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UK Research and Innovation

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DIGITAL TWIN

For East Birmingham & TEED

Contents of This Report

1. INTRODUCTION

1.1. Executive Summary

Birmingham City Council (BCC) and University of Birmingham (UoB) are working with Siemens to develop a framework for a digital twin. The intention is to use the project outputs as the basis of a funding bid to realise the digital twin, which becomes a digital asset for Birmingham and continues to develop and scale to provide real value to citizens. This report describes the objectives of the engagement, the process we have followed, and the outcomes in detail. This summary covers the key points of the report, with further detail provided in the relevant sections of the document.

What is a digital twin?
Digital twins provide cities with a bridge between the real and digital world, where smart buildings and infrastructure share information with a virtual environment. This project intends to identify an ambitious and innovative scope that pushes the boundaries of what a digital twin can do within a city environment, building upon global best practise and experience within the core group of project owners and broader contributors. As part of the report a group of senior stakeholders across Birmingham were invited to several interactive sessions and a two day in person workshop to explore the opportunity and identify a set of themes to shape the requirements for the proposed twin. Facilitated by Siemens, this guided value discovery workshop invited the broad stakeholder group to input, debate and shape the themes and potential implementation of an innovative digital twin model. Our focus was initially on the problems that the twin could potentially solve working through to a set of themes and use cases for implementation.

Selection of East Birmingham and TEED
To give a focal point for the digital twin development, choosing a specific geographical area for this digital twin engagement helps to ensure a well-defined and achievable scope, also reducing the effort and time required to produce a funding bid. Scope and reach of the digital twin can be increased later, building upon the success of the initial, focused projects. East Birmingham and specifically the Tyseley Environmental Enterprise District (TEED) was chosen as the starting point for the project; giving ample opportunity to explore broadly applicable and repeatable digital twin solutions. Of specific interest in TEED, there exist deep-rooted inequalities for citizens, plus a drive from local government through the levelling-up agenda to empower citizen focused change in the area. This is combined with the local concentration of businesses and jobs, plus natural, transport and energy assets. Additionally, there is the Tyseley Energy Park and the definition of the area as an 'Environmental Enterprise District', making this a strategic location for future investment.

As part of this process, we collated and summarised the broader picture of current initiatives and projects in TEED, East Birmingham, the wider city and the combined authority. Aligning these with the key themes for the digital twin we start with a shared awareness of these activities; ensuring we can build from existing progress and successes, avoiding repeating efforts and utilising data, information, skills and lessons learned from the delivery and outputs of these projects.

The process followed
To be successful in this digital twin project, it is important to get clear definition and a shared understanding of the scope and objectives for the digital twin, to ensure the outcomes are tangible and measurable. With such a rich and varied set of stakeholders and potential opportunities, it was critical to follow a collaborative and systematic process to derive the shared scope of the digital twin. Siemens introduced a proven, structured two-day 'Value Identification' workshop for this aim, followed by a period of concept solution design to propose an enabling digital twin architecture and framework.

The workshop process is built around 'Personas' or key stakeholder groups within the district as a starting point. Initially, we defined and described these personas before selecting a short list of four that provide a diverse representation of needs in the district: SME Business Owner, Policy Lead, TEED Resident and Institutional Investor. Following the process, we explored broadly these four persona's goals, needs, pains and gains, identifying how they are currently served by the district services and facilities. We collectively generated a long list of possibilities for enabling 'use cases' in the digital twin, which help to relieve pains and increase gains for the Personas. Participants clustered the use cases to combine similar and evaluated these based on feasibility and potential impact. In this way, we generated consensus around the broad scope and future roadmap of the digital twin. We finished by defining high-level solution requirements, functional or otherwise. Following this workshop, Siemens have fully documented the outcomes and further condensed and described the resulting use-cases into a set of eleven, aligned to four key themes described below. Finally, Siemens have

run a solution concept phase to design the high-level digital twin technological framework, required to deliver these use cases as a flexible roadmap into the future.

Digital twin use-cases
Use-cases are important for defining the application and use of the digital twin to generate value for the city and its citizens. Starting with use cases ensures that the objectives of the solution, and the resulting technical requirements, are defined based on genuine needs and potential opportunities, rather than being led by technology features or functionality. Within the report we define in greater detail the content of the use-cases and how these could be deployed in the digital twin. The set of distinct digital twin use cases are aligned to four main themes, aligned to wider objectives of the city: Driving Investment, Enabling Net Zero, Planning for the Future and City Assets & Solutions. The use cases have been arranged into a suggested roadmap to suggest how they could be developed in a modular approach, upon a common and scalable underlying digital twin solution. This roadmap is flexible and ensures that investments made over time provide a cumulative benefit and contribute to a digital asset that grows in value and impact. One or multiple use cases could be combined to form the basis for a funding bid, or city budget can be allocated to add or grow use-cases to the digital twin framework when available.

Solution requirements
Starting in the workshop and continuing in the Siemens-led concept solution design, we defined clear solution set of solution requirements for a digital twin, one which addresses the needs of the numerous stakeholder groups as part of a wider aspiration to lead the global conversation on smart and impactful digitalisation of a city. These requirements are both functional, relating to what the digital twin must do, and non-functional, describing the properties or qualities of the digital twin. The report details two sets of requirements. Firstly, the base requirements of the digital twin solution, which are broad needs of the technological framework that will form the core of the digital twin, regardless of the use-cases which are being delivered. These requirements were aligned with the Centre for Digital Built Britain Gemini Principles, that guide the national digital twin. Secondly, in a later section, we have defined the requirements related to the eleven use cases. These are specific functions, systems integrations and data sets that will be needed to achieve the use case as described. This set may be subject to change or expansion, based on further design and definition of the use cases.

Solution architecture
Based on the requirements described above and the use-cases currently defined for the digital twin, Siemens have proposed a high-level architecture for the solution. The architecture describes the various solution components needed to deliver the digital twin solution and future use case functionality, with a focus on reusability, modularity, and scalability. The architecture is vendor-independent, and each of the various elements and components can be provided in several ways, which would be decided later in a detailed solution design. The architecture describes a modular and federated basis by which all digital twin functionality will be enabled. This solution architecture is based on Siemens extensive experience and allows the city to utilise the best-in-breed components from the market. It allows inter-operability, maximising the benefit derived from existing investments and enabling connectivity across different public and private organisations. It will enabling open access to specified data, whilst ensuring security, privacy and resilience. We describe the main layers in the digital twin technology stack in the report, with further detail in the annex.

Data and systems
Data is a key enabler for the Digital Twin. Through the Value Identification workshop, we discussed the data available across the city, which could be utilised, along with data sets that exist but are not currently available. Data availability and quality is a significant success factor when deploying the digital twin and impacts the ability to implement the chosen use cases. For all the required data sets, it is an important preparatory task to understand the availability and accessibility of data sets, along with the relevant sources and responsible parties that would need to be considered as part of the digital twin implementation. The report describes a clear set of principles that should be followed for data, along with describing necessary considerations such as licensing and data ownership. Not all data required by the digital twin will be equally accessible and there may be some significant barriers in place that need to be overcome, which are introduced in the report along with potential mitigating actions.

Business and revenue models
The goal of the digital twin engagement is to define the potential scope and concept for the solution, which forms the basis of one or many funding bids, or other investment opportunities. It is assumed that an initial model will be developed as a funded innovation project, but it should not be a pilot project alone. Hence, the digital twin design consists of

a robust core build, which can be consistently iterated with new use cases and applications to support the region into the future. The twin should become an evolving digital asset to deliver long-term value for East Birmingham and TEED; one that can be expanded and scaled across the city and beyond. To ensure longevity of the solution and sustainable future investment, we explored potential scalable operational and commercial models for the twin, post-implementation. These are presented in the report, with description so the potential service-based models.

Conclusion
The output of this report, therefore, is an aligned consensus around the opportunities that exist to generate value with the digital twin in East Birmingham and TEED. It showcases the growing capability and potential of digital twin technology and aligns this to the key goals of Birmingham, and global cites generally. Furthermore, it presents the agreed potential scope and use cases for the digital twin and provides a feasible, scalable concept and architecture for the digital twin federated solution. Demonstrated also are the possibilities around business and revenue models to sustain the operation and expansion of the digital twin. The conclusion of this report reiterates the most prominent potential benefits of the digital twin especially around improving collaboration, and visibility, between city stakeholders and around creating a climate resilient city. It also reflects on the aspirations and goals laid out in this engagement and how these are met in the proposed approach.

1.2. Purpose of the Digital Twin

Following the initial workshops, the stakeholder group identified the following as a statement to encapsulate the purpose of the digital twin for East Birmingham and TEED,

...to accelerate investment, the net zero transition, citizen wellbeing and creating a global showcase for an innovative, forward-looking Birmingham with the application of a scalable and referenceable digital twin for East Birmingham and TEED.

