

SECTOR | Transport and Energy

STAGE | Procurement and Operations

TECHNOLOGIES | IoT, Sensors, Artificial Intelligence

SUMMARY

A Digital Twin is a virtual replica of a physical object or system. Today, digital twins can digitally replicate large objects like buildings, stations and cities. They are compiled of several layers of real-world data related to the object or system and can produce predictions or simulations of how that object or system will be affected or influenced by certain operational inputs.

Digital Twins can identify and monitor asset interfaces, maintenance, and enhance future asset operations. In that sense, Digital Twins are different from 3D infrastructure models and Building Information Models (BIM) (*see* also the *3D Infrastructure Modelling and BIM use case*), which are today largely used for the design and construction of new infrastructure projects. Digital Twins are built from operational data collected from sensors and IoT and are used to replicate infrastructure already in operation to be used for condition monitoring and asset management. The intention in the future is to integrate Digital Twins into BIM models, in order to complete the chain (from design to construction then operations and asset management) and fully integrate the asset management function into infrastructure models.

Using the Internet of Things (IoT) (connected assets and sensors capturing data on the condition of infrastructure) with "Iotic" types of data sharing (open models non-vendor or network agnostic), more data from various sources can be captured to enhance digital twins, where gaps are identified in data collection and data controls.

Digital Twins were developed by companies, initially constructors/manufacturers with remote operation requirements, to produce a digital replicate of an existing or future physical infrastructure. They enable a comprehensive understanding of an existing infrastructure's status and operations, and the future potential of integration; visualising all potential optimisation between sectors and their assets.

Essentially any project data can be compiled into a digital twin. Examples include costs, construction schedules, standards requirements, design requirements and expected performance. Compiling the data together enables interoperability in infrastructure projects, using and binding digital twins from several infrastructure projects and additional data from external IoT if there are gaps. The use of digital twins allows a government to start the development of an infrastructure project idea by reviewing how it can integrate with or use existing database infrastructure. It is also a great tool to create a visual representation of a piece of infrastructure and its operational/condition issues

Digital twins are machine readable and enable automatic identification of gaps in the data to make it complete. Thus, engineers can endlessly re-combine digital twins in an additive-subtractive way easily. Additionally, Digital Twins can communicate between different disciplines, thanks to visual supports.

The aggregation of data from various sectors, devices and sources through the use of Digital Twins is one of the ways cities and regions can become more 'connected', enabling more efficient management of infrastructure. Additionally, most infrastructure assets are not always completely tracked and traceable. With the use of digital twins, they can be fully monitored. An example of this, in the context of whole of life asset management, could be where sensors on an asset check the asset condition and its previous inspections ahead of triggering a maintenance visit. Another example would be where a trigger would result in the review of the design specification, which could be used to identify if the asset could be used for additional development. With Digital Twins, simulations can be run without impacting the physical asset (e.g. to test if operations could be increased in order to optimise the asset's use.

Additional potential applications include predicting failures, training staff, optimising individual performance, and enabling relevant IoT integration from planning and design phases. With Digital Twins, the overall objective is to better communicate between disciplines and sectors to maximise the value of the assets, and to apply this to larger infrastructure. Digital Twins are also expected to be developed at a larger scale to replicate cities and countries.

VALUE CREATED

Improving efficiency and reducing costs:

- Maximised value from investment legacy current and planned
- Estimated 10% improvement in construction business effectiveness and more than 20% gains in productivity[1].

Enhancing economic, social and environmental value:

- Create a single source of truth that will enable a reduction in costs, eliminate waste, avoid duplication, unlock hidden value
- Potential to generate new revenue by integrating Digital Twins from different nearby assets (e.g. a station, a mall and a hospital)
- Enhance visibility by reducing time spent finding and contextualising insights and integrate existing reporting systems.
- Better communication across sectors, and with the population, on future infrastructure projects integration into existing infrastructure

POLICY TOOLS AND LEVERS

Legislation and regulation: To enable the wider use of digital twins, governments should make the development of a Digital Twin of all existing and future infrastructure a requirement of any major project. Additionally, the collaboration between various sectors and actors (asset owners, providers, operators, etc.) to share asset data is essential and the right enabling legislation must be developed accordingly.

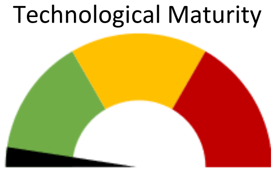
Effective institutions: Standards should be developed to ensure Digital Twins are consistent and complementary. Government agencies and related private entities should ensure consistency in the use of Digital Twins across all relevant infrastructure assets and services.

Transition of workforce capabilities: Engineering capabilities should adapt to use Digital Twins in addition to traditional plans and processes to enable a consolidated design and considerations of existing assets in their design and construction work. Operators should also be able to use Digital Twins to understand how the assets they operate contribute to meeting their Key Performance Indicators. Contract managers for public infrastructure contracts, should also be able to use elements of the Digital Twin to understand costs/schedules and expected performance and clauses that can be set for construction and for operations.

[1] "Prepare for the Impact of Digital Twins", Gartner, Accessed 20 May 2020.

Procurement: Digital Twins should can be mandated in operations contracts or be a requirement in new infrastructure projects as part of the delivery contracts.

IMPLEMENTATION

Ease of Implementation 	Given the lack of standards and skillsets to enable such extensive integration work, and the complexity of integration without disrupting existing methods of procuring infrastructure projects, it is easier to implement Digital Twins on major new infrastructure projects than existing assets. However, for example, global railway operators, such as Deutsche Bahn, Network Rail, SNFC, have started building their Digital Twins to optimise the visibility of their network and test opportunities to improve their capacities of operations.
Cost 	The costs of developing digital twins are relatively low as they rely on data and digital integration. However, if the existing assets are not 'connected' there will be a need to add IoT to them in order to capture their conditions. The costs of adding IoT to the infrastructure will significantly increase the implementation costs.
Country Readiness 	Most developed countries are already developing Digital Twins for their new major infrastructure projects (buildings, transport, health, water etc.) and are leveraging them to capture existing infrastructure too. However, some developing countries may not yet be ready, from a skillset and policy point of view, to integrate Digital Twins as a requirement in the delivery of infrastructure projects, as they focus their investments on building the infrastructure network.
Technological Maturity 	IoT enabling the connection of assets and data sharing solutions are today well-developed and can be easily used to provide a relevant and accurate use of Digital Twins for planning and operations. The capability for Digital Twins to automatically identify the missing data required to complete them already exists, which enables the decision of where and what IoT or sensors to collect this additional data should be installed.

RISKS AND MITIGATIONS

Implementation risk

Risk: Digital Twins are built based on the data collected from IoT. Poor or incorrect implementation of IoT will result in poor or inaccurate data collected. Additionally, if the Digital Twin is not visualised in a software application, it is possible to miss any gaps that exists in the data.

Mitigation: To ensure consistency of Digital Twins across sectors and eliminate opportunities to miss gaps or errors in data, a standardization of the data collection and identification of gaps processes should be developed. This will ensure the use of software is coordinated across difference sectors.

Social risk

Risk: Staff will be unfamiliar with Digital Twins and training may be required.

Mitigation: Staff should be upskilled in the use of Digital Twins for planning, design and operations. The tools should be simple and user friendly to facilitate this transition. Education programs for all actors involved in the planning, design and operations will also be helpful.

Safety and (Cyber)security risk

Risk: As with other data-based technologies, there is a risk that the system with be breach due to a cybersecurity threat and that the data will be accessed or the Digital Twin will be altered.

Mitigation: To mitigate the risk of data hacking the data used for operations must be secured. The Digital Twin converts data as event streams and can be configured to recognize significant events in real-time receiving data only when an event occurs. Additionally, technology disruptions can be avoided by maintaining 'normal' operations as a base case.

EXAMPLES

Example	Implementation	Cost	Timeframe
SNCF Digital Twin	Currently being built for existing infrastructure, while developing an asset library to capture more granular assets	High investments and a lot of research; great potential foreseen to move to predictive infrastructure maintenance	A full development can be expected by 2022
Tamba City, Hyogo Pulp factory, Japan	Hyogo Pulp introduced a virtual network infrastructure through Digital Twin to strengthen cyber security measures in plant networks and create a safer and more efficient network infrastructure anticipating more IoTs.	Direct operations savings recorded by the Head of Electricity Section of the Facilities Department	With the system, Hyogo Pulp can now better manage the devices connected to the network and the access and security status of each device, to troubleshoot problems easily.
Singapore Digital Twin	Virtual Singapore was created by the National Research Foundation. When completed it will be the authoritative 3D digital platform intended for use by the public, private, people and research sectors.	Virtual Singapore is an R&D programme initiated by the NRF at a cost of $73 million for the development of the platform as well as research into latest technologies and advanced tools.	The development of the Digital Twin took place over a period of five years and was targeted to be completed in 2018.

Digitising water access data for regulatory use

DETAILS

SECTOR | Water

STAGE | Strategy and Planning, Project Delivery, Operations and Maintenance

TECHNOLOGIES | Metering, telemetry, analytics

SUMMARY

s Typically, the cybersecurity is in the data transfer and collection component. This is where data is sent from the meter via a communications network to be stored either on a server or in the cloud. There are a variety of such transfer networks, such as the well-known phone telecommunication providers, but a variety of private networks are also available. Water authorities or regulators can also build their own networks but this is usually too expensive especially when other providers are available. When selecting a data transfer provider, a thorough understanding of data handling protocols should be developed to ensure data is keep safe and whole. The use of high-level encryptions is important, as is the storage location that data is transferred into. Data should only be allowed to enter or pass through data storage or handling that has the appropriate level of cybersecurity. It is important to ensure that data is not manipulated by the transfer process. The technology is available to ensure that this is the case, but the end-to-end system needs to be packaged together to meet policy and operational needs of water access regulators. The following is a list of typical components and how technology can address the cyber risk:

- Meters measure water volumes – use meters compliant with approved standards
- A local logger collects and stores meter data – use purpose-built loggers with tamper proofing and tamper alerts. Long-term data storage can be an option to have the original data available for comparison.
- A telemetry unit transfers the data via a modem – usually integrated with the logger. Use tamper proof and encryptions as per above and below.
- The telecommunications network carries the data - encryption such as IPsec and VPN
- A data collector to ingest the data – data cleaning without manipulation
- A cloud or server stores the data – use trusted provider or onsite storage

Water access regulation is a complex problem for many reasons. Water is a finite resource usually covering a wide geography such as a river, lake or underground aquifer. There are multiple users and stakeholders that may be using the water for irrigation, industrial purposes such as mining or for drinking water supply. There are also environmental requirements such as “environmental flows” required to let a river maintain its ecological health. The regulation of water access is required to ensure water entitlements are correctly allocated and that allocations are being adhered to. To ensure fair and equitable access of water, and to prevent water theft, regulators need to be able to measure the amount of water being abstracted and use this data for compliance and enforcement purposes.

The problem being solved by this solution is that existing systems are typically designed for billing purposes and do not provide the required data integrity and data security for purposes of enforcement of the legislation. Furthermore, in many areas, the abstraction of water is not metered correctly and so therefore not providing accurate data. In this case, a regulator cannot ensure compliance to the entitlements. Two important considerations need to be taken into account in the implementation of a secure system for digitising water access data:

- Ensure accurate metering and then provide a system that can transfer the data securely to the regulator.
- Ensure that the data collected is not being “touched” by any other party along the way during which it might be altered. Most data transfer systems, although secure, are about opening up data access and trying to improve integration. This is primarily to improve operational use of the data. The “locking down” of data for use by a regulator is in essence the opposite of this to ensure the data is not altered.

The desired outcome from this use case is data security and data integrity – sufficiently to enable the use of data for compliance and enforcement purposes. For data to be cybersecure, it firstly needs to be safe from other parties and it also needs to reach its destination with all the data accurate and intact.

The continued evolution of cybersecurity measures will always be needed as cyberattacks advance. Technology will need to keep pace to ensure that data is safe. The sovereignty of data, i.e. what country it is held in, is also an area that will likely need some progress. As we seek to collect more data using more global technologies such as low-earth orbit satellites, data is less likely to remain in country. Satellite-based technologies could hopefully address this issue by providing a solution that meets the needs of countries that require data sovereignty.

VALUE CREATED

Improving efficiency and reducing costs:

- Digitising water access data (and associated cybersecurity measures) typically costs more to implement, but overall, an effective and cybersecure system in place will enable regulators to have more confidence in data obtained, meaning less site visits and a reduction in travel costs and time.
- Digitising water access data, as applied to water access regulation, improves the efficiency of obtaining data on water abstraction or water use which may have traditionally been done manually or perhaps without confidence in the data provided digitally. This allows regulators to make more timely decisions and have early warning on any anomalies or breaches to regulations.

Enhancing economic, social and environmental value:

- Digitising water access data ensures fair and legal access for everyone to a valuable natural resource. The effective adoption of such a system will promote economic value by providing stable and foreseen water usage for irrigation and other commercial and industrial uses.
- This provides farmers and business owners confidence in the regulation and allows water users to plan their operations with confidence.
- It also allows regulators to effectively control water abstractions in line with sustainability requirements, helping to promote long-term health of the environment.

Reshaping infrastructure demand and creating new markets:

- As with any regulated process, digitising water access for regulation drives a reshaping of the market’s offering to meet this new demand. This will promote the development of secure and accurate devices to legislative requirements, including water meters, telemetry components, and data receivers and storage solutions.

- Demand from regulators will reshape technology development roadmaps to support the regulation. It is expected to create a technology advancement to meet the new markets created.

POLICY TOOLS AND LEVERS

Legislation and regulation: Natural resources (water) access regulation requires firm backing in legislation to drive the regulation and enforce change in water usage patterns. Application of cybersecurity standards must be included in legislation to ensure appropriate cybersecurity measures are included in any project development.

Procurement and contract management: There are several options for procurement of this digitised system. This can be procured by the regulator or by another part of government, or it can be procured by the water user in a 'user pays' system. Specifying the technology to be used can be determined through a competitive procurement process or a performance specification can be used to allow an open market to find solutions. In a user-pays system, water users will be required to make their own decisions in terms of the purchase and installation of the components. Government would use inspection and verification as tools to ensure compliance.

Funding and financing: Governments can choose to fund the digitisation or choose a 'user pays' systems. Where the system is not fully funded by a government, some government expenditure can be used to support certain elements of the project. For example, funding can be provided to promote technology development to meet the cybersecurity needs of state or national water access regulation. Funding can also be provided for testing of devices and protocols to ensure devices and data transfer is safe and secure.

Effective institutions: Natural resources access is better regulated through the use of effective institutions to help support the enforcement of legislation. Institutions such as industry bodies or associations can provide training to ensure qualified personnel are available for cybersecurity deployment, device management or installation. Institutions can be also be set up to carry out compliance checking. Cybersecurity depends as physical aspects such as vandal-proof installations and correct procedures are followed. Institutions can be used to ensure this aspect is well understood and enabled. National and international standards organisations e.g. ISO, can be used to maintain quality requirements. More specifically, standards and procedures can be used to set what protocols are to be followed when for example when a data breach occurs.

Transition of workforce capabilities: A small but dedicated workforce is needed for natural resources access regulation. Key skills are in-field meter and device management, telecommunications, meter data management and visualisation. Ensuring data accuracy and integrity also requires cybersecurity to be applied to the above elements so workforce capabilities need to include this.

IMPLEMENTATION

Ease of Implementation

The challenge for implementing digitised water access data with cybersecurity in this context is the extra effort required above typical operating parameters. Water users and industry partners may need consultation and education to understand the requirements and specifications for such an implementation.

Cost

Telecommunications typically operate in a competitive market so costs are not prohibitive. It is perhaps more important to ensure the provider has the right geographic coverage and actually has effective cybersecurity in place.

Country Readiness

Digitising water access with cybersecurity can be applied anywhere given the in-field devices are robust, telecommunications are in place and cloud services are available. The regional maturity of local telemetry and telecommunications providers and their approach to cybersecurity is the aspect limiting deployment across regions.

Technological Maturity

Digital systems for water access are fully mature and can be implemented now, pending compliance with regional data and cybersecurity standards. As telemetry and telecommunications technologies develop (e.g. 3G to LPWAN) it is important to ensure that new technologies retain the cybersecurity element of previous technologies.

RISKS AND MITIGATIONS

Safety and (Cyber)security risk

Risk: Cybersecurity always brings the risk of the unknown until it is tested.

Mitigation: Rigorous testing at all phases is required. Use protocols and encryptions that are known to be effective for cybersecurity.

Risk: To ensure data security and data integrity, the whole data transmission chain must be secure. “A chain is only as strong as the weakest link” applies here.

Mitigation: Ensure the same level of security is applied to every element in the transmission chain from meter to cloud.

Risk: In-field devices for capturing data are an access point to tamper with data.

Mitigation: Tamper-proof devices must be used with an appropriate level of vandal proofing. Tamper alerts and logs should be incorporated for any cables that are cut or doors that are opened. Access to the data logger must be password protected.

Risk: Interception of data transfer by a “stingray”

Mitigation: Have procedures in place to check when data is expected to be received and actions for when it is not.

Risk: Transfer of data is not secure

Mitigation: Ensure all connections are authenticated and encryption protocols are in place.

Risk: Data from another source is sent to the data collector/ingestor.

Mitigation: Ensure access to data collector/ingestor is authenticated prior to transfer from the logger.

Risk: Environmental factors can play a large part in causing loss of data. It is not just the "hacker" that is of concern as insects, heat, moisture and exposure can damage equipment.

Mitigation: All in-field devices should be manufactured to suit the environment they are to be deployed in.

Risk: Cloud Storage is accessed by 3rd parties.

Mitigation: Ensure cloud storage is encrypted.

EXAMPLES

Example	Implementation	Cost	Timeframe
NSW Dept of Planning Industry and Environment	Digitisation of approximately 8000 water abstraction points are planned for completion in 2021 to assist with enforcement of water allocations. Devices and components have been developed and are currently in field testing.	Cybersecurity requirements would expect an increase in vendor costs but the reshaping of the market from the regulatory driver, coupled with a free market procurement process, leads to telemetry devices being available at normal market prices ranging from A$500-$2500 per end point.	The timeframe to implementation is approximately 6 months due to two elements: custom build of a secure data receiving portal and time for the market to respond with development of new devices to meet the cybersecurity requirements.

Drones for Monitoring, Surveillance & Inspection

DETAILS

SECTOR | Transport and Energy

STAGE | Operations and Maintenance

TECHNOLOGIES | Drones/UAVs, WIFI, Sensors

SUMMARY

Drones are unmanned aerial vehicles (UAVs) that can be remotely piloted by a human pilot, or autonomously operated. They can be configured as quad-copters or hexa-copters, or as fixed-wing unmanned aircraft. Drones have been used for military applications for more than a decade. Today, drones are quickly being adopted by the commercial and private sector, as well as in people's everyday lives. This rise in popularity is leading innovators and decision makers to investigate the potential uses for this unique technology offering.

The use cases for drones are potentially endless. They offer a safe, cost effective solution to an array of previously time consuming or high-risk tasks typically performed by humans. Some of the specific opportunities for drone use in the Transport and Energy sectors today include:

- Monitoring and inspecting operational network assets from a safe location
- Monitoring construction or maintenance works for compliance to contract service level agreements; and
- Monitoring and surveillance of entire transport or energy networks and other sites for trespass, graffiti, anti-social behaviour and other situations such as bottlenecks in operations.

Drone technologies can enhance the process to inspect assets as the photos they take have a very high resolution, sharper than the human eye, and provide an opportunity for review multiple times. These photos can be used to gain a high-quality perception of the condition of assets. They also enable enhanced safety and security through persistent and flexible surveillance coverage of the transport network and can provide rapid-response when a security-related incident is detected.

Drones can also be coupled with sensors to collect data. Today's drones can be considered as Internet of Things (IoT) devices as that operate over Wi-Fi. They can share data with other IoT devices and systems and can provide real-time data as an input into 'big data' applications. This enables faster, more accurate enterprises, decision-making and analysis in terms of service offerings and infrastructure improvements, as well as acting as an enabler for more effective asset-related decision making.

As technologies advance, so will drones' ability to perform increasingly complex tasks. One such example is that it is expected for drones to have the ability to recognize faces, enabling them to identify people. This will of course pose issues relating to people's privacy and reliability of this facial recognition technology.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce the time required to perform tasks by replacing a human (typically on the ground) with a drone (from overhead) giving decision makers access to more up-to-date data

- Reduce the need for on-site inspectors as images taken by drones can be reviewed by a resource anywhere in the world and potential to reduce operating costs by minimising the number of resources required to perform tasks (there is a potential to share inspectors across multiple sites)
- Improve monitoring and maintenance capacity of organisations by ensuring better attention to detail and breadth of coverage

Enhancing economic, social and environmental value:

- Improve safety by enabling drones to carry out hazardous tasks previously done by humans
- Provide real-time or post-processed data as an input to 'big data' applications
- Ensure quick deployment to emergent situations and enhance the security of assets and people
- Contribute to faster, more accurate transport enterprises, decision-making and analysis in terms of service offerings and improvements

POLICY TOOLS AND LEVERS

Legislation and regulation: For many countries the regulation of drones has been managed as an extension of existing regulatory frameworks for the aviation sector. Drones are restricted to segregated airspace, prohibited from built-up areas, such as protected zones near airports and military installations, and must be operated within the pilot's line of sight. These regulations are generally considered too restrictive and an impediment to innovation. Enforcement mechanisms are also inadequate. To unlock the wide range of benefits drone technology can offer, existing regulations will require scrutiny and new safeguards for the screening and clearance of drone operators and effective encryption, or cybersecurity protocols, should be enacted.

Effective institutions: Regulation review should be done in collaboration with all relevant stakeholders including Air Traffic Control authorities, to ensure drone activities do not pose security or safety risks to airports, homes, schools or other sensitive locations. Further factors to be considered include noise limits, zoning rules, time-of-day restrictions, insurance and job-training.

These factors should be decided on in collaboration with regulators, residents, researchers and operators to ensure all opinions are considered.

Transition of workforce capabilities: Infrastructure operators may not be prepared or have the capabilities in-house to analyse the data and images collected by the drones or operate and maintain the drones themselves. A structured training and skills development framework should be developed to enable the workforce to upskill in response to the new requirements.

Governments can assist in developing these skills by encouraging or mandating their inclusion as part of school curriculums as part of a long-term plan to facilitate drone skills development.

IMPLEMENTATION

Ease of Implementation 	To undertake inspection, monitoring and surveillance activities, drones require relatively modest infrastructure to be in place. For these uses, drones require a take-off/landing area (which could simply be a flat surface like a part of a field or car park) and charging infrastructure. These drones can be charged using the same common power outlet as other devices.
Cost 	The cost of implementing drone solutions for asset management and network observation is relatively low. The requirement for additional infrastructure to support these technologies is low – drones will require maintenance and charging, but the cost of such infrastructure (when compared to that needed for passenger drones) is low. By greatly reducing the time required to perform tasks and increasing the level of accuracy in completing them, drones prove to be a cost-effective and accessible solution for monitoring and inspection operations. Cost reductions are greater in countries with high labour costs.
Country Readiness 	Countries should work proactively to develop drone legislation that will enable innovation in this space without compromising safety and security regulations already in place. As object avoidance technology advances, these regulations can be reviewed to potentially enable drones to operate in the same air space as other aircraft. As consumer adoption of drones increases, populations will become increasingly familiar and acceptant of these technologies in commercial use.
Technological Maturity 	Drones rely on several sophisticated technologies, many of which are still under development. Drones largely rely on human remote-control for operations. Drone autonomy is expected to improve over the next five years, enabling system-failure responses and dynamic routing. With advancements in this space, drones can be effectively used for more complex tasks and terrains including pipelines, mines and construction projects. Rapid improvements in battery capacity is expected to enable drones to fly in excess of an hour without requiring recharging.

RISKS AND MITIGATIONS

Implementation risk

Risk: In order to generate the value expected for more efficient monitoring, surveillance and inspection of infrastructure projects, setting the operating plans, getting the relevant permits to operate the drones and the qualified staff are key elements to successfully implement drone-related services. If these three elements are not properly developed, there is a risk that services implemented will not capture the relevant surveillance data.

Mitigation: Experienced drone pilots should train the future drone operating staff, and specific operating licences should be delivered (as it is the case today by the Australian Civil Aviation Safety Authority (CASA) for Remote Pilots). A specific planning of the drones-services operations should also be made according to the expected outcomes and surveillance regime and frequency expected.

Social risk

Risk: As with other digital technologies, drone usage raises ethical and legal questions surrounding how data collected should be used and whether and under what circumstance this data can be shared with government authorities for purposes other than those for which the data was collected. Privacy concerns would be particularly relevant for citizens living or working in proximity to monitored areas. There is also the potential that drones will create noise pollution.

Mitigation: Citizens should be made aware of drone operations and their purpose to address their potential safety and privacy concerns. Appropriate regulation and practices concerning overflying, data use and data storage will also be required.

Safety and (Cyber)security risk

Risk: Drones will operate in contested electromagnetic environments, consisting of many potential emitters, which can impact safe operation. Weather and high airflow environments can also result in unpredictable behaviour in drones. Satellite positioning system denied environments and system outages can also impact drones as they rely on satellite systems for position reporting and autonomous navigation. Such environments include bridges, tunnels and deep cuttings with limited view of the sky.

Mitigation: Selection of suitable aircraft should take these potential disruptions into account to ensure safety and reliability. Furthermore, the security of the technology and data from cyber or other hostile attack must be assured. Overall drone technology should reduce safety concerns as these can be used to curb vandalism, theft, trespass, assault on staff and customers, terrorism and sabotage.

Environmental risk

Risk: Drones will need to operate safely within the context of a range of fixed infrastructure and the natural environment and operate without disturbing local wildlife. The risk of collision or obstructions to the drone's visual line of sight must be managed. These risks are exacerbated by variable weather conditions.

Mitigation: Sensitive planning must be undertaken to avoid unwanted interactions with wildlife.

EXAMPLES

Example	Implementation	Cost	Timeframe
Pedestrian Monitoring Trial, Yarra Trams, Australia	Systra was engaged to perform a pedestrian and traffic monitoring trial during the Melbourne Grand Prix 2019. The aim of the trial was to assist Yarra Trams in understanding the operational issues that occur during large disruptive events in the city.	The trial cost approximately AUD 40,000 and provided several recommendations for improving operations during future disruptive events.	The trial required approximately three weeks of preparation to investigate relevant regilations and obtain the necessary licenses. The event lasted two days. A further three weeks of analysis and stakeholder engagement was conducted.
Dedicated Freight Corridor (DFC), India	Indian Railway is using drones for the first time to inspect and assess the progress of a mega rail project.	The drone was hired from a private operator and cost 3,000 Indian Rupees/km (approx. 40 USD/km) for undertaking the aerial survey.	The drone was used on a trial bases for three days cover the total 98 km on the DFC. A status report then prepared based on an analysis of the video recordings.
Network Performance Improvements, SNCF, France	SNCF is using drones to improve network performance and operations. The drones are equipped with airborne laser scanners that produce high-density 3D point clouds (LIDAR) that can be used across several tasks including inspections of assets and network mapping.	The drones were developed by SNCF subsidiary Altametris. SNCF's drone projects are part of a €14M/year budget for rail network innovations and monitoring projects. Altametris has developed successful automated surveillance management solutions using drone data and has since then shared this knowledge with other operators.	SNCF has been using drone technology since late 2012. It has since established a subsidiary, Altametris, to offer its expertise in using drones to other infrastructure managers.

Dynamic Road Pricing

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | ORT, DSRC tags, Automatic license plate reading, big data, drone

SUMMARY

Managed lanes are dedicated lanes within a highway set aside to specifically ensure non-congested free flowing travel throughout a specific corridor, thereby giving travellers an option of using the normal "congested" lanes, or the free-flowing lanes. High-occupancy vehicle (HOV) lanes are an example of managed lanes, as well as dynamically tolled lanes with the dynamically tolled lanes the only lanes able to utilize technology to manage demand to ensure free-flowing throughput.

Effectively managed dynamically priced managed lanes can form an important tool in the overall transportation management strategy of an urban region. This strategy can utilize managed lanes to maximize existing capacity, manage demand, offer choices, improve safety, and generate revenue.

Managed lanes utilize a number of Infratech, technologies to ensure a superior level of service for the highway users as well as the economic benefit of freeing up scarce funding resources for the public sector to invest elsewhere.

Advanced versions of the technology aim to maintain free-flow travel and minimum traffic density, as a consequence a dynamic tolling algorithm, while considering local factors and recalibrating toll rates based on traffic congestion every several minutes; with the toll rate being locked in from the time a vehicle enters the corridor until it exits the corridor. Users can be provided the flexibility to utilize electronic payment systems through either electronic tags, to facilitate the use of the lanes and make payment, or through post-pay billing done through the capture of their license plates with automatic license plate reading technology. Registration with third party providers can allow for utilization of additional discounts for HOV and carpooling as an incentive.

The technologies required to ensure the managed lanes work efficiently in meeting the broader transportation goals include a multitude of roadside equipment including, cameras, toll tag readers, dynamic message signs, roadway weather stations, air quality monitoring, over height detection systems and vehicle categorization technology. In addition there is a significant back-office component which requires a data warehouse, a business intelligence processor and a toll setting module algorithm.

Advanced lane management can also allow for priority utilization of smart vehicles that are integrated with smart infrastructure.

This use case is a contribution from the D20 Long Term Investors Club, with some adaptions from the Global Infrastructure Hub.

VALUE CREATED

Improving efficiency and reducing costs:

- Guaranteed travel times for congested corridors to ensure efficient throughput with priority for high value transportation needs
- Efficient demand management through big data developed algorithms which assess traffic patterns to optimize toll rates in real time
- Free flow tag reading allows for travel to efficiently continue while collecting the necessary data for tolling
- Automatic (video image reading software) license plate reading minimizes back-office for non-tagged users and provides flexibility to users with a non-tag option

Enhancing economic, social and environmental value:

- High value trips (school pick-up, airport trips, business etc.) are guaranteed travel time
- Expanded highway capacity has reduced emissions by reducing the fumes from vehicles idling in congestion
- Embedded technology and capacity for further technology will allow for integration with smart vehicles
- Optimization of toll rates to maintain travel time reliability, reduces the economic inefficiencies of traffic congestion
- Potential revenue generation mechanism when applied at scale. For example, in Stockholm net revenues have increased since the variable fares were introduced in 2016. The net revenue from the system used to be around 500 million krona/year (USD $51 million/year); after January 2016, the net revenue is now around 1.3 billion krona/year (USD $155 million/year)[1]

POLICY TOOLS AND LEVERS

Legislation and regulation:

- Congestion management tolling regulation
- Privacy and information sharing for license plate recognition and payment processes
- Revenue sharing mechanisms between private developer and the public owner

Procurement and contract management:

- Public private partnership development agreement with infrastructure developers
- Competitive DBFOM tender where all factors (technology, infrastructure development and cost, operations and maintenance and tolling) sit with the same party to ensure the developed solution is optimized for the long-term

Funding and Financing:

- Utilizes long-term financial infrastructure investors who are able to take a view on the effectiveness of the applied technology and economic benefits of the managed lanes over a number of decades, rather than the short-term to truly align interests with the public benefit

[1] "Road Pricing in London, Stockholm and Singapore: A Way Forward for New York City", Tri-State Transportation Campaign, Accessed 4th May 2020.

This use case is a contribution from the D20 Long Term Investors Club, with some adaptions from the Global Infrastructure Hub.

IMPLEMENTATION

Ease of Implementation

The rapid advancements in sensor and related technologies mean that implementation is becoming easier. One key element required to effectively manage pricing, is up-to-date integrated data from various input sources. This enables the data to be analysed in order to drive decisions and provide real-time information.

Cost

The incremental cost of implementing the technology associated with the priced demand management on the managed lanes is small compared to the cost to build the highway infrastructure. There is some additional construction infrastructure cost associated with ensuring separation of the managed lanes and direct connection ramps to the highway network it connects into. These costs need to be considered, however given the levels of congestion that would be in the corridor for this to be effective, these costs are generally outweighed by the additional capacity that is provided with the majority of funding being from the users who value the safety and reliability of the lanes, which is ensured through the active technology utilized on the highway.

In Stockholm, London and Singapore, the upfront costs of implementing the system, and the associated public transit improvements, were recouped in less than 5 years. It was estimated that alternatives to the system (e.g., ring roads to divert traffic away from the urban centre) would require far greater investment to achieve comparable traffic reduction goals.

Country Readiness

Dynamic pricing is one piece of a holistic traffic reduction strategy and begin to move away from privately-owned motor vehicles, and affordable, accessible public transportation options are also necessary. Complementary measures should be put in place, in addition to the dynamic pricing scheme.

Technological Maturity

Some technology associated with dynamic pricing is mature, and variations of the systems are already in place in multiple cities including Stockholm and Singapore. Vehicles using the infrastructure can be registered automatically by Automatic License Plate Recognition technology.

RISKS AND MITIGATIONS

Implementation Risks

The integration of technology into large linear civil infrastructure brings with it additional complexities, which are necessary to ensure the infrastructure can be an operational success for the transportation management plan. These complexities include the interface between the different technologies as well as the physical infrastructure as well as the inherently "short-term" life of technology versus long dated infrastructure. An essential tool in ensuring mitigating these complexities has been through effective partnering with and within the team developing the project. By aligning with long-term investors performance outlook a developer has the freedom to partner with technology provider's of choice and invest in both research as well as technological replacements to continue to foster the relationship with the highway users. Ultimately managed lanes success as a tool within a broader travel management strategy ensures seamless use and positive perception by users, so ensuring a constant review of the users experience and engaging with users will drive technological and infrastructure changes.

