Place-based Digital Twins

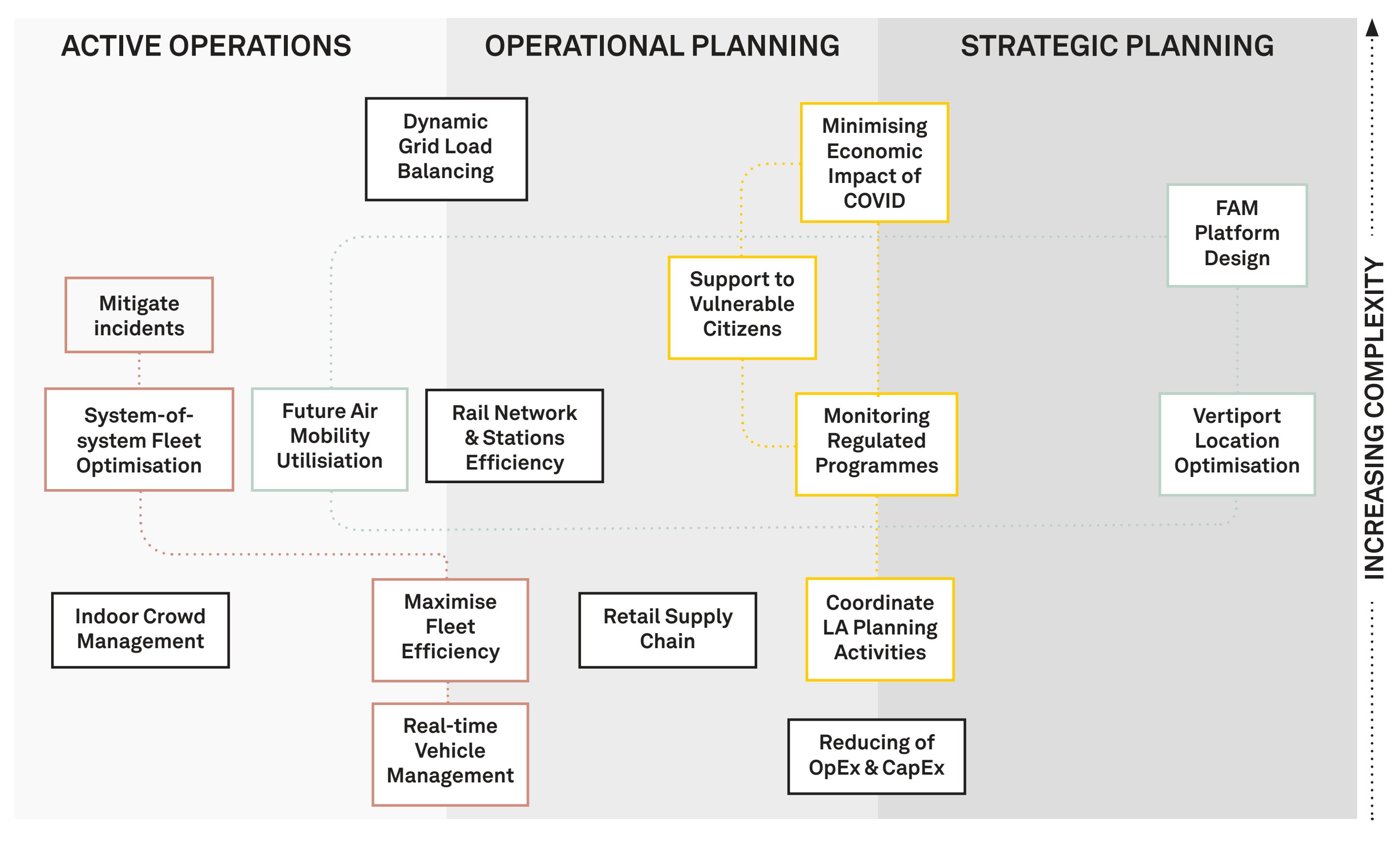
Use cases

December 2020

Executive Summary

Digital Twins promise significant improvement in efficiency of complex systems but are expensive to implement correctly. The sector also suffers from hype, making it harder to identify the best opportunities for deployment of digital twins.

To help inform the business case for investment in digital twins we have set out sixteen high-level use case themes where digital twins can have a significant positive impact on the design and operation of Connected Places:



The specific, tangible form these use case themes will take on will differ somewhat between organisations (dependent on type and sector, but also digital maturity of the organisation). Nevertheless we have identified the broad value propositions, solution map and data requirements for each use case theme. The latter shows that many use cases are restricted by lack of open (or shareable) data: increasing the availability of data is likely to be a relatively quick win to enable deployment of digital twins.

Reflecting that many organisations may have an interest in multiple use cases, we propose an assessment framework to prioritise use cases by their importance and achievability. The framework comprises 12 criteria that assess the use case itself (e,g. Is it strategically aligned, can it be financially sustainable, is the required data available, does it enable decision support at the right timescales and does it enhance efficiency?) and six criteria that focus on the required digital twin to deliver each use case (e.g. can it ingest data in real-time, can it be scaled, can its features and functionality be gradually augmented?). While this framework has been developed with Catapult aims and objectives in mind, it should be equally applicable across the sector (albeit with weighing of criteria and potentially scoring thresholds adapted to reflect the strategy and mission of individual organisations).

Content

1.0 Introduction

Digital twins are offering the promise of optimisation and control over complex systems but require significant investment to be implemented well. Clearly setting out and prioritising use cases of digital twins will help unlock investment and ensure it delivers economic and social value.

1.1 Definition of Digital Twins

A digital twin is a digital representation of a real-world asset, system or process, which is updated in near-real time and can be used to inform decisions about interventions on the real-world twin. The two twins are connected through a two-way data exchange: any changes in the physical twin (e.g. traffic volumes on a road or temperature in a building) are picked up by sensors and represented in the digital twin; while changes in the digital one (e.g. changes made to road lay-out or reducing the heating in the building) can be passed onto the physical twin when appropriate.

In some cases, the feedback from digital to physical twin can be in real-time (e.g. changing the heating of a building); in others, the feedback is far slower and indirect (e.g. sending out road workers to change the lay-out). However, even the latter affects the asset within its operational timelines. In contrast, a digital representation that affects planning decisions only (e.g. exploring how a housing development can accommodate the largest number of dwellings without losing quality and comfort) is not truly a digital twin but a ***digital model***. Such a digital model can be based on a digital twin (e.g. using the digital twin of a current housing development to inform planning decisions for a future development) but is not a digital twin in its own right.

In and of itself, a digital twin is backward-looking: being derived from current and historic data it cannot directly represent a future state. To make predictions, the data needs to be extrapolated, with new or changing trends and uncertainty included as additional layers. The strength of the digital twin approach is that multiple future scenarios can be explored and overlaid onto the current state, so that the impact of different actions is instantly and intuitively seen; once the best action is identified, the digital twin, immediately updates the physical twin (and the cycle restarts).

For the purpose of this project, we are interested in the use cases for genuine digital twins: the feedback should be operational; or there should, at least, be a credible pathway to make feedback operational in future embodiments of the use case.

1.2 Scope of work

Digital twins of individual assets are used in some sectors of the market already (e.g. high-end automotive, aerospace, building management); but there is room for Catapult activity to support wider uptake, both by companies in other market sectors and by the public sector. However, the real value of digital twins lies in sharing data, finding synergies and optimising activity across different organisations and sectors. Therefore, we are particularly interested in use cases where multiple digital twins are brought together, such as for integrated planning to reduce carbon emissions; ideally these would reach across various CPC domains (e.g. combining the digital twin of a building with the digital twin of the surrounding road network; or combining the digital twin of a business district with the digital twin of business processes used by tenants of the district).

1. 3 How to read this document

The aim of this report to twofold:

1. To inform the Connected Places sector of use cases for digital twin, thus helping to accelerate investment in and deployment of digital twins in our sector; and
2. To develop a business case for investment into a demonstrator digital twin, based on a high-priority use case aligned to CPC's strategy.

Chapter 2 of this report presents a selection of use cases, first setting out a general structure of a use case and then presenting detail on each of our long list. This chapter can be used as a standalone guidance for developing use cases that fit the reader's specific position in the market. The use cases we present are non-exhaustive, but we believe they will be good starting points for specific use cases that others will develop.

Chapter 3 describes a framework by which use cases can be assessed for urgency, importance and strategic fit. The framework has been designed with CPC's strategic priorities in mind, but most of it applies equally well (or can easily be adapted to) other organisations and their priorities. This chapter, again, can be used as a standalone resource to guide down-selection of use cases for investment in a digital twin – whether those use cases are presented in this document or generated elsewhere.

Chapter 4 sets out how we hope to proceed from this work towards creating a demonstrator of digital twins in the Connected Places sector.

2.0

Description of use cases

Use cases define not only what the digital twin would be used for but also who would be using it, what their need is and how the digital twin informs decision-making to address that need.

In its simplest form, a use case can be expressed in terms of a **beneficiary** who has a **specific need** that can be addressed by using one or more **features** of digital twins driven by certain **inputs**. For example – we might consider an **energy company** that needs to **balance supply of renewable energy with demand;** this can be addressed by combining **individual digital twins of buildings and vehicles** in a district and using this to **predict demand** (on a daily/monthly basis) and **manage charging/discharging** of selected batteries (on a minute basis).

Below this initial description, however, a use case needs a wealth of additional information, capturing the value proposition for the beneficiaries, the ecosystem of components that feed into or draw insights from the digital twin and the data required to make the digital twin function.

It should be noted here that **one digital twin can address more than one use case**, either at the same time or sequentially as the development of the digital twin progresses. In fact, use cases that can be addressed by a common digital twin may be particularly attractive, as the impact to investment ratio is higher (though complexity of the digital twin and the commercial relationship between beneficiaries may reduce that benefit).

In this work we have kept our use cases intentionally at a very high level: they are closer to general themes than specific use cases that are relevant to individual organisations. Take our first use case on real-time vehicle management as an example: for an urban car club that might focus on electric vehicle battery performance, while a logistics operator would focus on drive train and structural integrity. These require different sensors on the cars and will inform different decisions for the companies, but the general structure of the use case is the same. By keeping the use cases at this higher level, we expect to reach – and stimulate discussions with – a broader audience, who will delve into their specific requirements individually.

2.1 Categorisation

We have identified three broad categories of use cases:

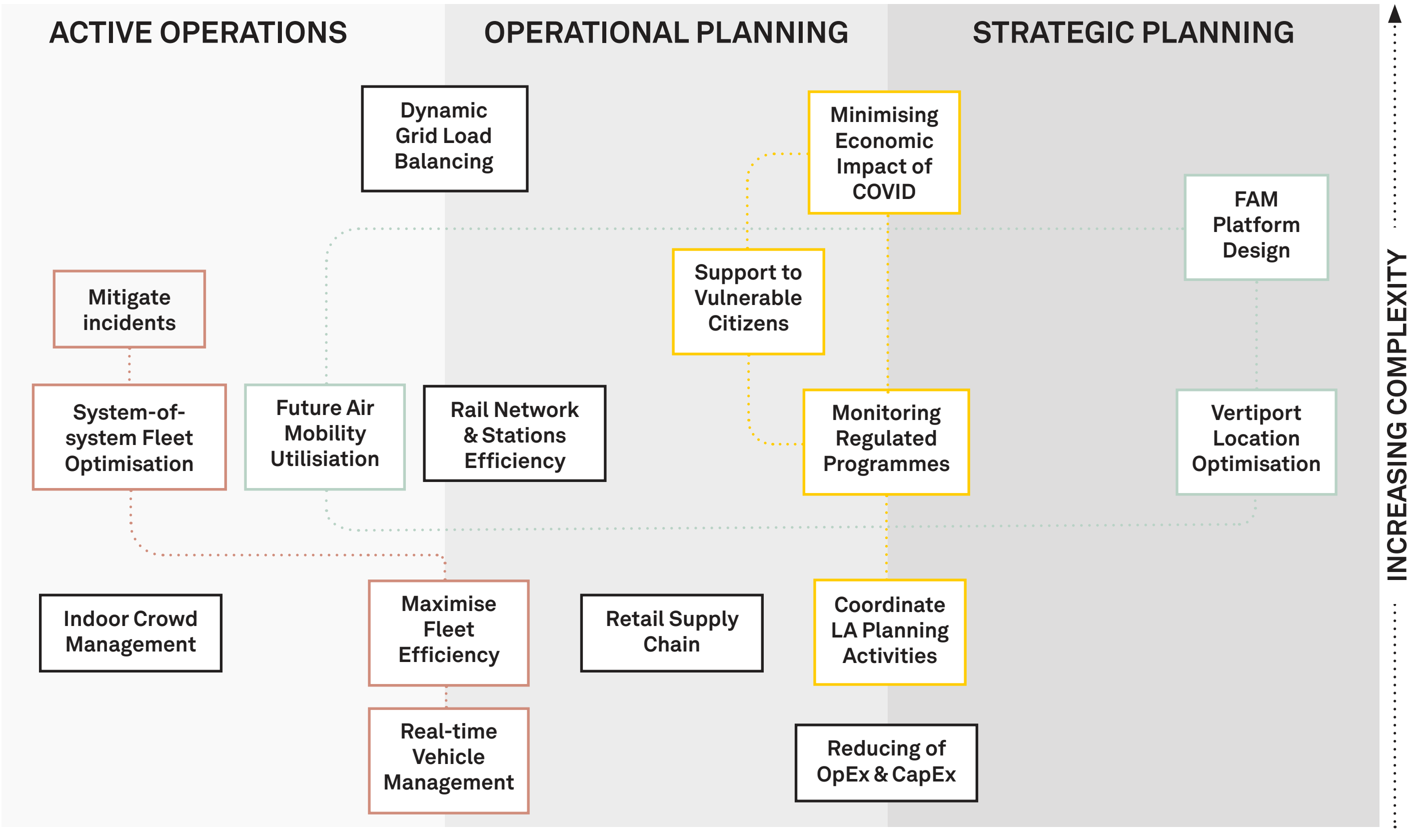
- **Strategic planning –** digital twins support long-term planning, exploring how the physical asset can be as effective and efficient as possible, before the asset is completely delivered.[1] A ***simple example is designing the road network of a new development to achieve the best environment and economic benefits.***
- **Operational planning –** digital twins can support short-term, tactical planning to optimise the use of already existing physical twins. ***A simple example is deciding on a monthly basis which roads to assign as pedestrian or cycling zones.***
- **Active operations** – digital twins can help maximise the value of and/or minimise disruption from a solution once it is implemented, by adapting its operation based on frequent feedback on conditions of use. ***A simple example is dynamically routing traffic around the road network to minimise congestion at all points.***

It is worth noting that these broad groupings overlap with 'Strategy & planning' and 'Managing assets' broad groups identified by the National Digital Twin programme's Change stream (the latter of which combines our Operational planning and Active operations groups).