1.3. Digital Twin Introduction

Digital twins present a wealth of opportunity for cities and districts, addressing many of the challenges that are present for both private and public companies. The cultural and functional landscape of city centres is changing, with macro topics and megatrends such as a move to flexible/hybrid working, globalisation, a changing job mix, major economic and political challenges as well as the wider responsibility to tackle carbon emissions. These changing external factors have knock-on effects on the demands and usage of the buildings, transport, public services, energy networks and more.

The digital twin has the potential to model all these systems, processes, and interactions, making it possible to visualise and track changes in the city and monitor the impact of these macro factors. The digital twin model and associated impacts can be optimised to meet the needs and goals of business and citizens alike, and project the future effects of decisions made now

Digital twin is a well-used and very topical phrase but can mean many different things to many different stakeholders depending on their point of view. The most appropriate definition in the context of this report is taken from Gartner:

A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes.

A digital twin can enable and create value for a wide range of applications for the urban environment. By integrating historically siloed existing systems, processes and assets a digital twin can enable stakeholders to combine, analyse and enrich data from different silos to resolve real world problems and deliver business value across the city ecosystem. For East Birmingham the digital twin can act as a bridge between the real and digital world, supporting the development of TEED but also addressing issues across the wider area.

There is a clear need to not only focus on the technology elements of the twin but to start at the beginning with identification of the problems to be addressed as well as the available data to deliver real benefit to the users of the model. Typical problems can include:

Lack of insight to achieve sustainability goals
With increasing pressure for city leaders to tackle sustainability, a digital twin can identify, measure and offer full transparency into what processes and functions have the largest impact on environmental, sustainability and government reporting.

Lots of data in different places
A city has lots of data but limited integration and value creation from this data. The delivery of multiple disparate services coupled with the complicated stakeholder landscape means data is stored in multiple different formats and locations, making it difficult to integrate and unlock the value of both data and the twin.

The need for operational efficiency and cost saving
Services in cities are typically delivered in a piecemeal fashion dependent on the multiple and complex stakeholders and their associated roles. This exacerbates the lack of data integration and prevents collaboration and optimisation across multiple agencies.

These are some examples of problems that can be addressed by a structured approach to data collection and integration and impactful visualisation via the digital twin.

A focussed and thoughtful implementation of a digital twin can address many wide-ranging challenges and objectives to deliver tangible benefits. It is, however, important to baseline the current environment and distil down the opportunity areas that exist for the proposed digital twin. We need to consider the needs of core stakeholders and the far-reaching impacts across the city, which will be central to the success of such a forward-looking initiative.

1.4. International Digital Twin examples

Barcelona City Digital Twin

Municipal authorities commissioned a public research entity, called the Barcelona Supercomputing Centre (BSC), which is responsible for the MareNostrum supercomputer housed in a 19th century chapel in Barcelona. This computing power is being used to revolutionise the urban planning process, ensuring that decisions are based on real data, anticipating the full impact and avoiding or reducing the negatives. The organisation has created a digital twin replica of the city, where it can test and validate potential city planning scenarios, ensuring decisions and policies are right before being implemented.

The scheme is still in a test phase but is expected to have become a basic urban planning tool within the next 5 years. The technology driven approach demonstrated here is expected to become normal practise across European cities looking to improve urban planning for the benefit of all citizens.

The Challenge

- Previous 'superblock' traffic and pollution management measures, implemented previously to tackle air quality and emissions issues, have pushed problems to different areas meaning additional measures are needed.
- Need to improve access to services and amenities citizens, including accessibility improvements
- Impacts of gentrification and regeneration of areas across the city
- Large scale interventions need to be identified to tackle climate change and reach 2030 and 2050 goals.

The Approach

- Simulate impacts of planning decisions e.g. clean air measures, prior to rollout, to identify and mitigate negative impacts, or plan additional measures ahead of time
- Tracking of gentrification trends based on indicative measures e.g. homestays
- Identifying areas which are underserved with public services and transportation
- OpenStreetMap and use of open-access technologies to encourage citizen involvement; allowing them to use the same data to challenge or contribute to the planning process and decisions.

The Impact

- Goal of creating a 15-minute city; redesigning cities so that people live, work and have access to all the services they need (education, health care, shopping etc.) within a 15-minute walk or bike ride.
- Evidenced, data-driven, decision making, with accountability to citizens

Aspern Smart City

Aspern Smart City in Vienna is a living laboratory for research into the future of urban energy. In Europe's most innovative energy-efficiency project, the Aspern Smart City Research company is investigating how smart energy systems and intelligent buildings operate together in a real urban suburb. The inhabitants of the smart city play an important role in the project – because in addition to being efficient, the city of the future must be worth living in.

The Second program phase launched in 2019 by Wien Energie, Wiener Netze, and Siemens, encompassing energy and smart infrastructure. It involves over 100 researchers from various disciplines and represents a total of € 85 million R&D expenditure. Key to this project is a digital twin for resilient infrastructure coupling e-mobility and grid management, which explores solutions for the energy future within an urban development zone.

The Challenge

The overall challenge of 'prediction improvement of charging demand & understanding of the impact on the infrastructure' is broken down into three main objectives:

1. Utilize the electricity network to maximize the supplied energy
2. Communication & information of extra network capacity reserves for electric car users
3. Improve system efficiency & operation by connecting charging points to buildings & their parking lots

The Approach

Implementing applications for network capacity prediction & providing the information for the end user, broken down into the activities below. Whilst the focus here is mostly on energy and e-mobility, there is a lot of alignment between the activities undertaken here and those proposed for the East Birmingham digital Twin; utilising data, building powerful ontologies and modelling systems and processes are all transferrable.

1. **Data Sources:** Ontology Electrical network data based on the IEC standard CIM (Common Information Model)
2. **Electrical load information:** Publicly accessible & open data platforms provide charging station information
3. **Digital Twin:** Correlation of transportation & electricity network data, charging stations & electric vehicle consumption by creating a graph-based data model (CityGraph)
4. **Visualization of correlated data:** Transportation information & traffic flows for end users in an interactive map
5. **Status of charging:** Prediction of charging point usage (occupancy & energy demand)

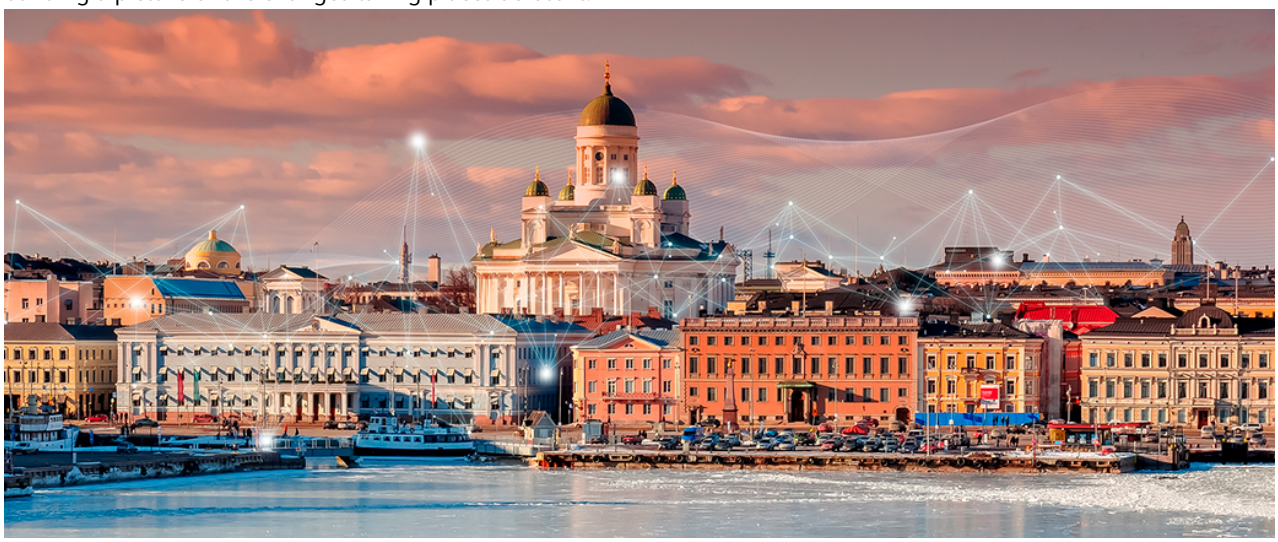
The Impact

The solutions implemented improved system efficiency & operation by coordinated interaction with the electricity grid. The impacts and outcomes are relevant for East Birmingham as an Environmental Enterprise district, whilst the user satisfaction improvement, plus the wider, cross-discipline applicability are both important goals we look to meet.

1. Enabling e-mobility through better planning of network capacities and related expansion
2. Providing services through open standards & interfaces, with the goal of affordability, monetization enablement & longevity
3. Digital twin can be extended with any ontology (e.g. heat networks, transportation, buildings) and related for many other business use cases
4. Increasing customer satisfaction & attractiveness of e-mobility through fast availability & transparency of charging capacities, leading to a reduction of emissions from combustion vehicles
5. The system implemented for providing & monitoring network capacity can help to secure the reliability of power supply in large cities

Helsinki Digital Twin

The city of Helsinki, Finland has a long history of using 3D modelling, going back around 35 years. Today they have developed a digital twin of the city, utilising advanced 3D modelling capture and visualisation techniques, plus semantic data modelling to enable modelling and exploration of scenarios across the capital.
Mapping of the city periodically allows them to update and advance the digital twin as technology improves, whilst building a picture of the changes taking places across it.