This use case is a contribution from the D20 Long Term Investors Club, with some adaptions from the Global Infrastructure Hub.

EXAMPLES

Example	Implementation	Cost	Timeframe
Dallas-Fort Worth region highways	The Dallas-Fort Worth region has some of the most congested highways in North America and is utilizing managed lanes as a way to effectively manage highway demand as well as to fund expansion of the transportation network.	This is demonstrated in Dallas-Fort Worth with the LBJ managed lane corridor realizing 20% more traffic (after installation of the lanes) and the general-purpose lanes have experienced a more than 70% reduction in congestion due to improved design of the roadway and traffic that has shifted to the express lanes.	
Stockholm Dynamic Congestion Zone and Bridge Tolls	The cordon scheme uses automatic number plate recognition, in a 35 km^2 zone. The scheme was launched in 2007 after a successful trial in 2006. In 2016 the scheme was updated to a dynamic pricing system based on time of day.	Initial investment of 2 billion krona (USD $236.7 million). Annual operating cost of 100 million krona (USD $11.8 million). Annual net revenue (for reinvestment in roadway improvements) of 1.3 billion krona/year (USD $155 million).	Scheme launched in 2007. Ancillary public transport also implemented to provide alternate travel options to previous road users.

This use case is a contribution from the D20 Long Term Investors Club, with some adaptions from the Global Infrastructure Hub.

Electric Vehicle Charging Cloud Platform

DETAILS

SECTOR | Transport
STAGE | Operations and Maintenance
TECHNOLOGIES | Cloud Computing, EV Charging

SUMMARY

The solution is Electric Vehicle Charging (EVC) system consisting of varying technologies of chargers (slow, fast and ultra-fast) and EV Cloud Platform. Scaling up EVC infrastructure and managing wide networks require these networks to be connected in order to manage charging points remotely. This solution aims at providing several functionalities including monitoring and analyzing charger's usage, setting prices, accessing to chargers and resolving incidents remotely, therefore lowering operational costs substantially and improving operational efficiency.

Mass customization and scalability benefits of the solution enable other operators to use this IT platform. In this way, operators who are willing to focus on improving user experience in charging delivery of smaller operators without capacity of doing substantial investment in the IT infrastructure might benefit from the proposed closed based solution depending on their IT needs.

EV market is expected to grow exponentially in the coming years. This trend requires abilities for faster scale-up and management of wide charging networks as well as capacity to manage vast amount of online transactions and analyze data. In this regard, cloud based solutions equipped with insights and reporting features have potential to handle these requirements.

VALUE CREATED

Improving efficiency and reducing costs:

EV Cloud Platform enables scaling up of EV charging operations and managing wide charging networks more efficiently. This lowers scaling-up and operating costs, and improves operational efficiency.

Enhancing economic, social and environmental value:

Taking EV charging and cloud based IT solution as a complete system, the proposed solution contributes to decarbonization of road transport. This results in benefits of reduced emissions and noise.

Moreover, the solution supports EV market uptake, therefore contributing to bring forward social and environmental benefits of electro mobility.

Project Investment Cost is EUR 100 million (2018).

This use case is a contribution from the D20-LTIC (Long Term Investors Club) together with the LTIIA (Long Term Infrastructure Investors Association) , with some adaptations from the Global Infrastructure Hub.

RISKS AND MITIGATIONS

Technological Maturity

Developments in cloud computing technology and cloud architecture enjoying the benefits of network economies and economies of scale along with the developments in EV charging technologies keep lowering digitally enabled charging technology cost. This enables improved returns on investment.

Cybersecurity

As EV charging infrastructures become more connected relying on vast amount of data transactions for operations, they are exposed to risk of cyber-attacks. Cybersecurity needs to be built in the system starting from the system design.

Privacy

Digitally enabled EV charging systems process vast amount of data, which might include also personal data. The systems should be designed, implemented and operated securing protection of personal data.

User Acceptance

Highly sophisticated management systems and user interfaces would limit user abilities to implement system functionalities causing resistance to use new technologies. Robust and user friendly systems and user interfaces might improve user acceptance. People's concerns over data privacy and cybersecurity issues should be carefully handled.

EXAMPLE: https://www.allego.eu/business/ev-cloud

This use case is a contribution from the D20-LTIC (Long Term Investors Club) together with the LTIIA (Long Term Infrastructure Investors Association) , with some adaptations from the Global Infrastructure Hub.

Electronic Tolling

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Electronic Toll Collection, DSRC, CCTV

SUMMARY

The solution is an Intelligent Transport Systems (ITS) Electronic Toll Collection (ETC) system for heavy-duty vehicles (HDVs). The system consists of a central system and roadside installations and equipment relying on Dedicated Short Range Communication (DSRC) technology using microwave tags inside vehicles to register vehicle passages under microwave receivers mounted on overhead gantries on each section of tolled road.

The solution replaces the toll-collection system based on tolling plazas and physical barriers, for which operational efficiency and long waiting times for vehicles are particular problems. The project is expected to result in savings in travel time and vehicle operating cost by reducing delays and enabling smoother traffic flows. It is expected to have an overall positive environmental and climate impact due to a significant local pollution improvement & fuel consumption/CO2 emission reduction. It allows a more refined application of user and polluter-pay principles in line with sustainable mobility policies. In addition, some positive impacts in the form of accident reduction, currently occurring at toll stations, may also be expected. As the system employs roadside ITS with capacity to generate traffic data, the system also enables such functionalities like (i) traffic information in real time; (ii) payment services; (iii) safe parking of trucks; and (iv) traffic monitoring (e.g. for transport of dangerous goods) and for measuring traffic flows and speeds, therefore contributing to improve transport efficiency on the road network.

As an effective way of applying application of user and polluter-pay principles, ETC systems (in particular, systems for implementing distance-based pricing policies) are expected to be implemented more widely in the current environment where public concerns intensify over climate crisis. There are variety of available technologies to implement ETC systems and project contexts might suggest different technologies. Besides the DSRC technology that has been adopted in this use case in Slovenia, such other technologies like Radio Frequency Identification (RFID), Global Navigation Satellite System (GNSS) or mobile communications using the GSM-GPRS standard can be given as examples of other technologies that could be used for ETC systems. Nevertheless, considering increasing traffic data intensity fed by different data sources and advancements in data processing technologies and artificial intelligence (AI), it might be expected to have more data and software intensive ETC systems rather than systems mostly relying on roadside equipment.

This use case is a contribution from the D20-LTIC (Long Term Investors Club) together with the LTIIA (Long Term Infrastructure Investors Association) , with some adaptations from the Global Infrastructure Hub.

VALUE CREATED

Improving efficiency and reducing costs:

The solution helps transforming the existing open system to a closed system, thus increasing the capture rate of vehicles using the network. This results in 8.5% increase in toll revenue, which can be used for financing of infrastructure.

The solution is also expected to improve operational efficiency of tolling system and transport network efficiency resulting in savings in travel time and vehicle operating cost by reducing delays and enabling smoother traffic flows.

Enhancing economic, social and environmental value:

Due to reductions in waiting times and congestion at toll plazas, the system offers travel time savings and reductions in fuel consumption as well as significant local pollution improvement and CO_2 emission reduction.

In addition, some positive impacts in the form of accident reduction, currently occurring at toll stations, may also be expected.

As the new scheme is proposed to replace an existing toll collection system, no modal shift impact is expected assuming there is no change in pricing policy.

Project Investment Cost is EUR 105 million (2017).

RISKS AND MITIGATIONS

Technological Maturity:

- ETC systems employ mature technologies (i.e. data processing, DSRC, ANPR, CCTV, RFID, GNSS, etc.). However, increasing data availability and advancements in data analytics might bring forward new technologies (e.g. AI, Floating Car Data) for the use of ETC systems. Project context and data availability should be taken into account when selecting the appropriate technology.

System Accuracy & Reliability:

- Although underlying technologies of ETC systems are mature, critical functions (i.e. vehicle identification, measurement) are exposed to prediction errors – posing risk in system accuracy and reliability.

Cybersecurity:

- As other digital systems, ETC systems are at risk of cyber-attacks.

Privacy:

- ETC systems process vast amount of data, which might include also personal data. The systems should be designed, implemented and operated securing protection of personal data.

Employment & Workforce Transition:

- Introducing automated systems inherently carry the risk of job loss (in case the automated systems replace labour intensive manual systems) and skill gap due to uprising need for workforce transition. Special job placement services and training programs might help to mitigate these issues and to displace people to gained jobs in new services like Help Desk and Customer Service Points.

User Acceptance:

- Introducing new pricing schemes might cause frustration on people posing significant risk to put systems in place. Therefore, pricing strategy should be an integral part of the project.
- People's concerns over data privacy and cybersecurity issues should be carefully handled.

EXAMPLE: https://www.darsgo.si/portal/en/about-us

This use case is a contribution from the D20-LTIC (Long Term Investors Club) together with the LTIIA (Long Term Infrastructure Investors Association) , with some adaptations from the Global Infrastructure Hub.

Heritage Recovery with 3D Printing

DETAILS

SECTOR | Transport, Energy, Water Waste
STAGE | Operations and Maintenance
TECHNOLOGIES | 3D Printing

SUMMARY

Heritage is often one of the treasures that humanity has a duty to preserve for the knowledge and enrichment of future generations, something that sometimes involves a compromise between the need to preserve it and to show it. We consider 3D printing we consider a very powerful tool, together with the help of scanner technologies, to achieve both objectives.

With the large scale 3D Printing technology with Concrete, we can reconstruct elements that were lost or damaged for different reasons, or totally or partially replicate heritage pieces (scale of choice), without the need to resort to skilled artisans, today difficult to find. This technology also helps optimize the consumption of material as well as the execution time of the replica, which undoubtedly constitutes a great contribution in this field.

Technology is capable of carrying out the entire process (scanning and printing of the model).

The phase in which the model to be printed is generated is very important for the final result. Here, Reality Capture technology manages to reproduce in the space with fidelity the geometry that you want to reconstruct or replicate, with advanced scanners that can achieve this objective at a very affordable cost and with significant time savings. These scanners are becoming increasingly competitive and improving its quality.

In turn, this capture must be treated so that 3D printing software can "slice" the figure correctly, for a correct impression. In this field we must say that there are significant advances that make this transition easier and faster, which undoubtedly contributes to reducing the impact that this task has on the total cost of the exercise.

Once we have the printing model, the technology that offers the best results for this type of reconstruction or replication work is that of Powder Bed in large-scale concrete. This technology offers us total freedom of forms, in addition to having a more than acceptable precision, and even in a very simple way to integrate in the final solution other types of solutions that lead us to increase this precision, such as subtractive printing, mix of elements in other materials, etc ...

One aspect to take into account is the transport of the final printed result. If the element to be rebuilt or replicated is of such a dimension as to pose a logistical challenge or an excessive transportation cost, we have different ways to solve the problem. We can choose to make the impression in smaller parts, and put them together on site as if it was a three-dimensional puzzle. Another alternative is to send the large-scale 3D printer to the place where we want to reconstruct or replicate, and print on site.

This use case is a contribution from the Government of Spain, with some adaptions from the Global Infrastructure Hub.

VALUE CREATED

Improving efficiency and reducing costs:

3D Printing is more efficient and less costly than conventional methods technologies because of its particular working process. Normally you would need formwork, especially when the element to replicate has complex forms, holes, etc. In these cases, we need the aid of an artisan to build the formwork that receives the mortar, with a significant impact on time and cost. With the 3D Printing process, no formwork is needed.

With Reality Capture it is a simple process to have the 3D model of a heritage element, insert it in a 3D Printing Powder Bed concrete machine, and build the element in concrete. We don't need an artisan. The element is formed here layer by layer, using only the material needed. The no hardened material around the printed element helps to hold it and this way, our Powder Bed machine has real free form manufacturing capabilities.

With the 3D Printing process construction, we arrive in two steps from the model to the real element with less people involved. It results in less time of working, thus more efficiency and lower cost.

Enhancing economic, social and environmental value:

From an economic standpoint, it is cheaper to use the 3D Printing technology to recover the heritage than conventional methods. Moreover, once we have made the 3D model, we can help preserve the element in a virtual way forever, using this model to make a Virtual replica that allows enjoy it in a virtual way, too. Further physical replicas can also be made on demand.

Social contribution is also an important input: helping preserve our culture for future generations is an example, bringing replicas to blind people that can touch and get to know heritage elements is another important benefit of this 3D Printing use case.

With 3D printing we come near to zero waste product generation in the construction process, as practically all the material we need for printing, and no hardened, can be reused. Constructing on site can also be a relevant environmental benefit of this technology, saving transportation impact.

POLICY TOOLS AND LEVERS

Legislation and regulation

To build a heritage element, the official entity responsible of the element has to give the permission to replicate it. Beyond this use case, the development of the concrete printing technique will need new building legislation and standards to be developed and help foster its normalization.

This use case is a contribution from the Government of Spain, with some adaptions from the Global Infrastructure Hub.

Dubai may lead regulation set to use 3D printing in the construction industry, as Dubai Future Foundation has already announced.

A future-enabled workforce

This technology will coexist with the conventionalmethodsof construction, and offer opportunitiesfor many workers, architects, engineers, public and private Entities etc related with culture and the preservation of the heritage, boosted by the concept of a new way of enjoyingit.

RISKS AND MITIGATIONS

Technology Maturity:

Technology is reaching maturity to fabricate in different types of materials, but further development of materials, machinery and new designing methods are still necessary, especially for concrete large-scale 3D printing.

Ensured Reliability:

This technology has proven its reliability for many use cases. Challenge is now set on large-scale printing, especially for structural elements.

Infrastructure Readiness:

Technology is commercially available: a high number of companies offer their own 3D printing technology, including printers and printing materials. New materials and use cases are under development.

For concrete 3D Printing, we find two main technologies: Powder Bed and Extrusion.

Powder Bed: This technology is based on printing 5mm full section layers. The process consists on extending one layer of dry material (paper) on which a printing head applies a binder (ink) on the corresponding section of a previously sliced 3D digital model.

Extrusion: This technology consists on the deposition of a mortar through an extruder following a predefined path, layer by layer to create exterior walls of an element to be filled later on with concrete.

Both are ready to print and give you a solution of build in concrete, but with differences.

“Powder Bed”		Extrusion
Shapes. Free form	Main value	Performance
Singular construction, Preservation of historical heritage, Urban furniture, Sculptures	Products	Prefab walls, buildings, extruded shapes.
Dry mortar + binder	Material	Extruded morat
Low	Presence on market	High
High	Design capability	Limited
Modular and assembly on/off site	Execution	Modular or In situ

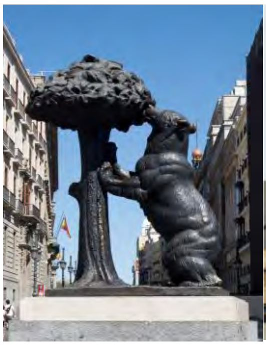
This use case is a contribution from the Government of Spain, with some adaptions from the Global Infrastructure Hub.

EXAMPLES

ACCIONA has the technology capable of carrying out the entire process (scanning and printing of the model), the experience of six years of research and development around 3D printing within our 3D Printing Skill Center, and the recently inaugurated global 3D printing center in Dubai.

Some examples related to conservation and the recovery of lost heritage (non-exhaustive):

- **Replica of "The Bear & Strawberry Tree". Madrid Emblem**
    - It represents in a real-life form the coat ofarms of Madrid Emblem.
    - Original Sculpture located Puerta del Sol Square (Madrid, Spain).
    - Replica donated to Guadalajara (Mexico) in 2017
    - A bear that supports its paws on the trunkof a strawberry tree and the strawberrytree.
    - Author: Antonio Navarro Santafé. Year 1697.




- **Replica of Romanic Arc "Arco de San Pedro de Las Dueñas de Leon"**
    - Life-size replica of one of the reference elements of the National Archeologic Museum collection, a XII century Romanic arc fully preserved.
    - Both original and replica currently located at the Spanish Archeological National Museum (Madrid, Spain).


This use case is a contribution from the Government of Spain, with some adaptions from the Global Infrastructure Hub.

Hyperloop

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Hyperloop, Solar, Magnets

SUMMARY

Hyperloop is a proposed mode of ground transport for passenger and freight transportation which consists of pods transported at high speed, through the length of low-pressure tubes that are elevated off the ground, due to a lack of air resistance or friction. Hyperloop has the potential to travel at speeds in excess of 1125km/h (700mi/h) which would reduce travel times over medium-range distances (up to 1,500 kilometres (930 miles)).

The concept of using low-pressure or vacuum tubes as part of a transport system has a long heritage. The Crystal Palace pneumatic railway in London used air pressure to push a wagon uphill (and a vacuum to drag it back down) in 1864. The 'vactrain' developed by Robert Goddard in the early twentieth century is another predecessor to the Hyperloop. Since then, many similar ideas have been proposed. Interest in the concept was reignited by Elon Musk's 'Hyperloop Alpha' paper published in August 2013, which explored how a modern system could work and how much it could cost.

Travel between cities is largely achieved today through road or rail travel or via air travel, which, though travelling at higher speeds, is problematic due to the additional travel time to/from airports, the need to arrive considerably in advance of departure time, security restrictions, and expense. Air travel is also susceptible to weather conditions, produces noise pollution and is a significant contributor to carbon emissions. Hyperloop is a potential alternative to travelling over medium distances between city centres, which combines the convenience of rail travel with the speed of air travel. It is proposed to be a cheaper and faster option to existing high-speed rail links that could revolutionise passenger and freight transport and supply chains.

Hyperloop is anticipated to be a fast and carbon-neutral way of connecting cities. Hyperloop systems are envisioned to run exclusively on renewable energies that would enable the system to generate more energy than it will consume. It has been proposed to install solar panels along the outside of the Hyperloop tube, which charge batteries storing energy for use at night.

Companies developing Hyperloop are also considering ways to build elevated tracks in major road medians and next to existing railway tracks to lessen the impact construction might have on ecosystems, natural spaces and people living nearby. Hyperloop could be built above or below ground. Building above ground is viable in regions where land is cheap and lacking in obstacles and dense communities, with tunnelling the more feasible option for more developed areas such as the UK, where it is challenging to clear densely built up areas.

VALUE CREATED

Improving efficiency and reducing costs:

- Hyperloop developers have suggested that it will be quicker and cheaper to build than traditional high-speed rail, however this has not been proven. In high income economies with fast urban growth and low density, where mass transit infrastructure is not yet developed, this statement might be relevant as the investment needs for mass transit are important and relevant operational choices for high capacity and fast travel times should be made. However, it is not the case for many countries and hyperloop will remain an expensive solution until a relevant business model is defined.
- Hyperloop developers have suggested that the systems are expected to be profitable thereby minimising or eliminating the need for government subsidies, however this has not been proven. Some level of public funding is still expected to be required in order to continue to promote further innovation and research to enable the technology to be efficient and to provide the expected public benefits
- Companies are exploring how to design the tubes and systems so that they require less maintenance and asset life is extended

Enhancing economic, social and environmental value:

- Improve connections between regional communities and urban centres
- Reduce air travel between cities thereby minimising emissions and improving air quality
- Shorter routes could be up to six times more energy efficient than air travel[1]
- Enhance economies and trade as people could more easily work in one city and live in another, or visit another city for social and cultural events
- Reduce the pressure on housing in cities by making commuting fast and enabling people to live further away

POLICY TOOLS AND LEVERS

Legislation and regulation: Hyperloop also presents a potential legislative challenge: Like autonomous vehicles, the uniqueness of this transport mode means much of the existing regulations and standards worldwide are not applicable to it and thus a new regulatory framework will need to be developed. Governments should collaborate with Hyperloop companies at the early stages of development to address the regulatory gap.

Effective institutions: Embedding hyperloop in strategic infrastructure planning would be necessary, and to do that, understanding the demand and the integration with other transport modes will be a prerequisite to implementing any regulations on its operational expectations.

Transition of workforce capabilities: Hyperloop operations and maintenance would require a whole new set of capabilities and the technologies of operations do not rely on any existing or operating systems. Appropriate training of operating staff will need to be made, such as on signalling and driving for example. Safety regulations and specific accreditations linked to the operating objectives of hyperloop should be anticipated and defined prior to the launch of any services.

Funding and financing: Funding for Hyperloop systems would probably be a combination of public and private investment. This is in order to continue to foster the innovation and research for improvement of the technology. It is also because most governments will be looking at sharing the risks with the private sector until the solution is proven to be efficient and to provide public benefits.

[1] "'Faster, cheaper, cleaner': experts disagree about Elon Musk's Hyperloop claims", The Guardian, Accessed 15 May 2020.

IMPLEMENTATION

Ease of Implementation 	At a large-scale with passengers and various routes and networks development, the operational performance of hyperloop has yet to be demonstrated. The success of Hyperloop will fluctuate between destinations. It will be influenced by local economies, cost of land, existing infrastructure, culture and geographies. It is expected that routes in regions with less infrastructure development will be easier and cheaper to get Hyperloop services up and running.
Cost 	While Hyperloop companies claim their services can be built between one-tenth and one-half of the cost of high-speed rail, there remains many integration engineering challenges that could push the costs up. The average construction cost of Hyperloop is estimated to be USD 116.8 million per kilometre (USD 73 million per mile)[2], but will vary depending on the region. Additional land acquisition costs could place Hyperloop at USD 256 million per kilometre (USD 160 million per mile). This is approximately on par with the California High Speed Rail Development (USD 283 million per kilometre / USD 177 million per mile), but cheaper than the proposed HS2 in the UK (USD 339 million per kilometre / USD 212 million per mile) [3]. The potential need for tunnelling in built up areas will increase the cost further.
Country Readiness 	As of today, the readiness requirements are understood in high income economies as a combination of fast urban growth; low density; low mass transit infrastructure availability, high capacity requirements and fast travel times. However, as the technology is not proven yet, the readiness assessment still needs to be completed. In low income economies, the implementation costs and high investments clearly impact on the readiness.
Technological Maturity 	Hyperloop technology has not been tested commercially. The next stage is to move beyond initial testing and feasibility studies, and to begin longer distance trials of the technology and passenger tests. The specific type of magnet required for Hyperloop may result in a supply bottleneck as large-scale manufacturing capabilities are not yet in place. Batteries will be critical if Hyperloop is to run completely off renewable energy, as batteries will provide the pod with power at times when solar panels are not effective. Batteries have been declining in price and increasing in capacity but require further improvements to ensure Hyperloop's success.

RISKS AND MITIGATIONS

Implementation risk

Risk: Critics have questioned Hyperloop's potential capacity due to the small payloads associated with the pod design. To match the capacity of conventional metro systems, Hyperloop systems would require hundreds of pod departures every hour, leaving an approximate 9 second headway between pods.

Mitigation: Organizations need to consider how many tubes should be built to prevent limiting capacity. Governments should consider whether the system is able to compete with existing high capacity modes (e.g. Metro, High-Speed Rail) as well as other upcoming alternative technologies (*see Supraways use case*).

Social risk

Risk: Critics of Hyperloop have argued that the extreme speeds may produce an uncomfortable riding experience for passengers due to G-forces and jostling. In addition, travelling in a concrete pipe in a windowless pod may not produce an enjoyable travel experience and may be too alien for passengers.

[2] "Hyperloop: Cutting Through the Hype", The Future of Transport, Accessed 5 May 2020.
[3] "Hyperloop: Cutting Through the Hype", The Future of Transport, Accessed 5 May 2020.

Mitigation: Hyperloop companies have theorised that travelling on Hyperloop will feel like travelling in an elevator or a passenger plane with gradual acceleration and deceleration. Developers will need to ensure travel is smooth and comfortable for passengers to ensure uptake. They should install personal entertainment systems and internal landscape imagery and/or mood lighting to create a more comfortable experience. Safety will also be a key factor in encouraging user adoption. Like in the aerospace industry, Hyperloop will need to effectively respond to incidents to improve safety over time and reassure potential customers.

Safety and (Cyber)security risk

Risk: The Hyperloop tube system could be vulnerable to terrorism or sabotage. Due to the raised or underground tube design, logistical questions will need to be considered regarding how operators will respond to common issues including equipment malfunction, accidents and emergency evacuations. Due to the high speed of travel there is a high risk to passenger safety if an accident occurs.

Mitigation: The aerospace and metro industries have faced similar safety issues and have had to improve tunnel and air travel safety over many decades. Hyperloop will have to go through a similar process. Hyperloop systems will also require comprehensive CCTV and other monitoring systems across their network and robust procedures to respond to potential emergent incidents.

Environmental risk

Risk: The environmental impact of the construction of Hyperloop systems is high, given the infrastructure and level of energy and operations required. The offset of such impact is not yet fully modelled or understood.

Mitigation: Clear environmental impact assessments and models should be developed and performed with models showing the long-term sustainable value or offset of CO_2 emissions of Hyperloop.

EXAMPLES

Example	Implementation	Cost	Timeframe
Virgin Hyperloop One	One of companies developing Hyperloop systems, with current projects underway in Missouri, Texas, Colorado, North Carolina, the Midwest, India, Saudi Arabia, and the UAE. The first hyperloop route in India will be built between Pune and Mumbai.	Implementation costs assessed, but operational costs not clearly assessed.	Concept design developed.
Hyperloop Transportation Technologies	HTT has signed a memorandum of understanding to build a Hyperloop between Vijayawada and Amaravati in India.	Implementation costs assessed, but operational costs not clearly assessed.	Planning phase, with only capacity and operations performance calculations performed to assess risks.
Hyperloop Alpha	Published in August 2013, Elon Musk's paper proposed a route running from the Los Angeles region to the San Francisco Bay Area.	Implementation costs assessed, but operational costs not clearly assessed.	Currently a pre-feasibility stage.

Intelligent process optimisation for water treatment

DETAILS

SECTOR | Water

STAGE | Operations and Maintenance

TECHNOLOGIES | AI Augmentation, Data & Analytics, Sensors / IoT

SUMMARY

Intelligent process optimisation for drinking water and wastewater treatment plants provides an opportunity to automate the control of treatment processes and/or provide real-time decision support for treatment plant operators.

Historically, treatment plants have been operated by humans based on scientific guidelines. The challenge is that the quality of the source water (i.e. influent) can vary significantly at each treatment plant and therefore requires different treatment processes and levels of chemical dosing etc. in order to meet the required treated water standards. Treated water must meet aesthetic standards (i.e. taste, odour, and colour) for customer satisfaction. But most importantly, treated water must also meet strict water quality regulatory standards for health and environmental purposes.

The requirement to meet these water quality standards costly, and includes chemicals, energy, and labour. Globally, industries and water utilities and municipalities spend approximately USD 76 billion annually to operate treatment plants[1].

Plant operators can develop significant knowledge that allows them to fine-tune the operations of a plant in order to meet water quality standards at a lower cost. However, this takes time. The efficient operation of a treatment plant relies on the knowledge and judgement of its operators. The knowledge and experience of previous operators can be difficult to document for future operators.

Artificial intelligence (AI) technology and a digital replica of treatment processes (i.e. a digital twin – *see also the Digital Twin Use Case*) provide an opportunity to optimise drinking water and wastewater treatment plant processes to achieve significantly reduced costs. Self-learning AI technologies can analyse historical and current treatment plant sensor data and patterns in real time to control the processes themselves and/or provide real-time decision support for treatment plant operators in the form of performance projections and recommended actions.

As well as improve the efficiency of drinking water and wastewater treatment plants, AI could also improve the reliability of the water quality (i.e. meet water quality standards for a greater percentage of time). For water

[1] Global water market: breakdown by OPEX and CAPEX Global Water Intelligence: Water Data. Accessed 29 April 2020

utilities and municipalities this presents an opportunity for greater customer satisfaction, higher levels of corporate responsibility, and improved environmental outcomes.

The use of AI and digital twins in this space is in its infancy. One major challenge is the creation of a digital twin that can replicate the chemistry of water treatment processes within a treatment plant. Without a digital twin based on sound theory, the AI could potentially provide poor decision support when faced with input data that varied significantly from historical data.

Another challenge is the availability of historical data, which in turn relies on the sufficient sensors throughout the treatment processes. Without enough historical data, the AI will take some time to learn how to best optimise the treatment processes. In the future, developments in sensors and IoT technologies (related to scaling up manufacturing and deployments) are rendering these technologies lower cost, therefore enabling more sensors to be used and therefore more historical data to be provided to the AI. As the AI has access to greater amounts of relevant data, it is able to make better predictions and decisions. Additionally, as research and development continue for machine learning prediction and control algorithms, they will be better able to optimise the treatment processes, selecting better operations that further reduce costs, and doing so with less data.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduced operational costs due to better operational treatment decisions and recommendations being made in real-time by AI.

Enhancing economic, social and environmental value:

- Improves aesthetics of water for society by providing real-time decision support during unusual operating conditions (e.g. extreme water quality events) to reduce human bias and the time required to respond to changes in operating conditions.
- Enables a higher level of service to customers through a consistent water quality
- Can provide more water from a given source. For example, water treatment plants must use some of the treated water to wash treatment plant filters. As a conservative measure, this "backwashing" occurs frequently, but the treated water used for backwashing must be treated again. AI would potentially be able to safely reduce the frequency of backwashing when the conditions were appropriate, and therefore produce greater volumes of treated water.
- Treatment plants that run with a higher efficiency may provide an opportunity to delay capital expenditure on treatment plant expansion infrastructure.

POLICY TOOLS AND LEVERS

Legislation and regulation: Regulation of both water quality and asset management can drive the implementation of these smart solutions. Government regulations, social responsibility, and sustainability targets drive utilities to improve health and environmental outcomes (e.g. a cryptosporidium incident in Sydney in 1998 was estimated to cost it in excess of AUD 700 million, including an increase in the regulatory burden and water quality monitoring[2]). An increase in regulatory requirements increases the cost of treating water. However, this creates financial pressure for water utilities, causing them to seek efficiencies that offset some of the increase in the cost of treating water.

Effective institutions: "Data-smart" institutions such as universities can help commercialise research in AI to technologies and make these tools business-as-usual.

[2] Regulatory Impact Statement for review of the Water NSW Regulation 2013. WaterNSW. Accessed 25 April 2020

Transition of workforce capabilities: Training and upskilling of workers is required to effectively explore the real-time recommendations from AI, sense-check these recommendations (AI cannot truly sense-check in its current form), and action the recommendations if appropriate.

IMPLEMENTATION

Ease of Implementation

Technology companies are already beginning to produce the required AI and digital twin technology (e.g. KOIOS DatalytiX and Createch360). However, the technology is still in its infancy and as such it is not yet common in industry. As AI technology improves and water treatment plants develop larger, cleaner, and more complete sets of historical data, these technologies will be more widely adopted.

A major challenge to implementation is a lack of sensors in treatment plants in developing countries. This prevents the training of AI on historical data. However, as the cost of sensors decreases and sensors become more ubiquitous, this problem will fade. The actual implementation is not complicated once all the necessary pieces are in place.

Cost

Sensors are inexpensive (relative to the cost savings that can be achieved) and are becoming even more so over time. Digital twins of treatment processes may require significant time and cost to develop. However, once a treatment process (e.g. filtration) has a digital twin created, it should be applicable across any treatment plant that uses the same process.

Country Readiness

This technology is most ready to be implemented in developed countries where sensors within water treatment plants are likely to have been operating for some time already, and therefore data is available for training the AI. In developing countries, money is required to obtain sensors and time is required to collect data that can be used to train the AI.

Technological Maturity

Currently, AI technologies require large sets of historical data to understand enough about the treatment plant to adequately provide real-time decision-support to operators. As AI improves, it may require less and less data.

Present-day AI technologies are sufficiently advanced to handle most conditions that drinking water and wastewater treatment plants encounter. However, it is still very important that treatment plant operators are able to sense-check the AI calculations, particularly if the treatment plant experiences unusual conditions. As AI advances, it may be possible for the AI to do this sense-checking, even in never-before seen circumstances.

RISKS AND MITIGATIONS

Implementation risk

Risk: Artificial intelligence is trained based on historical data. However, if the historical data is of low quality (e.g. due to short time frame of data, incorrectly calibrated sensors, gaps in the data, etc.), then the AI is also likely to be of low quality.

Mitigation: Any proper implementation of artificial intelligence requires skilled data scientists, software, and water treatment specialists to analyse historical data and ensure that it is accurate and of a sufficient quantity for the training of the AI. The AI should also be thoroughly validated through trials with operators.

Social risk

Risk: Automation can create the need for re-training of workers to operate, maintain and oversee automated systems and focus on more strategic activities focusing on longer term planning of treatment plant maintenance and operation.

Mitigation: Drinking water and wastewater treatment plant operators should be upskilled to learn how to interpret, make sense of, and action any decision-support that is provided by the AI.

Safety and (cyber)security risk

Risk: Control systems, especially those located in the cloud, are at risk of cyber-attacks that can leave critical infrastructure vulnerable.

Mitigation: Training of AI is generally done in the cloud, however, once training is complete the AI can be easily run on a desktop machine. Therefore, it is possible to have the AI in a desktop computer on-site at the treatment plant and to not have it connected to the internet, or to only have limited access to the cloud.

Environmental and social risk

Risk: Artificial intelligence is trained based on historical data and can be bad at providing decision support if it receives data that is dissimilar to the historical data that it was trained on. This can lead to severe health or environmental risks if water is insufficiently treated.

Mitigation: This can be mitigated through the use of highly skilled operators who can make sense of the decision support provided by the AI and ensure that it makes sense based on their knowledge of the system.