(1) *Note that use cases in this category may require a digital model rather than a digital twin; but where that digital model Is (or can be) based on a digital twin, the use case is still appropriate to capture, as it will drive investment in the digital twin itself.*

2.2 Use cases

Below these broad groupings we have identified 16 high-level use case themes, as shown below. Some of these cluster around fleet and traffic management (red), citizen services (yellow) and future air mobility (green); the remaining (white) are individual use cases that do not cluster.



There is logical hierarchy within the fleet cluster: complexity increases from vehicle management through fleet efficiency and system-of-system optimisation to impact mitigation of one-off incidents. This may offer a natural progression of use cases, with the simpler ones de-risking more complex ones. A different hierarchy exists in the future air mobility (FAM) cluster: both the platform design and location optimisation use cases are necessary for the utilisation use case, but the latter will mostly show a clear return on investment. However, it may be that all three use cases can be addressed by a single digital twin; in which case the utilisation use case can "subsidise" its own enablers.

More detail of each use case is shown below, in order that loosely replicates the diagram above.

NAME: Real-time Vehicle Management

TYPE: Operational Planning / Active Operation

Description:
Most vehicle operators have a fixed schedule for maintenance, which increases operational costs. A digital twin that uses real-time, sensor-collected data (e.g. on brake pads or drive train) allows vehicle operators to plan maintenance dynamically, reducing the costs of scheduled maintenance and reducing risks of unscheduled downtime. The collected data can be shared with OEMs to inform new product development (e.g. improved brake pads), while a shadow of the digital twin can offer a safe environment to test new products and features (e.g. explore whether driver behaviour undermines technical improvements).

Beneficiaries and their needs:
Vehicle operators have a powerful business need to minimise fault-driven vehicle down time, minimising the associated repair and opportunity costs. Real-world vehicle data is also needed to increase the fidelity of simulated scenario testing, informing the product design of future vehicles, reducing their time-to-failure and cost of fleet maintenance.

Value proposition(s):
Using real-world, vehicle-mounted sensor data collection to minimise the down time of vehicles, improve their future design, and increase the fidelity of non-destructive, simulation-based scenario testing.

Measurable impact(s):
Reduction in vehicle down time hours, reduction in vehicle failure rate and consequent loss of life or injury, total cost reduction of preventative (versus reactive) maintenance, cost reduction in destructive vehicle testing, increase in customer satisfaction.

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Required Features:

- Running multiple scenarios to affect outcome
- Real-time decision support
- Real-time ingestion of disparate datasets
- Fusing disparate datasets
- Communicate data between individual DTs
- Intuitive visualisation
- Predictive analytics
- Separating sensitive data from insights
- Secure environment for testing

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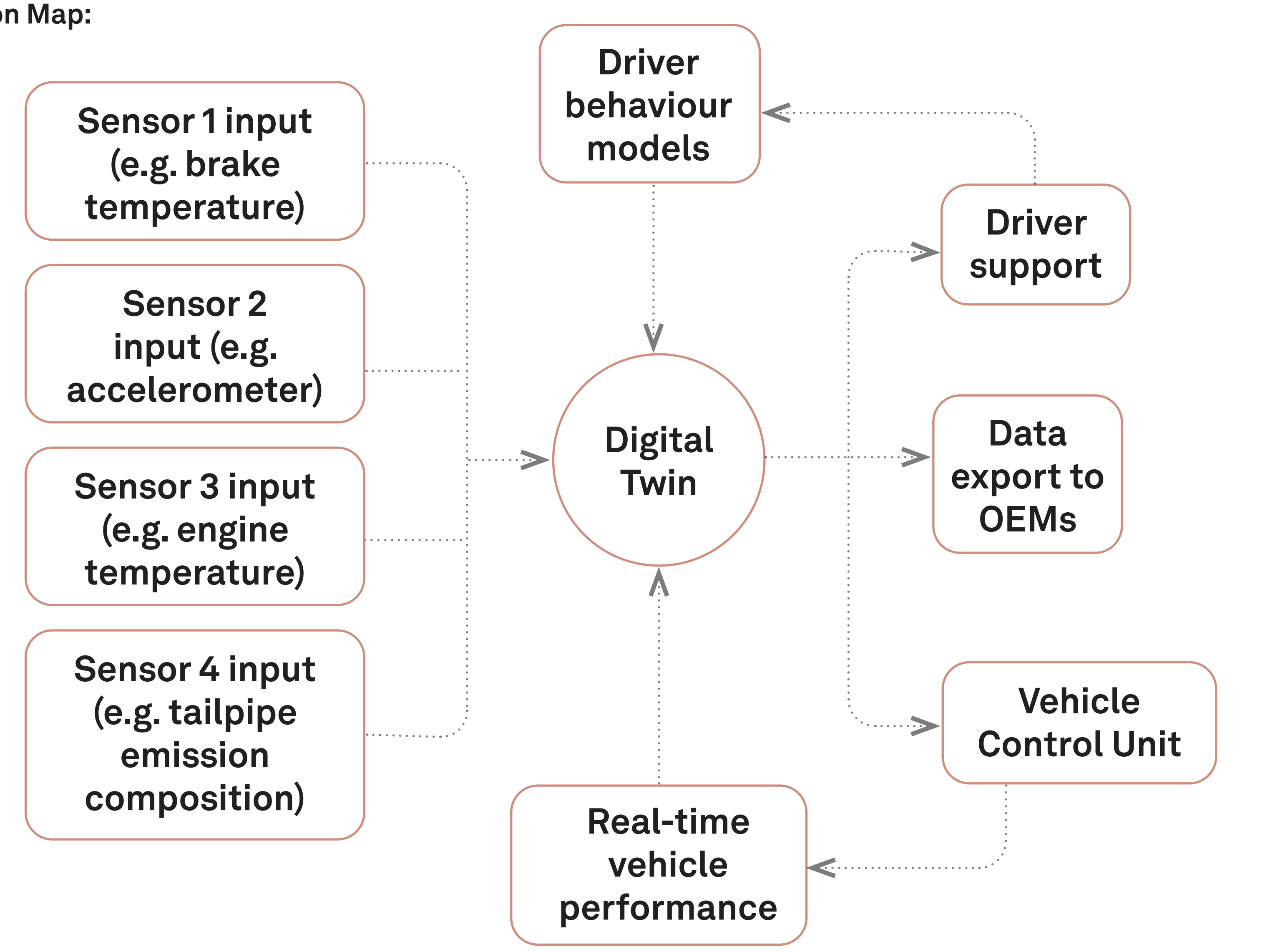

NAME: Maximise Fleet Efficiency For Fleet or Infrastructure Operator

TYPE: Operational Planning / Active Operation

Description:
Large numbers of vehicles, whether from one corporate fleet or from multiple fleets, are often inefficient in the use of the available space (road or parking). As vehicles wait for space to proceed, they contribute to pollution and generate no revenue for their owners. Digital Twins offer an opportunity to coordinate routing and timing across all vehicles to reduce (or at minimum purposely distribute) downtime to get the maximum return out of a given set of assets and infrastructure.

Beneficiaries and their needs:
Operators of fleet and/or infrastructure, e.g. airport or logistics operators need to extract maximum financial return from vehicles in their fleet and/or on their premises, while minimising the negative impacts (pollution, noise, congestion) on their neighbourhood and reducing their carbon footprint

Value proposition(s):

- Reduce waiting times of vehicles at destination or way points
- Reduce downtime of vehicles due to maintenance
- Reduce carbon intensity of activities
- Increase reliability of services

Measurable impact(s):

- Reduced operational costs (mainly fuel costs)
- Reduced air pollution levels measured by local authorities
- Reduced GHG emissions associated with activities (leading to reduced liabilities of internalised GHG costs)
- Improved customer satisfaction

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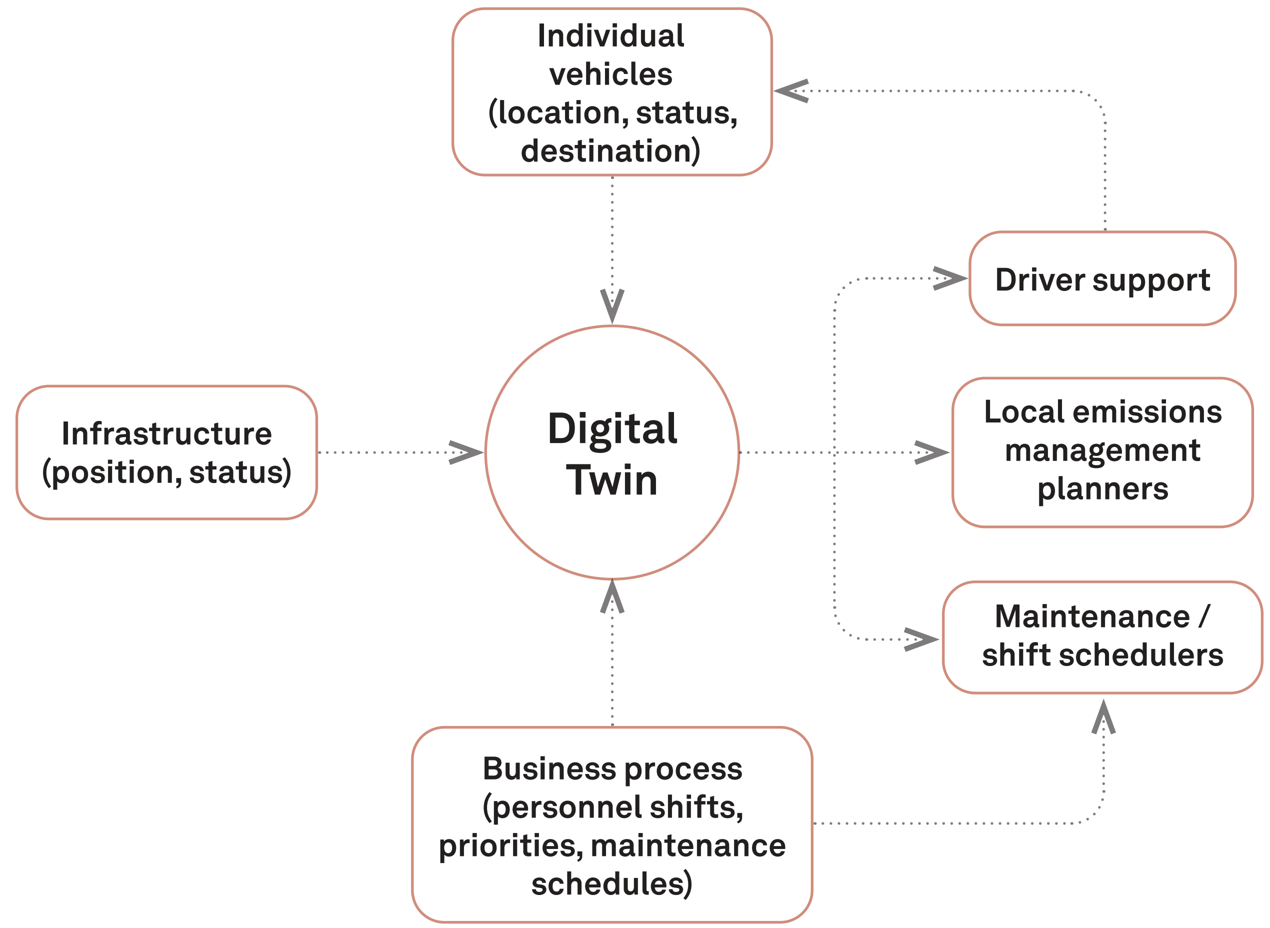

NAME: System-of-system Optimisation (e.g. of multiple fleets)

TYPE: Active Operation

Description:
When multiple organisations interact within one location (e.g. logistics operators in a city), optimising the efficiency within each organisation leaves the wider system suboptimal (through missed synergies or duplicated efforts). A Digital Twin that connects Digital Twins of the individual organisations would allow optimisation across all of them, either offering improvement for all organisations or facilitating trade-off where one organisation accepts an efficiency-reduction in support of an overall improvement

Beneficiaries and their needs:

- Individual fleet operators need to reduce their costs and emissions without reducing their revenues.
- Operators of infrastructure need to extract maximum value from their assets by increasing throughput.
- Local authorities need to minimise negative impacts such as congestion and local emissions

Value proposition(s):

- Identify opportunities for asset-sharing across organisations
- Reduce delays and waiting times caused by congestion
- Reduce negative environmental impacts

Measurable impact(s):

- Reduced OpEx for fleet operators
- Improved air quality
- Increased satisfaction of residents