The Challenge

- Seasonal solar generation variability
- Communication of the detail of city planning activities; the benefits, needs and impacts of new development to citizens and politicians
- Time taken to explore and validate new ideas for the city, with data gathering, calculations,
- Impacts of gentrification and generation of areas across the city
- Large scale interventions need to be identified to tackle climate change and reach 2030 and 2050 goals.

The Approach

- 3D modelling of the whole city, its built environment (such as land, buildings and infrastructure) including geographical information system (GIS) information[3] (including use of Bentley OpenCities Map[4]).
- City 3D modelling using the CityGML standard (open data model and format used to store and exchange 3D city models), applied in diverse city planning projects[3].
- 3D laser scanned point clouds and reality mesh modelling of the city (using Bentley Context Capture[4]).
- Simulation of wind speed, air flows and air pressure (simulated in ANSYS Discovery Live), and light and shadow modelling (using Bentley OpenCities Planner), both using the CityGML model[6].
- Semantic Data modelling, showing underlying and complementary data related to objects, and points within the model
- Open data approach for the reality mesh model and the CityGML city information model. Free availability of models is hoped to enable reach to a wide range of construction and real estate actors and their stakeholders[6].

The Impact

- Possibility to accelerate planning procedures, removing unnecessary tasks such as site visits,
- Ability to easily visualise and communicate city planning activities and projects for citizens and politicians, 'strengthening learning and knowledge-based decision-making'[3] (using Bentley OpenCities planner[4]).
- Federated source of truth model, serving as an up-to-date, accurate hub and archive of city data, information, and spatial views, with engaging and immersive VR headset exploration capability.
- A robust digital city model and data infrastructure enable urban simulations to be set up in an agile and rapid manner. [3]
- Drive public engagement by delivering access to the digital twin on mobile devices to communicate project information and gather input from crowd sourcing5

2. MAXIMISING IMPACT FOR EAST BIRMINGHAM & TEED

The previous section shows the size and potential complexity of the opportunity presented in a city-wide digital twin, illustrated by the examples presented of digital twin developments in Vienna, Helsinki and Barcelona. The digital twin for Birmingham should be an exemplar, showcasing how coupling innovative and aspirational vision can be integrated with digital twin technology to enable real value creation for the city. Funding for the development and deployment of the digital twin is not yet secured, meaning that a business case will be required to demonstrate the positive impacts that can be realised, along with the investment needed to achieve this. To do this successfully, outcomes from the digital twin implementation need to be tangible and measurable, demonstrating a causal link between the digital twin technology and the real-world outcomes for the city and its citizens.

Given the breadth of possible areas for digital twin development, coupled with the number and variety of stakeholders involved or impacted by this work, there is a risk of scope becoming extremely large or undefined. This could make the level of required investment too high, or mean that investment is spread too thinly, hindering progress, or making it difficult to measure or quantify outcomes. Choosing a specific focus for this digital twin engagement helps to ensure a well-defined and achievable scope, also reducing the effort and time required to produce a funding bid. Scope and reach of the digital twin can be increased later, building upon the success of the initial, focused projects.

The focus of East Birmingham, and specifically the Tyseley Environmental Enterprise District (TEED) was chosen as the starting point; narrowing the geographical scope of the project, whist giving ample opportunity to explore broadly applicable and repeatable digital twin solutions.

2.1. Why East Birmingham and TEED?

As the UK's second city, with a population of 1.15 million people[1], Birmingham is host to a growing list of transformative and engaging initiatives for its citizens – from HS2 which is actively underway and advancing the local economy during construction, to the Commonwealth Games due to take place in 2022. Public/ private partnerships are advancing investment within the city region on numerous fronts. This is a place with a young and vibrant population, representing a global city which prides itself on that very diversity of people and background as the bedrock for future innovation.

Yet, for all its successes, Birmingham faces widespread and long-term inequalities. The city council are focussed on delivering for all its residents and communities, addressing this clear need from central Government to support its levelling up agenda; one which is centred around 'people-powered change' and delivering impact in an economically and fiscally sustainable manner.

People-powered change incorporates 5 key ambitions for the city and its stakeholders:

1. Inclusive, sustainable growth
2. People and places
3. Empowering communications
4. Improving public services
5. Addressing structural inequalities

These five pillars and aspirations dictate the focus of city decision makers in the coming months and years. However, to accelerate and maximise the impact that can be made across these pillars, we propose a 6th 'digitalisation' pillar will also be required. One which can overcome the silos of man-made political and commercial boundaries to gradually weave together an ecosystem of data and digital assets with the clear purpose of accelerating these ambitions and maximising the city-wide assets which exist today.

East Birmingham and the Tyseley area, with a specific focus towards TEED (Tyseley Environmental Enterprise District) are areas of the city which struggle with the deep-rooted inequalities for its citizens. East Birmingham has a population of over 250,000 and is directly comparable to many smaller UK cities yet is one of the most deprived areas in England. With HS2, Midlands Metro and a commitment to create 60,000 new jobs and 10,000 new homes in the coming decade there are flagship policies and developments throughout East Birmingham which create a compelling case for future investment. Tyseley itself is home to around 250 businesses, providing 8,000 jobs within a 100-hectare site. It enjoys many strategic benefits due to its location and policy for inward investment. However, these associated benefits are far too infrequently witnessed by the 7,750 residents within the area.

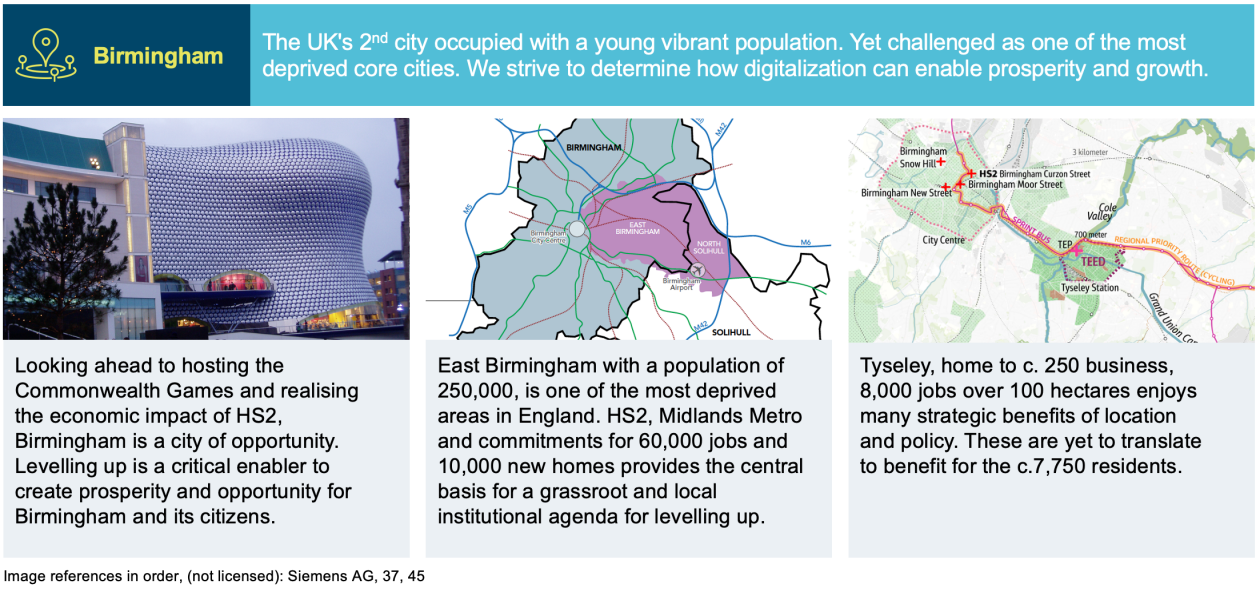


Figure 1 - Identifying the focus regions for the digital twin

A digital twin for East Birmingham and TEED can provide a vehicle for growth and change. Supporting the city council agenda and plans for levelling up, with clear and targeted use cases reflective of key ambitions whilst also being designed based on the need of the local citizens, residents, and stakeholders from the outset. This digital twin initiative is founded upon the need and desire to

1) Grow and scale digital investment within the area,
2) Expand Birmingham's reach as a testbed for innovation and
3) Showcase Birmingham as the leading digital city in the world.

A digital twin for East Birmingham and TEED will enable a joined-up approach to citizen engagement, creating an accessible digital representation of regional energy systems, transport, planning and land use. The digital twin will enable a living platform to drive engagement and attract external investment.

Due to Birmingham's scale, its population, geography, economy and aspirations make it unique in many ways within the UK. Addressing the opportunity to level up the city and region can have wider impacts beyond its boundaries, cascading throughout the UK. Creating a digital twin which focusses on areas such as East Birmingham and TEED will provide a blueprint for digitalisation with purpose and a lighthouse project for replication throughout the UK and beyond. The digital twin will focus on the underlying causes of the deep-rooted inequalities which these areas often face, supporting the ambitions of the City Council to create lasting people-powered change for generations to come.