EXAMPLES[3]

Example	Implementation	Cost	Timeframe
Createch360	Optimisation software has applied at the Brembate wastewater treatment plant in Italy, treating 53,600m^3 of waste water a day (236,000 Population Equivalent).	The software resulted in a 19% reduction on energy consumption. With a payback period of 1-2 years.	The system is custom developed for specific treatment plants and operation within 3 months.
Emagin HARVI	The HARVI systems was applied in the City of Calgary, Canada which serves over 1.2 million residents and over 20,000 industrial, commercial and institutional (ICI) customers. Using AI, HARVI generated real-time pump schedule to minimise the cost of operations while guaranteeing compliance and maintenance requirements, by collecting operational data.	EMAGIN was able generate 21% savings relative to baseline operations. This corresponds to a payback period of 3 months.	The AI system is custom built for different treatment plants. The timeframe of implementation is dependent on historical and live data available.

[3] Information for Examples in this use case was gathered via communications with commercial technology stakeholders.

Knowledge access platforms for construction and maintenance

DETAILS

SECTOR | All sectors

STAGE | Project Delivery, Operations and Maintenance

TECHNOLOGIES | Workforce mobility solutions, See-What-I-See (SWIS) applications, wearables

SUMMARY

Digital knowledge platforms centralise data and knowledge and make it readily accessible to workers both onsite and in the office. This is typically in the form of engineering drawings or maintenance information. In addition to these central platforms, mobile or wearable devices, such as smart-glasses or smart-helmets, can enable quick and easy access to this data as well as facilitate See-What-I-See (SWIS) applications, where skilled specialists can share their vision in real time back to a centralised specialist or supervisor. These two elements in combination, central and mobile, allow the provision of correct knowledge to the places it is needed and at the times it is required.

These tools have been developed to reduce inefficiencies and enhance onsite safety. The centralisation of data both visual and on paper, creates a single source of truth for increased accessibility between operators and planning staff, and allows easier version control of key documents or drawings. Having a single source of truth can ensure that workers are using the right information.

In a digital age, critical infrastructure and maintenance information is still being stored and distributed through physical copies which are difficult to keep track of and not readily available onsite. To compound this, on-the-job knowledge and skills are being lost due to the aging and increasingly mobile workforce. Existing communication and knowledge transfer processes between and within large or complex teams onsite can lead to increased health and safety risks as well as productivity inefficiencies.

The overall outcome of these tools reduces project time and cost, while improving quality and safety. Knowledge access platforms will enable workers to complete projects faster, maintain quality and reduce the chance of work site safety incidents, helping save lives. Access to the correct knowledge allows workers to complete the job the first time they visit the site. Access to specialist skilled resources at a central location allows remote workers to complete the job correctly and ensure quality.

Increased research and development of mobile workforce tools and wearable technologies are decreasing costs and increasing capabilities to enable hands free and seamless access to information.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce operational costs and increase efficiency and productivity through reduced asset downtime, improved time to resolve tasks and issues, and improve first-time fix rates by having resources and support readily available
- Less material wastage
- Less travel required to and from site

Enhancing economic, social and environmental value:

- Decrease health and safety risks by improving access to critical project specific information, such as correct procedures, troubleshooting and support
- Enable expertise to be remotely shared to less experienced staff in real time
- Ensure expertise is not lost when personnel move sites, change jobs or retire

POLICY TOOLS AND LEVERS

Legislation and regulation: Workplace safety regulations should not prohibit the use of innovation technology that has the ability to reduce accidents. A risk-based approach can be used to ensure that appropriate measures are implemented while keeping the responsibility on project and site owners.

Effective institutions: Develop or establish mobile and internet networks and infrastructure allowing information to be quickly accessed onsite and in remote locations. Collaboration between government agencies such as water utilities, public health and environmental protection is needed to prevent the replication of data that can be utilised by all stakeholders and enable funding from all agencies to share risks and rewards.

Transition of workforce capabilities: Training and upskilling in new methods and procedures of work will enable workers to utilise new platforms and technologies effectively. Make available experienced workers who can record and share expertise and skills for various projects and tasks.

IMPLEMENTATION

Ease of Implementation

These solutions are not too technically challenging, but will require some workforce planning and organisational change to adopt new methods. The uploading of physically-located information into digital platforms can be a time-consuming task.

Cost

These are relatively low-cost solutions compared to larger infrastructure solutions. The commercially available technologies have been designed to save cost thorough their implementation.

Country Readiness

Developed countries are well suited to adopt these technologies with established safety and reporting standards creating a ‘ready workforce’ environment. Established internet and communications networks will be needed to handle and transmit large amounts of real time data.

Technological Maturity

These technologies are currently commercially deployed and have been in operation for a number of years. The wearables aspect is less mature than document (e.g. engineering drawings) platforms.

RISKS AND MITIGATIONS

Implementation risk

Risk: The speed and complexity of integrating legacy systems into new digital data management processes and storage platforms.

Mitigation: Data management, data standards and quality control can assist in transitioning data into new platforms. Gradual change and adequate frontline worker engagement and training during trialling and piloting activities is vital for staff to “buy in” to new technologies and successfully transition to new digital working processes.

Risk: Too much information at once - access to additional or excess information can be a distraction for the worker from the task at hand.

Mitigation: Proper procedures to find the balance between insufficient and excessive information are needed. This can be one through trails initiated by governments, or the technology developers or users.

Safety and (Cyber)security risk

Risk: Data platforms and tools need to be robust, user friendly and scalable to manage large and complex projects and meet worker expectations.

Mitigation: New platforms will need to be built so they are reliable and will also need to be secure to protect sensitive or confidential information.

EXAMPLES

Example	Implementation	Cost	Timeframe
Hindsite	Hindsite have worked with Sydney and Melbourne-based water utilities to provide knowledge management and collaboration platforms, including See-What-I-See (SWIS), which reduced the amount of time staff were required in the field[1].	Benefits included 70% improved communication and knowledge transfer with error rates and personal safety issues reduced to almost zero, 88% lift in first time fix rates, 70% reduction in time, travel and delays, 83% of knowledge leaving the industry effectively captured, curated and preserved for future value.	Hindsite is in the early commercial stages and in developing use cases for water and adjacent industrys.
RedEyeDMS	Southern Nevada Water Authority (SNWA) started a pilot to with RedEyeDMS platform to establish "single source of truth" for engineering drawings so all personnel have the right drawing at the right time.	SNWA saw an increase in productivity and accessibility from using RedEyeDMS, with the time to find drawings reduced from 10 minutes to 2 minutes. This translated to 450 hours saved per month and a 20 month return on investment[2].	RedEyeDMS is was fully integrated into SNWA's existing engineering management systems within 12 months.
MaintenanceTV	It is in use in wind turbine infrastructure maintenance organisations, connecting more than 3000 technicians from 40 countries. The cloud-based knowledge system allows for easy collection and retrieval of asset specific information through their mobile device[1].	Cost benefits realised includes reduced infrastructure downtime, lower repeat call rates and reduced use of parts.	The project started with a 10-person demo and was rolled out to over 3000 technicians over 12 months.

[1] Information for this example was gathered via communications with commercial technology stakeholders.
[2] Case Study - Southern Nevada Water Authority, RedEyeApps. Accessed 22 April 2020.

Last mile infrastructure for water provision in developing countries

DETAILS

SECTOR | Water

STAGE | Operations and Maintenance

TECHNOLOGIES | Water kiosk, smart metering, innovative business models

SUMMARY

Last mile infrastructure for the water sector is the connection of water access to a user's home or community. This solution is a commercially viable way of providing that infrastructure to a broader range of stakeholders through the application of the correct treatment technology, digital metering and payment, and a business model that incentivises the provision of this infrastructure. This solution is available to both private and public infrastructure service providers. Public utilities can take on the elements of the solution or outsource it to a private provider.

The last-mile market segment refers to peri-urban and rural areas, who remain unserved by most water operators. Decentralised water technologies can provide cost-effective and sustainable means of accelerating national and global strategies (e.g. the Sustainable Development Goals) to provide access to safe drinking water without the substantial investment typically needed for conventional centralised water infrastructure. Digital technologies are enabling new, commercially feasible, business models and decentralised infrastructure options that can enable the provision of access to clean water for last-mile customers.

Developing countries often lack access to clean and safe drinking water, especially in non-urban areas. More than 785 million people currently lack access to basic water services, 80% of which lived in rural areas[1]. Technical solutions are known and available, but their application remains challenging, primarily because water operators and their funders lack the confidence that investing in the last-mile market will provide a financial return. Smart meters *(see also the Smart Meters Use Case)* and digital payment platforms allow water operators to service areas with increased confidence in the business case.

This combination of digital and treatment technologies can enable last-mile communities to have access to clean water through local water kiosks and community water automatic service providers.

The provision of this technology is currently limited to a few providers but future direction can include more providers offering this in more regions or governments could adopt a similar model for water provision where applicable.

[1] UNICEF. *Progress on household drinking water, sanitation and hygiene: 2000-2017*. 2017. Accessed 10 April 2020

VALUE CREATED

Improving efficiency and reducing costs:

- Avoids prohibitive upfront expense of large treatment plant and piping projects through scalable, portable and quickly deployable plants

Enhancing economic, social and environmental value:

- Increases access to clean water and therefore also associated benefits in health, development, productivity and social outcomes
- Access to water can help the management of health pandemics (e.g. clean drinking water and facilitating hand washing for personal and community hygiene)
- Increases revenue for water authorities and operators through the increasing customer base and more effective billing strategies (prepaid metering)
- Access to clean water is a platform to boost economic growth
- Water connected to the home or community allows residents to stay home rather than travel for water
- Successful early adoption, can potentially drive local economies and encourage more investment into developing last mile infrastructure
- Lower energy requirements of decentralised treatment enables off-grid operation on alternative energy sources
- Last-mile technologies and business models could assist communities to deal with natural disasters and pandemics by providing clean water to end users. Decentralised systems are less likely to be affected by large scale events

POLICY TOOLS AND LEVERS

Legislation and regulation: Local and national government strategies and development targets should be set for water supply coverage. Flexible tariff adjustments and regulatory frameworks should be allowed as new and alternative business models may be new ground for regulators managing tariff and pricing structures. Collaboration between regulators, operators, solution providers and communities is needed.

Funding and Financing: Funding is required to invest in technology for rural areas and technology transfer to bring proven technologies into developing countries. New business models enabled by these new technologies can help to attract greater private finance.

Procurement and contract management: Governments could open up the types of concessions they allocate to allow more micro-concessions that suit this style of operation. Incentivising entrepreneurship in developing areas will drive the uptake of new business models. In conjunction with this, the operator workforce will need to be upskilled to install and operate last mile infrastructure.

IMPLEMENTATION

Ease of Implementation

The technologies are not complicated but the environments they are intended for are challenging. The implementation of last mile infrastructure can be undertaken by either public or private entities but requires the cooperation of government to coordinate.

Cost

Last mile infrastructure is low cost, primarily because it is small scale and infrastructure is concentrated at the point of use. Therefore, large operational costs due to large transmission pipes and pressure boosting from centralised options are avoided. Decentralized water treatment and water meters are low-cost infrastructure items.

Country Readiness

These solutions are intended for developing countries so should be able to be adopted by any country. However, developing mobile and internet networks and infrastructure in developing countries may be necessary to enable access to mobile and digital payment platforms.

Technological Maturity

The underlying technologies have trickled down from mature technologies, although the use of them in this application is relatively new. Different business models for serving last mile customers are also in early commercial stages. More development and fine tuning is needed to ensure potential benefits are realised.

RISKS AND MITIGATIONS

Implementation risk

Risk: Due to water scarcity there may be insufficient water resources to supply rural areas.

Mitigation: Sustainable and innovative solutions in water reuse and treatment can assist in augmenting limited supply and should be coupled with education in demand management.

Risk: Currently, water operators in developing areas can lack confidence that they can provide necessary levels of service, i.e. clean water at an affordable price. As such, there is the risk of operator revenue reduction as customers will only pay for water they use rather than minimum service fees.

Mitigation: Investment into increasing service levels of operators through use of appropriate treatment methods and ensure adequate bulks supply to meet demand.

Safety and (Cyber)security risk

Risk: Digital payment platforms are at risk of cyber security threats which can jeopardize customer personal and banking details.

Mitigation: Appropriate cyber security measures need to be taken to ensure data safety.

Social Risk

Risk: Generally, water providers operate as an area-monopoly where they are the sole provider for a particular area. This may lead to predatory pricing where communities may overpay for water services.

Mitigation: Regulatory bodies will need to be created to scrutinize and ensure appropriate pricing for last mile operators. Given the decentralised model and the option for private entities to provide water, this may not be an issue where there will be competition from different "kiosks" and providers.

EXAMPLES[2]

Example	Implementation	Cost	Timeframe
UNTAPPED	UNTAPPED and Mathira Water and Sanitation Company (MAWASCO) ran a proof-of-concept project in Malindi, a coastal town in Kenya with a population of over 300,000 installing 6,500 Pay-as-you-Go Smart meters on an 18-month capital lease.	Over three years, MAWASCO recovered billing arrears and saved operating costs while covering their equipment lease payments. Moreover, the cash flow going through the UNTAPPED Digital Payments Platform was at 5.4 times of lease payments.	Untapped are expanding the metering service in Kenya to service and extra 550,000 customers by 2021.
CityTaps	In 2016, CityTap piloted its smart, pre-paid water meter (CTSuites) in Niger with the local water utility and has since been expanded from 20 to 1,325 CTSuites. This has positively impacted more than 13,000 people in the local community.	Households reported that they were able to better manage their water budget. The water utility Niger experienced commercial benefits from expanding their customer base and increasing the number of subscribers. 98% of subscribers have said would recommend CTSuite to a neighbour, while 72% of neighbours have said they would like to try the solution.	By the end of 2020, CityTaps expects to impact nearly 100,000 people in Niger through the installation of 10,000 additional CTSuites.

[2] Information for Examples in this use case was gathered via communications with commercial technology stakeholders.

Low greenhouse gas emission wastewater treatment

DETAILS

SECTOR | Water and Waste

STAGE | Operations and Maintenance

TECHNOLOGIES | Sensors / IoT, Data & Analytics, Treatment Technologies

SUMMARY

This use case explores technologies that change the standard emission-heavy wastewater treatment processes into more sustainable processes.

Greenhouse gas emissions of methane (CH_4) and nitrous oxide (N_2O) from wastewater treatment can be reduced through better monitoring technologies and optimising treatment processes. Data from monitoring technologies, such as atmospheric emission sensors or wastewater sensors, to measure dissolved CH_4 or N_2O will be critical to find short- and medium-term mitigation solutions and downstream technologies that use existing infrastructure and control systems to reduce or eliminate the emissions. Long-term solutions will look at alternative low greenhouse gas emission wastewater treatment processes that are not restricted by the current centralised treatment model.

Climate change is a critical challenge for the entire global community and natural environment. Reducing the generation of greenhouse gas emissions from wastewater treatment is one of the steps cities and countries can take to lessen their impact on the environment.

The amount of greenhouse gas emissions from wastewater treatment plants is often underestimated. Due to the physical and chemical reactions involving carbon and nitrogen in standard wastewater treatment process, CH_4 and N_2O are an inevitable by-product. N_2O is 300 times more potent as a greenhouse gas compared to carbon dioxide (CO_2)[1], so even a low emission levels will contribute significantly to a wastewater treatment plant's greenhouse gas footprint. Similarly, methane is 25 times more potent than CO_2. N_2O emissions from wastewater handling is estimated to contribute 26% to the total greenhouse gas emissions of the whole water supply chain (drinking water production, distribution, wastewater collection and treatment). This totals to approximately 330,000 tonnes of N_2O[2] globally, which is equivalent to nearly 100 million tonnes of CO_2 in the atmosphere.

[1]Matthijs R. J. Daelman et al. (2012) Methane emission during municipal wastewater treatment, Water Research 46(11), 3657-3670

[2] Kampschreur, M. J. et al. (2009). Nitrous oxide emission during wastewater treatment. Water Research, 43(17), 4093–4103.

The desired outcome is better monitoring technologies to better quantify emissions. This information can then be used to inform treatment alterations and optimise existing systems to mitigate emissions. These steps can reduce CH_4 and N_2O oxide emissions from current wastewater treatment plant configurations.

In the long term, the standard wastewater treatment process may need to be challenged to eliminate emissions. These future treatment processes will also need to be energy efficient; adaptable to climate change; as well as scalable with population growth. These types of solutions are still in research phase and may be in the form of different types of centralised or decentralised treatment.

VALUE CREATED

Enhancing economic, social and environmental value:

- Decreasing greenhouse gas emissions and associated benefits of climate change mitigation.
- Contributing to achieving local, national and international emissions reduction targets.

Reshaping infrastructure demand and creating new markets

- A focus on reducing greenhouse gas emissions from wastewater treatment will open up drivers for novel treatment types that do not emit greenhouse gases.
- It also has the potential to incentivise moves away from capital intensive centralised wastewater treatment and create demand for decentralised infrastructure.

POLICY TOOLS AND LEVERS

Legislation and regulation: Legislation on emissions reductions targets are already driving the change to lower emission wastewater treatment plants. Governments can ensure their policy is up to the highest standard and include clear regulations on wastewater treatment standards. Policy can include monitoring and measuring of greenhouse gases from wastewater treatment.

Procurement and contract management: Procurement for new projects and upgrade projects should allow for the use of innovative treatment methods. Contracts could include a requirement for greenhouse gas consideration in the form of measurement and reduction.

Funding and financing: Technologies that shift towards a low or zero emission wastewater treatment will be an added capital expenditure to water operators. Financial incentives and subsidies from government agencies on low emission technologies will assist in accelerating the shift in both publicly and privately owned treatment facilities.

IMPLEMENTATION

Ease of Implementation 	Monitoring and optimisation technologies are short- and medium-term solutions that will be an iterative process of quantification and plant upgrade. As wastewater treatment is an essential service, gradual optimisation is needed to ensure sewage is treated to environmental and health standards. Long-term solutions may not be able to utilise current centralised infrastructure and require substantial infrastructure development and investment.
Cost 	Low greenhouse gas wastewater treatment processes will have large associated costs in terms of integration into existing processes and development of new infrastructure. They will need to be thoroughly piloted and tested over a considerable time period to guarantee quality of water and sludge being released matches or exceeds with current methods to reduce environmental and health risks.
Country Readiness 	Developing countries may have a unique opportunity to leapfrog current wastewater technologies and invest in low emission technologies before investing in standard processes which may be obsolete within the infrastructure lifespan. Developed countries will be more inclined to invest in solutions that utilise and optimise current wastewater infrastructure rather than forgo the sunk cost of current assets.
Technological Maturity 	Currently, there is substantial research into novel treatment methods that prevent the formation of CH_4 and N_2O. These are still in lab scale pilots and need further development to be feasible at scale. Monitoring and optimisation technologies are further developed and can be implemented into treatment plants today.

RISKS AND MITIGATIONS

Implementation / Economic risk

Risk: New technologies may not be suited for current wastewater infrastructure, and there is a risk of not realising the full return on the substantial investment into current wastewater treatment plants.

Mitigation: Focus on treatment augmentation and monitoring programs that utilise the wastewater treatment infrastructure. Start planning for more diverse technologies when current infrastructure is reaching the end of its life. The decreased economic impact of climate change from reduced emissions may offset investment into new infrastructure.

Environmental and social risk

Risk: Changing and optimising wastewater treatment plants have the risk of affecting the quality of water or sludge being discharged and disposed of into the environment. This can be harmful to local water ecosystems and affect wildlife and increase health risks downstream.

Mitigation: Appropriate piloting programs are needed to ensure all changes to treatment processes do not result in a negative change to discharge sludge or water into environment.

EXAMPLES[3]

Example	Implementation	Cost	Timeframe
Cobalt Water	AI and machine learning N_2O risk model to identify emission mitigation strategies has been implemented in wastewater treatment plants in the Netherlands. 40% and 70% reductions in overall greenhouse gas emissions were achieved at the Eindhoven and Land van Cuijk plants, respectively, by focusing on N_2O emissions and proposing minor process adjustments.	Approximate costs of annual software subscription is USD 10,000 to identify and implement a mitigation strategy. A one-time greenhouse gas reduction fee is assessed based upon ton CO2e reduced.	Using SaaS tool, strategies can be developed and implemented within 2-3 months.
Organics	The thermal ammonia stripping technology has been installed on a 200 tonne per day food waste anaerobic digestion facility in Hong Kong SAR, China, removing ammonia from the digester centrate, preventing N2O formation and ensuring discharge compliance.	Cost are highly dependent on the volume of wastewater and ammonia concentration being treated. For example, to treat 500 m^3/hr of wastewater with an ammonium concentration of 2000mg/l to a level of 100mg/l would cost approximately USD 2 million.	A fully operational facility typically takes 10 - 12 months to deliver.
Cranfield University	A novel way of removing nitrogen and carbon containing compounds from wastewater using membranes and media filters to avoid the formation of N_2O and CH_4. This is currently in the pre-commercial phase and has not been applied to wastewater infrastructure yet.	Cost will vary depending on the size of treatment plant and volumes of wastewater.	This solution can be implemented within existing wastewater treatment infrastructure.

[3] Information for Examples in this use case was gathered via communications with commercial technology stakeholders.

Decentralized Microgrids and Peer-to-Peer Energy Transactions

DETAILS

SECTOR | Energy

STAGE | Operations and Maintenance

TECHNOLOGIES | Distributed Ledger Technology, Solar Panels, Batteries, Smartphone Application/Website

SUMMARY

A decentralized microgrid is a localized group of multiple electricity sources (usually solar panels) that can operate in either a grid-connected system, connected to the wider energy grid, or as a standalone system. Grid-connected microgrids can detach from the wider grid as required to operate autonomously in an ‘island mode’.

Microgrids function on a principle of community collaboration and enable individuals to be able to function as producer-consumers (dubbed ‘prosumers’) or just as consumers.

There are three types of microgrids: (1) a fully decentralized market, (2) a community-based market and (3) a composite market. A fully decentralized market sees participating prosumers operating independently and directly with one another to determine trading parameters without any centralized supervision. A community-based market can be applied to a specific community where the members share common interests and goals, where trading activities are managed by a community manager who also acts as an intermediary between the community and the wider energy grid. A composite market is a combination of a fully decentralized and community-based market. This use case will focus on fully decentralized microgrids that do not require centralization or intermediaries.

In a fully decentralized microgrid, prosumers participate in peer-to-peer (P2P) trading, which is a next-generation energy management technique that enables prosumers to transact their surplus energy. A P2P network is divided into two layers: the virtual layer and the physical layer. The virtual layer is the secured connection between prosumers within which all information passes. It provides equal access to all participants, facilitates buy and sell orders and carries out transactions. The physical layer refers to the physical network that facilitates the transfer of electricity from sellers to buyers once the transaction is completed in the virtual layer.

Distributed ledger technologies facilitate decentralized systems, by maintaining a digital record of transactions which is shared across multiple computers that are linked in a P2P network. This “digital ledger” is not new technology, but its use within the energy sector to facilitate energy transactions is new. One key benefit of distributed ledger technology is its security, thereby creating a trustworthy system for participants to engage in.

There are similarities between microgrids and Virtual Power Plants (*see also the Virtual Power Plant use case*). Where they differ is that a microgrid has a defined network boundary that can disconnect from the larger grid to create a power island. Virtual Power Plants can extend over a much wider geographical region and can expand or shrink in response to real time market conditions.

Recently there has been a growth in the small-scale distribution of energy resources. This is particularly apparent in the installation of solar panels in the residential housing sector, which is expected to increase worldwide by 11% between 2020 and 2026[1]. Residential storage systems are also expected to increase from 95 MW in 2016 to 3700 MW by 2025[2]. P2P trading has emerged to offer prosumers more control in setting the terms of transactions.

The demand for electricity is rising in line with population increases around the world as well as with other factors, such as technological advances which require more electricity. Increasing demand and increasing reliance on renewable intermittent sources of energy are straining centralized energy grids, which are experiencing an increased number of power outages and disruptions. Microgrids can respond to this issue by decentralizing control over the microgrid and enabling it to connect to or disengage from the wider grid as required. For example, when the electricity supply within the microgrid is not enough to meet the demand, additional energy can be purchased from the wider grid. Conversely, when the supply in the microgrid exceeds demand, the microgrid can feed the additional energy supply to the wider grid. Furthermore, should the wider grid experience an outage, the microgrid can disengage and function undisrupted in isolation mode, thereby ensuring a reliable energy source for users. P2P transactions can also help to reduce the demand on the wider energy grid, particularly during peak periods

P2P transactions within microgrids can reduce the cost of energy for participants as prosumers are able to sell electricity at a cheaper rate than that of the traditional market. This is in part possible due to the reduction in electricity transportation costs, as the energy is generated within a set geographical location in which sellers and buyers are in proximity to each other. It is estimated that 41.1% of electricity costs from major electricity suppliers go towards managing and maintaining the infrastructure that delivers power from generators to customers premises[3].

This system has the added benefit of giving the consumers more choice. They can deal directly with prosumers, thereby cutting out the middleman and by dealing with individuals rather than energy companies, the balance of power is levelled. Individuals can choose to purchase energy from their neighbours or friends, or give energy to their family and friends for free or at a discount. Furthermore, consumers have more control over the energy they use and its origins. This enables them to opt for sustainable sources in comparison to the wider grid that can be made up of multiple sources including fossil fuels. It enables private business and industries to include clean energy production and distribution initiatives in their projects (e.g. residential development) and public authorities to encourage sustainability by incentivising such initiatives.

Ultimately, P2P trading in a decentralized microgrid environment will respond to several challenges facing the energy sector today and increasingly in the future. They will reduce the cost of energy for consumers, increase and enable the sustainable use of renewable energy, enhance the engagement of prosumers in the network, and reduce the demand on the centralized grid.

VALUE CREATED

Improving efficiency and reducing costs:

- Accessible to all people in the outlined community even those not producing energy, so all participants are able to access electricity at a reasonable price.
- Reduce cost of energy for consumers in part by reducing the associated cost of transmitting the energy across large geographical areas - 41.1%[4] of electricity costs relate to managing and maintaining the infrastructure needed to deliver power from generators to customer premises.

[1] "Peer-to-Peer Trading in Electricity Networks: An Overview", Tushar et al, Accessed 13 May 2020.
[2] "Peer-to-Peer Trading in Electricity Networks: An Overview", Tushar et al, Accessed 13 May 2020.
[3] "What makes up the cost of your electricity bill?", Aurora Energy, Accessed 13 May 2020.
[4] "What makes up the cost of your electricity bill?", Aurora Energy, Accessed 13 May 2020.

- Reduce the cost associated with energy lost through transmission – an estimated 5% of electricity created in the US is lost in transit[5].

Enhancing economic, social and environmental value:

- Incentivize individuals and industry to include sustainable renewable energy production and distribution systems into residential and commercial building projects and incentivise individuals and businesses to participate in the system while minimizing pressure on central grids.
- Enable greater transparency for users over a distributed ledger.
- Provide a reliable energy source that is protected from outages in the wider energy grid.

POLICY TOOLS AND LEVERS

Legislation and regulation: The success of P2P trading in the future will be largely dependent on local government regulation and energy policy. Government will need to allow this type of market design to be implemented and determine how taxes and fees will be distributed. They will need to understand how this new market will interact and affect the existing energy market.

Effective institutions: Technology suppliers of P2P systems should collaborate closely with local authorities and business partners to ensure a long-term view that considers the strategic goals for the region. To be effective, the P2P microgrid will require a sufficient number of market participants with a subgroup of energy producing participants. The specific purpose of the P2P and the form of energy being traded should be defined. This will have a knock-on impact to the development of the pricing scheme and mechanism. Pricing schemes should be innovative and tailored to the P2P trading system.

Transition of workforce capabilities: Market restructuring is required to move to a system in which Distributed Energy Resources from microgrids are valued and fairly compensated by the electricity grid, rather than being viewed as a threat to existing providers. Electricity regulators should unbundle generation, transmission and distribution of electricity services to allow for independent producers to compete in markets.

Funding and financing: Government grants and clean energy incentives can be utilized to minimize the cost of implementing a microgrid system. For example, many states in the US are providing grants for microgrid development or other resiliency projects. Tax credits for renewable energy may also be applicable to microgrid projects.

Procurement and contract management: Energy-as-a-service contracts are becoming more commonplace, in which there is little or no upfront capital cost to the customer. They instead pay a fee for their energy on an ongoing basis in much the same way as if they purchased the energy from a traditional utility provider.

[5] "The Brooklyn Microgrid: Blockchain-Enabled Community Power", Power Technology, Accessed 13 May 2020.

IMPLEMENTATION

Ease of Implementation

A key issue to enable the implementation of P2P energy transactions within microgrids will be the adaptation of existing legislation in relation to energy production and distribution. In 2019, the European Union passed a directive that mandated all member states to enable P2P energy trading by 2021. In 2018, the U.S. and Asia each represented 42% of the global microgrid market. Europe represents 11%, Latin America 4%, and the Middle East and Africa together have a 1% share.

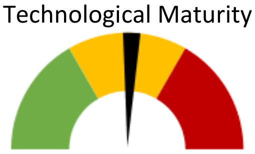
Cost

As micrograms will vary greatly based on many factors, including geographical size and complexity, it is difficult to provide an indication of the required capital expenditure. A cost study of microgrids in the US indicated that costs can range from USD 2 million/MW to 4.4 million/MW for complex projects[6]. The largest element of the required capital investment relates to the Distributed Energy Resources required to generate the energy (e.g. solar panels, energy storage batteries).

Country Readiness

For island microgrids, it is important that there are enough participants producing energy to meet the required level of security and supply reliability to consumers. For grid-connected microgrids, smart meters at connection points to the wider grid should be installed to measure the performance of the P2P network. Each prosumer will require the appropriate metering infrastructure to participate in trading: a transactive meter, an energy meter. Communications infrastructure will also need to be developed to enable trading and meet the performance requirements related to reliability, security, quantity.

Technological Maturity



Several technologies will be required to build the virtual layer of the P2P trading system. The information system is the heart of the network and is typically built using distributed ledger technology, a mature and secure technology that has been implemented in many other sectors.

In addition to these systems, renewable energy generation sources (e.g. solar, wind) will be required. These are mature technologies that are increasingly being used in residential and commercial settings (particularly solar panels). Batteries are also required to store energy generated through these sources.

RISKS AND MITIGATIONS

Implementation risk

Risk: In such a system there may be multiple stakeholders who request prosumer energy, with competing objectives.

Mitigation: Pricing scheme innovation should be explored to determine a means of prioritizing competing demand in order to ensure a non-congested service and minimizing network loss.

Social risk

[6] "Phase I Microgrid Cost Study: Data Collection and Analysis of Microgrid Costs in the United States", Giraldez et al, Accessed 13 May 2020.

Risk: Prosumers are vital to ensure the success of microgrid systems. Without a sufficient supply of energy, communities will need to access energy from the centralized grid, thereby reducing the benefits associated with microgrid usage.

Mitigation: To engage and incentivize prosumers to participate in the system, the system must be prosumer centric.

Safety and (Cyber)security risk

Risk: The digital trading platform will hold significant sensitive data concerning user's personal information, financial information, transaction history amongst other information. There is a risk that the system will be vulnerable to cyberattack, and that user data would be compromised.

Mitigation: To ensure participation from prosumers and consumers, the trading platform must be secure. Distributed ledger technologies have been shown to be particularly secure..

EXAMPLES

Example	Implementation	Cost	Timeframe
Brooklyn Microgrid	The first recorded P2P energy trade pilot in 2016.		First tested in 2016 on one street. Through 2017 it expanded into Brooklyn's Gowanus and Park Slope neighbourhoods.
Bangkok T77 Precinct	Power Ledger have 24 active projects across 9 countries. Power Ledger, BCPG and Sansiri launched a new P2P renewable energy trading project in Bangkok, the first of its kind in South East Asia and the largest commercial P2P trial in the world.	An estimated 2.8MWh solar energy generated daily with an average 10MWh P2P energy transacted per month. Power Ledger estimates this amounts to AUD 1,500 in monthly proceeds from P2P transactions.	On successful completion of the trial, Power Ledger and BCPG will be looking to deploy the solution across 31 new projects in Thailand, with total power generation capacity of 2 megawatts over a three-year period.
Hackney, Banister House Estate	The UK's first P2P energy trade using blockchain.	The trial was shortlisted for the Ofgem Regulatory Sandbox and received a significant grant from Innovate UK.	Phase 1 began in 2018. UK energy giant Centrica (British Gas) joined the trial in 2019 to explore the impact of P2P energy trading on customer bills.

Mobility as a Service

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Applications, Smartphones, 4G/5G, Sensors

SUMMARY

At its core, Mobility as a Service (MaaS) relies on a digital platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private.

The goal of MaaS is to leverage the best of today's technologies to provide users with the possibility to move easily and cost-effectively without owning a car, attracting new users to public and shared transport and, by utilizing captured data, creating new mobility services to respond and adapt to the evolving demand for each user type.

The global movement towards MaaS is fuelled by an overarching desire to make cities more liveable and connected, which has been widely understood to mean less vehicle ownership centric. Consumers have increasingly embraced new mobility options and apps over the last decade as journey planning apps have become commonplace. The natural next step is to bring all options together on a common platform, enabling journey planning across a range of transportation modes (public and private), offering flexible payments and personalization based on user preferences regarding time, comfort, cost, and/or convenience.

Congestion is a major issue for cities around the world. This is expected to worsen as populations rise, with millions more people expected to migrate to urban centres. In response to this growing issue, transport planners are exploring new solutions to meet this increasing demand, rather than simply expanding infrastructure capacity (e.g. more roads and/or more transit), that can support the development and catchment of mass transit solutions. Furthermore, users of transport services are increasingly expecting tailorable and flexible solutions to meet their changing needs. Through its integration of all transport modes and its route suggestion capabilities, MaaS solutions can provide alternate options for users based on their specific preferences (e.g. cost, travel time, directness, number of mode changes, environmental impact etc.)