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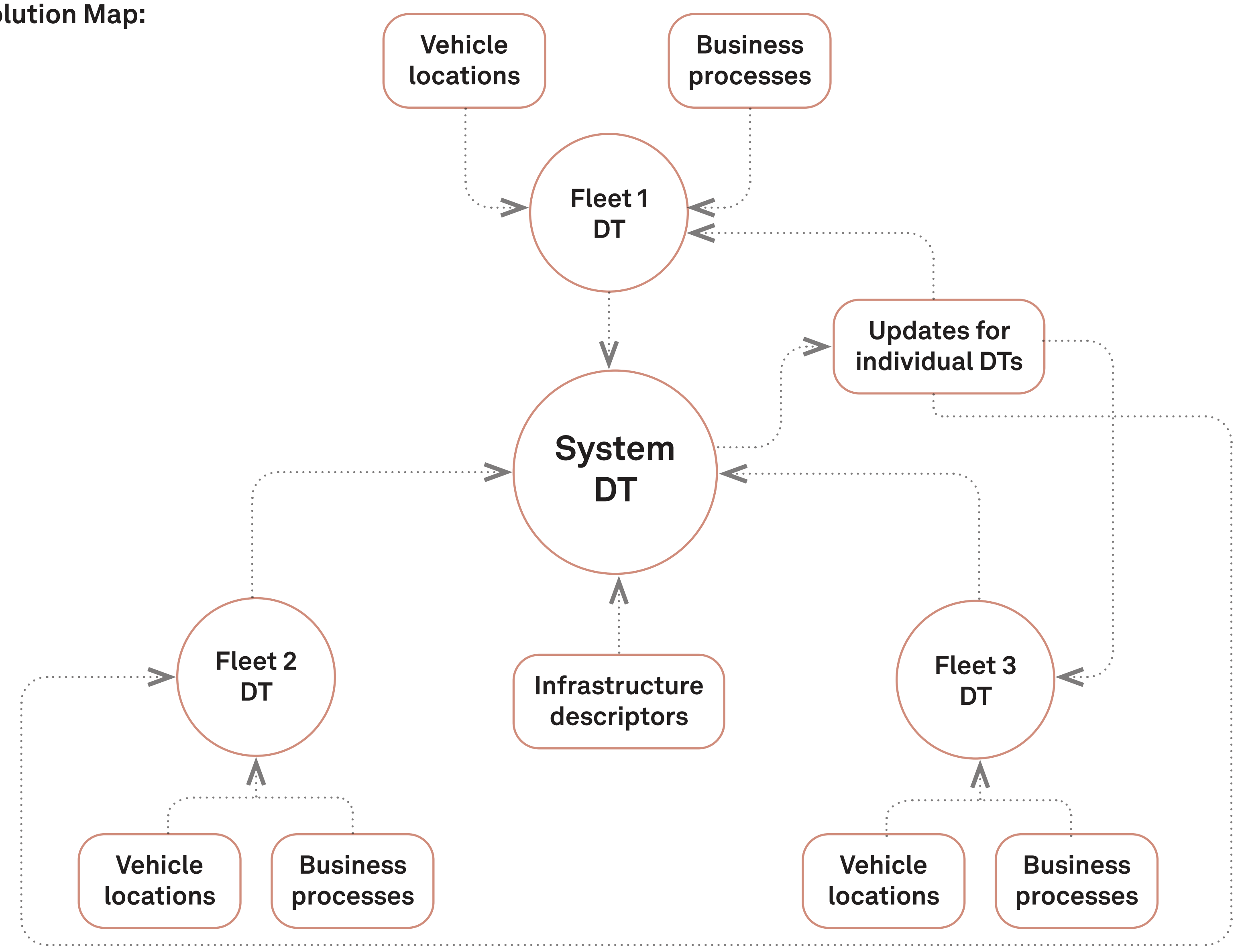

NAME: Mitigate Impact of Adverse Weather or Incidents

TYPE: Active Operation

Description:
Local and central government, as well as infrastructure operators, have a need to better understand the impact of incidents (such as adverse weather or large accidents) on the infrastructure network, in order to reduce that impact and make infrastructure networks more resilient. Digital twins could allow these stakeholders to bring together data on multiple infrastructure networks (e.g. the water or rail network), weather and the environment, and individual asset data to predict the impacts of incidents on those networks, plan effectively to reduce those, both short- and long-term and respond in real-time when incidents do happen.

Beneficiaries and their needs:
- UK /Central Government need to inform decisions to more effectively mitigate impact of adverse weather events and resulting emergencies.
- Infrastructure operators need to inform decisions to maximise resilience of key infrastructures (both existing and during the planning/ building of new infrastructures), and reduce impact from adverse weather events.
- Share this information with Emergency services to help respond to these events

Value proposition(s):
- Reduced impact of one-off incidents on key infrastructures, and therefore fewer secondary impacts
- Reduced down-time of infrastructure as a result of weather events
- Improved ability to understand potential impacts of future adverse weather events

Measurable impact(s):
- Better response to weather events
- Reduced cost of recovery after adverse weather
- Reduced downtime of key infrastructures
- Reduced economic impact of infrastructure downtimes

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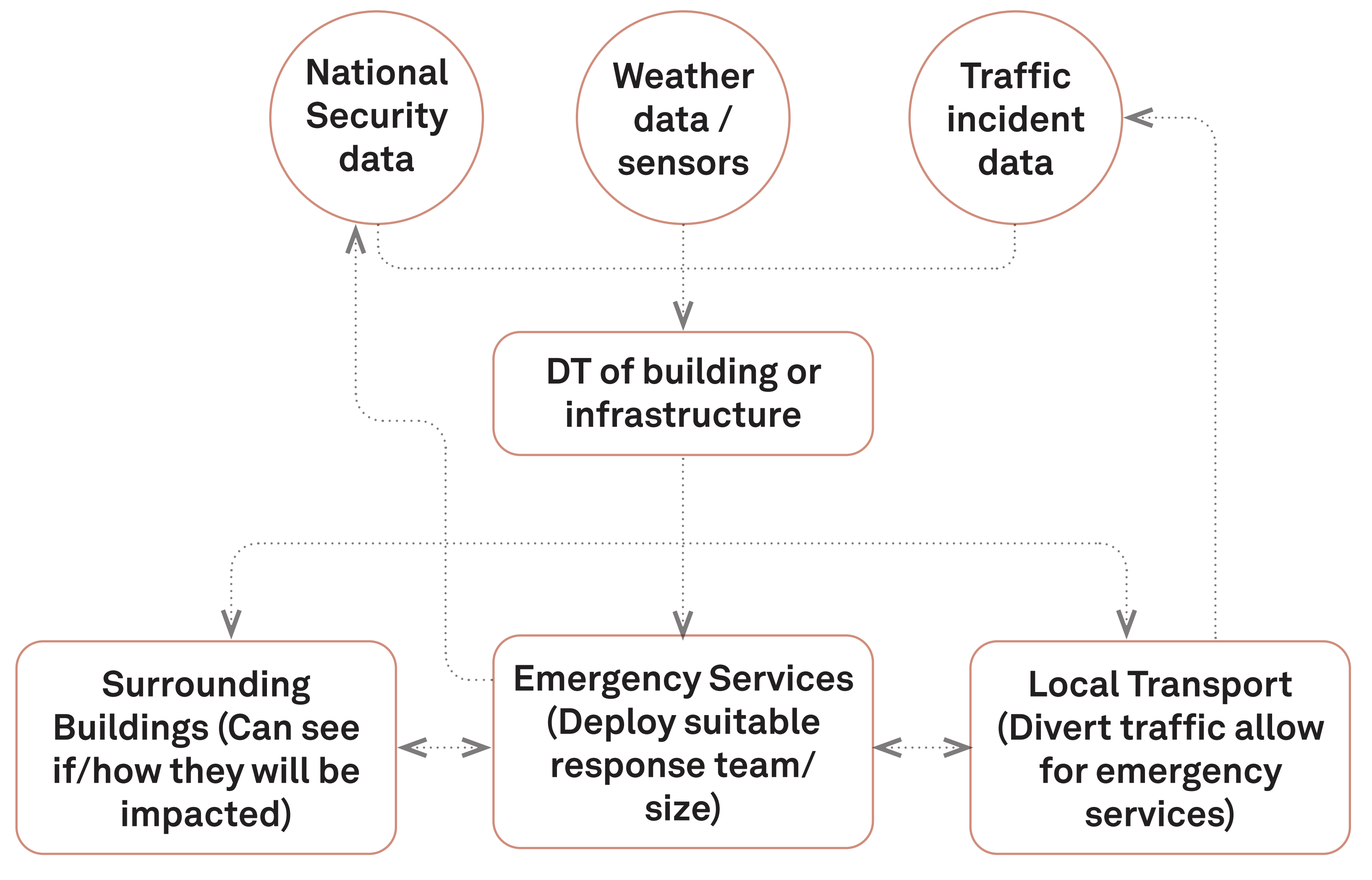

NAME: Maximise Future Air Mobility Vehicle Utilisation

TYPE: Active Operation

Description:
Future Air Mobility (electric, autonomous aviation) is only commercially viable if the vehicles are extremely highly utilised: running almost continuously and only with the full load of passengers/freight. A Digital Twin would allow optimisation in near-real time routing of vehicles and scheduling of downtime (for maintenance or charging) such that utilisation is continuously optimised; this may include frequently updating price and incentives to drive uptake by target customers.

Beneficiaries and their needs:

- Future Air Mobility service operators need to increase the utilisation of their vehicles to make them economically viable.
- Future Air Mobility vehicle owners (which may be the same as service operators) need to optimise efficiency of maintenance, in order to reduce downtime (and avoid unscheduled downtime).
- Indirect beneficiaries include local authorities, who need to reduce congestion and emissions caused by transport without reducing service levels.

Value proposition(s):

- Maximise revenue-generation by Future Air Mobility services and/or vehicles
- Minimise impact of downtime for vehicles on service delivery
- Maximise environmental benefits (reduced local / global emissions, noise, particulates) of Future Air Mobility services

Measurable impact(s):

- Increased revenues for Future Air Mobility services
- Increased uptake of Future Air Mobility services
- Reduced costs of maintenance of Future Air Mobility vehicles
- Improved air quality within city / region

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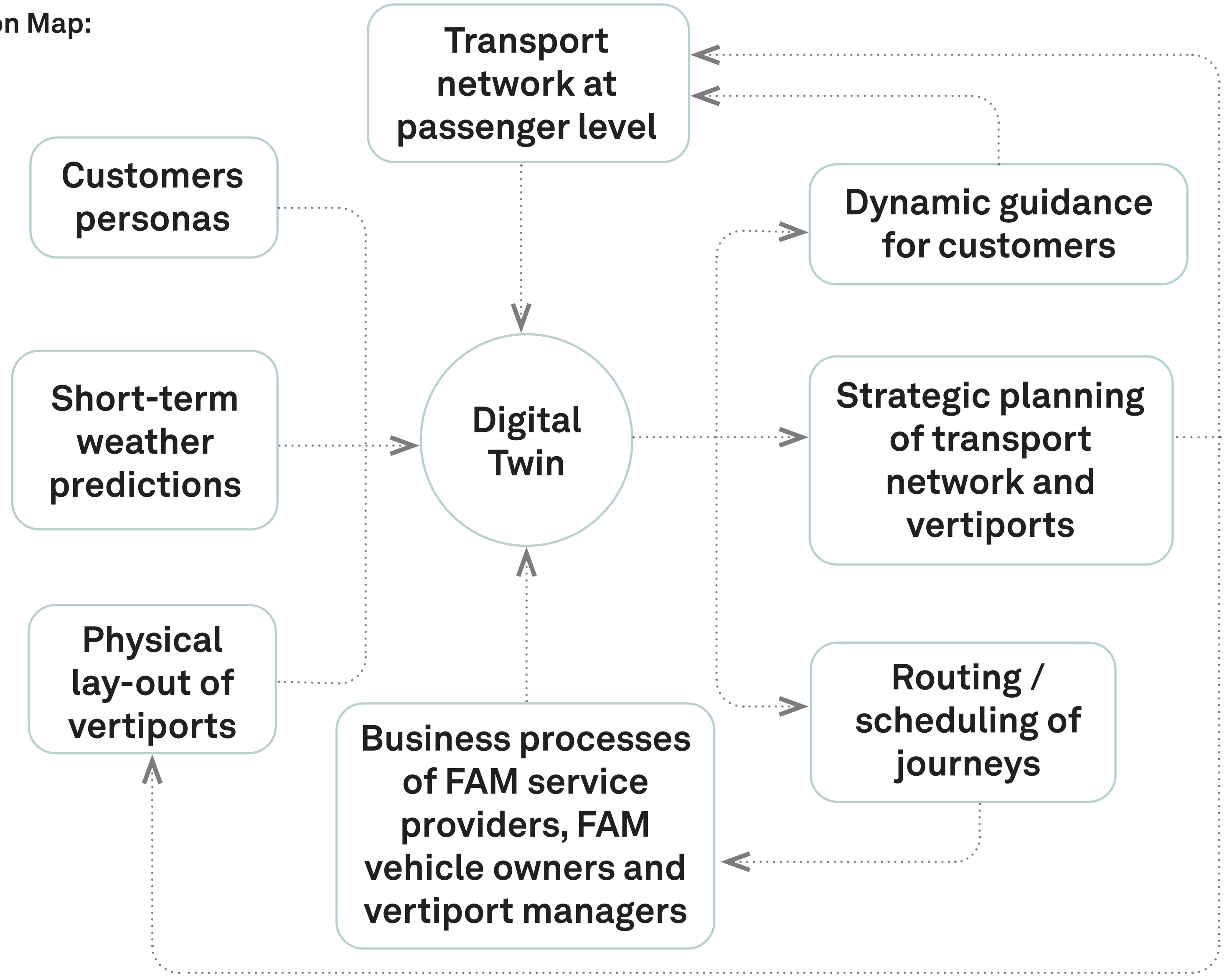

NAME: Improved FAM Vehicle Design & Business Model Fit

TYPE: Strategic Planning

Description:
The operating and business model of a FAM service is directly affected by the vehicle design, which informs its range, speed and capacity; downtime for maintenance, loading and recharging; and ultimately costs of operation. A digital twin that connects details of the vehicle itself, its components and materials with the transport system and expected business model of the services offers early testing and iterating of the vehicle design to ensure it fits the business model's requirements.