3. BUILDING UPON SUCCESS – CITY INITIATIVES AND PROJECTS

Birmingham is a city of extensive activity and existing digital initiatives are underway across a host of areas, which are relevant to the goals and ambitions of the digital twin. Starting with a shared awareness of these activities ensures we can build from existing progress and successes, avoiding repeating efforts and utilising data, information, skills and lessons learned from the delivery and outputs of these projects.

3.1. Map of Current Birmingham City Initiatives

A digital twin for East Birmingham & TEED, whilst being a bridge between the real and digital worlds, can also be a shared and open ecosystem of data and information from many collaborators and stakeholders. This platform could operate at scale, whilst delivering a meaningful output and service with an inclusive environment for all types of stakeholder and organisations both public and private. The focus of East Birmingham and TEED – chosen because of the existence of significant municipal interest and complementary activity around regeneration in the area – necessitates an understanding of the influencing projects and initiatives have gone before, alongside the strategic plans and ambitions for the region.

Figure 2 shows the activity that Siemens led, to chart the ecosystem of activities throughout Birmingham, see the online version[52] , which captures a snapshot of some of the multitude of activities throughout the region; reflecting and considering these will bring more value and relevance to the creation of a demonstrable digital twin. Each initiative outlined has been captured and broken down to identify the broad content and how these could relate to the digital twin itself. The consolidated results and explanation of the colour coding are shown in Figure 3 below.

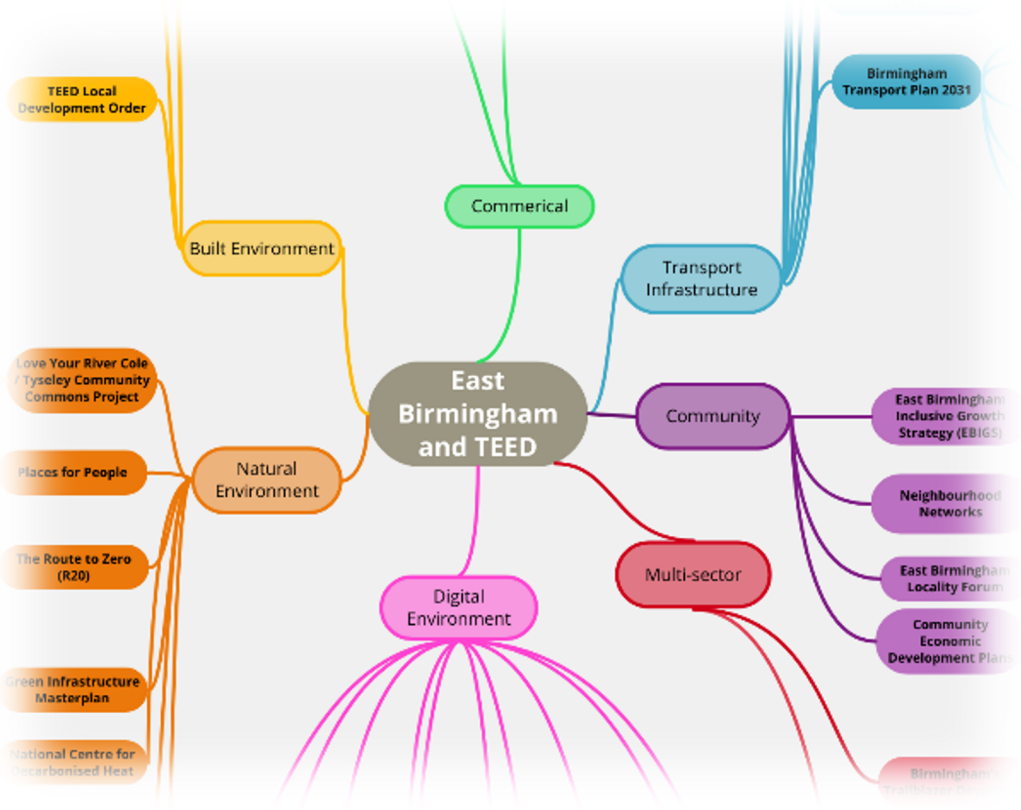


Figure 2 - Charting an ecosystem of activities throughout Birmingham

Through The Value Identification Workshop (see section 4), we have defined digital twin use cases and themes, described in detail in Section 5 Digital Twin Use Cases. These themes offer a consolidated view of the strategic direction of the twin, with the individual use cases outlining how these ideas could be brought to life. The key existing initiatives within Birmingham have been crossed referenced against the four digital twin themes of: ***Driving Investment***, ***Planning for the Future, Enabling Net Zero*** and ***Maximising Asset Performance***. This helps to identify the alignment between existing activity and proposed use cases, as shown in Figure 3 below.

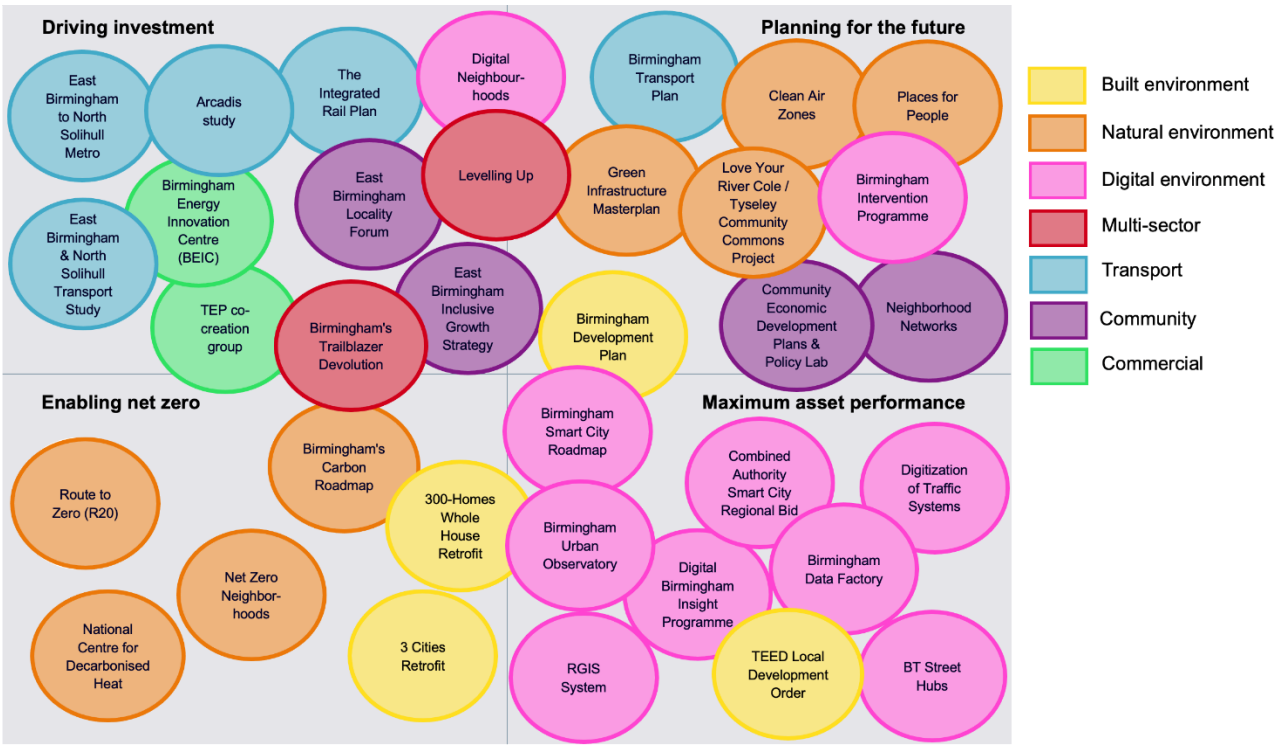


Figure 3 - Aligning activities to digital twin themes

Given the breadth of content across the multiple activities and strategies outlined above in Figure 3, which is not an exhaustive list, the full detail cannot be included in this report. Instead, a short synopsis of each has been outlined in Annex A: Activity and Project Synopses.

4. THE VALUE IDENTIFICATION WORKSHOP

To be successful in this digital twin project, it is important to get clear definition and a shared understanding of the scope and objectives for the digital twin, to ensure the outcomes are tangible and measurable. The proposed solution must be also clearly quantifiable to enable a successful future funding bid.

West Midlands, Birmingham City, East Birmingham, and Tyseley Enterprise Environment District (TEED), and the vast numbers of stakeholders operating within these regions, all bring differing views of what a digital twin is and what it could be for their organisations and citizens. Many will see the value in bringing data together, creating a common portal for both accessible data and comprehensive insight. Others will focus more towards the environmental and social impacts, including health and wellbeing, considering how a digital twin will enhance the environment and lives of the citizens who live within the district. Business impact and return on investment will be of prominence to other stakeholders who need to ensure value for money and measurable impact.