The development of MaaS is expected to rapidly increase in the coming 5-10 years. The solution will enable increased adoption of transport services, particularly new services such as Demand Responsive Transport (DRT) (*see use case*) and shared and micro mobility modes (e.g. car sharing, ride sharing, e-bikes, e-scooters). MaaS is also expected to provide a more tailored response to travellers' needs, providing them with accessible, adequately priced seamless transport solutions, while enabling the operators and government to better understand their needs. Thus, governments and operators can capitalise on the benefits of MaaS in transport strategies and policies to generate more public transport uptake and provide enhanced customer experience while optimising their operations costs.

VALUE CREATED

Improving efficiency and reducing costs:

- Improve utilization of transit providers and transport network
- Optimise cost of expanding physical infrastructure (roads, transit, first/last mile)
- Reduce fare cost to the user by implementing new payment structures such as subscription-based offerings

Enhancing economic, social and environmental value:

- Provide flexible door-to-door transport offerings tailored to user specific needs, improving accessibility to the transport system
- Reduce congestion and travel times and enhance user experience
- Improve energy efficiency and use of renewable fuels by integrating and encouraging eco-friendly transport solutions (electric vehicles, cycling, shared services)

POLICY TOOLS AND LEVERS

Legislation and regulation: MaaS is a "Multi-Sided Platform" (MSP) relying on existing and proven systems and technologies. However, it requires the buy in of all providers in the mobility ecosystem to ensure success. It is not certain that all private providers in a region will be interested in joining the aggregation platform nor in sharing their data (which could lead to multiple platforms operating in competition detrimental to the transport network). It falls to the government to introduce relevant regulations to achieve this aggregation. Incentives can be used to bring providers to the table.

Effective institutions: A diverse range of stakeholders need to cooperate; mobility regulators, telecommunications operators, payment processors, public and private transportation providers, and local authorities with responsibility for transportation and city planning. Government should define the vision and set the metrics by which success is measured using data shared by all the previously mentioned actors. Moreover, the public sector can encourage behaviour that aligns to broader public policy goals. To be effective, the mobility offer must be well integrated and delivered in a way that responds to customer demand and offers an enhanced customer experience.

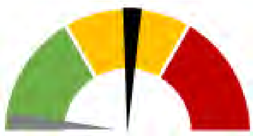
Transition of workforce capabilities: The success of MaaS relies on the right combination of key capabilities to develop the following:

1. Clear governance and set outcomes: Have the relevant strategic planning skillsets in Governments and transport authorities to develop relevant integrated mobility strategies and decisions to maximize public assets value
2. Customer-centric services: Scalable and flexible MaaS services with public benefit objectives, ensuring that transport providers understand how MaaS works so the points under 'effective institutions' and 'legislation and regulation' are enacted effectively.
3. Unified operating solution: Cooperation of public and private mobility actors and efficient aggregation of the overall mobility offer, technologies and data, ensuring the operator of the MaaS platform knows how to run the platform.

Funding and financing: To develop partnerships with mobility providers in each city is a resource-intensive endeavour that requires significant time and funding, particularly for private MaaS solution developers who may not already have relationships with local transport operators (public and private). Existing relationships between public authorities and public/private transport operators should be utilized to enable the delivery of an effective and affordable solution.

Procurement and contract management: The dynamics between public and private transport providers should be clearly defined. MaaS solutions require new contractual arrangements based on outcomes linked to public benefit objectives and key performance indicators that should be monitored more frequently with contractual management systems that would enable near real-time monitoring of the MaaS systems' performance.

IMPLEMENTATION

Ease of Implementation 	The implementation of MaaS is different from city to city, country to country. It will be affected by a multitude of local factors including existing supply and demand for transport services. To implement a solution, the MaaS developer is well placed to invite various public and private stakeholder to collaborate. A major hurdle will be the willingness of operators to get involved with such a solution and developing a business model that will prove attractive to all. The solution will require various inputs including route and schedule information, fares, construction works, weather information etc. and then consider the reliability of that information.
Cost 	For a MaaS business model to be sustainable, one cannot ignore the function of shared economy. The cost of operations of MaaS are relatively low, as the shared information enables an optimisation of the transport offerings and easy combination with other city services such as the electricity grid, commercial retail, etc. Ultimately, the viability and sustainability of MaaS hinges on a shared economy of infrastructure.
Country Readiness 	To work effectively MaaS requires widespread use of smartphones on 3G/4G/5G networks; high levels of connectivity; secure, dynamic, real-time information on travel options and updates; and cashless payment systems. There should also be a thoughtful integration of the transport network and its modes, that enables seamless and informed transfers between transportation services. To date, MaaS solutions have been adopted in more densely populated urban areas. Expanding to include wider geographical regions can be complicated by multiple authorities with conflicting objectives.
Technological Maturity 	While the application development and ticketing technologies already exists and can partially participate to provide MaaS services, the MaaS enabling platform that should aggregate all transport (public, private) operations data currently does not exist yet in a calibrated way. This is a result of the data sharing framework not being fully created nor implemented.

RISKS AND MITIGATIONS

Implementation risk

Risk: There is a risk that multiple MaaS solutions are developed, each encompassing different transit operators, rather than one holistic solution. This would be less successful, as users would need to use multiple applications to have access to the entire service offering, thereby reducing convenience, or would only choose one, thereby limiting their options.

Mitigation: If a government wishes to avoid this, they must act in collaboration with MaaS developers to ensure a single solution is developed that meets the needs of the area, the transport operator and its citizens. Governments should work to encourage operators to buy in to the solution, thereby providing users with the widest possible transport offering.

Social risk

Risk: There is a potential threat to transport and social resilience through over reliance on single operators of innovative services. In some places mass transit has been reduced in favour of shared service providers. Overreliance on major providers such as Uber amplifies business failure risks as failure of these providers could leave car-less residents with limited mobility options. There is also a risk that users will not buy in to the MaaS solution due to customer experience / satisfaction issues, ongoing competition or habit.

Mitigation: Appropriate regulations on the shared services linked to the public infrastructure should limit those risks. To mitigate this risk, users' requirements and preferences focus (cost, directness, environmentally friendly, travel time, safety, etc.) should be investigated prior to launching a solution; the design of MaaS should consider those specific preferences (including the cultural and geographical aspects). Incentives and personalisation of services can be introduced to encourage user shift to the MaaS service.

Government led safety guidelines should address issues around shared vehicle driving, service provision, consumer protection, liability, and equal access. Government entities can use their power to foster equity in transportation provision, ensuring geographic coverage and accessibility, as well as serving low-income and underserved populations.

Safety and (Cyber)security risk

Risk: Data-centric services inherently carry cybersecurity concerns, such as who owns the data, the user or the service? What constitutes ethical appropriate use? Should user data be automatically shared with law enforcement and emergency services or for specific purposes, such as managing crisis? The right combination of using user-specific data and transport preferences to match the multimodal transport offered, means a compromise must be made based on utility and priority order, between user data sharing and data protection to meet the management of demand and supply, such as during pandemics.

Mitigation: Governments must and are already answering these issues and users must be made aware of the implications on their privacy.

Environmental risk

Risk: MaaS subscriptions may have the unintended effect of encouraging users to select private options like taxis over public transport. If a user opts for a subscription that provides for unlimited taxi and/or carsharing usage, the cost incentive to use public transit is eliminated. This would lead to increased numbers of vehicles on the road, more congestion and ultimately more emissions.

Mitigation: MaaS providers should collaborate closely with local authorities to ensure the subscription options on offer are tailored to drive the desired behavioural outcomes.

EXAMPLES

Example	Implementation	Cost	Timeframe
Whim, Helsinksi, Finland	An all-inclusive MaaS application developed by MaaS Global. Initially the local transit agency did not open its ticketing to allow Whim subscribers to enjoy the convenience of the agency's monthly pass (instead, Whim users had to obtain a new ticket every time they rode). In 2018, the Act on Transport Services was passed requiring transport providers to make their full ticketing functionality available to third parties.	Whim offers three tiers of service: a pay-as-you-go option; a EUR 49/month (approximately USD 55) "Whim Urban" subscription for unlimited public transport and reduced rates for taxis and carshares; and a EUR 499 (approx. USD 565) "Whim Unlimited" package that adds unlimited taxi and carshare access. Most of Whim's Helsinki users use the Whim Urban option.	Developed for Helsinki in October 2016. Whim is now expanding to Singapore, Birmingham, Tokyo, Vienna, Antwerp and the US.
MinRejseplan	Created by the Transport Authority for Northern Denmark, MinRejseplan is a new generation of the Rejseplanen journey planner app, servicing the city of Copenhagen.		Launched in September 2018.
NaviGoGo	Pilot in Scotland's Dundee and North East Fife regions (part of the Pick&Mix program) aimed at improving how young people aged 16-25 relate to, use, and combine travel modes and transport services to meet their lifestyle needs, without the requirement to own a car.	The service aimed to be financially sustainable, offering value for money for the user, as well as creating economic value for transport providers. The 98 trial participants booked more than 480 journeys and paid for them using their NaviGoGo stored account balance. Users of the pilot spent more than GBP 3,500 (approximately USD 4,350) through the platform.	Six-month pilot held 2017-2018.

Pedestrian and Weather Sensors for Dynamic Traffic Light Allocation

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Motion Sensors, Thermal Sensors, Weather Detector, Bluetooth Sensors, Smartphone Accelerometer, Artificial Intelligence (AI)

SUMMARY

Pedestrian sensors are technologies that can be installed at road intersections to detect whether and how many pedestrians are waiting to cross the road. They can also detect pedestrians whilst they are crossing the road. They can differentiate between pedestrians, cars and cyclists using thermal and Bluetooth technologies. The information gathered by the sensors can be used to optimize traffic light operations. This aims to balance two main objectives: (1) improve safety for pedestrians crossing at intersections and (2) optimize traffic lights to minimize delays for vehicles.

Traditional intersections work using a loop system which allocates green light phases to road users and pedestrians in a pre-defined fixed order, not linked to the actual density nor the speed of pedestrians. Furthermore, the length of the green light allocation for pedestrians to cross is of a fixed length, calculated based on average walking speeds. Depending on the walking speed of the pedestrians crossing, and the density of those pedestrians, the length may not be enough, or, conversely, may be too long. The system also presents safety risks for pedestrians, if the length of time they are given to cross is not long enough, they may still be in the road when vehicles begin moving. Each year, over half a million pedestrians die worldwide in automobile accidents, which represents 65% of the total automobile-related fatalities[1]. An average of 29% of pedestrian fatalities and injuries occur at road intersections[2]. These pedestrian fatalities have an economic cost estimated to affect global GDP by up to 3%[3]. In low- and middle-income countries, road traffic accidents can cost USD 64.5 billion per year[4].

Through the utilization of pedestrian sensors, the traffic lights at an intersection can be made dynamic to respond to real-time conditions. If no pedestrians are waiting to cross, the system will skip the green light allocation for the pedestrian crossing, and instead extend the length of the green light allocation to road vehicles. Where large numbers of pedestrians are crossing the road, or a pedestrian requires more time to cross the road (e.g. elderly person, limited ability person, child) the sensors will detect this and lengthen the green light allocation until the crossing is clear. Pedestrian sensors can also gather pedestrian demand information to

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[1] "Pedestrian sensing for increased traffic safety and efficiency at signalized intersections", Wouter Favoreel, Accessed 7 May 2020.

[2] "Pedestrians Involved in Road Crashes in South Australia", Department of Planning, Transport and Infrastructure South Australia, Accessed 20 May 2020.

[3] "Pedestrian sensing for increased traffic safety and efficiency at signalized intersections", Wouter Favoreel, Accessed 7 May 2020.

[4] "Pedestrian sensing for increased traffic safety and efficiency at signalized intersections", Wouter Favoreel, Accessed 7 May 2020.

influence decision making, and enable call cancellation, dynamic clearance time, dynamic pedestrian countdown signals, pedestrian priority, and replace push buttons.

Similarly, weather sensors are used to gather data about the weather conditions (e.g. temperature, precipitation level, fog detection, humidity etc.) to optimize the road network in response to real time conditions. Trigger points are set for each weather condition or combination of conditions, which will prompt response programs across the network. These responses could include changes to traffic light phases for cars and pedestrians and changes to speed limits. Such responses can also be triggered manually by a traffic operating control centre.

Weather conditions can impact driver visibility (e.g. fog, precipitation) and capabilities (e.g. temperature extremes, high winds, precipitation), vehicle performance (e.g. traction, stability, manoeuvrability), and road friction (e.g. snow, sleet, ice, precipitation). These conditions increase the risk of road traffic accidents between vehicles, and with other road users such as pedestrians, cyclists, and motorbikes. In the US, weather conditions account for 21% (1,235,000) of road traffic accidents each year, resulting in 5,000 deaths[5]. The frequency and severity of weather conditions are increasing, thereby increasing the risk of road accidents. In some jurisdictions, sharp increases in temperature and the rate of sandstorms have altered rainfall patterns, which is believed to have led to an increase in road traffic accidents. Adaptation measures should be explored to address the increasing safety risk on road networks.

In the future, data from sensors may be utilized to create dynamic spaces that adapt to real time demand and safety requirements. Such sensors can also be utilized as part of a wider Internet of Things (IoT) connected network by feeding data to the wider network to integrate with traffic management solutions (see *Real-Time Traffic management Use Case*) and can similarly feed data to Smart Motorways systems to adapt the driving behaviour of autonomous vehicles in response to real time conditions *(see also the Vehicle to Infrastructure (V2I) Use Case)*.

VALUE CREATED

Improving efficiency and reducing costs:

- Improve optimization of road network (weather sensors) and intersections (pedestrian sensors) thereby reducing travel times and congestion.

Enhancing economic, social and environmental value:

- Reduce the economic cost associated with road traffic accidents – in 2015 the cost of road traffic accidents in Australia was estimated at AUD 22.2 billion, of that there was an AUD 3.17 billion cost to government through emergency responses, health services and foregone tax revenue[6].
- Reduce risk of road traffic accidents and enhance public safety of all road users by adapting the road network to suit the specific conditions and optimise crossings to encourage more active travel modes.
- Use collected weather data to monitor climate and air quality and track improvements made by environmental initiatives.

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments need to introduce policies and performance criteria to be met by the sensors, as well as the priority framework (i.e. should vehicle demand or pedestrian demand be prioritised) to ensure safety of all. Furthermore, governments could provide incentives for the technology to be developed, as it can be used for other purposes such as weather forecasting, scientific research and road conditions. Data privacy regulations and security procedures for the collection, usage and storage of sensitive information obtained should be developed.

[5] "How Do Weather Events Impact Roads?", US Department of Transportation, Accessed 7 May 2020.
[6] "Cost of Road Trauma in Australia", Australian Automobile Association, Accessed 7 May 2020.

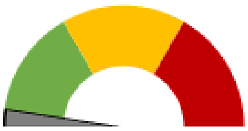
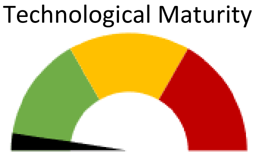
Effective institutions: Understanding and implementing requirements for pedestrian and weather sensors into the early planning and design phases of road and pathways infrastructure projects, as well as in city master planning, requires putting in place effective institutions looking at the 'whole-of-network' planning.

Transition of workforce capabilities: Understanding the demand and the planning of road crossings is important, as well as understanding how to use and maintain such sensors once they are implemented. Operations staff will need to be appropriately trained.

Funding and financing: The funding models should consider the benefits on traffic optimisation and safety improvement produced by investing in such sensors and their supporting analytical solutions.

Procurement and contract management: Contracts with technology providers could include clauses that encourage data sharing. This would enable local authorities to utilize the sensor data to enable intelligent asset management of the road network and assist future city planning by utilizing the data for other smart applications across environment, connected devices, lighting etc. By making the data open source, it could be used to facilitate the ongoing development of technologies for traffic management needs and to enable broader scientific and technological research in areas including weather forecasting and climate change.

IMPLEMENTATION

Ease of Implementation 	Such sensors and their analytical solutions are easy to implement by mounting them on existing poles or integrating them with Smart Streetlights *(see also Smart Street Lighting use case)*, or integrating them in to roadside solutions. The number and locations should be planned accurately to enable the expected outcomes and performances to be met.
Cost 	Sensor technology is relatively cheap today and is continuing to decrease in price, making the capital investment in this technology low. An investment in this technology can produce noticeable improvements in operations efficiency and road safety, with the cost benefiting the wider economy.
Country Readiness 	Such solutions already exist and are already in use in many global cities such as London, Paris, and Copenhagen. Most advanced countries are ready and already implementing them, while in developing countries these solutions are mainly at a trial phase in specific cities or suburbs.
Technological Maturity 	Two categories of weather-related road sensors have already been developed and used for detecting the condition of the road surface. The first of these is imbedded directly into the road surface and the second non-invasive option is installed either adjacent to or over the road. The main technical area for development is the communication interface. For thorough weather information relay, condition specific sensors for predicting rainfall or snowfall, monitoring road conditions, detecting fog etc. need to be implemented and relayed appropriately depending on the weather conditions vehicles are facing at that time. For Pedestrian Sensor systems, the detectors used (video cameras, sensors, etc.) are already developed technologies widely used throughout multiple industries. However, the integration of these technologies and the corresponding response plans need to be designed according to each government strategy.

RISKS AND MITIGATIONS

Implementation risk

Risk: The number and locations of the sensors should be planned accurately according to defined objectives in order to enable the expected outcomes and performances to be met, This is the first step to implementation and requires detailed planning and design.

Pedestrian Sensors: Integrating the individual technical components could pose a challenge to system designers, due to the real-time response requirements of the system. Furthermore, a monitoring system needs to be developed and implemented for maintenance purposes, enabling immediate communication with a designated response team.

Weather Sensors: Open-pored asphalt is used more commonly on roads since it is better for draining water and is less noisy, however sensors cannot be installed in this sort of material, therefore non-invasive sensor technology needs to be developed to the same level of competency.

Mitigation: To ensure reliable information, a maintenance plan needs to be in place, with regular checks of accuracy in weather and pedestrian density and speed readings. During the implementation, sensor providers must ensure calibration to reach the desired performance. Integration with traffic signals is also important and requires the right communication infrastructure.

Social risk

Risk: Personal security issues related to camera footage and sensor use could pose a hinderance to user acceptance. However, this can be mitigated by ensuring enough security in the acquiring and storing of personal information.

Mitigation: Personal data protection should be put in place and the benefits on safety should also be communicated to get the population on board with such systems.

Safety and (Cyber)security risk

Risk: With the incorporation of user location information with sensor technology, user's personal security is at risk. Therefore, the government and service providers need to ensure data privacy. Furthermore, the potential for hacking into weather sensors and dynamic speed limit signage could pose a threat to drivers. Therefore, developers must ensure that the weather sensor and connected dynamic speed limit system is secure.

Mitigation: Governments need to make decisions related to the implementation of such systems, such as which crossings should be dynamic or should utilise pedestrian sensors, and how regularly maintenance will be undertaken.

EXAMPLES

Example	Implementation	Cost	Timeframe
Smart Crossing Trial, Queensland	Smart-crossing trial at the Bourbong-Maryborough Street intersection in 2019 in Queensland, Australia.	The success of the trial prompted the State Government to commit AUD 3 million for an extra 300 installations across Queensland.	The trial took place in 2019. The subsequent roll out across the state was expected to take place over a two year period from late 2019.
Pedestrian Recognition IoT, Finland	Pilot of an IoT and AI based solution that detects when a pedestrian is planning to cross the street at an intersection. Partnership between the City of Tampere and Tieto software company.	The system was able to achieve up to 99% accuracy - and 75% at night.	The pilot was developed as part of the Smart Tampere development program's 6Aika City IoT project, in 2019.
Starling Crossing, South London	A pilot project was commissioned by the UK insurance company Direct Line and advertising agency Saatchi & Saatchi. The crossing was created by tech firm Umbrellium.	High investments, also including research budgets.	The prototype was tested in South London in 2017.

Predictive maintenance of physical assets

DETAILS

SECTOR | Water, Transport, Energy

STAGE | Strategy and Planning, Operations and Maintenance, Renewal and Disposal

TECHNOLOGIES | AI Augmentation, Data & Analytics, Sensors / IoT

SUMMARY

Predictive maintenance utilises monitoring and advanced machine learning methods to develop predictive models about failure of physical and mechanical assets such as pipes, pumps, and motors. These aim to prevent failure and optimise maintenance of critical infrastructure by providing early warning and predictive actions to issues before they occur. Key components include sensors that are installed in the machines, a communication system that allows data to be transmitted in real-time between sensors and a centralized data platform, and machine-learning predictive analytics to identify patterns and generate actionable insights. Predictive maintenance tools enable asset management workforces to automatically diagnose problems of industrial assets' breakdowns and inefficiencies and optimise maintenance scheduling ahead of asset failure as well as extend the life of the asset.

Traditional asset maintenance activities are beset by limited visibility of asset condition, infrequent monitoring, labour-intensive periodic maintenance, and manual data analysis processes. This leads to a slow response to asset deterioration, driving productivity losses, and unoptimised infrastructure capital and operational expenditure. Development of more sensitive and intelligent monitoring and modelling technologies have created opportunities to minimise labour needs and plan investments better.

Mechanical asset owners face inherent challenges with aging infrastructure and assets reaching their end of life. For example, a 2018 survey showed that USD 472.6 billion will be required over the next 20 years, to maintain and improve drinking water infrastructure in the USA. The majority of this (USD $312.6 billion) is for the replacement or refurbishment of ageing or deteriorating distribution assets[1]. The increasing need for water asset maintenance and renewal optimisation is evident in the USD $90 billion increase in 20-year investments required to repair, replace and renew existing infrastructure while there is a $30 billion decrease in investment requirements for new infrastructure [2].

Knowing which asset to maintain, renew or refurbish will potentially defer substantial amounts of capital expenditure. Increased usage of predictive failure models will be an essential planning tool to shift towards more proactive maintenance and optimise maintenance budgets. Proactive programs will prevent catastrophic failure of water distribution networks, pipe bursts and leaks causing damage to property and public infrastructure. This

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[1] Drinking water investment needs. Global Water Intelligence: Water Data. Accessed 29 April 2020

[2] Global water market: breakdown by OPEX and CAPEX Global Water Intelligence: Water Data. Accessed 29 April 2020

will assist water utilities to maintain critical water services to communities, eliminate unplanned downtime, reduce maintenance costs, improve asset reliability, and enhance operational efficiency.

As more water utilities start to embrace digitalization and generate large amounts of data, the technology can access better quality and quantity of data from various inputs to train the models and improve the precision of failures detected. This technology can also be further developed and applied to other sectors and scenarios such as with critical physical infrastructure such as energy generation, transport, and manufacturing. As infrastructure continues to age and renewal investment needs continue to grow, demand for more accurate and robust failure prediction models will grow and be more widely used in all industries. Predictive models from different industries can be combined to optimise maintenance of assets in close proximity i.e. pipes, electricity, communications, gas, roads, etc.

VALUE CREATED

Improving efficiency and reducing costs:

- Optimizes capital investment through deferment of current premature rehabilitation and replacement tasks, rerouting the resources to the assets that are most likely to fail.
- Reduces operational expenditure and overhead cost investment by keeping assets at optimal conditions reducing power waste, reducing downtime and maintenance costs.

Enhancing economic, social and environmental value:

- Minimizes the break rates of pipes that can cause water damage to surrounding infrastructure.
- Decreases traffic disruption and water service interruption by minimising unnecessary maintenance activities
- Extending useful life of assets and reducing material wastage.
- Minimizes the health and safety risks of operators in carrying out rehabilitation work as well as reducing risks during operation and inspection with the remote visibility of the state of assets in real-time.

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments can develop strategies to drive operators to invest in more efficient and sustainable operations of critical assets. Regulatory driven asset management plans can be implemented to maintain the efficiency of water infrastructure.

Funding and financing: Greater focus on committing funding to optimise and extend the life of existing assets rather than building new infrastructure is needed.

Transition of workforce capabilities: Training and upskilling workforce to have the skills to effectively interpret and action the insights from AI technologies.

IMPLEMENTATION

Ease of Implementation

The majority of solutions in this use case are easy to implement, however the models require sensors to be monitoring mechanical assets (such as pumps) and provide this data back to the machine learning (AI).

Cost

Costs per unit are relatively low but when there are a large number of assets, purchasing monitoring systems (sensors and analytics platforms) can start to add up. The costs however are often outweighed by the potential capital deferment that can be realised by using predictive data to extend the life of the assets.

Country Readiness

Very adaptable to use wherever there are mechanical assets and data communications. The countries with well-developed infrastructure can utilise predictive solutions. Collaborative investment from both government and industry may be needed to develop digital communication networks and infrastructure allowing information to be quickly accessed onsite and in remote locations.

Technological Maturity

Technologies in this use case range from established to early commercial. Updates to the technology offering have been common in recent years as machine learning algorithms improve their accuracy and tools become more user friendly.

RISKS AND MITIGATIONS

Implementation risk

Risk: Machine learning can only operate using good quality input data. There is a risk where incorrect data or lack of data can limit functionality or lead to incorrect actions, which can increase project costs and lead to poor infrastructure planning and investment.

Mitigation: Investing in sensors and monitoring solutions before investing in machine learning software.

Social risk

Risk: The shift from scheduled and reactive maintenance to predictive and proactive maintenance can create the need for re-training of workers to interpret and appropriately action results from predictive models.

Mitigation: Industry can assist through training and up-skilling programs to help mitigate these issues.

Safety and (Cyber)security risk

Risk: Control systems, especially in those located in the cloud, are at risk of cyber-attacks. Sensitive information about location and condition of critical infrastructure and potential attacks can have high risks on public health.

Mitigation: Organisations need to ensure a strong level of cyber security in their networks and data storage, for both local servers and cloud services. Focus should be on having strict data ownership models and the appropriate level of data security as needed by the application. Any implementation of data transfer and storage should be undertaken by suitable qualified and experienced professionals.

EXAMPLES

Example	Implementation	Cost	Timeframe
Data61	Sydney Water and Data61 are collaboratively researching advanced analytics approaches to solving water industry challenges, including water pipe failure prediction, predicting sewer chokes and prioritising active leakage detection areas[3].	Sydney Water found the potential to reduce maintenance and renewal costs by several million dollars over a four-year period and minimise inconvenience to customers from pipe breaks.	Projects are undertaken on case-by-case basis and can be completed within a few months.
Voda	Voda AI software have assessed more than 1200 pipes for a Florida water utility, prioritising pipe monitoring, maintenance, and replacements[4].	Voda predicted 18 avoidable breaks saving the water utility more than $100,000 in reactive maintenance and preventing negative coverage of bursts.	Projects are undertaken on case-by-case basis and can be completed within a 12 months.
Movus	The University of Queensland have installed the FitMachine on 22 chiller units, delivering 24/7 air-conditioning, on campus since March 2016 to detect the early warnings of failures, using machine-learning algorithms[4].	The University of Queensland realised 135% return on their FitMachine investment. They saved up to $100,000 in repair costs by discovering and preventing machine failure ahead of time	Movus solution was implemented in a short time frame (within 6 months).

[3] Vitanage, D. et al. *Success in Data Analytics – Sydney Water and Data61 Collaboration*. Water e-Journal 3 (1) 2018.

[4] Information for this example was gathered via communications with commercial technology stakeholders.

Real Time Traffic Management

DETAILS

SECTOR | Transport and Energy

STAGE | Strategy & Planning; Operations and Maintenance

TECHNOLOGIES | Sensors, Smart Cameras, GPS, Bluetooth

SUMMARY

Real Time Traffic Management systems manage traffic behaviours in real time by utilising a network of technologies including sensors, smart cameras, GPS and Bluetooth/Wi-Fi. This can be used to efficiently reduce congestion, bottlenecks and other traffic issues. Real-time data can be used to suggest alternate routes to drivers when routes are congested and indicate to public transport operators and decision makers where user demand and supply is located. Technology improvements have allowed the development of sophisticated services to operate networks to resolve the conflicting demands of all road and transport users.

Advanced traffic management systems improve the quality and performance of road services, as they provide accurate real-time data from multiple sources such as sensors, GPS, smart cameras, dynamic message signs, traffic lights and road weather information systems. Without this traffic information, network improvements, integration of new transport modes, and infrastructure development will not be suitable for current and future transport needs (i.e. it will not provide the flexibility and adaptability required from new transport infrastructure to respond to changing demand).

Smart traffic management services enable integrated optimisation of road and transport networks to match infrastructure demand and supply in near real-time, managing speeds, frequencies, and prioritisation of vehicles while abiding by regulations and safety requirements.

As the population grows and moves to urban centres, more people utilise the road and transport network resulting in growing congestion and more frequent accidents. Road users need information to avoid busy intersections and bottlenecks. Another issue is transport agencies not having the necessary information to have a holistic view of the network, in order to make short-term decisions to adapt to events and incidents. Using real-time traffic management system, traffic data can be combined across a network to provide a holistic picture of the current traffic situation in an area. With the right tool, future traffic can also be predicted, allowing agencies to develop strategies simultaneously to realise the best scenario and prevent the congestion from getting worse, to create connected cities with seamlessly integrated and efficient transport networks.

VALUE CREATED

Improving efficiency and reducing costs:

- Improve efficiency of infrastructure utilization with real-time information guiding resource use and potentially enabling money to be saved on such resources

Enhancing economic, social and environmental value:

- Utilize data for decision-making to ensure public funds are spent where they are most needed
- Improve customer trip planning through live multimodal transport updates
- Enable better routing for drivers based on accurate real-time information
- Encourage innovation from technology companies through open data
- Enable prompt responses from authorities and prioritization of emergency response vehicles (via Emergency Vehicle Priority (EVP) system), reducing response time to incidents and improving safety at intersections (eliminating the need for emergency vehicles to enter intersections on red signals)
- Utilize real-time data for adaptive network control
- Utilize real-time traffic data for dynamic road pricing
- Utilize real-time traffic information to guide the development and planning of future and sustainable transport infrastructure decisions (e.g. building bike lanes) *(see also the Vehicle-to-Vehicle, Vehicle-to-Infrastructure and Autonomous Vehicles use cases)*
- Utilize traffic information to support schemes to encourage greater public transport use through incentivises

POLICY TOOLS AND LEVERS

Legislation and regulation: Transport objectives must be translated into public benefits and set the basis to ensure targeted data collection and processing for the traffic management system. Digitalisation and near real-time performance requirements will make such systems accountable to deliver the expected outcomes. The government should make policies regarding what and how information can be collected and retained, to ensure compliance with relevant privacy and other laws.

Effective institutions: Stakeholders collaboration is crucial to create the adequate regulations for data collection and analysis across multiple travel modes, as well as for their operations. Road and transport infrastructure consist of multiple means for information collection (sensors, GPS, etc.), which will need to be analysed jointly to give a holistic view of the transport network.

Transition of workforce capabilities: Digitalisation of services and remote monitoring/corrective actions of traffic situations will need to be implemented. This requires training for traffic control centre staff in the use of new systems. Additionally, governments should be able to review the performance of the systems and have the relevant legal/technical skills available to them to enable these reviews.

Procurement and contract management: Where traffic management is contracted to the private sector, contracts will need to be developed in a way that implements outcome-based performance. The contract also should enable performance to be monitored in a more frequent way according to a KPI regime that will be set by the transport objectives of the authority or government. Operators must ensure the reliability and validity of their data as well as incorporating any necessary reporting and controls to demonstrate the performance of their systems against the set of contractual KPIs.

IMPLEMENTATION

Ease of Implementation 	Real-time traffic monitoring technologies have been integrated into the transport network for many different uses throughout the past two decades, however the development of connected cities (utilising assets communicating data in a connected near real-time way) is relatively new. Cities will inevitably change overtime, as population and traffic conditions are constantly varying. Therefore, real-time traffic data uses and collection methods must continuously adapt to this change to maximise the efficient use of existing infrastructure.
Cost 	The cost of implementing and developing such systems is high, in part due to the degree of testing and commissioning required. Each individual element of the system will require a corresponding specification. These elements will need to be tested individually to ensure they meet the requirements of the specification. They will also need to be tested together, to prove the overall value of the system. This process can be labour and time intensive. Operating costs are also high but can be optimised in the mid- to long-term, as specific contextual response programmes are developed in addition to the basic ones, using machine learning for example. The systems will need to consider licensing and managed services costs, as the maintenance of the traffic management systems (in addition to implementation costs of the systems and supporting monitoring technologies) will need to be captured. This will also impact the operating models and costs, in a way to optimise them over time.
Country Readiness 	Traffic management systems rely on the availability and accuracy of traffic data and the communications systems to transfer them and to receive corrective actions. Most of the underpinning technologies are not already fully implemented nor connected, thus impacting the readiness for such solutions in both advanced and developing countries.
Technological Maturity 	Sensors, cameras, GPS and Bluetooth are all developed and widely used technologies. However, use on such a large scale will require further improvement. For example camera and sensor repair detection and notification systems need to be developed, along with establishing a data hub accessible by analysts that is manageable and secure. Maintenance of sensors and cameras is key for the assurance of reliability. Algorithms reflecting the area transport objectives should be well developed and integrated in the real-time traffic management services to ensure reliability.

RISKS AND MITIGATIONS

Implementation risk

Risk: The government needs to address the following questions: who has access to the data? Will the information be stored and if so for how long? Data sharing between public and private parties will support the efficient implementation of holistic traffic management systems.