Beneficiaries and their needs:
- FAM vehicle owners need confidence that the vehicles can be operated sustainably under their chosen business models
- FAM vehicle developers need to have confidence that there is a market for their vehicle specification

Value proposition(s):
- Improved understanding of and evidence for vehicle's fit to requirements
- Increased agility of vehicle design process

Measurable impact(s):
- Reduced design and build expenditure
- Reduced vehicle time-to-market
- Increased passenger capacity

Required Features:
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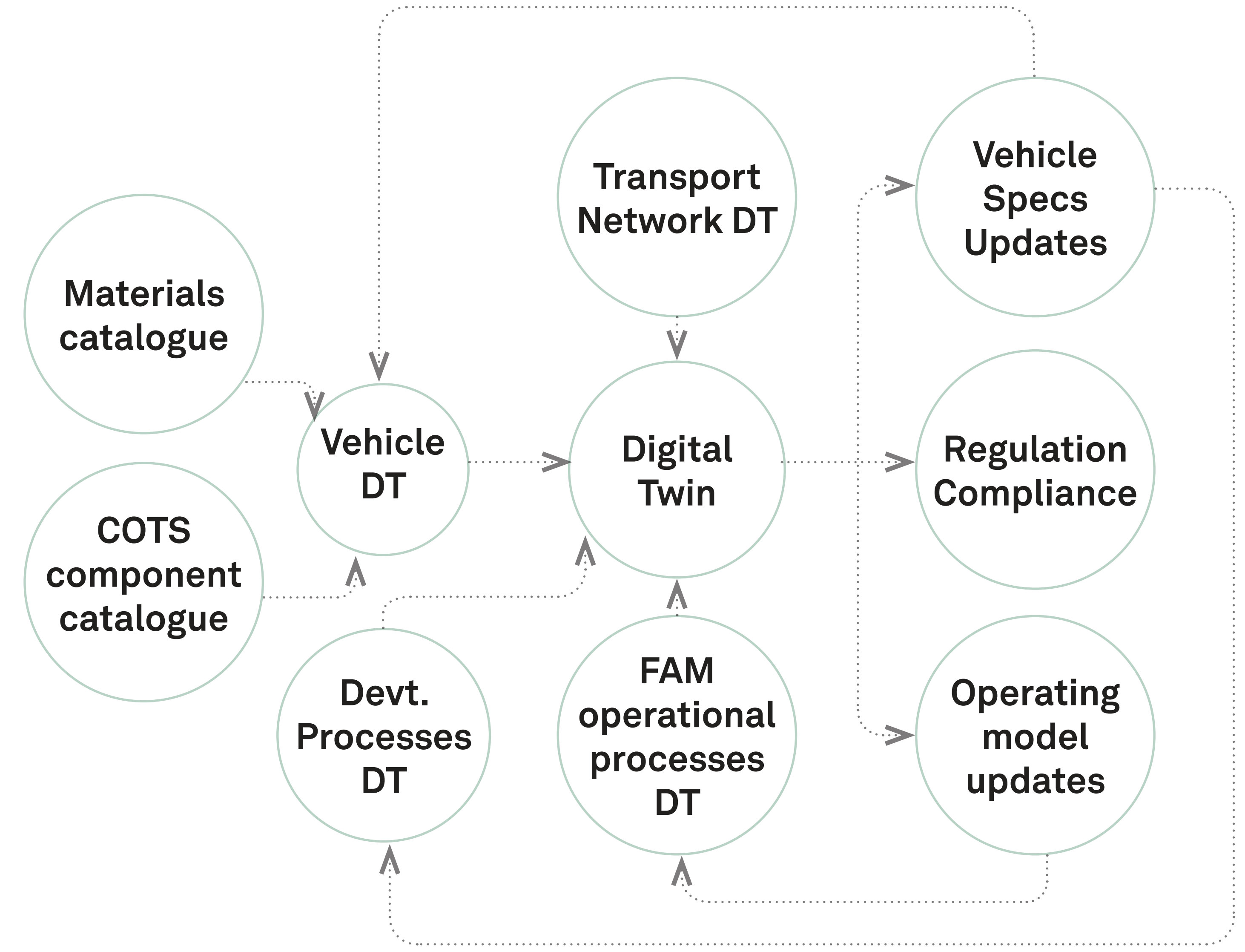

NAME: Optimise Location of Vertiports

TYPE: Strategic Planning

Description:
Digital Twins present an opportunity for Future Air Mobility providers to utilise data to optimise the location of future vertiports at a system level. By integrating data around infrastructure locations (and therefore potential sites), weather patterns, airspace classifications, and passenger demand and supply (through data on existing demand and supply as well as predicted passenger segmentation), FAM providers can plan for vertiports on a system basis rather than selecting sites ad-hoc.

Beneficiaries and their needs:
FAM operators need to understand the best locations for vertiports, and base planning decisions on data around areas of supply and demand, existing infrastructure, and planned developments. Regulators also need to be able to set standards and requirements for vertiport locations.

Value proposition(s):
- Improved ability to strategically plan vertiport locations
- Improved relationship/communications with infrastructure/site providers
- Potential for application of requirements/standards for vertiport sites
- De-risk the operations of mobility services, creating a sustainable ecosystem for users and providers

Measurable impact(s):
- Cost saving in planning of vertiport locations
- Utilisation of vertiports once complete
- Better understanding on uptake of air mobility

Required Features:

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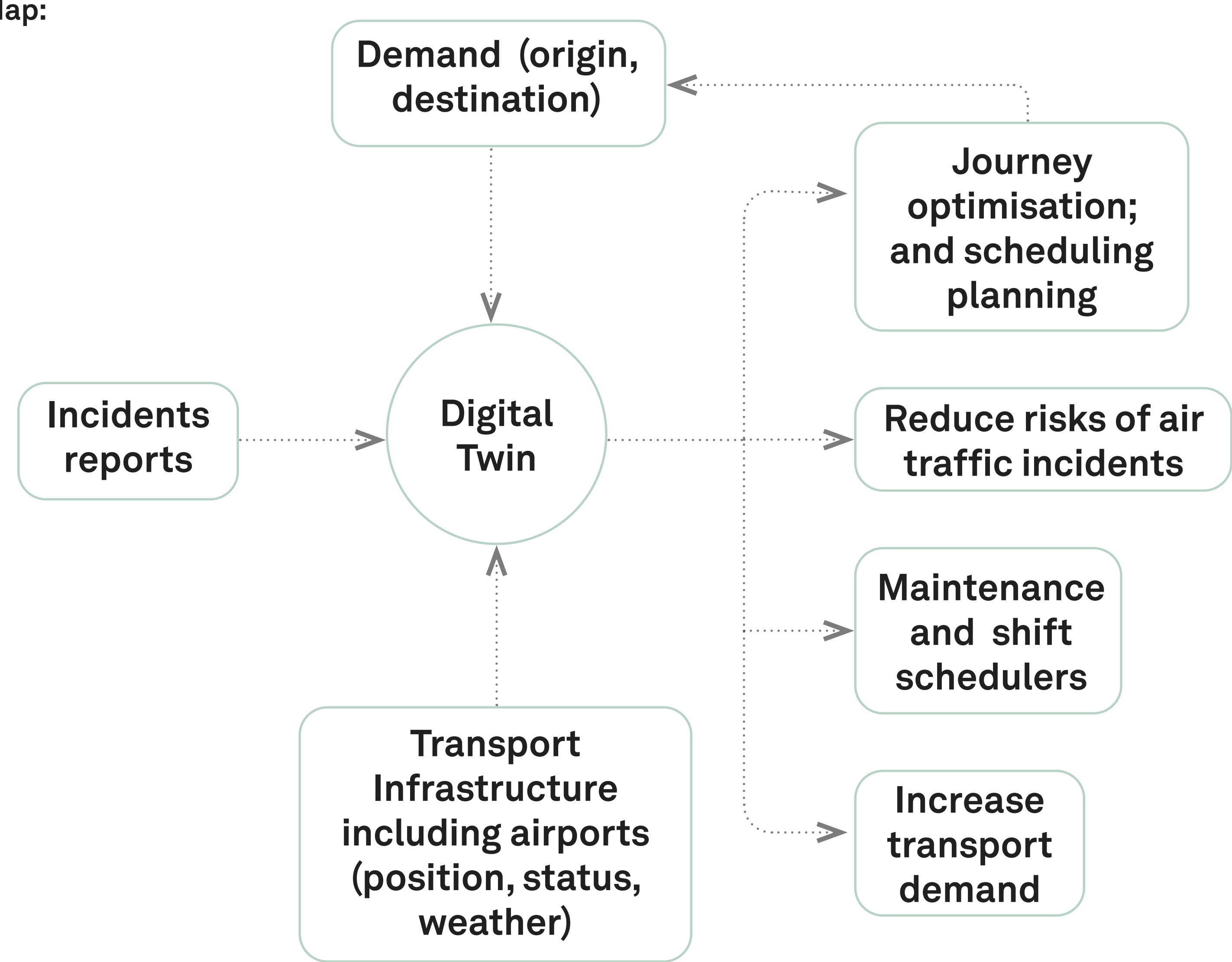

NAME: Increase Efficiency of Support to Vulnerable Citizens

TYPE: Operational Planning

Description:
Local authorities have a range of policy options to support vulnerable citizens – e.g. increasing community care, upgrading housing to support independent living or expanding outpatient care. Decisions on interventions are made on incomplete information, particularly on knock-on effects (e.g. increased outpatient care causing congestion and reducing air quality, impacting the health of other residents). A Digital Twin (of the town, population and LA resources) would allow an LA to trial multiple scenarios to maximise the impact of their interventions. Connecting DTs between LAs would further allow inclusion of out-of-region effects (e.g. on commuters) and identifying potential benefits of scale.

Beneficiaries and their needs:
Local authorities are under pressure to support more vulnerable citizens with decreasing budgets. This is exacerbated by the COVID-19 crisis and impending economic downturn as well as long-term trends (ageing population, increasing inequalities). Local authorities need to either decrease overhead costs or increase the impact of interventions (and ideally both); at the same time, they need to future-proof their services and avoid storing problems up for future generations.

Value proposition(s):

- Optimise interventions across vulnerabilities, demographics and locations
- Increase efficiency of intervention implementation (incl. Collaboration across boundaries)
- Simulate long-term impact of interventions

Measurable impact(s):

- Reduced overhead costs associated with implementation
- Increased social return on investment
- Increased quality of life for vulnerable citizens

Required Features:

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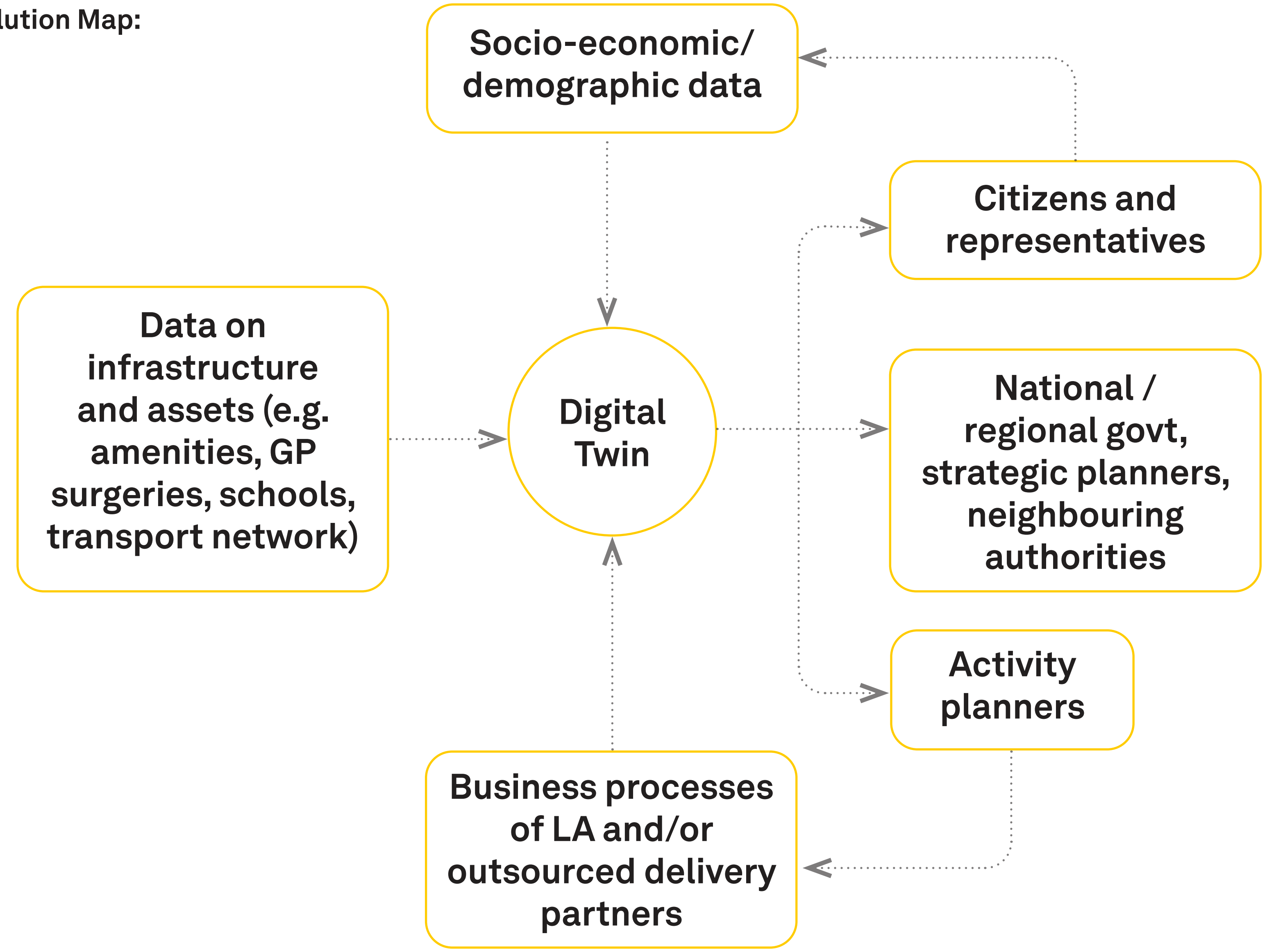

NAME: Track Progress on Regulated Programme (e.g. housebuilding)

TYPE: Strategic Planning / Operational Planning

Description:
Regulated programs (e.g. housebuilding, infrastructure etc.) often involve multiple companies and contractors operating at different granularities of the project. Coordination and communication of construction progress becomes a challenge as well as evaluating and reporting the risks involved to the wider environment (e.g. flooding, ground stability, vegetation etc.). Embedding a digital twin solution would enable visibility over the true (on the ground) progress of a project, at a detailed level, with timely indication of potential hazards or risks that might occur as a result of the construction progress. This detailed view can be built up and combined with borough or national DT to inform performance in relation to local and national plans.

Beneficiaries and their needs:
Stakeholders involved in a regulated program would be exposed to the different hierarchies of progress of the individual program's components, allowing them to adjust their operations in terms of overall delivery, quality of services and risk mitigation. This could be accessed and queried by Local Authorities or Central Government ministries to track building targets.