With such a rich and varied set of stakeholders and potential opportunities, it was critical to follow a collaborative and systematic process to derive the shared scope of the digital twin. Based on extensive experience working in similar engagements and global projects, Siemens have developed a proven process to follow. Initially, we explore broadly the possibilities, then follow a structured process to generate consensus around the scope and future roadmap of the digital twin, before developing a solution design around this. This ensures that any subsequent implementation is scalable and future proof. The steps of this process are described in Figure 4 below.

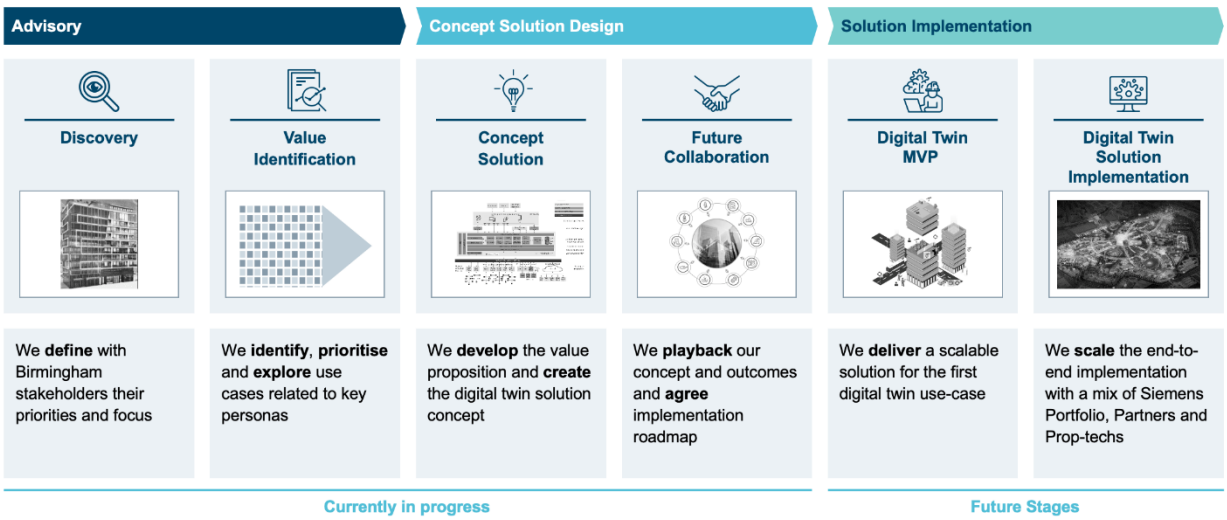


Figure 4 -The Siemens Value Identification methodology

4.1. Value Identification Process & Objectives

Following the initial discovery session, with the core team from Birmingham City Council and University of Birmingham, we defined the shared objectives for the digital twin and an agenda for the two-day Value Identification workshop.

During this process, participants were required to walk in the shoes of each persona individually, to capture a variety of perspectives and to encourage people to think outside of the typical areas of focus, allowing less obvious and potentially novel ideas. The overall objective of the Value Identification process was to capture and distil both known and unknown requirements from central stakeholders to provide a clear scope and rationale for the provision of a digital twin. By using this approach, we minimise the influence of pre-conceived ideas or biases from participants and avoid jumping to known use cases and requirements. Instead, we utilised the collective breadth of knowledge, experience, and insight from the participants, by providing a forum to generate, and constructively challenge, ideas around what the digital twin should do and be.
This process ensured the thoughts and perspectives of willing participants are central within the solution definition, as they help define what topic(s) and use case(s) the digital twin will address. The steps of the process are shown in Figure 5 below, and the results are shared in the proceeding Sections 4.2 - 4.4.

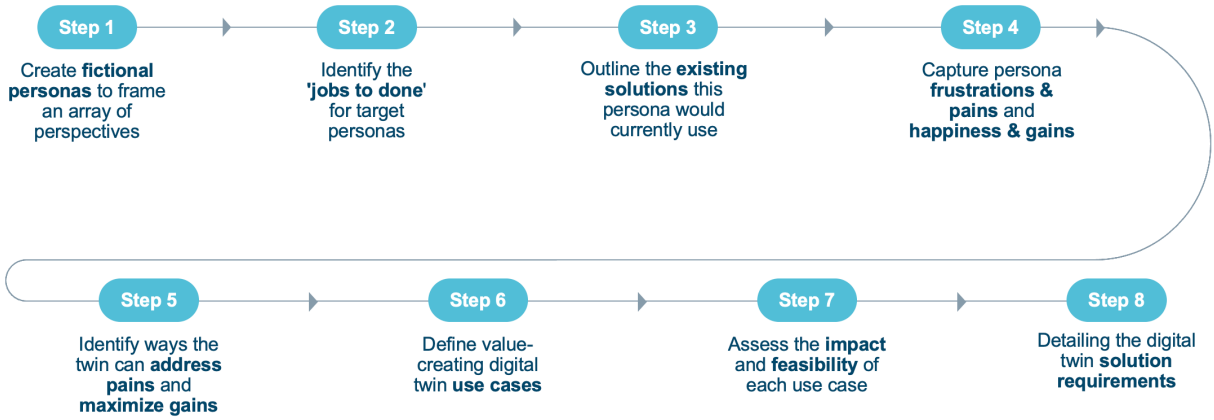


Figure 5 - Value Identification workshop process

4.2. Stakeholder Persona Mapping

The starting point for the Value Identification workshop was user Personas, these are fictional or illustrative user profiles that represent the needs and goals of broader group of stakeholders. Initially, the group openly brainstormed potential stakeholders for the Birmingham digital twin, as shown in Figure 6. Similar and complementary stakeholder roles were combined into groups, resulting in twelve distinct persona groups. Of these twelve groups, participants voted on the four to take through to the next stages of analysis. These personas were chosen based on their prominence, but also to ensure a good diversity and spread of perspectives. Below are the four chosen personas:

1) a small, medium sized business owner/ operator,
2) a regional, city, & residential policy lead,
3) a local resident of East Birmingham/ TEED,
4) an institutional investor.

For these personas, we followed steps 2 - 5 described in Figure 5, exploring each of these personas in turn to build a better picture of their goals and needs, which fed the use-case generation for the digital twin. A summary of the different types of persona groups generated is shown in Figure 6 below, while the four personas explored in detail are captured within Figure 9 and Figure 10. These show the outcomes of the persona mapping process.

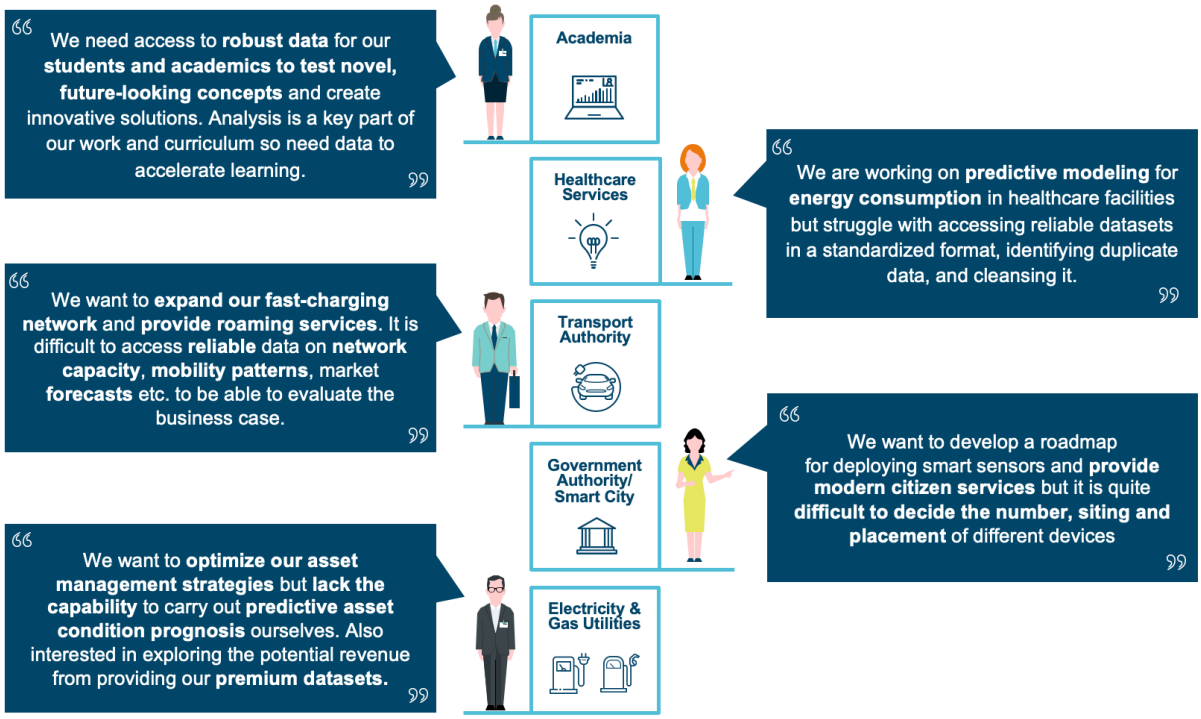


Figure 6 - User Personas identified but not detailed from the workshop

4.3. Defining Use Cases for the Digital Twin

Having explored the detailed needs of each of the four personas, we turned our attention to the digital twin, to determine how the technology can deliver against the defined needs and goals of the personas, described in steps 6 and 7 in Figure 5. A 'use case' is defined as a specific situation or task for which a solution can be used. Use cases are descriptive and are the first step in determining the requirements of the digital twin. Throughout the session, participants collaboratively generated use cases that were relevant for one or many personas which rationalised into a single set for evaluation.