Mitigation: Develop and implement data sharing regulations as well as public private partnership contractual arrangements.

Social risk

Risk: Individual data privacy will be an important consideration, as well as tax-related issues that might be raised through the investments in such solutions.

Mitigation: Government and traffic management operators need to develop public communication and engagement strategies. It is important to explain and engage with the community on the benefits of the real-time traffic management solutions, such higher safety, decreased congestion, increased productivity and transport experience enhancement benefits as well as potential tax optimisation.

Safety and (Cyber)security risk

Risk: There is some scepticism towards camera footage and sensor information being available to the government and private companies, for fear of their privacy being threatened. A cybersecurity breach is a particular concern, as real-time traffic monitoring involves the collection of sensitive data on user and vehicle location.

Mitigation: To address this concern, cybersecurity and data privacy must be adequately addressed. Users should be made aware of these security measures, and the positive impact the data collection could have on their livelihoods. Data collection, storage, analysis and distribution must be carefully planned and adhere to all necessary security measures.

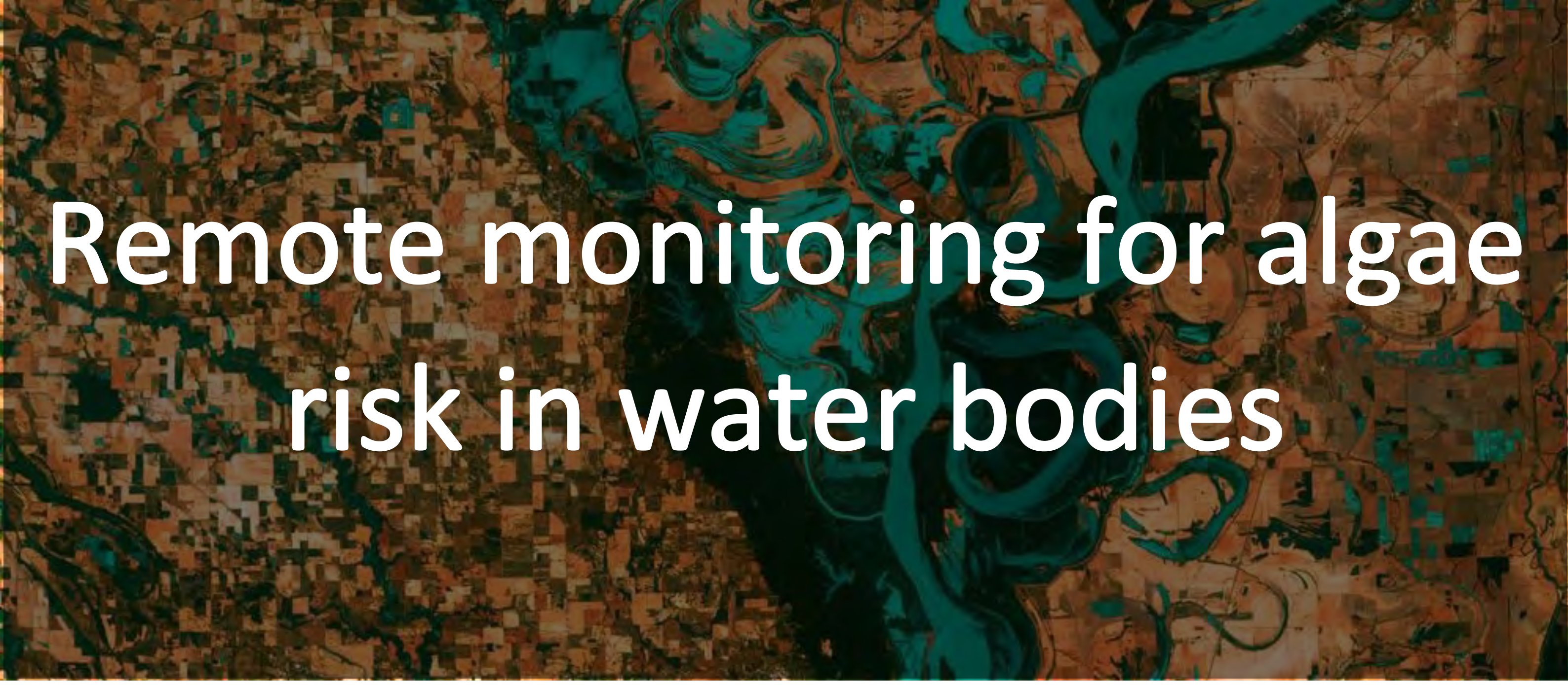
Environmental risk

Risk: If network coordination is not properly planned, with corrective actions focusing on improving safety and decreasing congestion, there is a risk of worse traffic and associated emissions.

Mitigation: Forecast models and environmental impacts assessment should be made for all response programs launched by the traffic management centre that will modulate the traffic operations to ensure environmental requirements are met.

EXAMPLES

Example	Implementation	Cost	Timeframe
Active Traffic Management Approach, UK	The development of a fully remotely controlled motorway with variable message signs, in order to manage traffic flow and lane use, even more precisely with the use of V2I (See also the *Smart Motorways* use case).	High and required multiple operations review, as business needs should have been defined in more detailed from the beginning.	Still being improved to meet congestion and productivity objectives, while already partially providing them.
Singapore LTA Intelligent Transport Systems	Implemented in coordination with ERP (Dynamic Pricing solution).	High investment and high operations costs optimisation.	Implemented in coordination with ERP (Dynamic Pricing solution).
The Urban Lab Dynamic Traffic Forecasting, Barcelona	Increase or decrease the number of green lights for available parking spaces, according to the level of traffic/demand.	Improved operational costs for traffic management and traffic signal coordination.	Implemented.



Remote monitoring for algae risk in water bodies

DETAILS

SECTOR | Water

STAGE | Strategy and Planning, Operations and Maintenance

TECHNOLOGIES | Sensors / IoT, Satellite, UAVs (e.g. Drones), Data & Analytics

SUMMARY

Remote monitoring involves using one or a combination of remote sensors, UAVs and satellite technology to monitor water bodies for precursors to algal blooms. Satellite technologies allow for monitoring of wide areas to optimise monitoring activities, leading to a significantly improved ability to manage and mitigate the harmful effects of potentially toxic algal blooms.

Monitoring the risk of algal blooms is labour intensive and can involve sending crews to remote and hard to access water bodies to collect physical samples. For health and environmental authorities, it is not feasible to manually monitor potentially hundreds of water bodies. Remote monitoring is providing a cost-effective way to monitor algae risk in real-time.

Algal blooms are usually triggered by high-nutrient conditions in water, which are emitted by agriculture and industry or other human activities. These blooms disrupt the natural ecosystem by blocking sunlight and depleting oxygen in water bodies and release toxic compounds. This can cause significant environmental and social harm in the form of increased health risks for humans and wildlife in contact with water. Freshwater lakes and coastal regions effected by algal blooms are often tourist and recreational areas. Blooms cause discoloration, high volumes of foam and noxious odours and increase the requirements for infrastructure in water treatment plants to remove algae related compounds.

Increased monitoring, bloom identification and predictive risk modelling will assist in improving management and mitigation activities by focusing resources in high risk areas and providing timely alerts to decrease health risks to the general public.

As satellite technology becomes more advanced, they will be able to provide higher resolution data capture and allow the monitoring of smaller water bodies and river systems that are not currently feasible. The higher resolution data will also enable more robust analysis improving bloom prediction capabilities. There may be future potential to fully automate the bloom management and mitigation process to remotely treat and prevent blooms without the need for human intervention. This solution will need monitoring technologies to be merged with effective algae treatment technologies.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce time and costs of labour-intensive manual monitoring programs.
- Decrease cost of treating algae related taste and odour compounds.

Enhancing economic, social and environmental value:

- Improves frequency and detail of monitoring programs enabling better mitigation and management of algal blooms
- Decrease health risks for the general public using waters for drinking or recreational activities.

POLICY TOOLS AND LEVERS

Legislation and regulation: Regulations are needed to register and monitor industrial and agricultural land use upstream of water bodies to assist in finding the root cause of blooms identified by monitoring technologies. Strict run-off and pollution laws are needed to mitigate industrial and agricultural pollution into waterways. UAV and regulations also need to be developed and implemented to ensure effective use of the vehicles within the law (see also the *Drones for Monitoring, Surveillance and Inspection Use Case*).

Transition of workforce capabilities: An increase in drone usage for remote sensing will also increase the need for drone pilots and data related staff. There will be a need for experienced algae management professionals verify results as well as manage and respond to insights from data analysis of remote sensing equipment.

Funding and financing: Collaboration between government agencies such as water utilities, public health and environmental protection is needed to ensure data generated can be utilised by all stakeholders and enable funding from all agencies to share financing risks and rewards.

IMPLEMENTATION

Ease of Implementation

Depending on the degree of remote monitoring. For satellite-based programs, implementation is relatively simple with access to historical data being the most important factor. For remote sensors and UAVs, installation and drone piloting need to be considered. Effective avenues for alerting the right agencies, industries and the general public of bloom risks need to be developed.

Cost

Cost of remote monitoring will depend on the resolution required. Satellite technologies are cost effective for large areas. For higher resolution data, in-field sensors or piloted UAVs and drones are needed. With rapid development, the cost of drones has decreased over the past few years. The main cost of drone surveillance programs will be in training operators and pilots as well as optimised strategies and methods for data collection.

Country Readiness

Need the technical expertise to manage and respond to data analysis. Monitoring is only effective if there are existing management and mitigation procedures in place such as tracking of and communication with upstream commercial and agricultural land users to prevent bloom-causing nutrients entering waterways.

Technological Maturity

Current satellite technologies are limited to monitoring coastal regions and large lakes due to their limited resolution. Machine learning methods of analysing drone, satellite and sensor data is also still developing, as more data and higher resolution data is collected algal bloom identification and prediction with become more accurate.

RISKS AND MITIGATIONS

Implementation / social / economic risk

Risk: Accuracy of bloom identification and prediction is critical for a successful remote monitoring program. Poor data and predictions result in false positives which can lead to unnecessary closures of recreation waters leading to poor public reputation. While false-negative results can lead to increased health risks for water users.

Mitigation: Data collection and analysis technologies need to be robust and provide confidence of identification and prediction results. While monitoring technologies are still developing, experienced algae management professionals are needed to action and verify results. Clear management process of acceptable economic and health risks is needed.

Safety and (Cyber)security risk:

Risk: Higher resolution satellite and drone imagery also means potential privacy concerns when individuals and their property can be easily identified. Though remote monitoring of water bodies is a lower risk activity as these are generally outside populate areas, there is still an element of risk for the public in the area. Outdated government policies and regulations may not have considered the significant satellite technology leap and are not be suited to address these concerns.

Mitigation: Policies and regulations need to be updated to address potential privacy concerns of a rapidly evolving technology. Collaboration between the satellite industry, data users, the public and government agencies is needed to create legislation that does not put privacy at risk.

EXAMPLES

Example	Implementation	Cost	Timeframe
Cyanolakes	EONEMP project in South Africa to integrate remotely sensed estimates of cyanobacteria (algal) blooms into the national water management database for near real time monitoring purposes.[1]	Study has lowered the risk posed from cyanobacteria blooms and water pollution to recreational water users and animals, while also educating the public.	EONEMP was a three year project (2015-2018) funded by the South African Water Research Commission, collaborating with the Department of Water and Sanitation, the Council for Scientific and Industrial Research and the South African National Space Agency.
NASA	CyAN is a multi-agency project among EPA, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS) to develop an early warning indicator system to detect algal blooms in U.S. freshwater systems.[2]	Payback is in the form of making faster and better-informed management decisions related to cyanobacterial blooms.	This is an ongoing research project.

[1] The Earth Observation National Eutrophication Monitoring Program. Cyanolakes. Accessed 15 April 2020.
[2] Cyanobacteria Assessment Network (CyAN). United States Environmental Protection Agency. Accessed 17 April 2020.

Satellite Based Navigation to Optimize Traffic Flows

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | GLONASS, GPS, M2M, GSM/GPRS (2G, 3G, 4G), RFID

SUMMARY

Regional navigation and information system (hereinafter-RNIS) is a system designed for information and navigation support of the transport complex of a constituent entity of the Russian Federation through the use of GLONASS/GPS technology aimed at enhancing the safety and efficiency of passenger and cargo transportation at the regional level.

RNIS serves as a single access point to the monitoring and reference information about public transport operating in the region. RNIS allows government agencies, local governments and their subordinate organizations to conduct online centralized remote monitoring of the current location and condition of certain vehicles, control their movement, as well as quickly respond to cases of unforeseen circumstances or violations of the route schedule. Also, all the necessary services are available for transport companies and residents of the region who have round-the-clock access to essential information about transport carriers, passenger bus routes, road repairs and street cleaning, hosted on specialized web portals.

Goals of the RNIS:

- improvement of the efficiency of public traffic management through continuous monitoring of the region's transport, its location and condition;
- better economic performance of transport organizations through downtime and unauthorized fuel drains prevention;
- improvement of the safety of passenger transportation, carriage of special, dangerous, heavy and oversized cargo due to rapid response to emergencies and various violations of the rules of transportation of passengers;
- control and monitoring of the constituent entity's transport system by executive authorities, automation of passenger transportation control and accounting for the carriers' performance under concluded government contracts;
- modelling and forecasting: visualization of the current and archive transport situation, increasing the accuracy of forecasting while planning further execution of transportation contracts.

- The RNIS represents a set of the following task-oriented subsystems depending on narrow-focused industry objectives:

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- unified regional navigation and information center for collection and visualization of monitoring summary of the constituent unit;
- integrated navigation platform aimed at obtaining, processing, storing and transferring of monitoring information to users through GLONASS or GLONASS/GPS technologies;
- transport industry monitoring subsystem including passenger transportation control within the territory of the Russian Federation constituent for regulation, dispatch control, security and keeping public informed about the passenger transport operation;
- school buses monitoring and control subsystem within the territory of the Russian Federation constituent for control automation;
- automated navigation and information subsystem of information exchange, call processing and management of ambulance vehicles;
- road haulage monitoring of special, dangerous, bulky and heavy cargo subsystem within the territory of the Russian Federation constituent for regulation and dispatch control in transit;
- monitoring of vehicles of public utilities and road facilities units of the Russian Federation constituent for regulation and control of public utility transport including sanitation trucks, harvesting and road equipment.

Before the establishment of the RNIS, there was no unified information and navigation core of the Russian Federation constituent to ensure consolidation of information flows and allow effecting centralized and transport control for socially significant transportation and special and dangerous freight traffic safety nationwide.

Accounting automation and establishment of complete analytics of the Russian Federation constituent entity's transport industry performance indicators (to achieve KPI, to follow traffic schedule, routes, timetable, speed limits, to fix schedule variance and to prevent unsanctioned transportation)

The desired outcome:

- Proper RNIS synchronization of the Russian Federation constituent with the systems of local transport companies
- Reduction of the time period for emergency response and taking appropriate measures
- Improving the quality of provided services by using feedback from citizens through online services

Further development and modernization of the RNIS provides for the enhanced functionality of existing subsystems, creation of new subsystems following forthcoming narrow-focus sectoral objectives of constituent entities of the Russian Federation, as well as the development of additional services that can be provided by using system capabilities.

VALUE CREATED

Improving efficiency and reducing costs:

- Cost reduction: for vehicle repairs by up to 10%; for fuel by 15 to 30 %
- Vehicle mileage reduction by 20 to 30 %
- 15 to 20% reduction in downtime of vehicles
- Labor productivity growth by 30%

Enhancing economic, social and environmental value:

Implementation of a high-quality and full-featured solution through creation (upgrading) of regional navigation and information systems contributes to:

- lower regional budget expenditures, better operational performance and more transparent management in housing and utilities, transport system by implementing end-to-end automatic reporting, eliminating the possibility of forgery and offline adjustments both on the side of contractors (budget recipients) and on the side of clients (public authorities);

- reduced number and severity of road accidents through the provision of an effective tool for preventing traffic violations and the ability to influence the situation proactively;
- increase in tax and non-tax revenues of regions driven by increasing transparency and efficiency of management of all categories of enterprises connected to the RNIS;
- more comfortable ground passenger transport with the optimized route network and guaranteed travel time;
- the popularization of public transport as an alternative to driving private cars, which, as a result, contributes to better environmental conditions;
- optimization of traffic load and reduction of the road wear.

POLICY TOOLS AND LEVERS

Legislation and regulation; Funding and financing:

For almost 10 years the RNIS operation in Russia has been ensured by federal and regional regulation which provides for:

- laws and regulations that make it mandatory for certain categories of transport to be equipped with satellite navigation, obligate executive authorities to exercise navigation control over passenger, special and dangerous goods transportation. The technical requirements for the RNIS and its structure are clarified at the federal level;
- co-financing of the implementation of regional programs for information and navigation support of automobile routes in 2013-2014 by the federal government;
- independence of the constituent entities of the Russian Federation in choosing and implementing their strategy for creating a RNIS.

IMPLEMENTATION

Cost	The cost of each project across the country is individual: it depends on the software and technical solution used by a constituent entity of the Russian Federation. The cost of one of the successfully implemented RNIS with the participation of the private investor is presented in the Examples section.

RISKS AND MITIGATIONS

Cybersecurity: cyberattack threats create risks for critical infrastructure and disorient the RNIS participants.

Sustainable investments: failure to present a coherent return on investment model for a potential investor who is interested in creating united GLONASS navigation space (for example, the prospects of recouping capital and operating expenses through charges for connecting regional carriers to the monitoring system).

Technical compatibility of the RNIS subsystems: the possibility of an unfavorable scenario such as the establishment of technologically incompatible subsystems in the region.

Creating services for decision-making within the framework of the RNIS: the complexity of processing a large amount of information about transport operations for executive authorities to make operational decisions in case of emergency.

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EXAMPLE

«The RNIS of the Moscow Region» project is implemented using the public-private partnership mechanism with the participation of Ministry of Transport and Road Infrastructure of the Moscow Region and AO "Group T – 1" providing navigation and information services in the Moscow Region using the system.

On May 15, 2017, the parties signed the *investment agreement* for 8 years. Within the terms of the contract, the investor modernized the RNIS by having invested 249,5 million rubles.

The launched RNIS allows real-time control of all bus services in the region. More than 105 thousand runs are under control daily in the passenger transport sector and the average monthly number exceeds 3 million.

Work within the RNIS system is mandatory for all carriers of the Moscow region. All public transport carriers in the Moscow region have already registered in the system - more than 11.5 thousand buses, as well as 5 thousand units of road and municipal vehicles. In case the necessary information is not provided to the system, penalties are applied to the carrier, up to the license revocation.

To improve the quality of provided services in the field of public transportation, as well as to respond promptly to emerging issues, certain RNIS capabilities allow consumers to use online tools of civic activity of the Moscow region, in particular the *«Dobrodel»* portal[1]. Any RNIS user can file a complaint concerning the public transport operation (e.g. schedule delay, vehicle failure), roads condition, violation of the rules for disposal and transportation of solid waste. The RNIS portal also allows asking questions of interest concerning the ground public transport operation and receive real-time responses.

[1] The official portal of the Moscow Region Government which allows all the region residents to file their complaints and recommendations on various issues via the Internet.

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Sensors and Robotics for Bridge Maintenance

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Technologies (robotic and sensor automation systems, data management, photovoltaic) to enhance infrastructure monitoring and maintenance and to guarantee sustainability.

SUMMARY

The adoption of technology (digital technologies) in "classic" transport infrastructure, across all stages of the lifecycle - from the planning, design, construction and maintenance - is becoming more and more relevant in order to enhance sustainability, efficiency, safety and longevity of the infrastructure to the benefit of the users and the society as a whole.

In the design, construction and maintenance of a motorway bridge, new technologies can contribute to reduce costs, shorten the construction time, increase quality, efficiency, safety and sustainability with a concrete positive impact over the territory. In the project taken as an example (case study), notably a motorway bridge, different technologies have been adopted such as robotic and sensor automation, systems for infrastructure monitoring and maintenance, special dehumidifying system to avoid the formation of salt condensation and to limit corrosion damage, photovoltaic panels, which produce the energy required for the operation of the bridge's own systems (lighting, sensors). Moreover, a specific database contributes to study and monitor constantly the infrastructure. Data can be also used for the future design of infrastructures of the same type contributing the development of public and private stakeholders' knowledge.

VALUE CREATED

Improving efficiency and reducing costs:

- The installation of photovoltaic panels will cut the energy consumption of the structure, limiting the dependence from external power supplies and thus reducing the costs to be incurred for the operation of the plant.
- The internal part of the structure may present particular thermo-hygrometric conditions, also very different from the external atmospheric ones, given the thermal inertia and exposure to solar radiation of the facility. The difference in these conditions could give rise to surface condensation which, notably in an area close to the sea with highly saline atmosphere, could potentially cause corrosion of the metal surfaces. The dehumidifying system avoids the formation of saline condensation in order to limit the risks of corrosion and at the same time reducing maintenance costs.
- The new bridge is equipped with robotic systems able to support both the advanced structural monitoring and the cleaning of the solar panels and the wind barriers. Robotic automation systems shall ensure the centralized plant supervision and help to limit and monitor the deterioration phenomena and any impacts

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of extraordinary events, and therefore to schedule the bridge maintenance beforehand and contribute to the reduction of maintenance costs.

Enhancing economic, social and environmental value:

- Photovoltaic panels make the bridge energy self-sufficient and reduce its energy consumption.
- Reusing the 100% of the excavation waste of a previous old infrastructure contributes to minimize environmental impact.
- Robots carrying out the structural inspection of the bridge and maintenance of the solar and acoustic panels, minimise the risk and the need for human workers.
- Control and monitoring of the infrastructure seven days a week, 24 hours a day, make it safe and extremely efficient.
- Innovative design of the bridge allows the light to slide off the surface and soften the visual impact and presence that the bridge has in its urban setting. Use of light colors for painting the steel elements makes the bridge bright, harmonizing its presence within the landscape. Use of high fall and wind barrier designed to mitigate the visual impact of the infrastructure within the urban context.
- Innovative solutions adopted also with regards to structural and seismic point of view, limit the size of the structures and especially foundations in a highly urbanized context.

POLICY TOOLS AND LEVERS

Legislation and regulation; Funding and financing:

The development of a sustainable infrastructure require a combination of support and participation at central and territorial governmental level, the commitment of public and private investment and a favourable regulatory framework.

In order to develop quality, reliable, innovative, sustainable and resilient infrastructures, in line with the targets of the UN Agenda 2030 (SDGs) and the Paris Agreement on climate change, the adoption of relevant incentive policies are crucial, including new procedures in order to simplify and speed up the delivery of public works.

Public funding is important, but private sector investment clearly needs to be scaled up. Elements to be strengthened to attract private investments in sustainable infrastructure projects include, among others, the adoption of long-term infrastructure plans, a clear pipeline of bankable and quality projects, fiscal incentives, shared sustainability standards, promotion of new technologies (smart roads programs, digital infrastructures, etc.), better data analysis, capacity building mechanisms and innovative financing mechanisms.

The adoption of technological advanced solutions in the construction phase is a key driver, coupled with an efficient administrative process involving different levels of Public Authorities (i.e. Central Government and line Ministry, Regional Authority, Municipality, Commissioner, etc.) committed to speed-up the administrative procedure and helping to avoid any possible bottle necks.

IMPLEMENTATION

Cost	The adoption of smart technologies in transport infrastructures brings great benefits for the maintenance costs during the long-life of the infrastructure.

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EXAMPLE

The new Genoa bridge over Polcevera river represents a key example of smart and sustainable infrastructure as well as a showcase of Italy's latent engineering and construction talents. Design by architect Renzo Piano and built by a consortium company established by Fincantieri (71,3% of shares owned by CDP) and Salini Impregilo (18,7% of shares owned by CDP), the bridge is a critical traffic artery for northern Italy. The new bridge arises 45 meters above the ground and has a continuous steel deck measuring 1067 meters (3500 feet) totally, with 19 spans, supported by 18 reinforced concrete piers. Work on the new bridge was undertaken at an accelerated pace. A project that would normally take three and a half years was squeezed into just over 12 months. The shape of the deck recalls the hull of a ship, and the gradual reduction of the section towards the ends of the bridge minimises the visual impact. Thanks to innovative, efficient and technological advanced solutions never used before in Italy and notably an innovative model, gathering private sector highest's expertise and public commitment and administrative support, allowed to reach a great result in a very short time. Over 1,000 persons involved in the direct and indirect activities concerning design and building. 202 million euros the total cost for the design and realization of the viaduct.

CDP (the National Promotional Institution of Italy), through its subsidiary CDP Equity (CDPE), acquired 18,68 % share of Salini Impregilo (current renamed Webuild) through equity investments, with the purpose of revitalizing the Italian construction sector and supporting the implementation of strategic infrastructure projects crucial for the economic and social development of the Country.

PERGENOVA S.C.p.A. is the joint venture set up by Salini Impregilo (WeBuild) together with Fincantieri for the design and construction of the Polcevera viaduct on the A10 motorway, the new bridge of Genoa. https://www.pergenova.com/it/index.html

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Smart AI-based Waste Management in Stations

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Artificial Intelligence (AI), Robots, Sensors

SUMMARY

Artificial Intelligence (AI) is technology that can perform tasks that require human intelligence, such as speech recognition, decision making and visual perception. AI technology can be used in a wide range of different applications including waste management, recycling and cleaning. The introduction of AI powered waste management is becoming more common place in public infrastructure such as train stations, as it provides a more efficient method for the collection and sorting of waste. Specifically, the AI used for this purpose includes 'bin-bots', that are mobile robot bins that can move through a defined area within the station, to detect waste on the floor and people wanting to dispose of waste. These bin-bots contain systems that can measure the amount of waste in their compartments and will automatically transport the waste to the station bin collection centre when the compartment is full.

An alternative means of conducting waste management and cleaning in stations is through automatic robots that spray cleaning chemicals (e.g. hydrogen peroxide) onto furniture and surfaces. This spray is atomised to a specific concentration, ensuring that the disinfectant can penetrate small gaps, which are difficult to reach otherwise.

The concept of AI was introduced during the early 19th century in science fiction books. In the 1950s, researchers studied AI in order to understand how machines could think and problem solve like humans. Today, our use of AI is largely related to "big data" across multiple industries. Waste management bin-bots are the next stage of this AI development, with functional cleaning capabilities proving them to be efficient and cost-saving additions to the cleaning workforce.

AI waste management solutions provide a more efficient and automated system for ensuring that station environments are kept clean and litter free. This is essential to provide an attractive and comfortable environment for passengers, that will help ensure they continue to use public transportation (*see also the Smart Stations use case*) and is also key to keeping shared spaces hygienic, particularly in response to biohazards and disease outbreaks.

Robot waste disposal can eliminate the need for cleaning staff to transport waste throughout the station to the main waste unit. Traditional operations would involve staff checking all the fixed location bins in a station at fixed time intervals. They would need to check if the bins are full, even if they are not. As the robots transport waste from the bins to the main waste collection area, staff no longer need to check the bins. Furthermore, the robot will only transport the waste to the collection area when it is full. Therefore, eliminating any unnecessary trips. This can provide a time saving for stations, allowing staff to concentrate on other tasks.

Due to their mobile nature and sensors, robots can identify when a passenger has waste to dispose of and can travel to that person to enable disposal. In large stations, passengers may be unable to find the fixed bins, or choose not to look for them. Therefore, waste is left in the public space, making the station look unkept and increasing the risk of injury from tripping on waste, pests being attracted to the waste and - if left for considerable time - damage or staining of the station and/or its furniture.

AI cleaning robots can be developed to complete more complex tasks such as mopping of floors, cleaning of bathrooms, cleaning of windows and furniture etc. They could also develop more interactive capabilities enabling them to move around more complex areas or throughout the station precinct.

VALUE CREATED

Improving efficiency and reducing costs:

- Improve efficiency of cleaning activities by optimizing trips to/from main waste collection points.
- Reduce staff cost by replacing with AI robots, or enable staff to be utilized on other often neglected tasks.

Enhancing economic, social and environmental value:

- Enhance the station environment and user comfort by ensuring waste is collected and reduce the risk of slips, trips and falls caused by litter.
- Improve commuter convenience by enabling bins to travel to people when they need to dispose of litter.
- Improve sanitation at stations by enabling continuous cleaning and therefore reduce the risk of disease spreading.

POLICY TOOLS AND LEVERS

Legislation and regulation: Legislation regarding the data security and safety standards of bin-bots and other waste management AI need to be determined, to ensure passenger safety within the vicinity of the technology.

Transition of workforce capabilities: Train station managers and employees should be informed of the methods for cleaning and repairing the bin-bots, to ensure they function correctly. In the case of a technical malfunction, a response plan should be developed to ensure that staff can reduce the environmental impact and hazard, repair the machinery and report the incident.

IMPLEMENTATION

Ease of Implementation

The station managers and technology providers need to collaborate to ensure the bin-bots are developed to meet the specific station needs, including familiarizing the robots with the station layout, enabling them to detect hazards (e.g. stairways, escalators). Technical developments of the bin-bots to enable additional functionality and service provisions should be investigated. Waste management plans, including recycling, should be incorporated into the system to enable separation of waste by type. This would minimize the need for sorting later in the process. Additionally, a plan for implementation should be developed that addresses where the technologies should be trialled, and where they should be later rolled out, to enable passengers to become familiar with their presence.

Cost

The capital investment in these robots is substantial, particularly when done on a large scale. Each robot can cost between USD 10,000 and USD 50,000 depending on the model and its functionalities. They can replace the need for alternative machinery (e.g. commercial floor cleaning machines) and eliminate the need for a human operator. They can reduce the cost of utilities by using water and power more efficiently. They can ensure consistent and efficient operations that reduce ongoing operations costs.

Country Readiness

Today, most of the implementations of these robots have occurred in more developed countries like France, Japan and Hong Kong SAR, China. This is in part a result of the higher labour costs in these countries, therefore making robots a cost-effective solution. Transport and station operators will need to take an innovative view of reassessing their operations and the place for these technologies. Implementations will be most successful in communities that are likely to react in a positive and accepting way to the robots, where their novelty is appreciated.

Technological Maturity

Bin-bots and other robot cleaning machines contain camera and 3D lidar sensors to detect obstacles and are reliant on batteries to enable them to move around the station freely. Today, these sensors are mature and are used in other applications across sectors. They continue to advance as autonomous vehicle technology is developed. Today's batteries can give them approximately 4-10 hours of operation depending on the specific machine. As battery capacity continues to improve, this will extend their hours of operations.

RISKS AND MITIGATIONS

Implementation risk

Risk: Technological risks related to sensor malfunctions or robot collision may occur, which could result in hazardous situations for passengers or damage to the robot or other station assets. The bin-bots run on battery power, which, if not charged regularly, could result in breakdowns throughout the day.

Mitigation: In order to mitigate the risk of technological malfunctions, maintenance and repairs need to be undertaken and continuous development of the technology must occur. Furthermore, to avoid AI cleaners running out of power, a regular system for charging needs to be implemented e.g. automatic return to a power station when low charge is detected.

Social risk

Risk: There is a risk of commuters being disrespectful towards the technology, for exampleundertaking vandalism and causing damage, which would result in financial loss. There is also a risk of travellers colliding with the AI waste collectors, if they are rushing through the station and/or are unaware of the robot's presence.

Mitigation: Video surveillance should be used to ensure that any individuals damaging the bin-bots are held accountable, and warnings should be displayed around the station. Furthermore, it is important to gradually integrate this technology into stations, so that users become familiar with their presence. Station managers can opt to initially have the cleaning robots working during quieter times of the day to minimize accidental collision with passengers.

Safety and (Cyber)security risk

Risk: The AI technology could potentially be hacked by external sources, resulting in technological and safety issues such as collisions with passengers or using the camera for surveillance. Additionally, hacking could result in sensitive information such as video footage and station information being acquired by malicious third parties.

Mitigation: The technology developers and providers need to ensure that their AI is cyber secure, and continual development and maintenance needs to take place to ensure this.

EXAMPLES

Example	Implementation	Cost	Timeframe
Whiz Cleaning Robot, Japan	The robot vacuum using LIDAR sensors to detect objects. It can clean for 3 hours on a single charge and cover up to 15,000 sq. feet at a time.	USD $499 per month from Japanese tech giant SoftBank. Can be deployed at offices, stations etc.	Central Japan Railway Co. has been using cleaning robots at its stations since 2016.
'BARYL' Smart Waste Bin, SNCF, France	The robot embeds LiDAR technology and cameras and uses beeps and flashing LEDs to interact with users. A probe analyses its fill level and controls the return of the bin to its base for cleaning. Station operators find the waste bin robot both unobtrusive and convenient.	It cost more than EUR 10,000 to develop BARYL.	The development of the robot was completed in 6 months (in 2016) and was then put on trial in Paris Gare de Lyon station for one week during peak hours. It was then trialled across 25+ stations in France through 2017.
Deep Cleaning Robots, Hong Kong SAR, China	Deep cleaning robots which spray vaporised Hydrogen Peroxide into the air, is being used in Hong Kong SAR, China improve train hygiene standards during COVID-19.	The robots cost HK 1 million each (USD 129,000). The MTR Corporation deployed a fleet of 20 to decontaminate areas where confirmed COVID-19 patients had been.	The transport agency began using this technology in 2020 in response to the COVID-19 pandemic.
Neo Floor Cleaning Robot	A commercial floor cleaning robot by Avidbots that is used across several sectors including airports, warehousing, facilities management etc.	Neo costs around USD 50,000 and a typical service plan costs USD 500 per month, adding another USD 6,000 a year. A ride-on floor cleaning machine would cost USD 15,000 and the labour cost could be USD 27,000. Therefore, the initial investment in Neo is paid off in two years.	Avidbots was founded in 2014 and has since expanded its operations to service many major clients across multiple industries.