Value proposition(s):

- Coordinate activities across stakeholders involved in the program
- Reduce the risk of deviations from regulatory frameworks
- Reduce the risk of deviations from delivery plan
- Create more accurate and detailed reporting across the country

Measurable impact(s):

- Ensure regulations are being enforced
- Ensure assets (housing/infrastructure) are delivered according to initial plan (reduce overspending)
- Reduce the cost of retrofitting completed infrastructure

Required Features:

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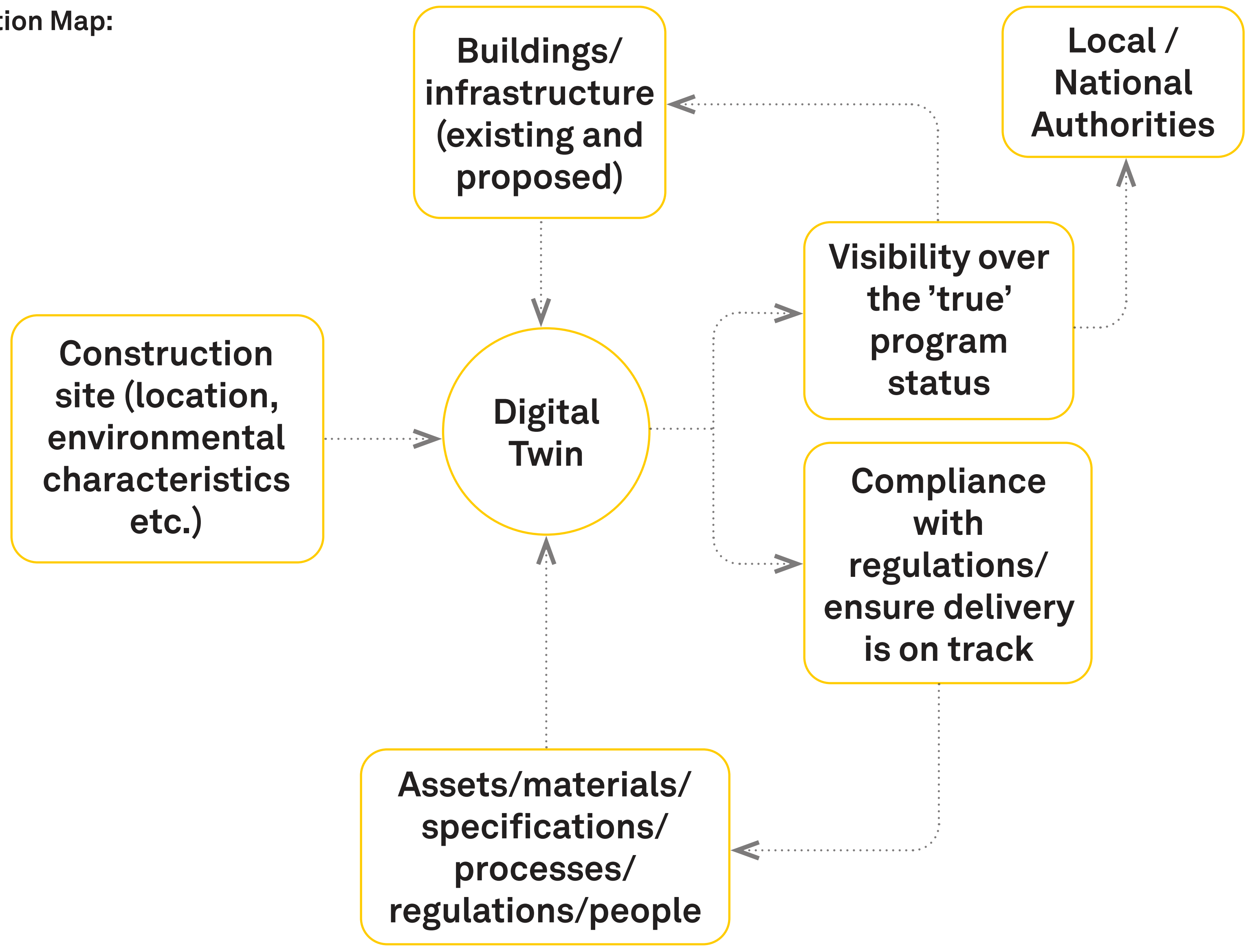

NAME: Coordinate Planning Activities Across Combined Authority

TYPE: Strategic Planning / Operational Planning

Description:
Combined authorities have a responsibility to manage access to key infrastructures for their constituents. Decisions made in one local authority have the potential to affect neighbouring local authorities. Examples include low traffic zones, new residential developments near transport infrastructure. By each Local Authority using the information from digital twins in their constituency to inform their use cases, they can feed into other local authorities plans as to create more holistic plans.

Beneficiaries and their needs:

- Local Authorities need to more efficiently plan and manage the construction, operation and maintenance of key infrastructures and services such as transport, water, energy, and housing, as well as social infrastructure. They need to coordinate with providers such as National Grid to effectively manage the provision of these services to match the demand.
- Combined authorities would benefit from reduced efforts to align different LAs, freeing up their time to focus on strategic policy making

Value proposition(s):

- Better evidence to build local plans
- Historic record of local plans and changes - displaying impact
- Digital communication between local authorities creating more holistic policies

Measurable impact(s):

- Cost efficiency from less sunk costs
- More accurate costings and forecasting's
- Policy objective performance can be measured more accurately and compared

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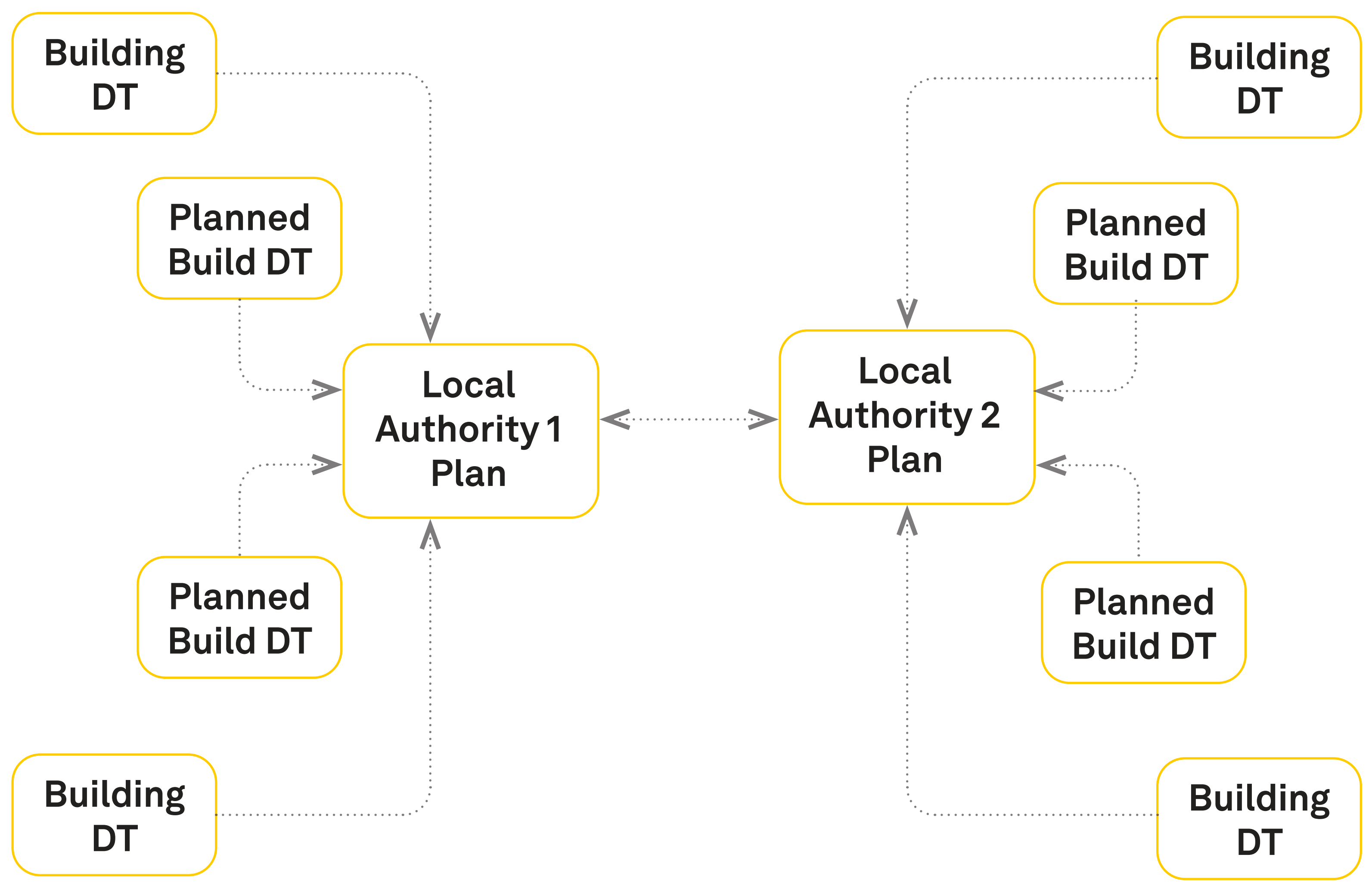

NAME: Minimising Economic Impact of COVID Lockdowns

TYPE: Strategic Planning / Operational Planning

Description:
Ongoing blanket and tiered restrictions to the movement of citizens are having a significant negative impact on the UK's economic output at local, regional and national levels. This impact is manifesting itself in large reductions in GVA and GDP, wide-scale job loss, business closures, reduced tax paid to the exchequer and increased volatility of global equities markets. Digital twinning technology could allow the collation of disparate datasets, affording authorities better strategic and operation planning capability.

Beneficiaries and their needs:
Local authorities need a better understanding of the specific drivers of negative economic impacts resulting from restricting citizen movement, and greater predictive and scenario modelling capability to ensure they can strategically plan for future lock down measures.

Value proposition(s):
- Minimise the negative economic impacts of local, regional and national lockdown procedures
- Support local economic growth (levelling up agenda)
- Reduce income and wealth inequalities exacerbated by lockdowns

Measurable impact(s):
Minimised reduction in regional and national GVA and tax paid to the exchequer, reduction in the absolute and relative rate of jobs lost, reduction in local Gini coefficient

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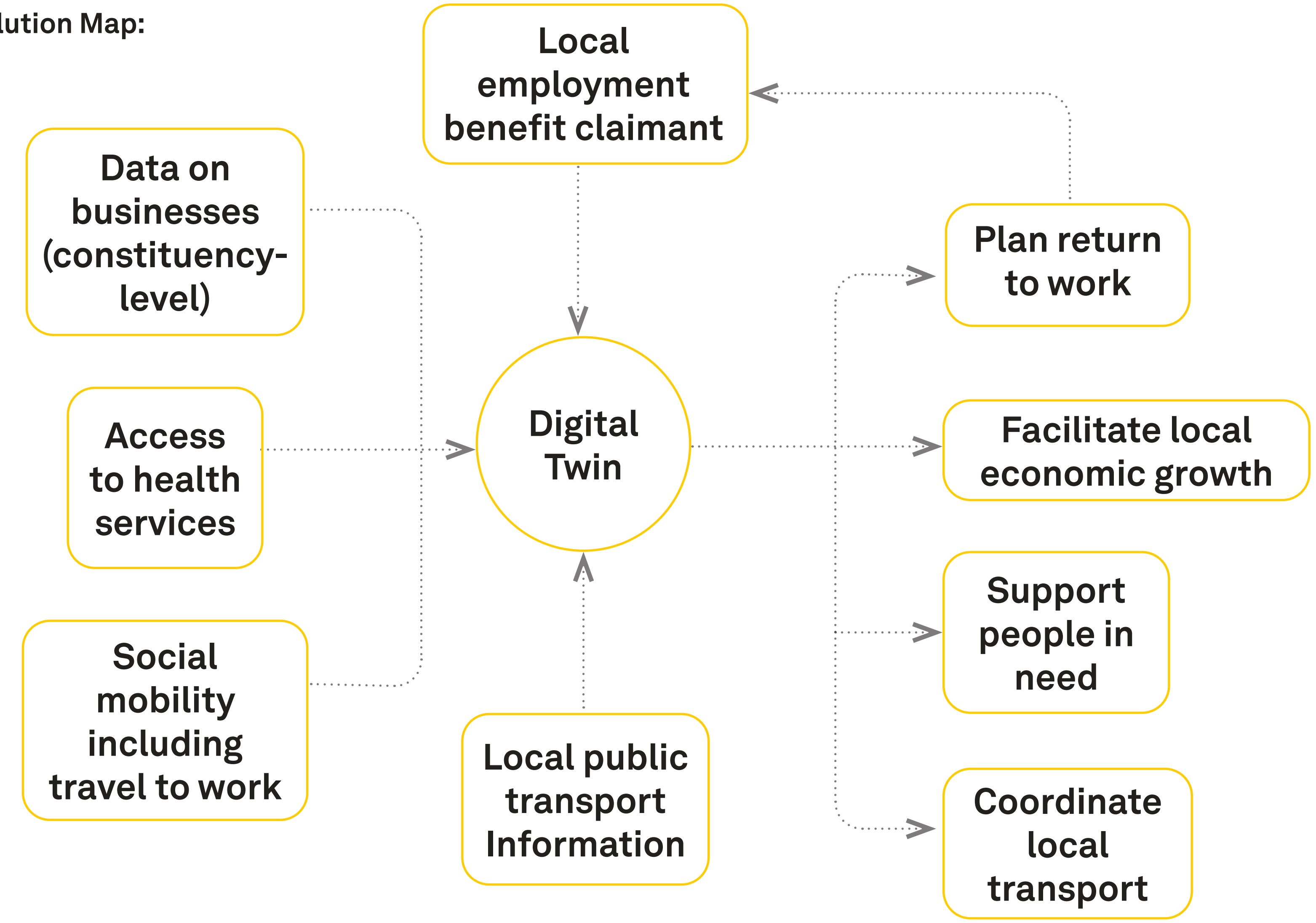


NAME: Increase Efficiency of Rail Network & Stations

TYPE: Operational Planning / Active Operation

Description:
Rail passenger numbers have increased substantially in recent years in the UK making the existing railway system under growing capacity stress. UK's rail network is already operating at full capacity so new and innovative ways need to be considered to further improve efficiency.

Digital Twin offers an opportunity to revolutionise existing operations of railway network and stations, as it can simulate, predict and optimise capacity of the network in real-time to respond to the changing passenger travel demand.