To assess the priority and relative value of different use cases, a qualitative assessment against two axes was employed, assessing potential impact against feasibility of implementing the twin. This resulted in a spread of over 23 distinct, use cases. High impact use-cases should feature more prominently in the digital twin roadmap and within these; the more feasible ideas represent short-term wins and less feasible ideas being longer-term, ambitious development areas which could be scaled more effectively once the core system and initial road mapped use cases have been realised. Participants reviewed this long-list of use cases, identifying commonality and clustering similar ideas together, supporting the development of a detailed description of the contents of each individual use cases.

Finally, participants agreed around four key themes which the use cases should be aligned to, based on the broader goals and objectives of the city and the personas. Figure 7 shows the resultant use cases that were defined, colour coded to these four main themes. This long list of use cases formed one of the main workshop outputs and these have been further combined following the workshop into eleven distinct use-cases; full descriptions of these use cases can be found in Section 5 Digital Twin Use Cases.

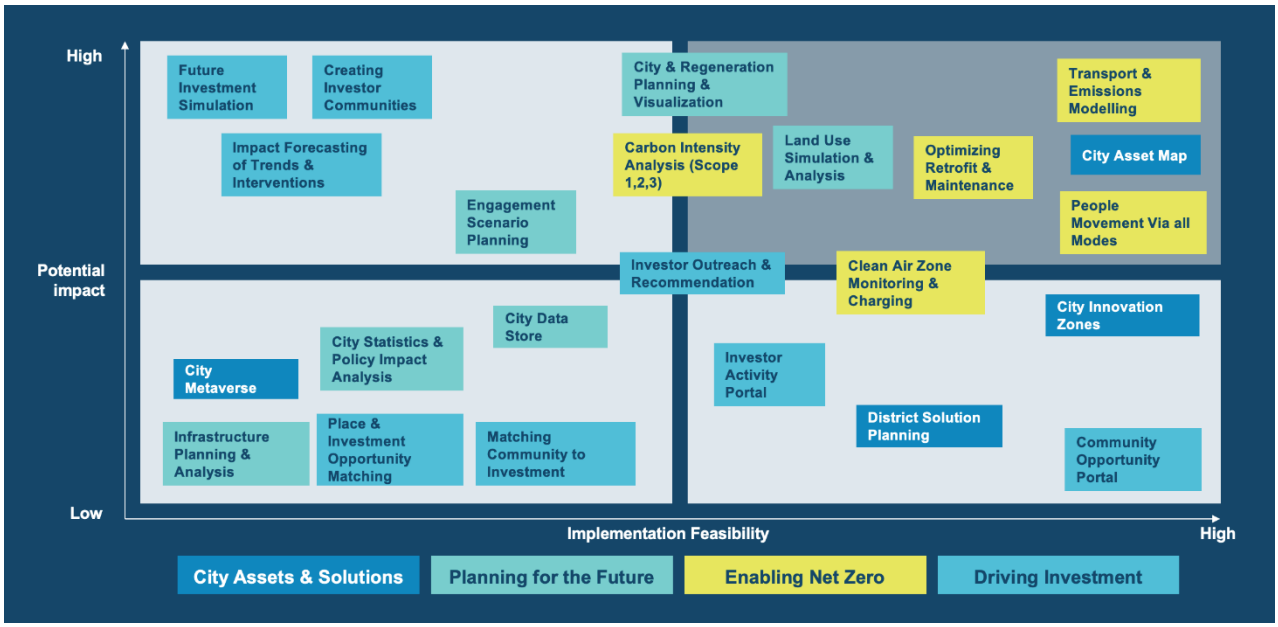


Figure 7 – workshop derived use cases aligned to key thematic drivers

4.4. Capturing Solution Requirements

For the final step of the Value Identification workshop process (see Figure 5), participants were asked to specifically consider high-level requirements of the digital twin based on the set of agreed and prioritised use cases. We captured ideas around what the digital twin needed to do and what it needed to be, to fulfil the strategic aims of the project. Brainstorming in the session captured a broad spread of requirements, both functional and non-functional. Following the workshop, Siemens rationalised this feedback and organised by type as shown in Figure 8 below. Such technical definition formed the basis of the solution concept outlined by Siemens, producing the expanded list of validated requirements and descriptions detailed in section 6.1 Key Digital Twin Requirements.

Architecture	Components	Functionality	Tools	User Interface	Security	Operation
Extensible & Scalable	API Layer	Workforce Management	Software Tooling for Open Data	Intuitive	Auditing (User Access)	Maintainable
Federation & Modular Structures	Common Ontology	Data-Driven Decision Support	Data Visualisation	Curation	Role- Based Access Controls	High Uptime/ Availability
Open Data Standards	What-if Simulation/ Prediction	Comparative Capability	Licensing Access Model	Engaging Look & Feel for Citizens	Privacy/GDPR	Timely Updates
Open (non-proprietary)	Computing Power	Near Real-Time (some use-cases)	Time-based Analysis	User Friendly Access & Interface	Secure (Trusted)	Value for Money
Data Accuracy	Multiple-Scenario Modelling	Historic Data	Re-Run Analysis	Collaborative	Transparent Governance	Sustainable Business Model
Plug & Play	Standard & Bespoke Analytics	Granularity/ Fidelity [of Data]	Dynamic Adaptation	User-Based Interface/ Needs	Evidencing & Verification	Technical Support Available

Figure 8 - Stakeholder derived digital twin solution requirements

Group	Personas	Jobs to be done	Existing Solutions/Approaches	Pains & Gains
Small, Medium Sized Businesses	**Owner** **CEO** **Employee** **Operations Manager**	• Attract and retain talent • Attract and serve customer base • Attract investment • Build efficient supply chains • Contribute to decision making across Birmingham • Understand decarbonization efforts • Understand synergies to benefit from activity and development within the area	• Utility & infrastructure • Co-creation groups • Incubator innovation center (BEIC) • Enterprise systems • Metering & monitoring • Funding from mixed sources • Training & people development solutions • Engagement & marketing tools – e.g., LinkedIn	• Energy costs & inflation/spending power • Access to data/grant funding/affordable finance • Regulatory complexity • Access & transport • Skilled talent & training ✗ --- • Attract and retain talent • Attract and serve customer base • Attract investment • Build efficient supply chains ✓
Regional, City & Residential Policy Leads	**Planning** **Net Zero** **Development** **Housing**	• Assessment of growth needs • Decarbonization roadmap • Understand carbon emissions in the area • Understand quality of environment and access to green spaces • Help to deliver affordable quality housing • Understand community needs within the area to aid with neighborhood development	• TEED local development order • East Birmingham program • Existing funding streams (ERDF, LEP etc.) • National emission data • TEED development report • Robust housing data • Remote hiring	• Inaccurate reporting/access to data to map progress/forecasting of solution impact • Non-universal buy in to net zero ambitions • Access to funding • Balancing competing priorities ✗ --- • Attract and retain talent • Attract and serve customer base • Attract investment • Build efficient supply chains ✓

Figure 9 - user Persona deep dive

Group	Personas	Jobs to be done	Existing Solutions/Approaches	Pains & Gains
TEED Residents & Citizens 	**Tenant** **Home-owner** **Visitor** **Employee**	• Acquire basic needs – welfare, wellbeing, health, prosperity) • Provide and support family • Access to services (visibility & transparency) • Minimize cost of living relative to earning • Participating and influencing local environment • Utilizing transport	• Public transport services – road, rail, air • Citizens' advice • Smart energy meters • Household recycling services • Local government website/support applications • Healthcare services, NHS • Community groups • Charities	• Congestion, road safety & air quality • Lack of low carbon mobility • Poorly insulated properties, cost of energy • Lack of leisure/green spaces • Poor digital connectivity & digital ability • Limited voice and influence • Transparency in public decision making • Active and tailored information for local services • Community engagement • Acceleration of digital services • Information to the pros/cons of future investments as balanced appraisals
Institutional Investor 	**Large Investors** **Pension Funds** **Funding** **Community**	• Secure return on investment • Access to grants & incentives to support investments • Access to well formed, impactful, stakeholder groups • CSR benefits • Workforce/supply chain to undertake work(s) • Ability to shape and influence leaders • Managing impact of regulation • Assessing lifecycle of investment	• Community and social value framework portal • Stakeholder networks, lobbying mechanisms • Capital markets & venture capital • Planning & land use analysis • Building on community strengths	• Physical access limitations, transport • Constant upgrades to key infrastructure • Risk to investments • Reputation of area & associated risk • Feedback mechanism for investment proposals • Community resourcing & capabilities • Reducing community resistance to proposed investments

Figure 10 - user Persona deep dive continued

5. DIGITAL TWIN USE CASES

The potential of any Digital Twin is limited only by ambition and resources; it is feasible to create a digital representation of any process, asset or place within a digital twin. However, a critical input into defining what role the digital twin should play, and thus how it will deliver value and impact, is to frame central use cases which tie the art of the possible into tangible outcome(s) for the region and its stakeholders.