Smart Containers

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Internet of Things (IoT), Sensors, Solar Panels, Batteries, GPS

SUMMARY

Smart containers are shipping containers used in freight and logistics that are integrated with Internet of Things (IoT) technologies, sensors, GPS tracking and solar panels. The containers are designed to regulate the internal conditions (e.g. temperature), provide real time GPS tracking, enhance security, and provide condition information that can alert operators to any potential issues with the cargo. The information gathered is automatically fed into digital shipment records, which can be shared with the customer to provide up to date tracking and can be used to better predict arrival times at ports to enable optimized unloading of containers and distribution to the next phase of the supply chain. Smart shipping containers can be self-powered by solar panels on their exterior and have batteries to enable energy to be stored.

Traditional means of tracking the progress of shipping containers are heavily manual and unreliable. Information provided is consistently outdated, which makes it difficult to accurately predict the containers arrival time at the port. This can lead to congestion at the port and delays in unloading the cargo for the next stage in the supply chain. The data collection process is very costly, prone to error, incomplete and can be fraudulent. Smart Containers can relay the data automatically and in real-time during transportation and provide accurate information that enables port operators to better plan their facilities for incoming shipments, storage and onward distribution.

Supply chain requirements have changed in recent years. Today, to satisfy higher demands, better track the movement of cargo and respond to issues, supply chain stakeholders are focussing more on the ways to improve the visibility, quality and security of their containers. The IoT technology inherent in Smart Containers can provide accurate real-time data about the condition, location and the environment directly to the operators. While refrigerated containers have existed for some time, they were limited in that they only allowed operators to set temperature conditions inside containers at the start of transport, to maintain the quality of perishable goods (such as food or medication). Smart Containers improve upon this technology. Operators can track, remotely control and adjust the internal conditions as required. This enables the temperature to be adjusted in response to fluctuations in the container's external environment, which may vary dramatically during its transportation. The data collected can be used to demonstrate the goods have remained within regulated temperature thresholds throughout their journey. They can also detect movements nearby and enable burglary prevention systems.

Another issue related to traditional shipping container operations occurs when they arrive and are unloaded at ports. Containers can be left on docks or delivered to the wrong port; these problems are usually discovered months after the occurrence. Smart Containers can solve this problem by providing real-time information to the authorities to enable rapid issue detection.

Autonomous Shipping Ports *(see also the Autonomous Shipping Ports Use Case)* and Autonomous Shipping Vessels are also developing in many countries. With these additional developments, in the near future, Smart Containers will be able to communicate directly with the autonomous systems on ships and at ports. This will result in streamlined, error-free and efficient operations from start to finish.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce the time required to gather data on the location and condition of containers by implementing an autonomous system that provides automatic updates.
- Enhance productivity and reduce the cost associated with lost or damaged cargo by ensuring optimized operations and reducing the probability that containers will be damaged or lost.
- Minimise the cost related to wastage by extending container's life with technologies and reducing theft and spoilage of goods by utilizing temperature control and anti-theft functionalities.

Enhancing economic, social and environmental value:

- Enhance safety and security of cargo and improve customer service by tracking the container's location and condition information and providing real time data enabling better optimization of the entire supply chain.

POLICY TOOLS AND LEVERS

Legislation and regulation: Government and industry must develop standards for Smart Containers such as testing equipment to ensure the quality of the goods, effective technologies and safe operation of the Smart Containers.

Effective institutions: The supply chain must have a secure communication system to transfer data between the Smart Containers and the operators. In addition, collaboration between the logistics companies and product suppliers is important to understand the requirements in conditions of the goods during transportation thereby ensuring the quality of the goods.

Transition of workforce capabilities: Several capabilities in areas such as technical engineering, software engineering and system integration are required across the production, management and maintenance of the Smart Containers. While the production of the containers would be outsourced, the management and maintenance of the containers could be achieved in-house and would therefore require the upskilling of staff to meet this need.

IMPLEMENTATION

Ease of Implementation 	As Smart Containers are shipping containers with IoT technology integrated, all types of containers can be converted to Smart Containers. Electronics and/or devices can be retrofitted for existing containers or built in during manufacture for new containers. Many companies around the world (e.g. Mediterranean Shipping Co. and Telenor) are already making the transition to Smart Containers.
Cost 	The capital expenditure requirement of the Smart Containers is more than the cost of a traditional container due to cost of the additional technologies. However, the cost of the sensor technology is relatively low and is decreasing over time. The subsequent operational expenditure will be reduced as a result of the reduction in staff, the optimization of tracking, and the knock-on improvement in planning and decline in damaged, lost or spoiled cargo.
Country Readiness 	Data transmission and long distant communication will require a secured and speedy communication network (satellite-based or internet-based network). The coverage of the communication network will need to expand in order to transmit and receive real-time data.
Technological Maturity 	IoT technology is used widely in different applications such as cars, houses and phones. The technologies are mature enough to meet container and service demands. For example, Mediterranean Shipping Co. is committed to 50,000 Smart Containers by 2020. It is predicted that about 10% of container fleets around the world will be outfitted as Smart Containers by 2023[1].

RISKS AND MITIGATIONS

Implementation risk

Risk: Containers are made of steel and usually stacked several deep on shipping vessels. This can interrupt communication between the container and the operator, which can make the data inaccurate or lost.

Mitigation: The quality of the data transmission depends on the communication network. The network may need to be upgraded to improve coverage to ensure data can always be transmitted.

Social risk

Risk: The implementation of Smart Containers may result in redundancies for existing employees. Since Smart Containers can obtain real-time data automatically while at sea, the traditional manual work is eliminated. This could have consequences for the company such as negative press and impact to the brand's reputation.

Mitigation: With the new technologies installed, the work on shipping vessels will become more technical. There is an opportunity to upskill employees to meet this need. Companies should also develop a strategy to deal with human resources changes any potential media response.

Safety and (Cyber)security risk

Risk: Smart Containers generate data and communicate with authorities through a satellite-based or internet-based system. Therefore, there is a risk that data collected could be hacked or altered due to cybercrime.

Mitigation: Institutions should ensure their systems are robust to mitigate the risk of cybersecurity breaches. Furthermore, governments should set legislative frameworks to outline the requirements of these systems to repel cybersecurity attacks and protect data.

[1] "No 'one size fits all' for smart container use", JOC, Accessed 17 May 2020.

EXAMPLES

Example	Implementation	Cost	Timeframe
Silk Road	CIMC develops and deploys technologies integration into the company's container.	Technologies allow connectivity for individual containers easier and at lower cost.	In early 2018, the first smart shipping container was transported by truck, train and ship along the Silk Road.
Port of Rotterdam Pilot	A smart container (container 42) has left the port of Rotterdam on a two-year multi modal journey.	Pilot investment to assess the efficiency over a short and mid-term of the IoT used in different modes and weather conditions.	The container goes on a two-year journey to collect data about its condition during transport and measure the conditions and environment inside and around the container.
Mediterranean Shipping Co.	The company has committed to 50,000 smart containers by 2020.	The high volume of containers will enable a lower cost of investment while savings through operations will also likely offset them.	The company aims to integrate 30% of its containers with IoT technology by 2015.

Smart Metering

DETAILS

SECTOR | Water
STAGE | Strategy and Planning, Operations and Maintenance
TECHNOLOGIES | Sensors / IOT, Big Data, Data Analytics

SUMMARY

Smart meters collect and transmit real time water usage data from residential and industrial end users. The usage data assists in reducing water loss, demand forecasting and optimising network operations, as well as increasing community water efficiency. The latest versions of these devices take advantage of increased innovation in communications technology and data analysis systems and, more importantly, have drastically reduced in cost to make these more affordable. Smart metering has often been likened to the use of internet banking where every transaction can now be seen online rather than waiting 3 months to receive a statement.

Installation of meters by water companies has primarily been driven by the need to collect billing data. There are opportunities for using this data to improve water efficiency and the customer experience. The need for enhanced water utilisation and better understanding of customer demand and expectations, in coordination with advancements in metering technology, has contributed towards a global shift towards digital metering and intelligent networks within the water industry.

Meters are typically manually read at specified time intervals ranging from several weeks to months. This is labour intensive and poses safety risks to field teams. The lack of data granularity makes it impossible to do meaningful data analysis to inform water saving policy.

Smart metering data insights regarding customer consumption and network operations will allow the water sector to operate water networks more efficiently and create a more engaging experience for customers. Studies have shown a decrease of 7-22% of water consumption after the installation of metering technologies[1,2].

There are multiple potential end users of the data apart from water utility businesses, such as the government and academia, who can use the data to enhance our broader understanding of how people consume water and subsequently better inform policy and investment decisions. Examples may include deeper insights into consumption and price / income elasticity, willingness to pay and scarcity pricing. Technological advances and increasing data granularity can tell customers the exact location and cause of leaks inside their premises.

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[1] Ornaghi, C. et al. The effects of the universal metering programme on water consumption, welfare and equity. Oxford Economic Papers. 2019

[2] Davies, K. et al. Water-saving impacts of Smart Meter technology: An empirical 5 year, whole-of-community study in Sydney, Australia. Water Resources Research 50 (9) pg. 7348-7358. 2014

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce water utility operating costs (for example, in areas of billing or process optimisation)
- Earlier identification and remedy of leaks on the customer side, increasing utility revenue by reducing water loss
- Reducing water consumption through smart metering can reduce the cost of sourcing bulk water, treating it and transporting it. An example in Singapore where water usage is already low for a developed country, showed smarting metering reduced consumption by a further 5%[3]. Further studies have shown smart metering saving up to 46% of total water usage for customers through finding leaks[4].
- Better understanding of user demands can lead to better public investment decisions

Enhancing economic, social and environmental value:

- Reduced use of water restrictions. Digital water metering and intelligent network devices can support the lessening of water restrictions by providing a range of alternative mechanisms to stimulate consumption reduction.
- Intergenerational equity digital water metering and intelligent network devices provide the infrastructure and the information required to influence long-term water policy and vision, and thereby support the sustainable supply of water resources for future generations.
- Reduced energy consumption and greenhouse gas emissions. The more efficient usage of water with digital meters will reduce water and sewage pumping rates, and will also reduce the volumes being transported to water treatment plants. This can ultimately reduce the energy consumption of pumping stations and treatment plants.
- Increased resilience to climate change driven water scarcity by making better use of limited water resources.

POLICY TOOLS AND LEVERS

Legislation and regulation: Regulators allowing tariff flexibility is important to allow customer to receive benefits from reduced water use. With new granular data available from smart metering, lower tariffs are possible during 'off-peak' times when water and sewage pumping loads are lower (in turn lowering pumping costs for water businesses) to incentivise load shifting. It is however important to learn lessons from the energy industry by ensuring any new tariff structures do not serve to confuse customers. This is particularly true for previously unmetered customers on fixed water rates that are set against property size or included in other land owner rates. With the collection of additional data, data security on customer data needs to be ensured through data governance standards.

Transition of workforce capabilities: Training and upskilling workers to have the skills to effectively action the insights from smart technologies. This includes leak identification online and then leak detection in the field as well as the analysis of other insights, such as demand.

Funding and financing: Smart metering can be expensive. Consideration should be given to the larger benefits of smart metering (described above) and whether funding can be made available to assist with procurement and installation.

Effective institutions: Collaboration between government agencies to coordinate installation of smart meters, data collection and analysis will assist in realising potential benefits of water usage data to inform infrastructure decisions and water policy.

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[3] Making the case for smart water metering. Australian Water Association. Accessed 8 May 2020.
[4] Smart water metering technology for water management in urban areas. Australia Water Association. Accessed 12 May 2020.

IMPLEMENTATION

Ease of Implementation

Smart meters have been employed for several years and implementation risks are low. Water utilities that have meters will be familiar with meter roll outs. The use of smart meters is a logistics exercise in terms of procuring, distributing, and installing at customer connections. The more challenging component is meter data management and there are many tools available to help with this.

Cost

Currently metering costs are quite large (typically more the USD 100 per meter + installation costs + monthly telemetry costs). Multiplying these costs by the amount of connections can put metering projects beyond the budgets of most utilities. Metering selected sections of the network is a way of keeping costs down as utilities wait for technology to further reduce in cost.

Country Readiness

Developed countries with existing infrastructure and metering are best placed to realise the benefits from smart meter installation. Many countries are already installing smart metering. Costs are the main barrier as noted above. Developing countries may be able to make use of smart meters in urban areas though their water saving benefits are insignificant compared to upgrade and optimisation needed for the typically less well-maintained water infrastructure. There is an opportunity to “leapfrog” the current generation of technologies into next-gen smart meters.

Technological Maturity

The technology is fully developed and operational in many countries around the world. The next step for full technology maturity is lower device costs to enable full network roll outs.

RISKS AND MITIGATIONS

Implementation risk

Risk: There can be an impact on customer bills, known as “bill shock”, as more accurate meter reading is introduced. Some customers will pay more while others pay less.

Mitigation: Governments and water utilities can conduct community consultation and introduce smart metering through trials, subsidies or progressive staging. For example, a transitional tariff can be used where the switch to a metering charge can be delayed. During this period, customers can be provided with comparison letters at e.g. 3, 6, and 12 months, showing their current rateable bill and what the bill would be if they paid by meter. A higher ‘metered’ bill will encourage greater water efficiency; a lower bill should prompt a request to switch early.

Risk: Utilities do not reduce consumption in an effort to maintain income from water sales. This can occur where bulk water supplies are in abundance or where a retailer on sells from a bulk supplier.

Mitigation: Financial incentives can be provided to retailers to reduce water consumption where the marginal cost of water is high, i.e. where the cost to obtain new water sources is greater than the cost of selling more. Performance indicators and terms in retailer contracts can also help influence the shift toward smart metering.

Safety and (Cyber)security risk

Risk: There can be perceived health risks associated with smart meters as well as a risk users may not be fully informed to get the most utility from the smart meters.

Mitigation: Education on the purpose and safety of smart meters should be included with roll outs.

Risk: Personal information may be gathered from personal usage patterns of water use and privacy concerns may be raised by users.

Mitigation: Data security on customer data must be ensured through data security measures.

EXAMPLES

Example	Implementation	Cost	Timeframe
Suez Singapore	A trial by SUEZ and the Singaporean water authority PUB showed they can help change customer behaviour and reduce water use.	The project, which involved smart meters in 1000 households and an app that rewarded users for certain results, led to a 5% reduction in daily water consumption[5]. Good results considering Singapore already has very low water usage rates at less than 143 L per person per day (USA averages more than 300 L per person per day (USGS[6])).	This program can be implemented immediately subject to supply availability. Results can be obtained as soon as it is installed.

[5] Making the case for smart water metering. Australian Water Association. Accessed 8 May 2020.
[6] How much water do I use at home each day? United States Geological Survey (USGS). Accessed 8 May 2020.

Smart Parking Infrastructure

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Sensors, Cameras, GPS, WIFI, Applications, VMS, Automatic Number Plate Recognition

SUMMARY

Smart Parking is a parking solution that can include in-ground Smart Parking detection/counting sensors or cameras. These devices are usually embedded into parking spots or positioned next to them to detect whether parking bays are free or occupied. This happens through real-time data collection. The data is then transmitted to a smart parking mobile application or website, which communicates the availability to its users. Some companies also offer other in-app information, such as parking prices and locations. This gives the user the possibility of exploring every parking option available to them.

Populations in urban areas are predicted to rise from over 55% of the world's population today to 68% in 2050[1]. Alongside this, private car ownership remains high in developed countries, and is increasing in developing countries. Urban centres are becoming increasingly congested. It has been estimated that drivers looking for parking account for 30% of total traffic volume in a city[2]. This congestion impacts health, productivity and satisfaction of residents. Expanding parking in cities is expensive and lessens the attractiveness of the area. Governments are seeking new mechanisms that can influence driver behaviours to increase utilization across the existing parking supply, and to decrease the usage of on-street parking overall.

Widespread deployment of smart parking will change driving in urban areas, improving the user experience of finding available parking, and enabling governments to modify driver behaviours. Smart parking will also significantly contribute to transportation-sector greenhouse gas and pollution reductions by minimising driving time and fuel consumption. On average, to find a parking space a car will drive an extra 4.5km. A typical car will emit approximately 140g of CO_2 per km. This, therefore, equates to approximately 630g of CO_2 emitted per car looking for a parking space[3], and will be significantly higher during times of congestion. Smart parking solutions can eliminate this unnecessary driving, by leading users directly to an open parking space.

By integrating smart parking infrastructure with a dynamic pricing system, local authorities, can further shape the behaviour of drivers in line with their local objectives. A dynamic pricing system would assign a value to each parking space based on its proximity to a specific location (e.g. the urban centre). This fee would vary based on the time of day, day of the week, month of the year, in line with recognized demand. Dynamic pricing could be

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[1] "68% of the world population projected to live in urban areas by 2050, says UN", UN Department of Economic and Social Affairs, Accessed 12 May 2020.

[2] "World's First Pilot Project Started in Berlin: Intelligent Search for Parking Space", Traffic Infratech, Accessed 5 May 2020.

[3] "World's First Pilot Project Started in Berlin: Intelligent Search for Parking Space", Traffic Infratech, Accessed 5 May 2020.

used to discourage users from driving into the urban centre to park and may encourage uptake of other modes such as park and ride, cycling or mass transit either for the entire journey or part of it. By integrating this pricing scheme with a smart parking application, users would be able to better plan their trips in advance, either by opting to park in a specific location or choosing to use another mode, or travel at a different time.

VALUE CREATED

Improving efficiency and reducing costs:

- Increase utilization of existing parking and increase revenue for parking owners
- Minimise the need to build additional parking infrastructure by directing drivers to underutilized spaces
- Reduce operations costs by replacing parking rangers with technologies such as automatic number plate recognition (ANPR) and implement a more efficient payment process for users

Enhancing economic, social and environmental value:

- Reduce congestion, bottlenecks, car emissions and improve air quality as drivers will not spend additional time circling looking for available parking spaces
- Shape user behaviour to utilize parking in lesser used streets / locations and keep traffic out of the city centre
- Enable data driven decisions to better manage parking supply
- Optimize the use of existing parking to drive decreased demand for parking space surplus highlighting opportunities for repurposing of the infrastructure to create or expand living space

POLICY TOOLS AND LEVERS

Legislation and regulation: Regulation of pricing for smart parking infrastructure should be made with a logic to meet mode shift expectations and transport strategies and objectives.

Effective institutions: Individual smart parking efforts so far have been locally successful but uncoordinated, operating in their own bureaucratic or entrepreneurial vacuums without taking advantage of universally applicable insights to scale their operations citywide or globally. This is a missed opportunity for cities. A lack of collaboration among communities with smart parking pilot programs and lack of coordination among software developers, hardware providers and municipalities also contribute to slower adoption of smart parking, while considerable positive effects could benefit the physical road and city infrastructure.

Transition of workforce capabilities: Transport economists should consider in their pricing models the implementation of smart parking pricing and the related dynamic infrastructure management.

Funding and financing: By enabling new methods of paying for parking (such as applications) additional revenue can be produced. For example, if a user needs additional parking time they can do it through the app remotely, thereby reducing the instances of parking fee avoidance. By utilizing sensor technology, parking payments can be calculated on a pay as you go basis e.g. the user will pay for the exact period they parked there for, rather than guessing the amount of time they will require. This can encourage users to park for longer. By implementing a smart parking system alongside a dynamic pricing scheme (*see also the Dynamic Pricing for Roadways and Parking Use Case*) additional revenue can be accessed through the variance of parking fees in response to real time demand.

IMPLEMENTATION

Ease of Implementation 	Occupancy data, if it exists, tends to have many owners and is not standardized or accessible in a way that would allow software developers to turn it into user-friendly applications. Owners of data can also be reluctant to open this to developers. If existing data cannot be accessed, widespread sensor technology must be installed. As a relatively new concept, this will require careful planning to be implemented correctly, without issues involving sensor accuracy, relay of information, cooperation with applications etc.
Cost 	The cost of sensors and hardware-based solutions is decreasing drastically, for the first-time allowing cities and companies to gather detailed new data on transportation patterns. Furthermore, with smart phones and connected vehicles capturing more and more of the global telecommunications market in both developing and developed nations, software entrepreneurs can collect and analyse data and deliver insights and information to consumers in brand new ways that does not require the installation of new hardware.
Country Readiness 	Fragmentation between public and private parking providers can hinder widespread deployment and development of smart parking. For the smart parking system to be truly effective, it must span an entire city or region. Thus, governments will play a key role in bringing together different stakeholders and developing appropriate regulation that will encourage innovation in this space: dynamic pricing (*see also the Dynamic Pricing for Roadways and Parking Use Case*) will be a key to a successful implementation of smart parking.
Technological Maturity 	There is a selection of technologies that can collect real-time occupancy information including vehicle detection sensors and surveillance cameras. These technologies range in levels of accuracy and cost. Simple sensors can detect occupancy but cannot detect a change in vehicle. They therefore cannot be used to calculate occupancy time to determine a parking fee. High-precision sensors combine several technologies and offer enhanced responsiveness as well as additional indicators, like vehicle occupancy time.

RISKS AND MITIGATIONS

Implementation risk

Risk: The durability of sensor technologies is an issue. Where placed outdoors, care must be taken to ensure their functionality is not impeded by weather elements, and damage is not caused when cars move over them. The power management algorithm (for the longevity of the sensor batteries) and the actual positioning/placement of the sensors are also vital to ensure their reliability.

Mitigation: Consistent maintenance practises should be developed to ensure all aspects of the system are functioning properly.

Social risk

Risk: The introduction of new technologies, particularly utilizing mobile application technologies, can pose difficulties in user adoption for some citizens. The modification of user behaviour towards smart parking will be gradual.

Mitigation: To encourage users to buy-in to the solution, awareness levels must be increased. This can be done by emphasizing the benefits of the solution and implementing cost-related incentivises. Ease of use of the app, cost and reliability of the solution will also influence user acceptance.

Safety and (Cyber)security risk

Risk: Data-centric services inherently carry cyber security concerns, such as who owns the data, the user or the service? What constitutes appropriate use? Should user data be automatically shared with law enforcement and emergency services? Data privacy should be maintained for all users and they should be able to select if they accept their data to be used for tailored services as well as for crisis management. Smart parking can optimize safety within cities by minimising the stress related to driving and finding parking in urban areas. Drivers should be able to concentrate more on driving directly to the assigned space. However, there are safety concerns related to driving whilst using a mobile phone, and this should be considered by government's when regulating the use of such applications.

Mitigation: Governments must answer with regulations and users must be made aware of the implications on their privacy. As vehicles become inherently smarter and connected, they will have the inbuild capability to perform many of the same functions as a mobile phone. In car internet will enable smart parking applications to be accessed directly from the car without requiring the use of a mobile phone.

EXAMPLES

Example	Implementation	Cost	Timeframe
SFpark Smart Parking Pilot	SFpark combines real-time data indicating where parking is available, and dynamic parking pricing to make parking easier for drivers in San Francisco and improve utilization of parking infrastructure. It has since been implemented permanently.	The SFpark trial project was federally funded. The hourly rates at meters were decreased for the trial. Whilst overall parking demand grew, parking availability improved dramatically in SFpark pilot areas. The amount of time that the target utilization rate (60%-80%) was reached increased by 31% in piloted zones compared to 6% in control areas.	The trial ran from August 2011 to June 2013. During that time SFpark adjusted on-street rates every eight weeks (ten rate adjustments were made).
Intelligent Search for Parking Spaces Pilot, Berlin	The world's first smart parking pilot project utilizing a radar sensor system. The project aimed to reduce carbon dioxide, pollutants and noise emissions caused by road traffic. Data collected was open source, to enable app operators to utilize it for the end user.	The project was part of the City2e 2.0 project and was funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).	The pilot was conducted in 2015 with results available in 2016.
AppyWay Smart-Parking Scheme, UK	AppyWay's solution is the first to integrate technical capabilities (sensors and sensor-enabled payments) into a mobile application for customers, whilst also providing analytics to local authorities. AppyWay hosts the largest dataset of the UK's kerbside restrictions and has over 450 UK towns and cities mapped.	Paying for parking is simplified: app users benefit from the option of One Click Parking™, a concept created by AppyWay with Visa. The app pairs the user's mobile device with the sensor under their vehicle via Bluetooth, enabling them to pay-as-you-go rather than hourly rates.	AppyWay conducted a one-month trial in Westminster, London in 2015. It has since launched its scheme in Harrogate, UK (January 2019) and Halifax, UK (October 2019).

Smart Sensing System for Water Service and Urban Mobility

DETAILS

SECTOR | Transport, Water

STAGE | Operations and Maintenance

TECHNOLOGIES | 5G, Internet of Things, Blockchain, Artificial Intelligence

SUMMARY

Sometimes, public goods and services can experience mismanagement issues deriving from imperfect information, coordination problems and market failures. Considering public transport inefficiencies possibly faced by public authorities may include sub-optimal supply, inadequacy, high infrastructure maintenance costs, longer commuting, environmental impacts and energy consumption. Similarly, the water service sector needs to deal with billing accuracy, data access and security, over-consumption, lack of quality.

This use case aims at creating a distributed, secure, reliable and smart sensing system in urban and suburban areas capable of collecting information and data to be shared with local governments and public authorities to improve management, quality and provision of public services.

The monitoring system can be applied to different sectors. One is tested to mobility, where sensing devices are placed in specific areas of the city and suburbs, as well as public transports, to collect information on flows of people in certain situations and events (e.g. when disembarking tourists from ships, city festivals, events). The purpose is to determine environmental features starting from the analysis of images and sounds captured in the surrounding environment. Another system is tested for managing and planning of urban water service, to allow both citizen and public providers to precisely monitoring consumption and quality. Detecting devices systems and smart metering are installed in private houses' drainpipes to gather information.

The following technologies are required for this use case: IoT (Internet of Things) for the development of applications needed for the realization of the project; Blockchain, to ensure a secure and decentralized system for the exchange and storage of data; AI (artificial intelligence) for data analytics; finally, everything is implemented through the 5G technology network.

Considering all the above, developing advanced, replicable and efficiency-driven monitoring systems could provide useful tools for both public authorities and private companies to increase efficiency in service management and planning, energy consumption and quality of both public goods and resources. Moreover, the use case represents a significant testing ground to implement new smart city solutions improving environmental sustainability and citizens quality of life.

In January 2020 SIP won approval to receive public funding from the Italian Ministry of Economic Development following a public invitation to tender. The use case testing and implementation has recently started in a pilot city.

This use case is a contribution from the Government of Italy, with some adaptions from the Global Infrastructure Hub.

VALUE CREATED

Improving efficiency and reducing costs:

- Increase public sector planning and management abilities in both public services and utilities provision
- Reduced costs resulting from water wastage by precisely monitoring resource consumption and needs
- Improved and well-managed urban mobility
- No need of additional capital expenditure as sensing systems can be applied to existing infrastructure

Enhancing economic, social and environmental value:

- Improved quality of public water supply in houses and buildings
- Reduced emissions by better planning and managing of urban traffic, increasing sustainability
- Optimization of people's flows in specific situations and events, reducing crowdedness and improving safety
- Creation of replicable and scalable sensing system that can be applicable to other contexts and sectors

POLICY TOOLS AND LEVERS

Legislation and Regulation: the installation of sensing systems in public spaces requires municipal authorities to be willing to take an active role in providing permissions and allowing access to supporting local equipment (sites, antennas) needed. Also, private Telcos should be willing to provide access to their broadband services.

A more flexible approach on sharing of data will be required in order to foster the replicability of the new developed model in other contexts and sectors.

Contract management: sensing systems in private housing might require residents' permission by establishing contracts or private agreements. In this sense, also an effective communication and/or public incentives might be also useful to encourage uptake.

IMPLEMENTATION

Cost	The use case received an initial total amount of approximately 1 million euros to start testing and implementation. However, the project is still at an early stage at need to be fully tested to evaluate full scalability and replicability at a larger scale and assess specific additional costs.

RISKS AND MITIGATIONS

Technological maturity: sensors and related technologies needed for data analysis already exist. However, 5G technology is still under testing in many areas and countries.

Cybersecurity: sensing systems are at risk of cyberattacks resulting in increased infrastructure vulnerability.

User Acceptance: there is a need to prove collected data, especially in private houses, won't be used beyond this specific use case. Communication with the public about the service and its role for the community can be an effective way of capturing user expectations and encouraging uptake.

EXAMPLE

"Smart, Secure, Reliable and Distributed Monitoring through 5G" – University of Cagliari

The project was developed by the University of Cagliari in collaboration with the Italian Telcos Linkem and Tiscali, together with the National Institute of Nuclear Physics and two Italian innovative SMEs (GreenShare and FossaLab). The idea has received public funding from the Ministry of Economic Development following a public invitation to tender. It is currently being firstly implemented and tested in the urban and suburban areas of the city of Cagliari (Sardegna).

This use case is a contribution from the Government of Italy, with some adaptions from the Global Infrastructure Hub.

Smart Street Lighting

DETAILS

SECTOR | Transport and Energy

STAGE | Operations and Maintenance

TECHNOLOGIES | Sensors, LED, Digital Signage, CCTV, EV Charging

SUMMARY

Street lighting has been developed to undertake much more than simply lighting urban and suburban areas. It can now be integrated into a wider management platform for collecting and processing smart city sensors' data related to transport, energy and city management, safety and security. Smart street lighting adapts the lighting in an area to the traffic and light conditions. For example at darker times it can use sensors to detect cars/cyclists/pedestrians and adapt the light level along their trip. By strategically approaching the implementation of this technology, service providers and governments could increase the safety of urban areas and neighbourhoods, improve the efficiency and quality of services, and enable greater sustainability in energy use. Smart Street Lighting Infrastructure and sensors can also be combined with communication technology, digital signage, CCTV, speakers and electric vehicle charging (*see also the Electric Vehicle Charging Use Case*).

As Smart Connected Cities[1] grow and develop globally (with climate action and safety initiatives being push forward), new methods for information collection, safety monitoring, and renewable energy use are of great value. The primary benefits of Smart Street Lighting are to provide lighting adapted to the movements in a city while having a bird's eye view of the surroundings, connecting streetlights across a city or region. They provide an optimised lighting services, according to movements and traffic, using electricity more efficiently and collecting data to be used to improve transport networks and traffic safety. The use of LED bulbs with built-in sensors allowing for detection of approaching or departing vehicles and pedestrians, helps enable this.

With the global population continuing to grow at 1.1% per year[2] and migrating to urban centres, smarter land and resource use is becoming a significant area of research. Information collection through innovative technologies such as Smart Street Lighting are important sources of data and insights for Smart Cities to improve asset management and service efficiency.

Potential ancillary components of Smart Street Lighting include dynamic information signage and sense marketing for mood calming. Dynamic information signage linked to sensor technology could be used to display areas of congestion, travel delays or nearby hazards (*See also the Real-time Traffic Management use case*).

The idea of sense marketing has been used in retail outlets throughout the world, with certain smells, sounds and light effects encouraging users to purchase their products. The concept of mood calming through senses has been explored in underground stations in France and in Japan. There is potential for these ideas to be

[1] Defined as cities utilising connected technologies to communicate and process data to manage more efficiently the city services

[2] "World Population Prospects 2017", United Nations, Accessed 6 May 2020.

implemented within the Smart Street Lighting to enable better demand management as well as safety management, for instance playing music and changing the lights to improve the perception of nightlife, using scents (designed for outdoor or city spaces) to improve ambience, and soundscapes to notify users of public transport vehicles approaching and departing.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce energy usage through dimming when motion isn't detected. Can reduce energy usage further when couple with lighting technology such as LEDs: LED lights require less energy and can reduce lighting bills by 50-70%[3]. LEDs can last for 15-20 years therefore saving time and money for bulb replacement colours during events or becoming brighter when there is a safety concern).
- Enhance road lighting by improving road conditions and safety
- Reduce the costs related to road accidents

Enhancing economic, social and environmental value:

- Improve lighting around events and busy shopping or dining areas at night, encouraging increased economic activity late in the night
- Improve public safety and security through better lighting as well as CCTV and other sensor technology use
- Improve energy efficiency (as mentioned above) resulting in lower energy demand, lower electricity generation and more a sustainable use of resources
- Utilize technology for visibility and communication (change of lights, speakers for music, alerts and announcements) to improve the quality and safety of the urban space
- Ensure a satisfactory return on investment by utilizing the collected data to accurately inform network changes and decision making

POLICY TOOLS AND LEVERS

Legislation and regulation: The maintenance of Smart Street Lighting posts, as well as safety check-ups should be discussed and planned by governments, to ensure that standards are met. Furthermore, data collection – how it's stored, who it's available to and how it's formatted for research purposes – should be determined, to ensure user and public security and acceptance of the technology. The implementation of added technologies including EV charging and available hotspots, requires the government to consider and answer the following questions: Will use of these features be free of charge? If so, who will pay for the electricity and WIFI? Will there be a cap on the time to charge or use the hotspot?

Effective institutions: As is the case with implementing new technology, the government needs to develop a business case to quantify the benefits and justify capital expenditure of upgrading to Smart Street Lighting, amend regulations surrounding variable service delivery, and develop standards and specifications. These standards include smart street lighting metering, and general smart street lighting and luminaire/pole specifications. Other areas for government and stakeholder review include the transformation of and integration into existing electricity grids and other relevant infrastructure assets, and determining how to pay for the street lighting infrastructure upgrades.

Transition of workforce capabilities: New technologies and remote asset maintenance systems of the smart street lighting require the operations and maintenance workforce to be trained and follow specific maintenance activities and procedures. Government and relevant authorities should be in a position to have the right tools to monitor the expected outcomes and performances of the solution.