Beneficiaries and their needs:
- Network rail as the efficiency of the network can be optimised and increased
- Train operators as a real-time DT would enable a much accelerated response to incidents, and last mile operator for demand responsive transport
- Station operators as DT would improve crowd control on platforms and station concourse
- Passengers: improved journey comfort, reliability and communication

Value proposition(s):
- Improved network capacity and efficiency
- Better and faster incident responses
- Better passenger experience on platforms and stations
- Improved train operation performance, which has positive financial impacts

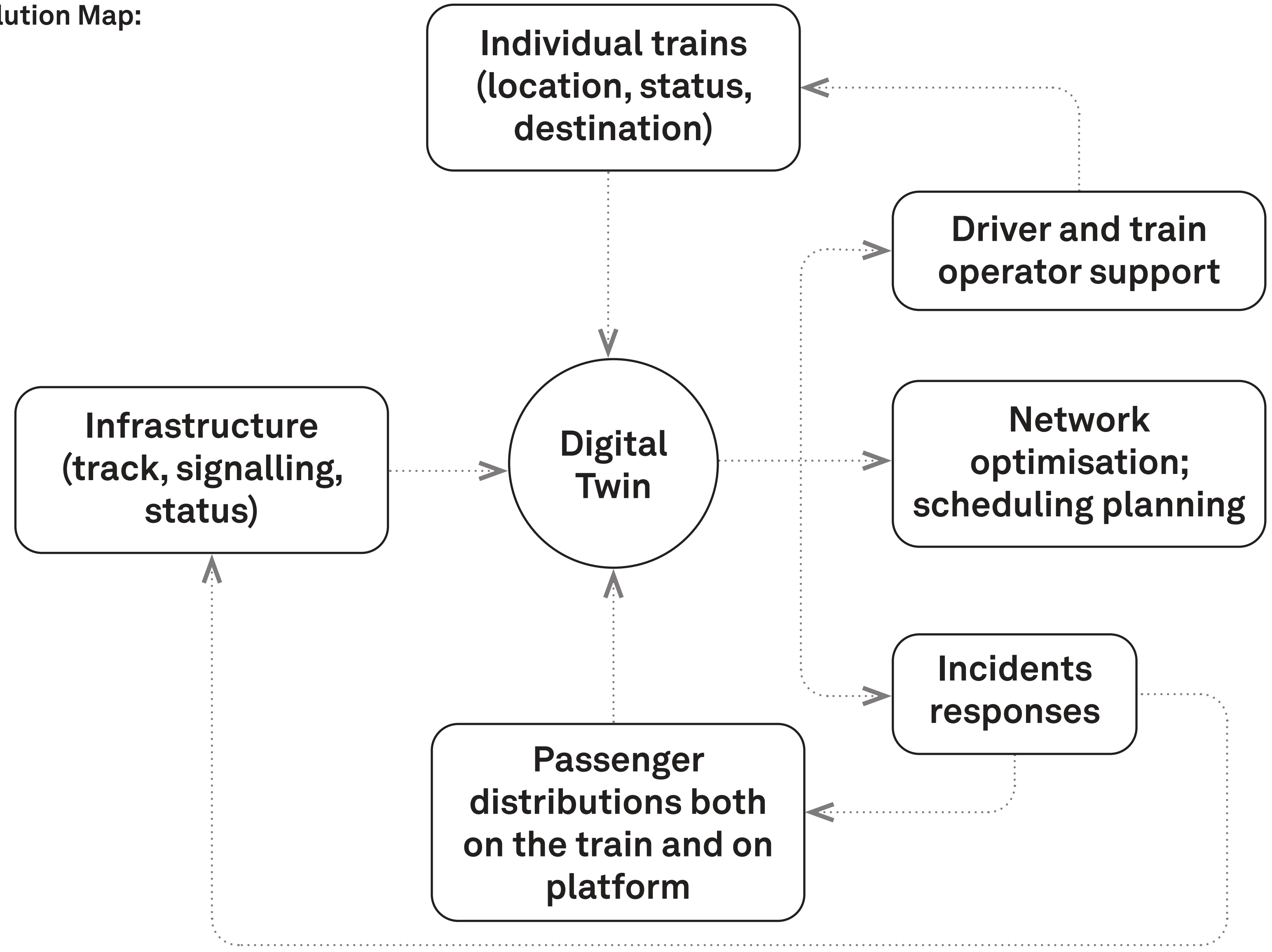
Measurable impact(s):
- Increased capacity in total passenger numbers
- Better reliability in improved punctuality statistics
- Improved customer satisfaction ratings
- Reduced impacts from incidents from overall incident delay statistics

Tangible

Visionairy

Required Features:
- Running multiple scenarios to affect outcome
- Real-time decision support
- Real-time ingestion of disparate datasets
- Fusing disparate datasets
- Communicate data between individual DTs
- Intuitive visualisation
- Predictive analytics
- Separating sensitive data from insights
- Secure environment for testing

Solution Map:



NAME: Better Manage CAPEX & OPEX Infrastructure Spending

TYPE: Strategic Planning / Operational Planning

Description:
Large utility and service providers such as National Grid have a need to more effectively manage CAPEX and OPEX infrastructure investment costs. Digital twins, if interoperable, could allow those providers to better understand external factors influencing demand and operating costs in order to more effectively manage (and prioritise investment into) the maintenance and new builds of those key infrastructures; for example, prioritising energy network CAPEX investment in an area where there a new housing development is planned.

Beneficiaries and their needs:
Utilities and service providers need to more efficiently plan and manage the construction, operation and maintenance of key infrastructures and services such as transport, water, and energy. They need to coordinate with central government and local authorities to better match supply to demand and therefore improve service provision.

Value proposition(s):
- Better matching of supply and demand
- Improved access to key infrastructures for customers
- Better interoperability/less silo-ing of different infrastructure actors

Measurable impact(s):
- Reduced CapEx of laying new infrastructure
- Reduced OpEx of maintaining infrastructure
- Reduced downtime of infrastructure for customers

Required Features:
- Running multiple scenarios to affect outcome
- Real-time decision support
- Real-time ingestion of disparate datasets
- **Fusing disparate datasets**
- Communicate data between individual DTs
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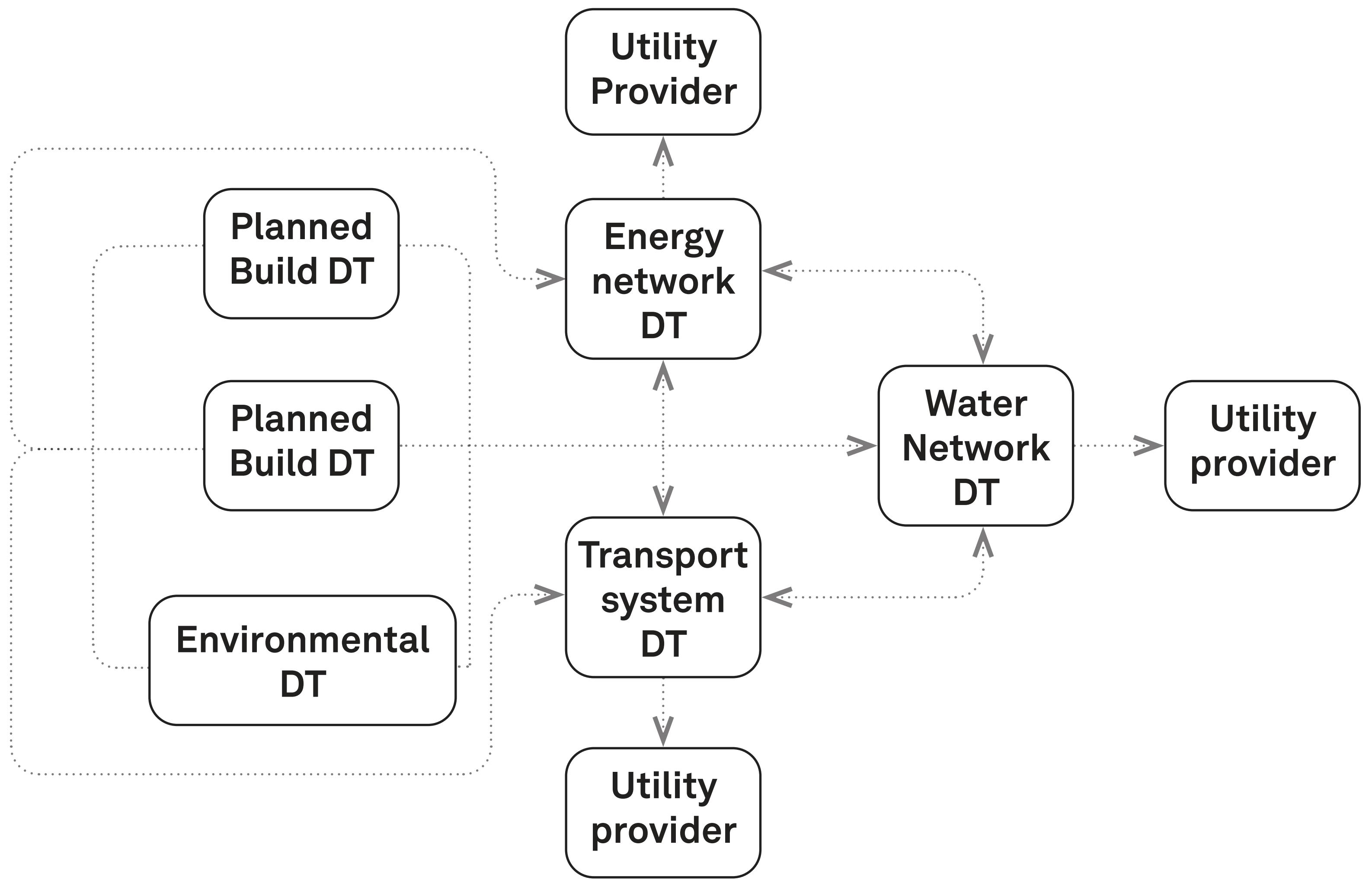
Solution Map:



NAME: Manage Crowds in Indoor Spaces

TYPE: Active Operation

Description:
Large indoor spaces (e.g. shopping malls, train stations, hospitality venues) often experience unequal distributions of crowds, resulting in localised “congestion” that reduces efficiency of the venue and comfort of the users; and poses health & safety risks. A DT that builds on existing maps, crowd modelling and behavioural models offers venue operators an opportunity to manage crowds by actively directing individuals to (or through) certain parts of the space: e.g. some passengers can be “kept” in coffee shops while others are sent to trains early to reduce crowding at ticket barriers. The same DT can also inform (re-)design decisions by modelling crowd behaviour in the new space.

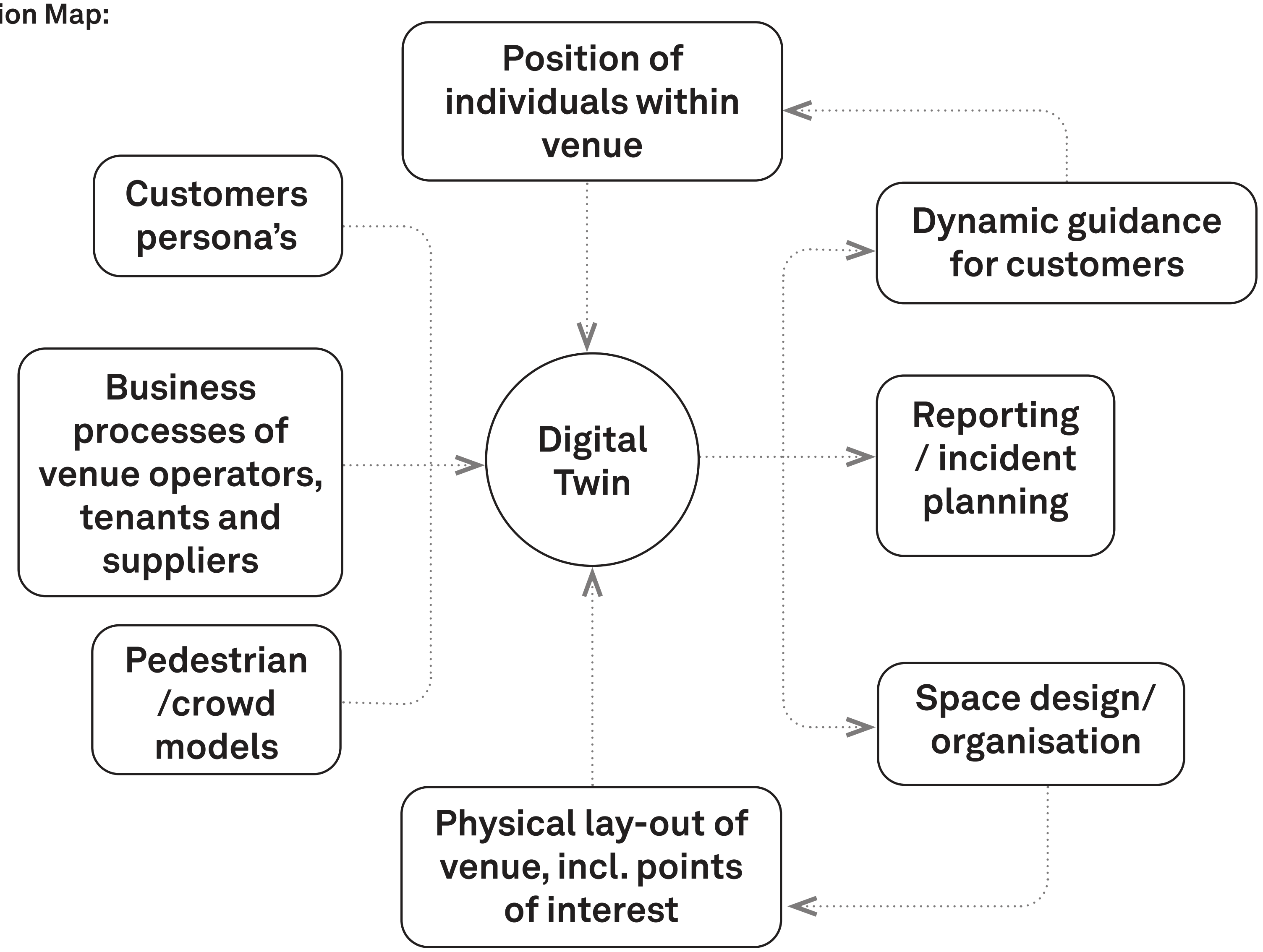
Beneficiaries and their needs:
- Operators of destination venues (e.g. museums, music venues) need to maximise occupancy without breaching health & safety regulations.
- Operators of pass-through venues (e.g. train stations) need to balance speed of individuals passing through with the ability to extract revenue from those individuals as they pass through.
- Customers of the venue need to have a positive experience, including confidence in management of the venue.

Value proposition(s):
- Increase effective capacity of venue without significant CapEx
- Increase efficiency of revenue extraction from venue customers
- Minimise and mitigate dangerous build-up of crowds within venue
- Increase transparency of health & safety compliance

Measurable impact(s):
- Increased revenues for venue operators and/or tenants
- Increased footfall within venues
- Increased positive feedback from customers on their experience

Required Features:
- Running multiple scenarios to affect outcome
- Real-time decision support
- Real-time ingestion of disparate datasets
- Fusing disparate datasets
- Communicate data between individual DTs
- Intuitive visualisation
- Predictive analytics
- Separating sensitive data from insights
- Secure environment for testing

Solution Map:



NAME: Improve Resilience of Retail Supply Chain

TYPE: Operational planning

Description:
Retailers and other businesses have often complex supply chains, and have a need to understand how events in specific areas of the supply chain might affect other areas of the supply chain and therefore the retailer itself. This could be through integrating data on stock levels, predicted demand (such as purchase trends, or new developments), transport (for example predicted transport and freight delays), business processes, and potential influencing factors. Sharing this data between digital twins could allow retailers to understand these external factors and plan their operations to be resilient to their potential impacts.