Based on the personas developed during the workshop and their respective challenges, jobs to be done, and pains/ gains, the stakeholders were able to determine a broad set of use cases aligned to four main themes. Siemens have further worked to cluster and combine similar use cases, merging the descriptions and content of these, resulting in eleven distinct use cases for the East Birmingham/ TEED Digital Twin solution. Many of the resultant use cases satisfy the needs and goals of multiple personas simultaneously. Figure 11 below shows the final use case titles aligned to the four thematic drivers. Section 5.1 Use Case Descriptions gives further detail around these.

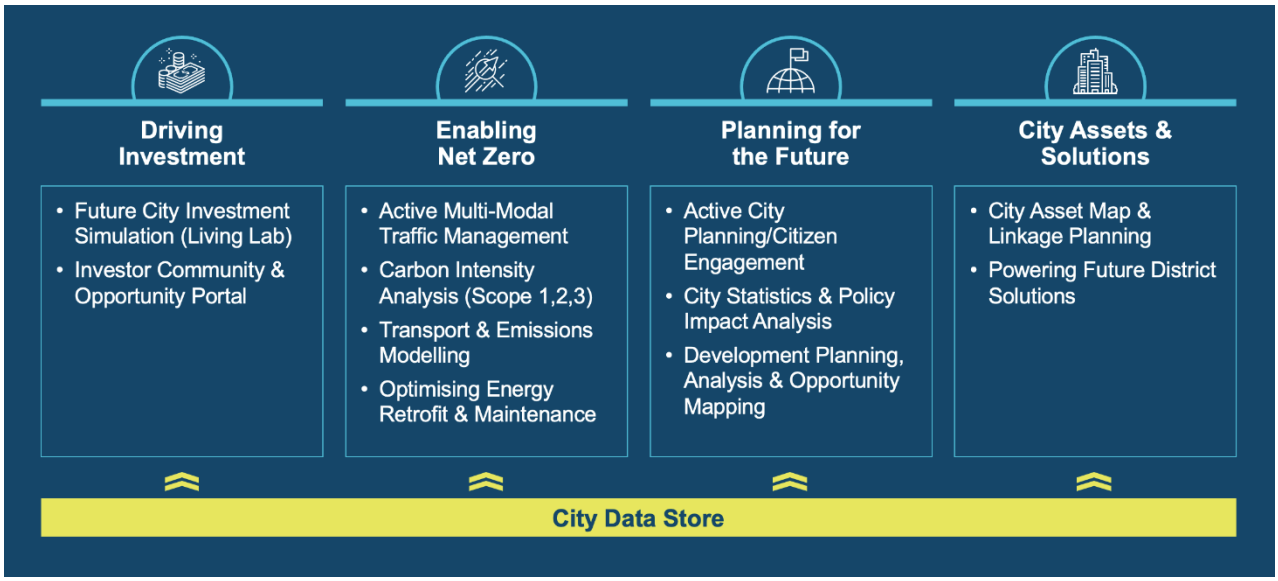


Figure 11 - consolidated digital twin use cases aligned to key themes

5.1. Use Case Descriptions

Full descriptions of the eleven condensed use cases for the East Birmingham digital twin solution are shown below, numbered for ease of reference only. The priority and implementation order of these use cases is shown within an indicative roadmap (Figure 14) however this is intended to be shaped based upon the targeted funding streams available. Section 6.5 shows an indicative roadmap based on the assessment of potential impact and feasibility of use cases, but this is flexible and to be confirmed.

1. **Use Case Title:** **Investor Community & Opportunity Portal**

Use Case Description: Creating an ecosystem and environment which supports active investment within a city is critical for its continued growth, development and to enhance the lives and experiences of its citizens. For East Birmingham and the TEED district this is a central part of the levelling up agenda, creating impactful and lasting people-powered change. In equipping the digital twin with capability to support the varied investor community, this use case seeks to enable a prosperous and equitable approach to regional investment.

This could include creating a common portal for investors and investment related activities, considering how investors undertake and coordinate individual investment activities and submissions within the East Birmingham and TEED region. Providing not a trusted shared centre, for data and digital asset exchange between relevant parties (for example the

investor and city council), and additionally supporting stakeholders with the provision of data related to the specific investment in question.

Providing access to key data sets and modelling capability may also allow the green credentials and local value add of the proposal to be analysed. For example, reflecting how proposals may enhance regional workforce provisions, impact availability and skills of citizens, and possibly assess relevant emissions associated with the proposal.

Further, such a trusted shared centre for investment could give rise to community-led investment proposals. Allowing local communities and citizens to define credible proposals which would enhance their environment and livelihoods, supporting either external investment to realise the idea or optional crowdfunding from the citizens and communities themselves. Should such proposals be generated and modelled within the digital twin, the ability to proactively engage investors to raise visibility of such opportunities could also be provided.

2. **Use Case Title: Future City Investment Simulation (Living Lab)**

Use Case Description: A city, and its regions, are in constant flux – always evolving based on many micro and macro influences. For an investor, whilst such change and variability are inevitable, there is a need to manage the exposure to significant unexpected changes which could materially impact the investment.

Using a digital twin to bring together the living 'layers' of the city; to create a holistic digital representation of the built environment which can be used to model future investment simulations, forecast the impact of applicable trends and the potential impact of specific interventions. The digital twin can accelerate and enable the due diligence process required when deciding on investments. Furthermore, such ability within the digital twin to model and simulate a specific investment scenario – alongside the forecasted evolution of the area in question – will mitigate perceived risk throughout a given timeline, whilst identifying challenges which may need to be addressed to maximise the opportunity itself.

Creating a living prospectus of potential investments, to offer comparative analysis of the pros and cons of a specific area and sector, including a necessary feedback loop to investors, central stakeholders such as planning authorities, and additionally for the citizens and residents themselves. The digital twin could provide overall access to information and insight around future developments within the region.

Integrating data from such a broad set of systems in a city, to create a digital living lab, will necessitate access to infrastructure data, multi-modal transport data, multi-vector energy systems, built environment data (including property, residential, commercial and industrial) amongst others.

3. **Use Case Title: Active Multi-Modal Traffic Management**

Use Case Description: Understanding and forecasting how future mobility will look within an evolving city is a task with high importance, to ensure that decisions taken today result in services and solutions for the city and citizen of tomorrow. Increasing the understanding around current transport in all its modes, in a vibrant and busy city such as Birmingham, will give rise to vital insight around not only citizen behaviour, but also transportation suitability.

This use case will provide a holistic representation of the various modes of interconnected traffic and people flow management throughout the region, including bus, train, tram, taxi, car, cycle/scooter, foot. With a focus on improving traffic flow, especially during peak times and in key areas, with near real-time analysis to enable timely interventions. Historic data can support longer term retrospectives and the digital twin will enable more robust mid-to-long-term decision making and policy development, whilst also supporting enhancements in the existing transportation operations throughout the city.

The digital twin will look to identify, facilitate and measure the effectiveness of transport improvement measures over time; for example, dynamic clean-air monitoring and charging zones or public transit schemes, to drive behavioural change. Further detailed monitoring and predictive analysis can help to pre-empt build-up of traffic ahead of time, allowing effective interventions to be deployed quickly.

4. **Use Case Title: Carbon Intensity Analysis (Scope 1, 2, 3)**

Use Case Description: All environments represent an ecosystem of stakeholders, assets and services. Within a city such as Birmingham the breadth of these ecosystems increases exponentially as 1.15m citizens undertake their daily activities. Each of the underlying activities and services has a carbon impact, or cost, to the city and increasing visibility of scope 1, 2 and 3 emissions will be critical to baseline and advance activities in support of the cities Net Zero ambitions. This broader and deeper analysis of carbon emissions requires a significant amount of data to be collected from multiple sources and processed to give a full picture. Collaboration across the downstream and upstream sources of emissions in a reliable and repeatable way will require the digital twin to link a multitude of council, supplier, consumer and partner systems to enable regular data sharing.

In delivering accurate and reliable localised data for analysis, the digital twin will look to create a robust reflection of emissions with the intent of identifying areas for improvement and suggestive actions for the city and its stakeholders. The digital twin will combine direct and indirect emissions data from many sources, including government and national databases plus others as they become available. Within a progressive future, the digital twin could also enable crowdsourcing of data to allow citizens to map and share data directly within a peer group and/ or to the digital twin itself.

In this environment, the digital twin will be central in aligning and collating relevant data sets, whilst actively monitoring and analysing actual progress against high-level and detailed steps on the road to Net Zero within East Birmingham and TEED.