[3] "Lighting the road to smart cities and sustainability", Tomorrow Mag, Accessed 15 May 2020.

IMPLEMENTATION

Ease of Implementation 	Smart Street lighting relies on the implementation of the relevant lighting technologies and communications systems. These systems exist and are easy to implement but require appropriate planning to ensure effective implementation and use.
Cost 	The management systems for Smart Street Lighting do not represent high cost to implement and maintain. The main sources of cost are in the assets' (lights and communications devices, as a minimum) implementation, operations and maintenance.
Country Readiness 	Advanced countries have already started implementing and operating such solutions. For example Copenhagen, Denmark, have already assessed the proven safety and traffic management benefits. Cloud solutions will be required that can cater to the data capacity required.
Technological Maturity 	Whilst the individual components of Smart Street Lighting are already developed and implemented, in retail for example, the type of sensors and their range of detection is specific to locations, and therefore needs to be strategically designed. An advantage of LED luminaires is that they include cabling and connectors capable of accommodating the connection of sensors and communication devices later.

RISKS AND MITIGATIONS

Implementation risk

Risk: The features of Smart Lighting (dimming LED, sensor, CCTV, EV charging etc) are mostly developed for use in other applications. With a large network of Smart Street Lighting, implementation, management and maintenance of these various features can be challenging.

Mitigation: Planning the use case and then the number and locations of implementation of the required assets, is essential. The roll-out of the required assets and the related construction works to implement them should also be clearly assessed and prepared along with failure responses and incident management. An individual metering and monitoring system should be applied to each post, to ensure accurate energy readings (for the LEDs) and notifications of technological malfunctions. Additionally, the processing and compiling of CCTV footage and sensor data needs to be tailored to the type of information and the aim of data collection.

Social risk

Risk: The safety and environmental components of Smart Street Lighting are recognised as beneficial for safety related concerns. The main concern relates to sensor and camera use, which users could perceive as a privacy threat.

Mitigation: Mitigating this risk requires promoting the advantages of the technology, specifically how it will improve safety, congestion, public transport services and the quality of the urban space as well as having the right controls in place around personal data.

Safety and (Cyber)security risk

Risk: Data privacy related to connected technologies such as street lighting will need to be anticipated as well.

Mitigation: Data protection regulations, safety responses and policies should be developed that are linked to the impact these technologies can have on traffic and people.

EXAMPLES

Example	Implementation	Cost	Timeframe
Barcelona Lighting Masterplan	The installation of 10,000 LED streetlamps with sensors enabling dimming, remote management and free WIFI across the city. Additional sensors collect data on air quality.	High costs to implement the backbone assets infrastructure; safety and operations benefits assessed. The improvements resulted in a 30% reduction in energy usage across the urban lighting system[4].	The first masterplan was published in 2012. By 2014, 1,1000 lampposts had been transitioned to LED.
Shanghai Smart Lighting	Streetlamps with touch screen, surveillance cameras, free WIFI, area traffic condition information etc.	High costs to implement the backbone assets infrastructure; safety and traffic management benefits assessed.	Proven benefits of the implementation.
Tilburg Smart Philips Streetlights	Provide light on demand according to sensor activity.	High costs to implement the backbone assets infrastructure; safety and operations benefits assessed.	Proven benefits of the implementation.

[4] "How Smart City Barcelona Brought the Internet of Things to Life", Laura Adler Harvard EDU, Accessed 15 May 2020.

SmartCities-as-a-Service

DETAILS

SECTOR | Smart cities, Smart communities

STAGE | Operations and Maintenance

TECHNOLOGIES | 5G, Blockchain, Artificial Intelligence, Machine Learning, SmartCities-as-a-Service (SCcaas) and Platform-as-a-Service (PaaS)

SUMMARY

The Smart Ivrea Project (SIP) envisages the design and implementation of a sustainable, inclusive and technologically advanced city where public services, energy and economic efficiency and social inclusion are the center.

The model is developed according to the following pillars: (1) integrate, design and optimize the provision of existing public services by using enabling technologies (Blockchain, AI); (2) replacing the traditional vertical chain model (applied to key sector as smart energy, smart mobility, etc.) in favor of a more efficient scalable and interoperable architecture based on microservices, by redesigning processes to facilitate the implementation of services and innovative systems and making existing resources and infrastructures interoperable; (3) fostering an inclusive governance by introducing behavioral economics principles (e.g. rewarding systems for virtuous citizens behaviors and sentiment analysis), eVoting and crowdfunding platforms, to promote citizens participation to social, cultural and political life of their territories.

The management of SIP is made through a national digital platform using latest technologies such as Blockchain, Artificial Intelligence and IoT and making full use of 5G connectivity. Innovative solutions and related activities lie in the development of a *SmartCities-as-a-Service* (SCcaas) and *Platform-as-a-Service* (PaaS) model to optimize the provision of existing public services. The SCaas-PaaS aims at delivering or enabling core municipal services through digital platforms that are data-driven thus connecting infrastructure, civil servants and citizens to improve its management.

SIP aims at being classified as the most advanced among national best practice of an efficient, inclusive and technologically driven national ecosystem that could be taken as an example to be replicated at an international level. The innovativeness of the proposed solution lies in its ability to match innovation with society by using the most innovative technologies and at the same time testing the first social model of inclusive governance, thus paving the way to a “smart community”.

In January 2020 SIP received public funding from the Italian Ministry of Economic Development following a public invitation to tender. Starting from the first quarter of 2020 the use case testing and implementation has started in a pilot city for a total of 24 months.

This use case is a contribution from the Government of Italy, with some adaptions from the Global Infrastructure Hub.

VALUE CREATED

Improving efficiency and reducing costs:

- Public authorities can optimize and maximize the provision of existing public services and goods
- Cost reduction resulting from a more efficient management of the city by using smart solutions

Enhancing economic, social and environmental value:

- Replacement of traditional vertical chain models in favor of more efficient, scalable and interoperable architecture based on microservices
- Encourage e more inclusive and interconnected society, resulting in a more active participation to social, cultural and political life
- Pursuing at the same time the development and implementation of innovative hi-tech solutions cities together and social inclusion
- Creation of replicable solutions that are applicable at a larger scale

POLICY TOOLS AND LEVERS

Legislation and regulation:

The implementation of digital integrated systems requires the collaboration of both central and local public authorities. Particularly, municipal authorities should be willing to take an active role in providing permissions, establishing or leasing access to sites, antennas, sensors, equipment, transmission/fiber etc.

Pooling and partnership:

Since collaboration, coordination and pooling of skills among many different actors (public sector, private sector - Telcos and innovative SMEs - and utilities managers) is essential to ensure an enabling environment for SIP, well-structured partnerships might be required.

Future-enabled workforce:

Recruiting and training workers to have the skills to effectively manage and monitor advanced infrastructures and related technologies (e.g. PaaS, SaaS, Blockchain, microservices architectures etc.).

IMPLEMENTATION

Cost	The SIP use case is still at an early stage and needs to complete its testing phase (24 months stating form first quarter of 2020) in order to evaluate full scalability and replicability at a larger scale and related specific costs.

RISKS AND MITIGATIONS

Technological Maturity: the whole model makes use of many different advanced technologies and some of them might still require adaptation and optimization.

Cybersecurity: the PaaS and SaaS models are mainly based on Cloud infrastructures and this might imply security challenges due to the shared nature of Cloud itself. As a consequence, data protection and security threats should be addressed to reduce vulnerabilities.

User acceptance/integration: communication with citizens about the service and its role for the community might be needed, as an effective way of capturing user expectations and encouraging high participation rates.

Digital divide: considering the importance of digital skills among population for the success of SIP, the existence of gaps between demographics and regions that have access to modern information and communications technology and those that don't or have restricted access, might hamper a widespread and uniform inclusion process.

This use case is a contribution from the Government of Italy, with some adaptions from the Global Infrastructure Hub.

Workforce transition: the replacement of traditional vertical chain model (applied to key sector as smart energy, smart mobility, etc.) in favor of microservices architecture and the using of advanced systems (as PaaS and SaaS) might require additional resources and training for the workforce to learn how to effectively manage and monitor those infrastructures and related technologies.

EXAMPLE

Smart Ivrea Project – Agency for Digital Italy (AgID)

The project was developed by the Agency for Digital Italy in collaboration with Politecnico of Turin, the Italian telco TIM, Olivetti and Trust Technologies. The use case has received public funding from the Ministry of Economic Development following a public invitation to tender. It is currently being firstly implemented and tested in the urban and suburban areas of the pilot city of Ivrea (Municipality of Torino, Piemonte).

This use case is a contribution from the Government of Italy, with some adaptions from the Global Infrastructure Hub.

Transition to Electric Vehicle Transport Networks

DETAILS

SECTOR | Transport and Energy

STAGE | Strategy and Planning, Operations and Maintenance

TECHNOLOGIES | Batteries, Electric Vehicles, Charging Networks

SUMMARY

An Electric Vehicle (EV) is an alternative to traditional gasoline-based vehicles that can be powered through a collector system by electricity from off-vehicle sources (such as overhead power lines), or self-contained via a battery, solar panel, or electric generator. EVs can be applicable to a variety of road and rail vehicles (cars, buses, shuttles, trains etc.). Popularity of EVs is growing, with the worldwide number of electric vehicles sold annually growing at a rate of 40% in recent years (2011 – 2017)[1]. To transition to EV fleets, transport providers and operators will need to ensure multiple changes in the existing infrastructure (maintenance facility upgrades, more power supply sources and stations).

EVs were first used in the mid-19th century as the preferred energy source for motor vehicles. With the invention of modern internal combustion engines, electricity became less widely used, although remained commonplace for trains and some small vehicles. As governments, industry, and populations have become increasingly aware of the environmental impact of petroleum-based transportation, together with technological advances, support for widespread adoption of EVs has grown.

With climate change becoming a widely discussed social and environmental issue, it is important that governments take measures to lessen their global carbon footprint. Past improvements in vehicle efficiency have been offset by the greater overall volume of travel taking place. The transport sector (road, rail, air and marine) contributed 24% of total global carbon emissions in 2016 and their emissions are projected to grow at a faster rate than any other sector[2]. 72% of those transport emissions come from road vehicles[3] in upper middle- and high-income countries, where private motor vehicle use is widespread. A shift to EVs could have a significant impact on global carbon emissions, particularly if charged from renewable energy sources. By shifting to EV transport fleets with a sustainable and planned approach, governments will build strong momentum to eliminate exhaust emissions.

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[1] "Economic and Social Benefits of Electric Public Transport Vehicles", *Victorian Government*. Accessed 17 April 2020.

[2] "Everything You Need to Know About the Fastest-Growing Source of Global Emissions: Transport", *World Resources Institute,* Accessed 20 April 2020.

[3] "Everything You Need to Know About the Fastest-Growing Source of Global Emissions: Transport", *World Resources Institute,* Accessed 20 April 2020.

EVs can also improve the quality of urban and suburban spaces, with their zero exhaust emissions reducing air and noise pollution, generating a healthier environment for people to live and work in. This is especially significant for individuals with chronic illnesses or newborn babies, as the health implications associated with air pollution can be greatly reduced.

The use of EVs is still in the early stages of maturity, and one main area for development is the battery capacity. The capacity restricts the length of service (e.g. bus) routes due to the frequency of charging. As demand for electric energy sources grows and they become more widely used, additional technological advances are expected to occur (for example in the past 15 years there has been about a 70% improvement in battery life capacity)[4].

VALUE CREATED

Improving efficiency and reducing costs:

- Reduced operations and maintenance costs due to fewer moving parts and potentially cheaper fuel source, with potential to reduce fares or government subsidies due to the lower operating costs
- EVs are quieter and provide a smoother journey, which can improve the customer and driver experience and can increase patronage

Enhancing economic, social and environmental value:

- Governments can meet societal environmental expectations and improve public opinion of services utilising EVs
- Improve air quality and people's health through the reduction of exhaust air pollutants (nitrogen oxides) and particulate matter
- Reduce carbon emissions by replacing internal combustion engines, particularly where coupled with a transition to renewal energy sources to produce electricity to power the EVs
- Improve the quality of the transport service offering through less vibrations, less noise and zero exhaust emissions
- Improve quality of life through reduced air and noise pollution in urban spaces

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments must develop requirements for issues such as occupant safety, avoidance; management of electric shock; and exposure to electromagnetic radiation. Additional requirements should be developed relating to public safety including the risk with vehicle recharging (electrocution) and road safety risk related to vehicle operation. Application of concessions and incentives (tax breaks, subsidisation etc.) on EVs or taxes on non-EVs can be used to increase EV uptake.

Effective institutions: A clear government decision is key for the implementation of EV technology. Collaboration between the energy and transport sectors is also critical to capturing benefits. Energy providers, public and private transportation providers, and electric vehicle and associated infrastructure manufacturers, should collaborate.

Transition of workforce capabilities: Operations specialists of electric services and power systems specialists should be involved in the process of defining electricity-based services. They can ensure the availability or adequate provision of power supply in the electric transport plan that is to be implemented. Understanding and assessing the existing city / country electric resources (internal or imported) is central to understanding the sustainable impacts of implementing electric technologies.

[4] "Impacts of Electric Vehicles - Deliverable 2: Assessment of Electric Vehicle and Battery Technology", Delft, CE Delft, Accessed 16 May 2020.

IMPLEMENTATION

Ease of Implementation 	Public transport authorities, operators and vehicle manufacturers around the world (like RATP Paris, Qbuzz Netherlands, and BYD in China) are already making the transition to EVs. The technology has already been implemented through multiple changes to ensure compatible electric infrastructure is in place. This includes changes to maintenance depots and stabling facilities. Charging stations within maintenance and stabling facilities as well as along the vehicle's route, should also be considered. These should be strategically designed structures that enable fast turn-over of vehicles (e.g. overhead charging structures, wireless inductive charging plates for 'premium' vehicles, etc.). Upgrading depots for electrification and creating electric stations requires dealing with the smart grid and sharing electricity between services. Governments should establish standards and a strategic construction and implementation process, in which depots and fleets are gradually reconstructed, aiming for minimal disruption to services. Service providers also need to gauge the size of the electric fleet required and develop the best charging and operations plan to suit the infrastructure available.
Cost 	The development of truly sustainable EVs is ongoing, with initial costs requiring a large reduction in order to make the decision economical for transport providers. However, the ongoing development of this market, through electric fleet utilisation in the public transport sector, will likely result in operational expenditure and fare costs going down over time. Initial implementation costs related to upgrading maintenance facilities and installing charging infrastructure is significant.
Country Readiness 	A shift to EVs will create a higher demand for electricity and therefore the energy network must be prepared for the surge in demand. Specialists in operations of electric services and power systems should be engaged to assess whether the existing electricity infrastructure can meet this additional demand, or what additional energy sources (preferably renewable-sources to achieve greater environmental benefits) can be drawn upon.
Technological Maturity 	While current batteries are mature enough to meet certain vehicle and service demands, battery capacity and energy billing are still improving through further technological advances. Such advances will decrease the need for infrastructure changes.

RISKS AND MITIGATIONS

Implementation risk

Risk: Any high uptake of EVs will result in the need for considerable additional electricity to be generated. Without coordinated investment, this may put significant stress on the electricity infrastructure. Strategies to manage this will vary by country depending on the types of renewable energy and conventional power generation and networks available.

Mitigation: Management strategies should be tailored to the energy sources available and additional grid reinforcement or the implementation of "smart charging" approaches may be required to ensure efficient and flexible electricity generation and distribution infrastructure.

Social risk

Risk: User acceptance may be affected by the perception that the lithium mining required for EV batteries is unsustainable and invasive on the environment (due to its substantial water use and potential chemical leak) and local communities. Furthermore, questions over battery recycling may lessen user acceptance of the technology.

Mitigation: Technological advancements will continue to improve battery technology (e.g. alternate materials and new ways to recycle lithium-ion). Until such developments can be made, users must be educated to understand that EVs are significantly more environmentally friendly than existing petrol-based vehicles.

Safety and (Cyber)security risk

Risk: Safety risks such as potentially dangerous voltages; exposure to conductive parts of the system; hydrogen emissions etc. arise from using electric fleets. This can put drivers, depot workers and the general public at risk.

Mitigation: These risks can be managed through the implementation of safety precautions including providing isolation between both sides of the circuit, preventing contact with live parts etc.

Environmental risk

Risk: The increased numbers of EVs on the road will significantly reduce direct carbon emissions and air pollutants associated with exhaust emissions. However, these benefits are partially offset by the additional emissions associated with the production of the additional electricity required, where the energy supply is from fossil fuel use.

Mitigation: To realise the greater environmental benefits of EVs, a country or region can couple adoption of EVs with appropriate investment in, and transition to, renewable energy sources.

EXAMPLES

Example	Implementation	Cost	Timeframe
Quebec Public Transit Electrification	Société de transport de Laval (STL) procured 10 fully electric, 40-foot long buses.	Procurement of the buses was possible due to CAD 9.6 million in financial assistance from the governments of Canada and Québec, through the federal Gas Tax Fund and the public transit capital acquisitions assistance program of the SOFIL.	Quebec sought to establish its first line of entirely electric buses by the year 2020.
Paris RATP And IDFM Electric Bus Plan	Major ecological transition from 2014, that will make RATP the world leader in green technology with a fleet of 4,700 clean buses planned by 2025.	Hybrid buses were used in the interim period before EVs, generating fuel saving of 20-30%, compared to diesel buses.	Testing began in the 2015-17 period. The transition is expected to be completed by 2024-25.
Luxembourg Heliox Fast Charging Stations	One of the first examples of a multi-standard charging station, that allows dual manufacturer electric buses to charge with different interfaces.	The inverted pantograph enables the use of a low-cost and low weight interface on the roof of the bus.	The implementation of this project was less than 2.5 months.

Unmanned Aerial Vehicles for Passenger Travel

DETAILS

SECTOR | Transport

STAGE | Operations and Maintenance

TECHNOLOGIES | Unmanned Aerial Vehicles (UAVs), LiDAR, CCTV

SUMMARY

Unmanned Aerial Vehicles (UAV) are drone-like aircrafts without an onboard pilot. UAVs operate with varying degrees of autonomy, such as remote control by a human operator or autonomously by onboard computers. They operate using a combination of technologies, including computer vision from CCTV, artificial intelligence and object avoidance (LiDAR) technology. Several prototypes are in production and they are projected to become revenue earning in 5-10 years from now (2025-30)[1]. To operate they require specific station infrastructure to be developed across urban areas and cities.

Drones have been successfully used for military applications and are quickly being adopted by the private sector, as well as in people's everyday lives, for a variety of applications. Today, various passenger UAV prototypes exist, most taking the form of vertical take-off and landing vehicles: an aircraft that takes off, hovers, lands vertically and does not require a runway. UAVs can accommodate between two and five passengers or an equivalent cargo weight and present an ecofriendly and efficient alternative to traditional helicopter usage and other forms of road and rail transport as they are powered using electricity

Congestion is a major issue for urban areas around the world. This is expected to worsen as populations rise, with millions more people expected to migrate to urban centres. In the most congested cities, drivers spend 50 to 100 hours per year in traffic which impacts their health and the environment. Traffic also impacts the efficiencies of operations (freight and goods delivery, tradespeople, emergency services) resulting in wasted time and higher prices of goods and services. One opportunity to provide some relief is to look to the sky and utilize the airspace above urban and suburban areas for the movement of people and goods.

There are multiple potential applications for UAVs as new models of mobility. It is foreseen that they could amount to one leg of a multimodal journey as part of a wider Mobility-as-a-Service (MaaS) system (*see use case*). UAVs can operate as point-to-point passenger transport (air taxis), operating in much the same way as today's car-based ride hailing services. They could act as short-range shuttle services to/from airports in urban centres and/or medium- to long-range intercity fixed flight operations. In the freight sector, UAVs could act as a point-to-point freight last mile solution (see also the *Unmanned Freight and Logistics Use Case*) or consumer delivery service, minimising road congestion, delivery costs, fuel emissions and lessening the demand for street parking in the urban centres.

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VALUE CREATED

Improving efficiency and reducing costs:

- Reduce demand for more road space and parking as vehicles move to the skies and utilize rooftops
- Complete existing transport networks with an additional mode and offer a premium alternative for shorter travel times on specific trips (such as airport to business districts)

Enhancing economic, social and environmental value:

- Reduce emissions as UAVs are powered by electricity (shared if connected to the grid) and are more energy efficient than helicopters
- Create additional fare revenues complementing the existing transport chain with an additional solution (i.e. Airport to City/Business centres)
- Provide users with an alternative means of transport which will be less impacted by road congestion

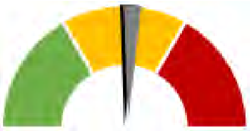
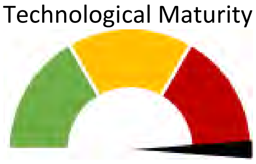
POLICY TOOLS AND LEVERS

Legislation and regulation: UAVs for passenger travel will require a robust air traffic management system to ensure safe, consistent and efficient operations, including the collaboration and co-operation with local Aviation Safety Authorities. In addition, a reliable traffic management framework should be developed with focus on the integration with other modes, especially in urban areas. This will be enabled through the collaboration with commercial stakeholders and local councils.

Effective institutions: Strong collaboration between multiple stakeholders will be required to navigate the complex challenges related to UAV development. Similar challenges have been faced by the aerospace industry before. Authorities will need to develop a comprehensive regulatory framework to guarantee the safety of people, facilities and third-party property.

Transition of workforce capabilities: Key success factors for passenger UAV manufacturers include technology maturity and integration, the ability to get their aircraft designed and built, a scalable supply chain, production capacity, and getting their aircraft certified and safe to operate with passengers. It is unlikely that individuals will own a UAV, like a car, due to their expense. Fleet operators will own or lease the vehicles and be directly responsible for the full set of operational and maintenance requirements, like the model for the on-demand executive jet market today. Training and certification requirements will need to be legislated for remote pilots and controllers. Mobility managers will be responsible for providing seamless trip planning, ticketing, and payments incorporating this mode into their interface. Digital infrastructure would be key to ensuring safe, secure, and reliable communications between fleets of passenger aircraft.

IMPLEMENTATION

Ease of Implementation 	UAVs will require strategically placed take-off and landing zones/parking, battery charging stations and maintenance facilities. A wide network of vertiports would either require new infrastructure to be built or existing infrastructure, such as helipads, rooftops of large public buildings, and unused land, to be modified (see also the Vertiports Use Case). To create a truly unified traffic management system, additional infrastructure may need to be installed along predefined flight corridors to aid high-speed data communications and geolocation.
Cost 	The costs of planning, and implementation of the enabling policies and infrastructure for the safe operations of UAVs is high, as it requires important work on interface integration with the energy sector and with other modes of transport.
Country Readiness 	Each country's priority on safety, cost, travel time, reliability, comfort and new technologies, will define the level of readiness required to enable operations of UAVs. In passenger-oriented city with existing infrastructure, UAVs would mainly be deployed as an additional transport solution to complete the transport chain.
Technological Maturity 	UAVs will require advanced technologies, such as artificial intelligence and cognitive systems, to enable advanced detection and avoidance capabilities. Machine learning could be essential as operations move to fully autonomous. They will also require on-board sensors (radar, optics, geolocation sensors) to operate in GPS-denied environments. These technologies are currently being utilized in autonomous cars (*see also the Autonomous Cars Use Case*), but they need improvement to provide longer-range sensing and recognition capabilities necessary for the multidirectional and convergence speeds associated with autonomous flight. Energy management is crucial: to increase capacity and extend the ranges of passenger drones, battery technology will need to improve, or alternatives need to be found.

RISKS AND MITIGATIONS

Implementation risk

Risk: Developing the supporting communications and energy interfaces along with the infrastructure is essential. Well integrated hubs will need to be developed from a structural and systems perspective, with the rest of the city's structure and systems/technology requirements.

Mitigation: Planning solutions, operating permits and regulations will need to be implemented to enable UAVs to be used for passenger transport. Business plans should showcase the value UAVs can add for transport authorities and the community (economically and liveability), and their limited impact on infrastructure.

Social risk

Risk: To achieve long term success and avoid becoming a niche and expensive transport mode reserved for a very few, UAVs will need to quickly demonstrate themselves to be safe, quiet, convenient and affordable and integrate with the wider transport network.

Mitigation: UAV service providers must select the right products and collaborations to offer attractive and affordable services to the public. Users will need to overcome psychological barriers associated with flying in a pilotless aircraft which can be achieved through regulatory authorities ensuring UAVs are as safe as a traditional aircraft and community education.

Safety and (Cyber)security risk

Risk: Current research looking at UAV cybersecurity threats has focussed largely on GPS jamming and spoofing. However, there is also a potential for attacks on the controls and data communications stream. Threats are like those applicable to airplanes, but they are amplified with UAVs due to the potential for high numbers of vehicles flying in relatively small urban areas.

Mitigation: For scaled adoption, operators of UAVs would have to demonstrate a safety record, covering both mechanical integrity as well as safe operations, and operations should be regulated. The UAV autonomy and its systems reliability should be proven through specific verification and validation processes, that have started to be developed in areas like Dubai with the Velocopter.

Environmental risk

Risk: The use of shared energy sources (e.g. from buildings for the stations that could be developed on them) to operate the UAVs is an asset as well as a risk. The energy requirements need to be clearly defined.

Mitigation: Sharing the power with buildings hosting the vertiports can be a risk but also a great advantage to both charge the UAVs or collect their power when they do not need it.

EXAMPLES

Example	Implementation	Cost	Timeframe
CityAirbus	Electric four passenger vertical take-off and landing craft initially pilot operated, moving to full autonomous mode when the technology allows.	High implementation costs for the UAV development, for the testing processes and for the required supporting infrastructure.	To be implemented with existing airports and aviation related clients 'first/last mile' UAVs.
Volocopter	Volocopter already has a permit to fly in Germany and hopes to be part of Dubai's commercial pilot program in the early 2020s.	High implementation costs for the UAV development, and for the required supporting infrastructure. Safety is a challenge to achieve and requires additional safety requirements to be checked.	Operations expected prior to 2025 as part of Dubai's 15% autonomous transport objectives.
Ehang 184	Passenger drone built by China-based Ehang using 100% green technology.	High implementation costs for the UAV development, infrastructure not yet developed.	

Used cooking oil and grease trap waste converted to biodiesel

DETAILS

SECTOR | Water, Waste

STAGE | Operations and Maintenance

TECHNOLOGIES | Grease traps and fat, oil and grease (FOG)/ used cooking oil collection, Biodiesel production

SUMMARY

A novel grease trap collection system for the harvesting and removal of problematic fat, oil and grease (FOG) waste build-up at the commercial, industrial and municipal wastewater premises. It uses oleophilic (oil-attracting) and hydrophobic (water-repelling) technology to increase the capture of FOG for better management of waterways. The harvested FOG waste can also be more effectively managed, including by being converted into high-quality biodiesel feedstock.

FOG is the primary influencing factor of sewer overflows, with hundreds of thousands of incidents per year globally. Inconsistent installations of correctly-sized grease traps combined with infrequent maintenance, results in FOG waste being released into the sewers, which can deposit on the pipe's surface and solidify as it cools over time, causing pipe clogging. In addition, there has traditionally been no positive value chain created for the application of collected FOG waste other than sending to landfills which could impose environmental and health problems.

All wastewater effluent coming from food establishment sink drains or other FOG producing sources can be intercepted before entering the sewer networks, preventing FOG build-up which can lead to sewer blockage and overflow. Traditionally FOG is captured in grease traps which are periodically emptied and then sent to landfill or other recycling facilities.

This new technology increases the capture rate of FOG in the grease trap and reduces the unnecessary transport of water. In addition, the usage of high-value FOG feedstock can divert from the disposal route of conventional landfills to energy recovery. The repurposing of FOG into biodiesel is performed at a processing plant where impurities are removed to ready the FOG for chemical biodiesel production process. FOG can be an attractive alternative feedstock for biofuel production to meet the energy recovery needs from renewable sources. For example, analysis in the USA shows that waste to energy technologies converting FOG and other waste feedstocks to biofuel could potentially provide 26% of aviation fuel needed in the USA[1].

[1] Skaggs et al. Waste-to-Energy biofuel production potential for selected feedstocks in the conterminous United States. Renewable and Sustainable Energy Reviews 82 (3) (2018), Pages 2640-2651

VALUE CREATED

Improving efficiency and reducing costs:

- More effective waste removal at source eliminates frequent manual maintenance in the grease traps and the extended sewer networks
- Prevents substantial costs potentially incurred to clean up and repair the downstream damaged sewers and public infrastructure from sewer overflows
- Collects and converts waste into biofuel as an additional revenue source and alternative renewable energy source
- Extends grease traps and sewer assets life

Enhancing economic, social and environmental value:

- Eliminates negative human and environmental health consequences due to greenhouse gas emission and leachate pollution from landfill waste
- Turns a problematic waste stream into a reusable stream.
- As waste production increases, it builds a circular economy for the continuous use of resources to protect the environment without waste being unused and disposed of.

Reshaping infrastructure demand and creating new markets

- Creates a new technological market that enables innovations in both waste recovery and processing into a renewable energy resource.
- Establishes a new revenue-generating business model by giving out incentives to stakeholders contributing to FOG management.

POLICY TOOLS AND LEVERS

Legislation and regulation: This solution requires a compliance driver to enforce FOG interception. Governments should enact a national/regional standard and policy for trade waste discharge and penalties. The establishment of FOG management programmes can streamline the regulations for grease trap design, installation and servicing requirements. Governments can provide incentives to reward wastewater utilities for promoting a circular economy.

Effective institutions: Collaborating with municipalities and utilities to develop incentives and comprehensive compliance programmes can accelerate the uptake of this solution. Implementing solutions to prevent discharge of FOG remains challenging because it involves active collaborations between multiple stakeholders such as regulators, customers, grease trap service providers, and utilities.

Transition of workforce capabilities: Recycling programs are typically associated with plastic, paper, and cardboard. FOG is a low priority product to be recycled into valuable products. Educating the public and commercial and industrial producers on the potential of FOG recycling and the benefits of a circular economy is essential to accelerate the shift to sustainable FOG and biodiesel infrastructure.

IMPLEMENTATION

Ease of Implementation

This use case is relatively easy to implement. Wherever there is an established FOG compliance regime the grease traps may be retrofitted and provide a steady source for biofuel. Even for cities without grease traps, the implementation is relatively easy once a compliance policy is established as a driver and the industry has accepted and understood the new interception requirements. Getting to large scale adoption from commercial and industrial producers as well as building biodiesel production infrastructure would be the most difficult aspect of the implementation. This may need government or regulatory incentives

Cost

A relatively low-cost solution and is typically done at a smaller scale initially. The FOG collection can be started with a low number of installations. The construction of a processing plant is a larger cost requiring more upfront investment.

Country Readiness

Developed countries have the necessary infrastructure and demand for biodiesel. Developing countries have less developed sewer infrastructure and FOG may not get collected. This would be a value add for the basic sewer infrastructure.

Technological Maturity

Technology for both collection and processing of FOG is at early stages of at-scale production but are both technologically and commercially proven on multiple projects.

RISKS AND MITIGATIONS

Implementation risk

Risk: Variable quality of wastewater streams due to larger items such as rags, cotton and other debris could potentially clog the equipment and decrease the removal efficiencies.

Mitigation: Pre-processing equipment to have first-pass screening in place to remove unwanted debris.

Risk: Lack of FOG management initiatives. There can also be inherent limited flexibility of introducing new solutions and changes to the existing FOG service standards that may slow down the overall adoption across the wastewater supply chain. A resulting lack of financial incentive or government support to implement the technology will inhibit wastewater utilities and their customers from making changes to their existing grease traps

Mitigation: Drivers need to be created through government and regulatory policies that provide commercial incentives to shift towards higher FOG standards.

Environmental risk

Risk: Turning waste into biodiesel is a new market. General scepticism about the tangible benefits of biodiesel production over the incumbent method of direct landfill disposal.

Mitigation: Education on the environmental advantages and commercial case of biodiesel.

EXAMPLES

Example	Implementation	Cost	Timeframe
Pumpfree	In Sydney Australia, PumpFree are rolling out the technology to a global restaurant chain with over 180 sites in the region. They will be deploying to Victoria and Queensland later this year[2].	The technology reduces Biochemical Oxygen Demand (BOD), FOG and Suspended Solids to sewer by 54%, 75% and 65% respectively, reducing the load for downstream wastewater treatment plants. Increases the availability of high-quality waste feedstock which is lower priced than traditional UCO or tallow to the biofuel industry (approx. 2 tonnes per site per annum).	The roll out on the 180 sites will take approximately 3-4 months.
Argent Energy	Argent Energy constructed a which is the first of its kind biodiesel production plant in Europe, will process up to 250,000 tonnes of waste fats and oils into around 85 million litres of biodiesel a year. Biodiesel made from waste can produce 90 per cent fewer greenhouse gas emissions compared to fossil fuels.[3]	The facility cost £75 million.	Construction started in 2016 and the plant is fully operation.

[2] Information for this example was gathered via communications with commercial technology stakeholders.
[3] Ellesmere Port's new £75m waste chip oil plant will power cars. Cheshire Live. Accessed 10 May 2020.