Beneficiaries and their needs:
Retailers need to minimise the impact of externalities on their supply chains by accessing data and making predictions based on that data; for example, by understanding the locations and times of events which might impact suppliers or supply channels (such as problems with the rail network, for example). Can combine external DT data such as Weather and political risk, with internal DT with IoT sensors on packages and transaction records.

Value proposition(s):

- Reduced supply chain disruption
- Can simulate increase/decrease in production on supply chains
- Improved understanding of links between externalities at different levels
- Improved ability to plan more resilient supply chain

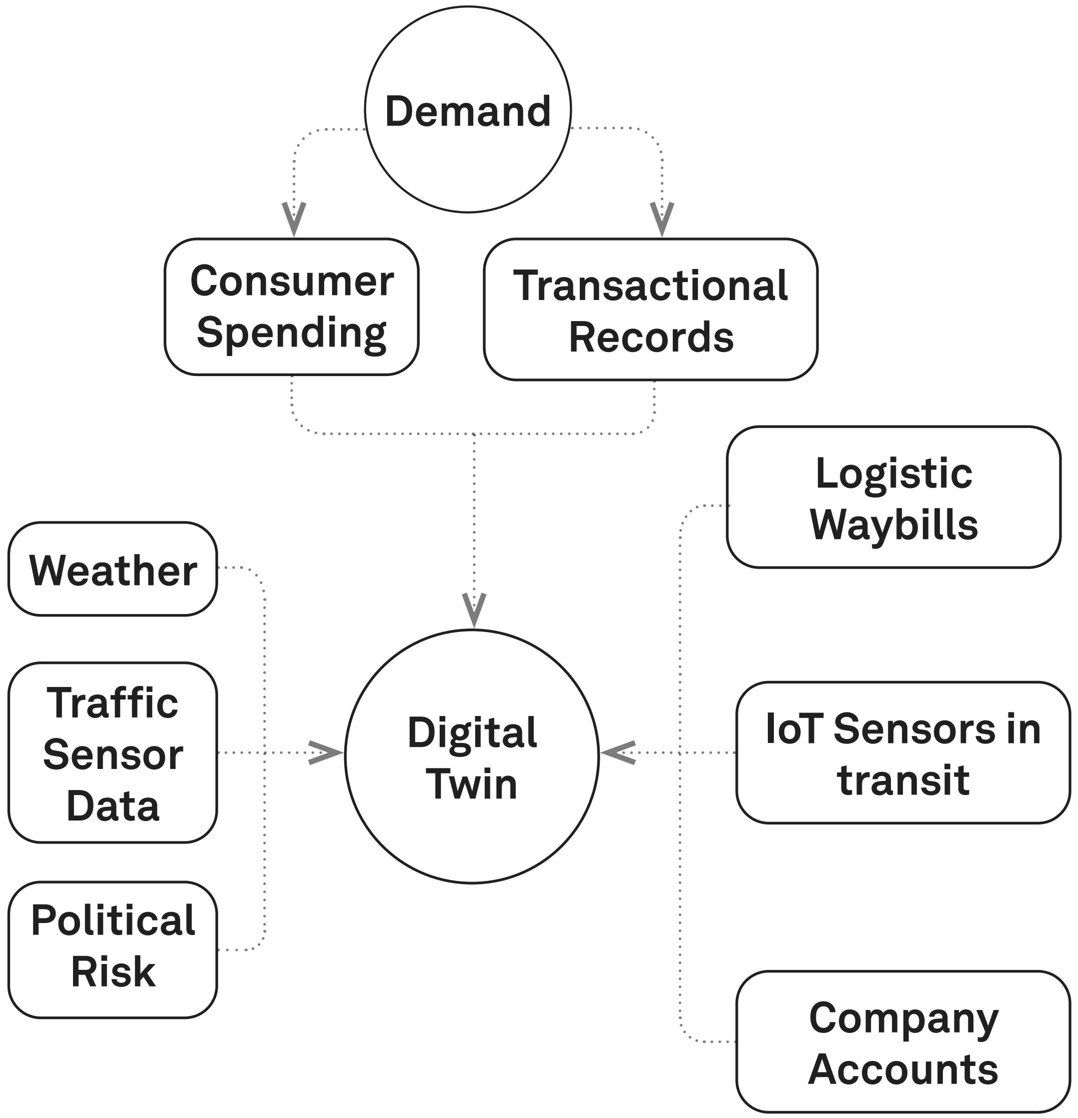
Measurable impact(s):

- Reduced cost to recover supply chain losses
- Can change supply chain volumes with confidence after simulations
- More personalised products can be delivered to individual customers
- Regulators have better access to the processes they are regulating
- Knowledge of provenance

Required Features:

- Running multiple scenarios to affect outcome
- Real-time decision support
- Real-time ingestion of disparate datasets
- **Fusing disparate datasets**
- Communicate data between individual DTs
- Intuitive visualisation
- **Predictive analytics**
- Separating sensitive data from insights
- Secure environment for testing

Solution Map:



NAME: Dynamic Grid Load Balancing (including EVs)

TYPE: Operational Planning / Active Operation

Description:
With continued electrification in many sectors, there has been an increasing challenge in finding a better way to use existing grid infrastructure , without the needs to run expensive and highly polluting "peaking capacity" power stations, or to upgrade existing substations which can be very expensive.

A Digital twin of network wide grid system with dynamic load balancing capability would dramatically reduce peak demand by shifting non-essential charging to off-peak periods, and some Evs with V2G capability can work as an electrical storage to even better balance out the peak demand.

Beneficiaries and their needs:

- National grid for peak shaving, de-carbonisation. In addition a better balanced supply and demand through optimisation of EV charging time and locations
- Commercial users, such as electric vehicle fleet operators, a dynamic grid load balancing DT would essentially increase charging capacity at a depot without the needs of large capex investment on grid infrastructure

Value proposition(s):

- Speed up the de-carbonisation of electrical grid
- Improve utilisation of existing grid infrastructure
- Reduce usage of highly expensive and polluting "peaking capacity" stations
- Improve network resilience and faster responses to incidents and outage

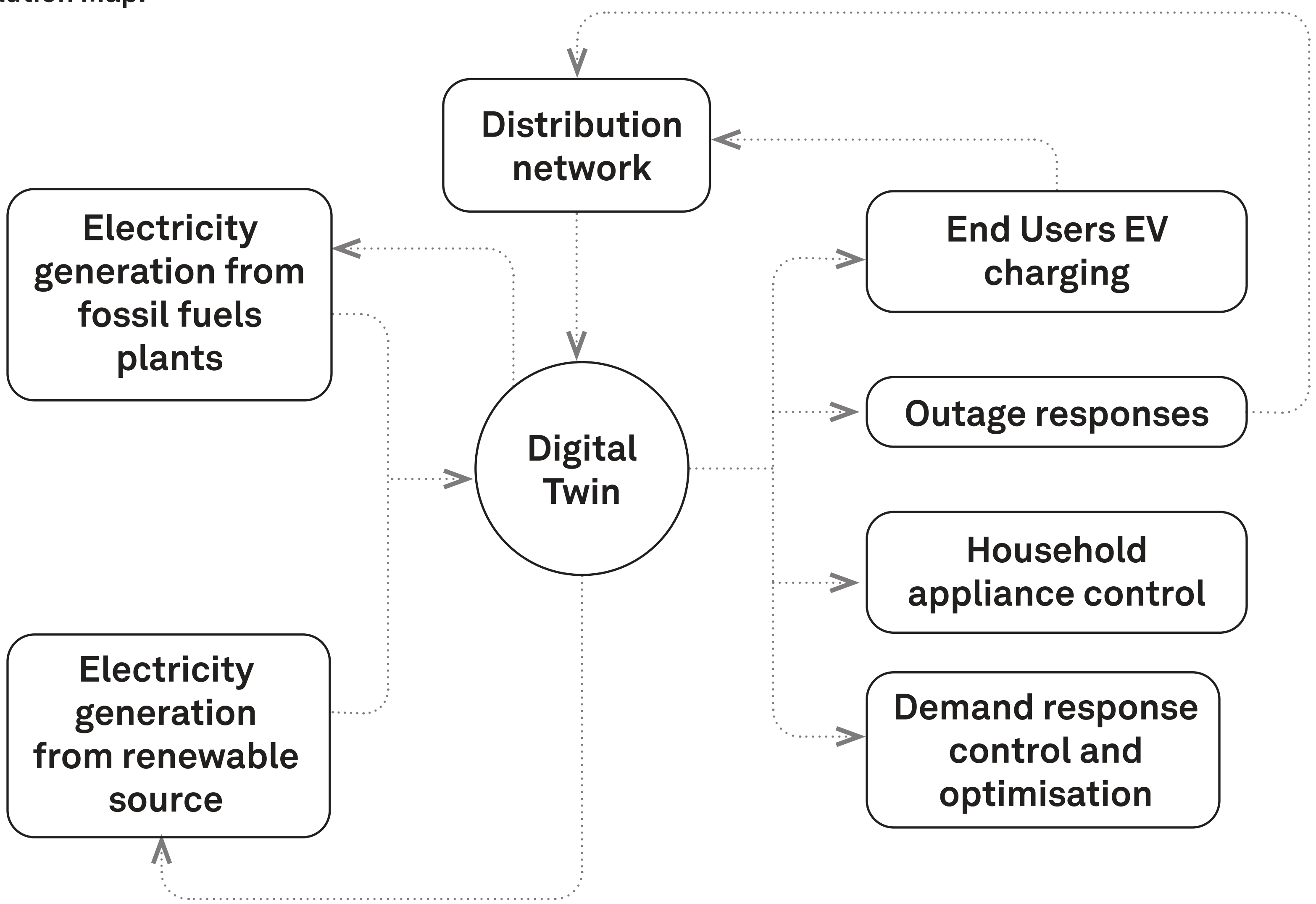
Measurable impact(s):

- Flatten peak demand curve
- Reduced Carbon Emissions
- Reduced operational costs
- Reduced outage impacts and durations
- Improved grid throughput

Required Features:

- Running multiple scenarios to affect outcome
- Real-time decision support
- Real-time ingestion of disparate datasets
- Fusing disparate datasets
- Communicate data between individual DTs
- Intuitive visualisation
- Predictive analytics
- Separating sensitive data from insights
- Secure environment for testing

Solution Map:



2.3 Data requirements

We have explored the availability of datasets required to address each use case. It should be caveated that this is a not a full data discovery, which would at the very least also consider the quality, standards, interoperability and provenance of datasets. Such a full data discovery can only be performed on a short-list of use cases. Nevertheless, this can give a rough indication of the feasibility of creating digital twins for the use cases.

The full list of datasets considered is presented in Appendix 1. The table below captures the main information:

- The number of datasets applicable to each use case, which indicates how complex the data infrastructure and sharing agreements would be, but also indicates whether the data mapping is comprehensive; [(2)]
- How accessible the datasets are, where:
  - Green indicates that the vast majority is open
  - Amber indicates that the majority is open
  - Red indicates that the majority is not open
- How often the data gets updated,[(3)] where:
  - Green indicates that the majority of datasets is updated daily or in real-time
  - Amber indicates that the majority of datasets is updated monthly or more often
  - Red indicates that the majority of datasets is updated less often than monthly

Use Case	Data Sets Mapped	Availability of Data Sets	Update Frequency of Data Sets
Real-time Vehicle Management	4		
Maximise Fleet Efficiency for Fleet or Infrastructure Operators	13		
System-of-system optimisation (e.g. of multiple fleets)	8		
Mitigate Impact of Adverse Weather or Incidents	10		
Maximise Future Air Mobility Vehicle Utilisation	14		
Improved FAM Vehicle Design & Business Model Fit	7		
Optimise Location of Vertiports	11		
Increase Efficiency of Support to Vulnerable Citizens	11		
Track Progress on Regulated Programme (e.g. housebuilding)	6		
Coordinate Planning Activities Across Combined Authority	14		
Minimising The Economic Impact of COVID Lockdowns	12		
Increase Efficiency of Rail Network & Stations	13		
Better Manage CAPEX & OPEX Infrastructure Spending	24		
Manage Crowds in Indoor Spaces	9		
Improve Resilience of Retail Supply Chain	6		
Dynamic Grid Load Balancing (including EVs)	7		

[(2)] *It should be noted that data mapping could be more comprehensive for the more tangible use cases*

[(3)] *Note that update frequency is not reported for some datasets and it is reasonable to assume that these tend to the lower end of the spectrum. Therefore, this assessment is likely to be somewhat optimistic.*

This immediately highlights the problem with deploying digital twins in this market sector. With the sole exception of increasing the efficiency of rail network and stations, every use case theme has restrictions in the datasets. Availability is a barrier for more use cases than update frequency; where update frequency is a barrier, it is more likely to be a big one.

Of course, closed data is not necessarily a blocker for development of digital twins: where data is intentionally closed (e.g. to protect a competitive advantage that it offers or to leverage its value elsewhere), it may be an indicator of high data maturity. But where data is closed by default, it is likely to be a blocker. In these cases, availability can often be improved by updating business processes; this implies that making more data open and discoverable would be a relatively quick win to support deployment of digital twins for these use cases.

3.0 Assessment framework

Organisations with available capital to invest in development of a digital twin are likely to have multiple potential use cases for it. Rigorous assessment of the use cases is essential to build confidence that the investment achieves maximum returns.

To support this we have developed a multi-criteria assessment framework, which assesses not just the use case itself but also the digital twin that would address it. Different organisations have different priorities, which will inform the weighting of the different criteria. Nevertheless, we believe none of these criteria should be completely disregarded by any organisation (though some organisation may wish to adapt definitions and thresholds to resonate closer with their strategies).

We have formulated 18 criteria of which 12 focus on the use case itself.

Criterion	Description
Decision support times	Will the use case demonstrate the ability to support decision making within operational time-lines?
Efficiency	Will use case demonstrate viability/efficiency gains in existing processes/operations?
Data availability	Whether the relevant data exists or to enable testing the use case
Strategic Alignment	Does the use case align with key imperatives – levelling up, net zero or post-COVID recovery?
Self-sustaining	Is the use case or profit-making or at least self-sustaining?
Synergies	Is the use case synergistic with other use cases on the longlist
Users	Will the use case benefit many users i.e. multiple organisations / departments?
Direct benefits	Does the use case offer visible and direct benefits to citizens or businesses?
Private Investments	Is there evidence of private sector investment in the use case?
Innovation	To assess the degree of originality that is embedded within the proposed use case.
Global market	Projected global market size near 2030
UK competitive strength	Is there a country that is a clear international forerunner?

A further six criteria consider the digital twin that would address the use case:

Criterion	Description
Data exchange	Does it have the ability to ingest real-time data to enable the use case to be tested in re-al-time ?
Scalable	Is it scalable over wider geographical catchment?
Functionality upgrade	Can functionality be augmented over time?
Multiple scenarios run	Can it optimise multiple scenarios?
Multiple use case	Can it support evaluation of multiple use cases?
Prototype	Is it easy to prototype and incrementally develop through TRLs?

Scoring thresholds for the criteria are set out below. Reflecting the Catapult's focus on unlocking economic growth through acceleration of innovation, the "innovation" and "direct benefits" criteria are considered deal breakers – i.e. if any use case scores low on either of those it is ruled out completely (even if it scores high on every other criterion).

Criterion	Low	Medium	High
Innovation	Use case has been imple-mented within the sector and in UK	Use case has been imple-mented in our sector, but outside the UK OR inside the UK but outside our sector. However, use case aligns with CPC's strategy and can be applied to our domain.	Use case is first of a kind – there is no known application in any sector in the UK or elsewhere.
Strategic Alignment	Use case does not align with any of the key imper-atives	Use case aligns with only one of the identified imper-atives	Use case does align with two or three the specified imperatives
Direct benefits	The use case has no sig-nificant direct benefit for citizens or businesses.	The use case offers some direct benefits for citizens or businesses. These ben-efits may or may not be visible/perceptible.	All benefits are intended to be direct and visible benefits for citizens or businesses.
Private Investments	None or very little evidence of investments from the likes of VCs/Angel Inves-tors/Hedge Funds.	Some evidence (1-3 instanc-es) of private sector invest-ments in the use case	Major VCs/Angel Investors/Hedge Funds investing substantial amount (>3 instances) in the use case.
Self-sustaining	There is no pathway to reve-nue generation at all.	There is a pathway for some revenue generation, but no self-sustainability	There is a pathway for the use case to be financially self-sus-tainable
Decision support times	Use case does not support decision making within op-erational timeline as is and has no path to achieve this	Use case does not support decision making within op-erational timeline as is, but has a path to achieve this	Use case supports decision mak-ing within operational timeline as is
Efficiency	Use case will give marginal efficiency over an existing process	Use case will result in sig-nificant efficiency gains over an existing process	Use case will revolutionise an existing process or result in a completely efficient new system
Users	Use case will be beneficial only to one team on team in an organisation	Use case will be beneficial to many teams within an organisation	Use case can be used across multiple teams within multiple organisations
Synergies	Use case is not synergistic with any others	Use case has synergies with one other use case	Use case has synergies with two or more other use cases

Data availability	Data is currently not available to demonstrate the viability of the use case, but this data can be collected when required.	Data is available as part of an existing process and can be used to demonstrate the viability of the use case	Data is available as part of an existing process and can be used to demonstrate the viability of the use case. New data can be collected when required
Global market	Below £10bn	Between £10bn and £1tn	Above £1tn
UK competitive strength	Forerunner is one of US, China, India or one of the EU countries	There is a forerunner, but not one that merits “low”	There is no forerunner OR forerunner is UK
Multiple use case	Uses of the DT is limited to one use case only	DT can be configured to simulate 2-3 use cases	DT can be configured for more than three uses cases
Multiple scenarios run	DT can simulate only one of several options at a time	DT enables up to three interventions to be simulated and evaluated at the same time	DT enables more than three interventions to be simulated and evaluated at the same time
Data exchange	Ability exists for one -way data exchange between the physical and digital twins at low bandwidth	Ability exists for two-way data exchange between the physical and digital twins at low to medium	Ability exists for two-way data exchange between the physical and digital twins at medium to high bandwidth
Prototype	There is no obvious route for incremental development (i.e. only the initial or ultimate form are clear)	Stages of incremental development are clear but have gaps between them	There is an obvious and complete route to incremental development
Scalable	Geographical coverage is limited to individual regions within UK	Geographical coverage is limited to UK only	Can be applied internationally
Functionality upgrade	Platform has limited capacity and therefore no room for additional functionality	Additional functionality can be added but this is limited	Additional functionality can be added over time

4.0

Next Steps

This work provides a steppingstone to accelerate uptake of digital twins in the Connected Places market. Building on existing activity and on the insights in this report, we are looking to develop a demonstrator of a digital twin that cuts across many aspects of Connected Places, such as mobility, the built environment, public space and decision-making institutions.

Such a demonstrator should be designed not only to showcase the benefits of the digital twin to the end user(s), but also to address some of the technical barriers to deployment in a reproducible way (i.e. such that industry can apply the methodology – with minor modifications – to their own use cases). Achieving this would require:

1. Using the assessment framework to short-list the identified use cases; in some cases (the more visionary ones), that may require defining the use case more tightly.
2. Exploring the data landscape for short-listed use cases more comprehensively.
3. Developing a full business case for one use case (based on the assessment framework and data discovery output); this may draw on the Digital Twin tool-kit being developed under the National Digital Twin programme.
4. Building a consortium of technology suppliers (in industry and academia), customers, end users and government around the chosen use case.
5. Designing and specifying the minimum viable prototype that addresses the use case and overcomes the data and technology barriers.
6. Developing and deploying the prototype digital twin.
7. Disseminating both the design of the prototype and outcomes of its deployment, enabling industry to deploy digital twins commercially.

These actions are not necessarily sequential: in particular 3, 4 and 5 are likely to happen in parallel or iteratively. Importantly, this cannot be delivered by a single organisation; we will be actively looking for collaborators to join our mission as early as possible. The earlier we can engage with collaborators, the better the final prototype will fit with all partners' ambitions and strategies. **We call on all interested parties to reach out and explore opportunities for collaboration.**

Appendix 1 - Required Datasets

Datasets considered for the availability assessment are listed below. Further details on these datasets and how they map to use cases are available on request.

Dataset Name	Type of Ownership	Update frequency	Source	Temporal Coverage	Spatial Coverage
Mobile Network data	Private	real-time capability	Mobile Network Operators	unclear but potentially decades	UK
Traffic counts data	Open	can be daily, monthly or yearly	Department for Transport (data.gov.uk); Highways England; Local authorities	years to decades	UK (combined sources)
EPC data	Open	Monthly	MHCLG	Unknown	England and Wales
Travel demand data	Private				
Building Information Modelling (BIM)	Private		BIM models held with property owners		
Traffic flow data	Open	Monthly	Highways England	2006 to 2020	England's motorways and major A-roads
Journey time	Open	Monthly	Highways England	2006 to 2020	England's motorways and major A-roads
In vehicle data	Private		Vehicle/Fleet Operators	Unknown	depends on deployment
Location-based services	Private		Google maps, Waze, Apple maps	depends on deployment	depends on deployment
Public Transport Access Nodes	Open	minimum 2 years	Department for Transport (data.gov.uk)	2014 to 2020	England
Average speed, delay and reliability of travel times	Open	minimum 3 months	Department for Transport (data.gov.uk)	2018 to 2020	
Weather data	Open	hourly/daily/monthly	Met Office (MIDAS)		UK
IoT Sensors	Private		Proprietary monitoring sensors		
Train planning data	Open	twice a year	Network Rail	unclear but potentially decades	GB
Location reference data)	Open	monthly	Network Rail	unclear but potentially decades	GB
Train positioning and movement data	Open	real-time	Network Rail	unclear but potentially decades	GB

Real-time train performance	Open	Updated at the rate of one message per minute	Network Rail	unclear but potentially decades	GB
Daily train schedules	Open	overnight each night	Network Rail	unclear but potentially decades	GB
Train describer berth offset data	Open	monthly	Network Rail	unclear but potentially decades	GB
Train positioning data at signalling berth level	Open	real-time	Network Rail	unclear but potentially decades	GB
Temporary speed restrictions on rail network	Open	once a week on a Friday morning	Network Rail	unclear but potentially decades	GB
Train schedules in very short-term plan	Open	real-time	Network Rail	unclear but potentially decades	GB
Railway infrastructur model	Open	overnight, each night	Network Rail	unclear but potentially decades	GB
Local housing data	Open	quarterly	House of Commons Library	between 1995 and 2020	England and Wales
Local indices of deprivation	Open	every few years	House of Commons Library	mostly based on 2015/16	England and Wales
Local population by age	Open	once a year	House of Commons Library	between 2012 and 2019	UK
Local ethnicity	Open	Census data	House of Commons Library	2011	UK
Local unemployment benefits	Open	monthly on the day that new data is released	House of Commons Library	between 2013 and 2020	UK
Universal Credit rollout	Open	monthly, in line with data releases from HMRC	House of Commons Library	from 2018	GB
Local broadband coverage an speed	Open	three times a year, in line with data releases from Ofcom	House of Commons Library	between 2019 and 2020	UK
Parliamentary activities	Open	every month when Parliament sits	House of Commons Library	from 2019	UK
Magistrates' court closures by constituency	Open	in line with data releases from the Ministry of Justice	House of Commons Library	between 2010 and 2020	England and Wales
Local educational-attainment data	Open	once a year, in line with the Department for Education's data release	House of Commons Library	between 2012 and 2019	England
Local schools funding	Open	in line with data releases from the Ministry of Justice	House of Commons Library	between 2013 and 2020	England
Local traffic accidents	Open	real-time	DfT and House of Commons Library	between 2010 and 2019	GB
Data of local businesses (constituency-level)	Open	once a year, in line with data releases from the Office for National Statistics	House of Commons Library, ONS	between 2010 and 2019	UK
Local authority finances data	Open	once a year, in line with data releases from the Ministry of Housing, Communities and Local Government	House of Commons Library, Ministry of Housing, Communities & Local Government	between 2011 and 2020	England

Local Social Mobility Index	Open	on most recent data available at the time	House of Commons Library		England
Local health data	Open	on most recent data available at the time	House of Commons Library, NHS Digital, ONS	2016/18	England
Travel to work (constituency-level)	Open	using Census data	House of Commons Library, Census 2011, Nomisweb	based on the 2011 Census	England and Wales
Local housing tenure	Open	using Census data	House of Commons Library, ONS, 2011 Census Table KS402	based on the 2011 Census	UK
Sensor data on pedestrian movement	Private	real-time capability		depends on deployment	depends on deployment
Planning application data	Open	Per case	Local authority	N/A	N/A
INSPIRE Cadastral Parcels	Open	Unknown	Register of Scotland		
Unique Property Reference Numbers	Open	Unknown	Ordnance Survey		GB
Electronic Property Information Mapping Service	Open	Unknown	Gov.uk		
Satellite image data	private	Unknown	Private		
Route history	Private	Unknown	Private	depends on the tracking device	depends on the tracking device
Roadworks data	Open	Unknown	DfT		EngEland
Tracking devices (e.g. GPS)	Private	Unknown	Private	depends on the tracking device	depends on the tracking device
Basket of Goods	Open	Annually	Open	Annual	UK
Data of building location and characteristics	Private	Unknown	Geomni		UK
Aviation incidents and airport map data	Open	Unknown	DfT and Civil Aviation Authorit		UK
Public experiences of and attitudes to air travel	Open	Unknown	DfT		UK
Road congestion and reliability	Open	Annually	DfT	annual	UK
Electric Chargepoint Analysis 2017: Domestics	Open		Gov.uk	2017	UK
Postcode level electricity statistics: 2018	Open		Gov.uk	2018	GB
Elexon	Open	Real-time	Elexon	real-time	UK
National Grid assets data	Private	Unknown	NG		UK
Event Data	Open	daily	Multiple	Real Time	UK

Personal Independence Payment	Open	in line with data releases from the Department for Work and Pensions and Ministry of Justice	House of Commons Library	2018 to 2020	GB
EV charge point data	Open	Unknown	ZapMap	Real time	UK
Policies and priorities of individual orgs	Private				
Origin-destination data	Open	Every 10 years	ONS		
Up-to-date origin-destination data	Private				
Child povertyb-data	Open		House of Commons Library	2020	GB
Schedule Management data	Private	Unknown	operators/schedule management software vendor	depends on deployment	depends on deployment
Construction output data	Open	quarterly	ONS	From 2019	GB
Infrastructure investment data	Open				UK
Working flexibly in the public sector	Open	annually	ONS	2012 to 2018	UK
National Trip End Model	Open	forecasts	Department for Transport (data.gov.uk)	2017 to 2051	UK
Real-time aviation performance measure	Private	hourly	Private	depends on deployment	depends on deployment
Satellite view data	Private	hourly/daily/monthly	Private	depends on deployment	depends on deployment
Business processes data	Private		Private		
Materials catalogue	Private		Private	N/A	N/A
Transport Netwok Data (rail, rail and air)	Open/private		Open/private		UK (combined sources)
Asset utilisation data	Open/private		Open/private		UK
Long Term Development Statement (LTDS)	Open		Open		UK (combined sources)
Flexibility service data	Open	annually	Open		UK
Current Power Outages data	Open		Open		UK (combined sources)
Asset Locations	Open		Open		East of England and the South East
Electricity meter point data	Private		Department for Business, Energy and Industrial Strategy	Last updated: 10 February 2016	UK
Water put into public water supply	Open	annually	Department for Environment, Food and Rural Affairs	1990 to 2011	UK

Gas meter point data	Private	annually	Department for Business, Energy and Industrial Strategy	last updated: 10 February 2016	UK
Water abstraction data sets	Open	annually	Department for Environment, Food and Rural Affairs	2000 to 2017	England and Wales
Water pollution, substantiated incidents	Open	annually	Department for Environment, Food and Rural Affairs	1990 to 2005	England and Wales
Drinking Water Safeguard Zones (Surface Water)	Open	Sep-20	Department for Environment, Food and Rural Affairs	Sep-20	England and Wales
Electricity consumption by households	Open	annually	Department for Environment, Food and Rural Affairs	2000 to 2008	UK
Annual carbon dioxide emissions relating to UK consumption	Open	annually	Department for Environment, Food and Rural Affairs	1990 to 2017	

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