Vehicle to Vehicle (V2V) Connectivity

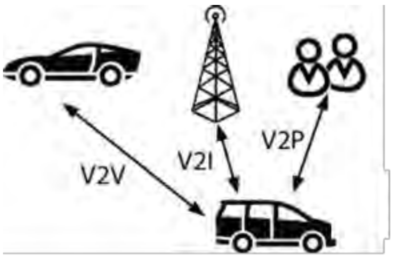
DETAILS

SECTOR | Transport

STAGE | Operations

TECHNOLOGIES | Applications, Bluetooth/Wi-Fi, 4G/5G Networks, Sensors

SUMMARY



Cooperative Intelligent Transport Systems (C-ITS) are emerging technologies that allow road users and roadside infrastructure to share information with each other. Connectivity can be primarily between vehicles (V2V) or between vehicles and infrastructure (*see Vehicle to Infrastructure (V2I) Connectivity and Smart Motorways use case).*

V2V technologies are C-ITS designed to enable communication between vehicles to avoid accidents and warn drivers of impending crashes, as well as to enable the optimisation of the overall traffic flow. They are being developed with a view to facilitate the implementation of Autonomous Vehicles in the future, which will heavily rely on their efficiency. Their functionalities include Turn Assist, which warns drivers not to turn in front of oncoming traffic, and Intersection Movement Assist, which warns drivers not to enter an intersection because the probability of colliding with another vehicle is high. When combined, Turn Assist and Intersection Movement Assist prevent up to 600,000 crashes per year, according to the US Department of Transport[1].

Road crashes have major and long-lasting impacts on communities, as well as on infrastructure and its costs. For example, the World Health Organization (WHO) estimated that globally road crashes cost more than USD 250 billion per year[2]. Australia's Bureau of Infrastructure, Transport and Regional Economics (BITRE) estimates the total cost of road crashes in Australia is AUD 27 billion per year[3]. Around 38% of this cost is attributed to injury or disability, 37% to fatalities and 25% to property damage[4]. V2V technology combined with autonomous vehicles will greatly reduce accidents caused by human error, which account for 94% to 96% of road traffic accidents in the US each year[5].

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[1] National Highway Traffic Safety Administration, Accessed 18 May 2020.
[2] "The global impact", World Health Organization, Accessed 18 May 2020.
[3] "Government estimates road crashes costing the Australian economy $27 billion a year", ABC News, Accessed 18 May 2020.
[4] "Australian Road Deaths Database", Australia Bureau of Infrastructure, Transport and Regional Economics (BITRE), Accessed 19 May 2020.
[5] "Evidence stacks up in favor of self-driving cars in 2016 NHTSA fatality report", Digital Trends, Accessed 17 May 2002.

V2V technology can also help improve traffic flow management, decrease congestion, and optimise utilisation of existing infrastructure, thereby minimising any unnecessary expansion of infrastructure capacity (e.g. more roads and/or more transit). V2V provides data on traffic flows, which is processed and used to share traffic information on variable message signs and variable speed limit signs, and to enable vehicle platooning if all vehicles are connected. It is also used for route planning (*See also the Demand Responsive Transport use case*).

A successful, safe and sustainable road transport network will continue to be a critical part of the mobility mix. The innovative deployment of connected technologies and the increased use of data, analytics and artificial intelligence will enable countries to stretch capacity and minimise infrastructure disruption while leveraging existing road infrastructure. The increased use of data from V2V, combined with smart technologies such as advanced telematics, the evolution of connected vehicles, and urban and inter-urban traffic flow management will all be essential to meeting major environmental and cost challenges. Critically, a key benefit of continued technological innovation is that for drivers, passengers and pedestrians, a safer future will be secured.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce infrastructure costs and disruption time and costs as vehicle traffic is optimised with better coordination. Existing infrastructure is fully utilised and less new road infrastructure expenditure is required.
- Reduce costs associated with road traffic accidents which will result in reduced expenditure on medical services, police, infrastructure repair etc.

Enhancing economic, social and environmental value:

- Reduce congestion and improve connectivity between destinations, as traffic flows are optimised.
- Enable longer term infrastructure investments through the data collected and the more efficient demand management removing the need for additional 'immediate' capacity improvement.
- Improve road safety (generating costs savings) and infrastructure management.
- Facilitate the use of private vehicles for new shared models: the usage and availability of connected vehicles can be managed in an area, thus it is easier for a private vehicle owner to integrate their vehicle into a shared transport fleet (such as ride-sharing).

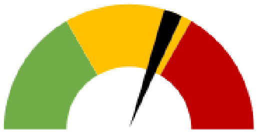
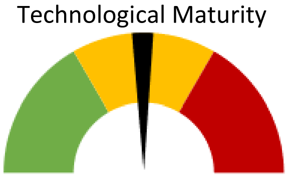
POLICY TOOLS AND LEVERS

Legislation and regulation: A diverse range of stakeholders need to cooperate; mobility regulators, telecommunications operators, manufacturers and technology providers. In 2010, the European Commission launched a group to internationally standardise C-ITS. International standards exist for the fabrication, accreditation and use of V2V technologies, focused on safety. Using international standards, governments should define accreditation and certification requirements to ensure all vehicles sold in countries with V2V technologies enabled are interoperable. The interoperability of the V2V technology is critical to realising its benefits.

Effective institutions: Governments must ensure they can affect necessary change in the market to support the upholding of public value. The connected aspects of V2V solutions and the use of data must provide an economic benefit to the user who 'agrees' to share their data. This should be established and communicated to the population.

Transition of workforce capabilities: Governments need to develop skills for the accreditation of manufacturers' vehicles. They also need to ensure there are enough mechanics to maintain V2V technologies in vehicles and they need appropriate skills in house to regulate the technology effectively.

IMPLEMENTATION

Ease of Implementation 	Implementing V2V technology is primarily executed by vehicle manufacturers who should follow (and jointly develop with governments) relevant international standards to ensure interoperability of vehicles, which today is proving challenging. For governments, to effectively utilise V2V, it is important to make sure that the right regulations are in place. These should comprise communications and international and local standards.
Cost 	Implementing V2V requires high upfront costs to 'connect' the vehicles with the right technologies, as well as to operate them in a consistent way. Manufacturers must heavily invest to develop these technologies, with the support of research funds from governments. The costs will be filtered through to consumers through the price of the vehicle or service.
Country Readiness 	To work effectively V2V requires widespread communications networks. There should also be a thoughtful integration with the transport network, that enables seamless and informed data sharing between transportation services.
Technological Maturity 	Many do not trust sensors like V2V to perform better than humans. Today not all V2V technologies can communicate with each other as they are provided by different manufacturers using different international standards. This is an area of continued development.

RISKS AND MITIGATIONS

Implementation risk

Risk: To work effectively V2V requires widespread communications networks. In addition, standards for the technology's development and uses should be aligned and followed by all manufacturers. There should also be a thoughtful integration with the transport network, that enables seamless and informed data sharing between transportation services.

Mitigation: To mitigate this issue, internationally agreed V2V standards should be developed with a plan that ensures the right communications networks are in place.

Social risk

Risk: Users may be reluctant to accept V2V technology due to perceived data privacy issues.

Mitigation: Businesses providing V2V should focus on the scenarios for the use of V2V to improve the experience of travel so that ultimately on-demand, personalised, and autonomous transport services *(see Autonomous Vehicles use case)*, utilizing V2V, can provide a tailored experience for individual customer needs. It is also important to encourage competition in order to provide users with greater choice and flexibility, and improve customer service standards, while driving innovation.

Safety and (Cyber)security risk

Risk: Communications network vulnerabilities are one of the most important cyber security risks as wireless communication introduces a different set of cyber problems called "WiFi like" network vulnerabilities: wireless services can be vulnerable to signal intercept, signal hacking or deterioration and other similar threats linked to the transmission of data. This main vulnerability points are located both at the level of the communication networks (the channel transmitting data) and its supporting devices on the roadside (which collect and emit the signal).

Mitigation: Organizations should ensure their systems are robust to eliminate the risk of a cybersecurity breach, and governments should set regulatory frameworks to outline the requirements of these systems to repel cybersecurity attacks.

Technological solutions include the use of licensed and standardised radio/comms channels to reduce exposure to the known problems and make sure all communications and V2V providers can comply with those requirements when developing their networks and devices. DSRC (Dedicated Short Range Communication), a wireless standard developed specifically to support V2V applications, has been developed to respond to this threat and is currently being developed to capture all communications threats and have a response program to stop them for all vehicle types.

EXAMPLES

Example	Implementation	Cost	Timeframe
Queensland CAVI Program	Trials of several V2V technologies from different manufacturers.	High costs and a lot of research contributions.	Trials are still on-going with Autonomous vehicles.
CETRAN Singapore	Centre of Excellence for Testing & Research of AVs-NTU (CETRAN) – LTA (Singapore).	High costs and a lot of research contributions.	Trials are still on-going with Autonomous vehicles.
Nevada	Certification and regulations are a key focus of the trials.	High investments to develop regulations guidelines.	Trials are still on-going with Autonomous vehicles.

Virtual and Augmented Reality for Planning and Design

DETAILS

SECTOR | Transport and Energy

STAGE | Strategy and Planning; Design and Project Delivery

TECHNOLOGIES | Virtual Reality, Augmented Reality, Smartphones, Applications

SUMMARY

Augmented Reality (AR) and Virtual Reality (VR) are both part of a wider field of technology called Mixed Reality (MR). MR describes different technologies that can blend the physical world with the digital world. VR replaces the real-world environment with a simulated environment, where computer simulations influence the user’s senses and perception through the production of images, sound and other sensations. The user can look and move around the artificial environment and interact with its virtual features. Similarly, AR is a blend of the real world and the digital world, which is achieved by overlaying virtual computer-generated objects onto real-world objects. Where AR alters the user’s ongoing perception of a real-world environment, VR completely replaces the user's real-world environment with a simulated one.

Several devices are used in the field of MR including head mounted displays, AR tablets, Cave Automatic Virtual Environments (CAVE), and AR projectors. These devices provide MR visualization and other functionalities for user interaction. In addition, tracked controllers, object recognition and tracking, or haptic feedback can be integrated to support intuitive usability. MR therefore provides an enhanced interface between digital data and users, due to improved visualization and controls.

MR technologies have several potential uses across industries. These include:

- Simulating environments
- Creating immersive experiences
- Visualizing and interacting with data
- Enabling maintenance
- Enhancing education
- Improving public health and safety, and
- Supporting investigations and case management.

MR technologies can be integrated in all stages of infrastructure planning and design as they can transport users into virtual environments that reveal what a design will look like when constructed and how it will interact with and impact upon the existing environment. These solutions can be utilized to enhance the visualization process by providing engineers, builders, managers and other stakeholders with insight to a structure before it is even built. This can provide opportunities to identify and resolve potential design flaws, risks and issues before and during the construction phase. These systems can also be utilized to garner public feedback in relation to proposed and ongoing works.

MR technologies can bring technical drawings to life in a way that has never been achieved before. They enable users to experience a proposed design or concept in a real-life environment which considers an array of factors and integrations. They can bring to life otherwise difficult to imagine qualities like sunlight passing through, or the sound absorption properties of a space. For stakeholders and the public, this can help to garner greater involvement in the decision-making process and prevent detrimental surprises and expensive or impossible alterations during project delivery. Ultimately this delivers an improved product; fewer impacts to the schedule; and a positive experience for the project team and stakeholders with easier and more effective collaboration.

When used for public exhibition or consultation, these interactive presentations can provide public stakeholders with a more comprehensive understanding of a project including the look and feel of the structure being built or renovated; the integration with the existing environment; and the potential benefits the public will experience once the project is complete. These tools can be a mechanism for garnering public opinion and feedback and can be utilized to shape ongoing policy and planning agendas.

Researchers are now investigating ways to integrate MR with Building Information Modelling (BIM) in order to bring BIM data into a virtual environment. While MR enables the visualization of and interaction with virtual environments, BIM enables the creation and manipulation of that data. Therefore, combined, the technologies will present a further opportunity for process improvement and efficient and accurate collaboration.

VALUE CREATED

Improving efficiency and reducing costs:

- Enable easy to visualize variables or modifications to a design thereby presenting a unique opportunity to perfect a design before construction begins and minimise the cost of changes during construction

Enhancing economic, social and environmental value:

- Introduce an efficient mechanism for displaying and updating a design that can integrate feedback from multiple stakeholders with minimal effort, providing an opportunity for broad stakeholder engagement
- Allow planners to create real scale virtual prototypes that would otherwise be very expensive to analyse, and present them augmented in a real scenario with a low-cost solution
- Engage the public to achieve buy-in and receive feedback, which can improve the perception of the project (including during construction, when communities can be negatively impacted by noise, restricted access issues or the closure of business and amenities)
- Improve designs that are more resistant to natural disasters and can withstand multiple scenarios *(see 3D Infrastructure Modelling use case)*

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments will be responsible for establishing certifications of the VR/AR content information and operations, as well as regulating the appropriate and safe use of VR/AR systems.

Effective institutions: Leaders from business and government should act pre-emptively now in preparation for these technologies and the risks they present. Technology developers should focus on designing how these technologies will ultimately work and the business models that can support them, whilst governments should set the rules for using them, and adapt any existing legislation or contractual standards that may unnecessarily restrict their use.

Transition of workforce capabilities: Where previously 2D and 3D models would have been used to produce architecture and technical designs, workers will need to learn how to produce, present and adapt immersive technology visualizations. Associated human factors processes will need to be developed.

Procurement and contract management: Provide contract terms enabling the use of VR technologies for planning and design and anticipate procurement programs requiring these expertise and skills, as well as the associated licensing costs. Contracts and Key Performance Indicator regimes need to be adapted to include expected performances.

Funding and financing: Investment costs and licensing costs should be considered in funding models for new infrastructure design, in addition to estimated savings.

IMPLEMENTATION

Ease of Implementation 	There are three main components required in most applications: the camera used to capture the real environment; a computing unit to process the video with the virtual information; and a device to display the final augmented information (e.g. a flat screen). Additionally, further hardware including GPS, human motion sensors, accelerometers, gyroscope, etc. can be included into the designed system in order to serve a specific purpose.
Cost 	Balancing cybersecurity and privacy concerns against costs is usually the underlying driver in decisions about where and how to host MR solutions. As the technology continues to progress, organizations should observe the development of new security standards and solutions specific to MR that can help them strike the right balance between security and cost.
Country Readiness 	Models for design / construction should be compatible with VR/AR applications to be directly uploaded. Additionally, those models need to be compatible with other construction programs in order to ensure continuity of design. Today most advanced countries use models and construction programs that can be used in VR/AR environment; however, in developing countries, this may be yet to be developed.
Technological Maturity 	Until now, the widespread adoption of VR and AR technologies has been limited by high costs, technology limitations and lengthy production times. Recent developments in simple to use and accessible applications and hardware have largely removed these barriers.

RISKS AND MITIGATIONS

Implementation risk

Risk: Models used and created for MR devices need to be compatible with construction and planning models in order to be used in a way that aligns with industry requirements.

Mitigation: Governments and industry need to establish requirements for the development of models to be used for MR design applications that ensure their compatibility with industry standards and requirements.

Social risk

Risk: While head-mounted displays are a key component of the technology, it is also the most likely component to compromise the user's safety. Substandard design and manufacturing processes can potentially result in impairment to the perception of the user, which may lead to serious consequences depending on the application. There is also the potential that frequent and/or prolonged exposure to these immersive environments could have a detrimental impact the user's mental health.

Mitigation: Ensuring the compliance of this equipment to the highest standards of quality and safety will ensure the technology can be utilized without subjecting users to danger. Organisations and governments will also have to monitor these solutions as they are increasingly adopted and be prepared to act quickly if adverse consequences materialize.

Safety and (Cyber)security risk

Risk: There can be risks associated with collecting and managing the personal biometric data of individuals (e.g. feelings, behaviours, judgments, and physical appearance).

Mitigation: It is importance to any major information system implementation that an assessment of the system's security strengths and weaknesses is conducted to ensure the sensitive data of the users is protected. The intended or unintended misuse of users' intimate data must be a top-priority concern for all organizations seeking to use this technology.

EXAMPLES

Example	Implementation	Cost	Timeframe
Cross River Rail (CRR) Experience Centre	A VR Station lets users experience CRR's future stations and precincts, to understand how the project will impact the city.	High investments in creating the relevant 3D models and digital twin; a specific asset library is developed for all new rail assets.	Early planning for the design and VR station implemented at CRR experience centre.
Sydney Metro	VR and AR helped inform project design decisions and communicate complex 3D issues, options and scenarios, and problems to stakeholders.	High investments in creating the relevant 3D models, but savings in their use for identification of interfaces clashes between design disciplines and for multi-disciplines teams' communications.	Implemented: Using the BIM design approach, the project was able to quickly and efficiently publish immersive VR data.
Uppsala, Sweden Virtual City	An interactive Virtual City was developed to assist city officials in deciding on whether to commission a solar-powered Personal Rapid Transit system in the city.	Low investments in the technology and in the model used more for communications than design initially; additional investments since then.	The Virtual City was developed and analysed with stakeholders over a four-year period. It played a key role in the evolution of the conversations between the stakeholders, with focus moving from technical and operational concerns to design and how best to integrate the system with the city.

Augmented and Virtual Reality for Training and Inspection

DETAILS

SECTOR | Transport and Energy

STAGE | Operations and Maintenance; Asset Management

TECHNOLOGIES | Virtual Reality, Augmented Reality, Smartphones, AI & Applications, Sensors, Cameras

SUMMARY

Augmented Reality (AR) and Virtual Reality (VR) are both part of a wider field of technology called Mixed Reality (MR). MR describes different technologies that can blend the physical world with the digital world. VR replaces the real-world environment with a simulated environment, where computer simulations influence the user's senses and perception through the production of images, sound and other sensations. The user can look and move around the artificial environment and interact with its virtual features. Similarly, AR is a blend of the real world and the digital world, which is achieved by overlaying virtual computer-generated objects onto real-world objects. Where AR alters the user's ongoing perception of a real-world environment, VR completely replaces the user's real-world environment with a simulated one.

Several devices are used in the field of MR including head mounted displays (HMD), AR tablets, Cave Automatic Virtual Environments (CAVE), and AR projectors. These devices provide MR visualization and other functionalities for user interaction. In addition, tracked controllers, object recognition and tracking, or haptic feedback can be integrated to support intuitive usability. MR therefore provides an enhanced interface between digital data and users, due to improved visualization and controls.

MR technologies have several potential uses across industries. These include:

- Simulating environments
- Creating immersive experiences
- Visualizing and interacting with data
- Enabling maintenance
- Enhancing education
- Improving public health and safety, and
- Supporting investigations and case management.

MR technologies are well suited to support organizations across the Project Delivery, Operations and Maintenance stages of infrastructure delivery. They have been successfully used to deploy training programs and can assist workers in performing asset inspections and maintenance works. As VR creates an entirely simulated environment, it can be used to place a user in an immersive training environment, where they can experience real-world situations without any of the associated safety risks. AR, conversely, is better suited to building on the job skills and assisting workers to complete tasks. It does this by overlaying digital information on to real-world assets. For example, the system could project the maintenance history record and relevant maintenance manuals for an asset, whilst also displaying information regarding on-site parts, so that a worker can perform the task with minimal distraction. These technologies can also be used to connect an on-site worker with a skilled off-site worker, who can support them in undertaking the task *(see Knowledge Access Platforms for Construction and Maintenance use case).*

These project stages have high safety risks for workers. Workers with limited on-site safety knowledge or a lack of safety awareness and/or training, can further contribute to these high-risk environments. Traditional construction safety training takes place in a classroom style setting using presentations or videos. This setting is limited in its ability to represent real site conditions and prepare workers for on-site hazards. VR is instead able to place each worker in a virtual replica of the site and effectively familiarize them with existing and potential hazards in advance of them stepping on site.

MR technologies can also be used to assist in performing inspections. Traditional inspection processes are timely and require one or multiple resources to perform a detailed on-site inspection. This requires specialist resources to be available on-site, often across multiple days, and has the potential for errors due its manual nature. Documenting and communicating findings is also a timely process. AR can be used during both the construction and maintenance phases to enable inspectors to compare a site or asset with the original designs/BIM model, perform quick measurements, add notes, and document findings in real-time. This can be done by an on-site inspector using HMD or Connected Glasses, or by an off-site inspector utilizing drone technology to facilitate a virtual walk-through of the site or asset. This is particularly useful if the inspector cannot be on-site, or if the safety risk is high (*see Knowledge Access Platforms for Construction and Maintenance use case*).

Organizations that have implemented MR technologies have experienced reductions in the time required to perform tasks and train staff[1]. The Aveva Group, who work with companies including the Kuwait Oil Company in the Middle East utilizing MR systems for staff training, have seen a 30% to 40% reduction in time required for training and a resultant reduction in the cost to perform maintenance by as much as 3% per year[2]. In the rail industry, MR technologies have produced a 30% time saving and a 30% to 50% cost saving[3]. The technologies have also benefitted employee's satisfaction and productivity levels. Additionally, the tracking of information is more accurate and better documented, resulting in infrastructure being better maintained and utilized.

MR technologies can provide insights into preventative measures, the consequences of which extend further and further into the future, such as enabling pre-emptive maintenance. They can also be used to build construction and Building Information Models (BIM) directly from the images captured *(see Virtual and Augmented Reality for Planning and Design use case)*.

[1] "Enterprise AR Use Cases", Forbes, Accessed 6 May 2020.

[2] "How VR is Changing the Oil and Gas Industry", CIO, Accessed 6 May 2020.

[3] Systra Maintenance Report

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce time and OPEX costs through increased efficiency and speed in completing tasks. For example a Skylight trial showed that eliminating the seemingly minor inconvenience of glancing back to a book for information resulted in a 34% increase in speed to accomplish a task[4].
- Improve productivity by accelerating and enhancing experiential learning in comparison to traditional classroom-based learning and reduce errors, resulting in time savings, safer procedures and lower operational costs
- Reduce fixed costs, such as those related to the purchase of various items, as virtual objects can replace physical ones and enable remote training and inspections thereby saving time and money associated with travel costs and trainer fees

Enhancing economic, social and environmental value:

- Prepare workers for stressful or hazardous circumstances without putting them at risk and reduce the number of on-site accidents and injuries through effective training
- Improve employee satisfaction through effective training, mentorship and on the job support and by enabling workers to begin work quickly due to speed of training and begin utilizing new applications with little prior information

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments will be responsible for establishing certifications of the VR/AR content information and operations, as well as regulating the appropriate and safe use of VR/AR systems.

Effective institutions: Specific training organisations and accredited trainers will need to be put in place in order to upskill staff in the use of such devices. Therefore, accreditations should be delivered by specific institutions, following standardised validation and accreditation processes.

Transition of workforce capabilities: There is a need to transition worker skills from a site-based skillset to a remote operations based-skillset, supported using new technologies. Furthermore, human factors processes will need to be set up.

Procurement and contract management: Performance specifications and required experience and expertise in procurement processes will need to be revised to consider those new services. Contract and expected contractors Key Performance Indicators regimes will need to reflect the new performance expectations.

Funding and financing: Investment in VR devices and licensing costs for the analytics of data provided to and from the devices will need to be included in the investment costs and funding models of such services for training and inspection, in addition to consulting services.

[4] "Augmented reality is already improving worker performance", Harvard Business Review, Accessed 6 May 2020.

IMPLEMENTATION

Ease of Implementation

While these technologies can typically save money for an organisation once they have been implemented, difficulties in budgeting can mean projects go unfunded. For example, while VR training can save money or improve outcomes compared to traditional training, the costs of implementing the solution may rest with a training department while the benefits may accrue to an operational department. Benefits should be tracked to ensure the expected return on investment has been achieved.

For businesses to access the benefits associated with the processing of large amounts of data, AR and VR systems typically need to be integrated with other company software. In practice, this often means integrating with a multitude of legacy systems which can be difficult and may pose many issues.

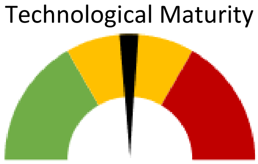
Cost

Investment costs in VR technologies for inspection and training are low and operational costs savings, as well as time savings, can offset the initial investment for most sectors.

Country Readiness

Most advanced countries are already using such solutions for inspection and training. In developing countries, for new infrastructure projects, there is a great opportunity to implement those solutions, however most of the procurement processes or institutions to support their implementation are not yet in place.

Technological Maturity



Until now, the adoption of VR and AR has been limited by cost and technology shortcomings and lengthy production times. Recent developments in simple to use and accessible applications and hardware have largely removed these barriers.

RISKS AND MITIGATIONS

Implementation risk

Risk: For businesses to access the benefits associated with the processing of large amounts of data, AR and VR systems typically need to be integrated with other company software. In practice, this often means integrating with a multitude of legacy systems which can be difficult and may pose many issues. Furthermore, it can be difficult to coordinate legacy simulators to produce an accurate, complete training experience, and systems can be unintentionally influenced by human bias.

Mitigation: Attention should be given to ensure multiple simulations can operate in the same virtual space. Organizations must ensure their algorithms continue to produce reliable results each time new data is added, in order to understand if additional human layers add biases. They must act to resolve this when inconsistencies are discovered.

Social risk

Risk: For emerging technologies like AR and VR, getting stakeholder buy-in can be challenging either as a result of a lack of understanding of the benefits; conflicting stakeholder priorities; or miscommunication about the goals of the technologies. There is also a potential for information overload which can cause stress, indecisiveness and can lead to inaction. This defeats MR’s purpose of enabling quick action using real-time information.

Mitigation: It is important to ensure all stakeholders are aligned in their expectations of the technology prior to its implementation. Furthermore, the amount of data that can be accessed through MR applications should be regulated to secured authorized data for organizations seeking to apply this technology.

Safety and (Cyber)security risk

Risk: Like other connected technologies, AR and VR are vulnerable to security threats and unauthorized access by hackers and malware. These attacks can result in a denial of service or the overlaying of incorrect information. Any errors in safety or cybersecurity that could potentially harm customers or employees can significantly impact businesses by destroying trust, brand, reputation and future prospects.

These technologies also present their own unique privacy challenges in how the technologies interact with users, and in the types of data they interpret. They actively assess how users react to new experiences including eye movements, pupil dilation, and other reactions. These are used to generate data points to improve future programs. It has been suggested that such information could be utilized by hackers for identity theft.

Mitigation: It is importance for any major information system implementation that an assessment of the system's security strengths and weaknesses is conducted to ensure the sensitive data of the users is protected. This type of data collection needs effective controls to protect the privacy of users.

EXAMPLES

Example	Implementation	Cost	Timeframe
Sydney Metro AR Safety Induction	An immersive safety induction program for the Sydney Metro project rolled out to more than 500 users.		The development of the AR training took 10 months to complete. This included user design development, filming, animation, scripting, solution building and testing, user feedback, final build, training to deploy solution and final deployment.
University of Cambridge Trial	Use of headsets to perform inspections on a bridge. High-resolution photos are mapped to 3D models and using a HoloLens connected to the cloud, the user can zoom in and out, rotate, and move around the structure from anywhere in the world.	The solution enables more accurate diagnoses of structural issues, which resulted in fewer large-scale repairs, less downtime, and reduced traffic delays and congestion.	The trial took place in 2017.
BP Virtual Reality Training	BP collaborated with Maersk Training to deliver VR training to their offshore drilling teams.	The training enabled BP to safely complete a drilling task 40% under budget.	The training enabled BP to safely complete a drilling task 114 days ahead of schedule.

Water Height and Flood Management System

DETAILS

SECTOR | Transport and Energy

STAGE | Planning and Design; Operations and Maintenance

TECHNOLOGIES | GPS, Sensors, Radar

SUMMARY

Water height and flood management modelling involves the use of sensors (GPS, water level, radar for thermal images) to collect data on the water level, resources, quality and water-related hazards, for a set geographical area. The data collected is transmitted to a central system and then analysed to enable flood prevention and better water resource management.

Such flood management systems can process data on flooding and water quality in near real-time and can track patterns to identify areas likely to be flooded, looking at the probability that flooding will occur. This enables local authorities to determine mitigation solutions (e.g. dams and water management systems) or to identify alternative areas where the risk of flooding is lower.

Flooding is a frequent occurrence particularly in coastal regions, and near rivers and lakes. Flooding events can cause damage and destruction to property and infrastructure. Flooding is becoming increasingly frequent with climate change and rising sea levels. As urban expansion continues, flooding in these areas can become more frequent due to insufficient drainage. This requires action to lessen the risk of urban flooding for infrastructure.

A water height and flood management system will enable local authorities to predict future flooding and avoid building major infrastructure in high risk areas. Solutions such as water level control and flood prevention have been implemented around the world and have shown some success. For example, the Thames River barrier in the UK helps authorities to control the water level in the river by closing the barrier to stop additional water flowing in. This keeps the water level of the river consistent.

Sensor technologies can enable the collection of real-time data about water height, conditions and quality. This data is then analysed to create flood patterns for the region. Local authorities can use the flood patterns to identify the probability of flooding for each area and provide this information to engineers to improve decision-making when selecting suitable locations for future housing and infrastructure.

The data collected can be integrated into 3D models (*see also the 3D Infrastructure Modelling use case*) to control the design of future infrastructure and analyse the flooding risks on existing infrastructure. Implementation trials can be performed with prototypes in near realistic conditions to that of the location in question, to test the efficiency of the structures.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce the costs related to flooding and any potential loss of property, infrastructure and life by identifying flooding requirements upfront or avoiding building infrastructure in high risk areas.
- Provide real-time monitoring of water levels to enable accurate decisions and timely responses.

Enhancing economic, social and environmental value:

- Increase the resilience and safety of infrastructure by reducing flooding or the impact of flooding on infrastructure by enabling the implementation of mitigation solutions to prevent flood or enable the better placement of infrastructure at sites with lower risk.
- Enable authorities to understand the current water environment, and alert them about water-related hazards.

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments should develop requirements for issues such as safety of workers during installations of monitoring stations since most of the stations are located remotely and the works are dangerous.

Effective institutions: Geotechnical and utility experts should be able to use the outputs from the flood modelling to drive better flood response and government decisions in relation to infrastructure projects.

Transition of workforce capabilities: Infrastructure planners and builders will be required to learn to use flood modelling and management systems to build their infrastructure.

Funding and financing: Governments should invest in flood studies and management systems. The public sector should finance flood management system projects as it provides benefits to both the environment and the city infrastructure. The private sector is also investing in the relevant sensor technologies and solutions that can be used to further develop water height and flood management systems.

IMPLEMENTATION

Ease of Implementation 	The implementation of flood management systems is relatively easy once the sensors have been implemented in locations where flood monitoring is required. It is usually easier for new infrastructure in areas not already developed with existing infrastructure. However, where there is existing infrastructure or for an existing infrastructure, the accessibility of the relevant areas to install the sensors might be an issue, which can be mitigated in the future with the development of less intrusive sensors or 'wider-range' sensors (that are able to collect data for a larger area). The system development can be quickly developed/implemented with the right data available.
Cost 	The initial capital cost of implementation is low for new infrastructure, but will be higher to retrofit existing infrastructure, as explained in the implementation section. The installation of sensors and the use of a communications network does not require investment as high as the construction costs for the infrastructure itself. The real-time data provided from the sensors will provide ongoing and potentially substantial benefits over the mid- to long- term, by reducing the severity and likelihood of flood damage.
Country Readiness 	The sensors will require installation and maintenance over their lifetime. Operators will need to learn how to collect and analyse the data to facilitate decision-making.
Technological Maturity 	The sensor technology is mature. It has been implemented in multiple projects across different sectors around the world, however they can be made less intrusive to improve the implementation. Additionally, the flood modelling and management systems can be further developed to make the forecast more accurate and use more benchmarked data.

RISKS AND MITIGATIONS

Implementation risk

Risk: The implementation of the flood management system requires the installation of sensors in potentially remote, difficult to access locations. It may be difficult to find a suitable location to install the sensors due to the presence of existing infrastructure (e.g. utilities) and the need to avoid disturbing ongoing operations by installing the sensors. Furthermore, any available location may prove to be unsuitable or provide poorer data than the ideal location. The system requires a consistent communication network to transmit real-time data to the system.

Mitigation: The installation of sensors should be carefully planned to ensure there is no disruption to other operations and to find the most suitable location that will provide the highest possible quality of data. This should be done in collaboration with all relevant stakeholders to ensure minimum impact to operations.

Safety and (Cyber)security risk

Risk: The data is collected and transmitted by a computerised communication system, which means it is at risk of potential cybersecurity attack.

Mitigation: The operator must ensure the security of their communication and flood management systems to prevent data loss or theft during transmission or storage of data.

Environmental risk

Risk: The installation of sensors in remote areas can affect their surrounding environments and ecosystems.

Mitigation: Experts in areas such as aquatic biology, aquatic chemistry, and water/civil engineering should collaborate to ensure the water ecosystem is maintained and not affected or polluted because of the infrastructure developed and the technologies installed to monitor flood risks.

EXAMPLES

Example	Implementation	Cost	Timeframe
Maeslant Storm Surge Barrier, the Netherlands	The operation of the barrier is fully automatic via a connection to a computer system that links to weather and sea level data.	The cost to construct the barrier was EUR 450 million.	Construction took 6 years to complete. Operation started in 1997.
WaterNSW Water Monitoring Network, Australia	Over 5,000 monitoring stations measure the quality and quantity of New South Wales (NSW)'s rivers, streams, groundwater bores and dams. Over 1,300 of these stations deliver real-time data through NSW's telemetry and remote data capture networks.		The data collected is available on the waterNSW website for up to 90 days.
Oxford Flood Network	A project built in partnership with Nominet UK and ThingInnovations, comprising of 30 wireless water level sensors to detect levels of water around the city to visualise flooding and river conditions.	The network gives a high spatial resolution than at a low cost, making it suitable for temporary deployment for catchment studies, community projects and site-specific monitoring.	Set up in 2014 following a series of storms that hit the UK causing flooding over the winter of 2013 and 2014.