5. **Use Case Title: Transport and Emissions Modelling**

Use Case Description: As one of the big three emitters within any city, transport is a key focus of all city stakeholders, from the citizens who use personal or public transport to commute and travel, to city planners who consider how and where investment should be made to best support the needs of the current and future citizen. Transport however is not an isolated emitter, as we witness a push towards electrification of transport and heat as part of a wider low carbon transition, cities and communities will increasingly rely upon the underlying energy system, specifically that of the power grid. The low-carbon transition will bring together these three main city emitters of transport, buildings and energy in an increasingly integrated manner.

Digital twins can support the simulation of this mid-to-long term energy transition, coupling data feedback from the transportation networks alongside wider data sets, to support the strategy and policy of city-wide mobility. The digital twin could map various transportation modes, associated infrastructure, and usage patterns across the city; producing a model to calculate projected growth of emissions. This could be extended to model the associated impact to public health, to support what-if scenario planning and wider citizen engagement campaigns to drive sustainable behaviours within the transition to net zero.

The focus of the digital twin could be expanded to cover other forms of data and information related to infrastructure including green and blue spaces, social and demographics, building stock, energy, and air quality – to enable optimisation of one or multiple of these factors. For East Birmingham and TEED this could include the use of on-site energy generation in transport planning.

6. **Use Case Title: Optimising Energy Retrofit and Maintenance**

Use Case Description: Buildings are a significant carbon emitter within cities, Birmingham is no different. From a council perspective, these physical assets can range from City and Local Council offices to public facilities (e.g. swimming baths and community centres), to central services (e.g. waste and environmental management) and council owned residential properties. Of course, this perspective can be widened to consider assets from other public and private owners, including commercial, industrial and residential building assets.

Within this use case there is clear intention to focus upon the condition and retrofit of residential housing and building stock owned and managed by the council. Such buildings exist throughout the city and ensuring these are upgraded to

minimise their energy and carbon footprint, including retrofit measures to reduce consumption and even those which enable local generation at source. This is a vital activity for the city to reach its climate targets.

The digital twin will support the evaluation of a range of different retrofit measures or initiatives, modelling the impact and investment expected across the various building architypes present in city. In conducting such a modelling activity, the digital twin will enable simulation and modelling of various digital or physical retrofit measures. These can each be tested within the specific archetypes and cross defined regional areas, to inform and even optimise the overall rollout and implementation throughout the housing stock itself, balancing impact and value for the city and its stakeholders.

7. **Use Case Title: Active City Planning & Citizen Engagement**

Use Case Description: For Birmingham to succeed in its ambitions for levelling up, driven by people powered change, this use case is developed around the belief that citizens should take a much more active role in future planning decisions. This digital twin can make this process more seamless, with reduced consultancy efforts, by providing a platform and clear visualisation of planning proposals and potential impacts. As a result, it can enable more robust policy determinations and shorter feedback cycles, within a digital and publicly accessible environment.

The digital twin is intended to enhance city policy and regeneration planning, bringing citizen requirements and feedback directly into the process in a timely manner, based upon the insight captured within the digital twin. The outcomes and benefits are based upon increasing citizen and stakeholder engagement and awareness of planning proposals; making visible the factors which influence planning decisions, whilst enabling improved and aligned decision making against the residents' priorities. This forms a tool to communicate the reasoning behind policy decisions and desired outcomes, creating engagement and transparency with citizens, and providing a feedback loop to gather input to shape policymaking. Assessment of policy outcomes can be achieved, by analysing data sets relating to measurable outcomes and direct qualitative assessment from citizens.

The digital twin could provide a visual gateway capturing current and past planning decisions, inclusive of intended goals and outcomes, on a localised and aggregated city-level. This simulation tool will allow for the evidencing of the reasons behind planning decisions, plus and projected short and long-term outcomes.

8. **Use Case Title: City Statistics & Policy Impact Analysis**

Use Case Description: The role and voice of citizens will be central to successful levelling up, and the long-term impact of the associated investments and interventions. Ensuring the digital twin is a public tool to drive engagement is vital, as outlined within the use case 'Active City Planning & Citizen Engagement' however as is the need for city and local council teams and stakeholders to model pre-public scenarios as to where and how policy proposals could be focussed and constructed.

The digital twin enables powerful and intuitive visualisation of real-world data, with the available data or level of detail tailored to the user who is accessing it. The twin allows simulation and scenario modelling, targeted to analyse the overall impact of policy decisions at a city, region or hyper-local level, especially related to levelling up and regeneration. The city council can use these capabilities to both improve the policy decisions being made based on projected impact, but also to compare and visualise the merits and drawbacks of multiple possibilities to show the reasoning behind policy decisions.

Further, this use case can provide wider access to city statistics and data for operational use, improving efficiency and effectiveness of day-to-day activities and processes.

9. **Use Case Title: City Operational Planning, Analysis & Opportunity Mapping**

Use Case Description: A city is broadly dependent upon its, often underground, ecosystem of services, from utilities, to transport and on. Any works undertaken in these subterranean environments will have a consequential impact to the citizens and stakeholders of the city. From vehicle and transportation disruption by independent organisations, to service down-time and interruptions for down-stream users.

In developing a digital twin to enhance the operational and planning requirements of the city, it will help limit user disruption faced during times of maintenance outage or interruption of key infrastructure and citizen services. The twin could allow for coordination of planned outages, for example within subterranean duct works holding multiple utility assets, limiting disruption to the city. Further, the digital twin could enable the identification of potential bottlenecks within the underlying infrastructure connecting the city; visualising the interlinking planning projects and considering process flows, all within an interactive model.

10. **Use Case Title: City Asset Map & Linkage Planning**

Use Case Description: In a world of connected devices, assets and systems, there is a vast amount of data – data growing at an exponential rate throughout all sectors. Within a city and its regions, many stakeholders create, own, and even share data – from citizens to councils, to utilities and beyond. In accessing existing, and future, data sets for the digital twin, the countless assets and systems which underpin a modern city can be digitally represented. This use case utilises the approach of standardising and formatting data from multiple sources into a common ontology; this ontology will identify and map the relationships within the data.

This application of the digital twin will provide a holistic representation of this complex-built environment, mapping public and private assets throughout the city. It will have a primary focus towards energy and utility, transport, public and authority data, and environmental data. Mapping and charting the core assets and systems throughout the city region will provide insight into where and how a 'whole systems' approach can yield enhancements, from existing assets – offering simulation and predictive modelling abilities to support planning and operations.

11. **Use Case Title: Powering Future District Solutions**

Use Case Description: engaged citizens and broader stakeholders, who have a vested interest the district and its people, can be empowered to create significant positive impact, drive community initiatives, and help define and progress topics which are of primary importance to the people in the area. They can go the extra mile in supporting the definition of issues and problems they and their fellow community members face; problems which could be addressed with targeted actions identified the digital twin. Moreover, this is a service which can be utilised to model and plan new initiatives that could bring benefit to the city, e.g. new communications networks.

Consider how the community can use the digital twin to highlight common issues, providing early and measured indication of emerging and current concerns of citizens as a voice for their community.

The digital twin can power top-down or bottom-up analysis of a region, enabling planners to model the impact of future district solutions and engage with citizens as to the impact, benefit, and costs to undertaking key activities. This will form a basis from which to build analyses and simulations, modelling future solutions and prospective opportunities within the region. Not only will this support the citizens in identifying and raising challenges/ opportunities, but also provide support for informed policy making, advancing stakeholder engagement strategies, and enhancing investment approaches.

This approach will enable the impact assessment of new technologies, innovations, policies and societal behavioural change measures. Examples include: planning and investment in EV charging infrastructure, 5G+ communications, alternative fuels and renewable generation projects, changing work patterns and coworking, industrial ecology and environmental initiatives and more.

6. REALISING THE DIGITAL TWIN

In defining the solution concept for a digital twin, one which addresses the needs of the numerous stakeholder groups as part of a wider aspiration to lead the global conversation on smart and impactful digitalisation of a city, it is critical to jointly define a set of solution requirements.

6.1. Key Digital Twin Requirements

The Digital Twin represents an opportunity for Birmingham to empower and enhance activities across the city, now and into the future. It is therefore important to consider future use-cases from the start, to create a digital twin that will scale, and will last far beyond the initial scope; to create a valuable Digital Asset for the city to continue to benefit from. In the value identification workshops, we explored the requirements that form the basis for the digital twin solution framework, covering several areas:

- **Functional Requirements –** specifying what the digital twin must do to achieve the use-cases defined i.e. the features, capabilities or tasks that it must accomplish to enable users.
- **Non-Functional Requirements –** these describe properties or qualities of the digital twin that determine its effectiveness and wider impact beyond specific features i.e. *how* the digital twin achieves tasks.
- **Data Requirements –** data sets that will be required to enable the digital twin functionality and use-cases
- **User Experience –** describing how users should be able to interact with the digital twin and its overall look, feel and accessibility.

Requirements across these categories have been distilled down into a set of key requirements for the digital twin solution as a whole; specific functions relating to a single use-case will be described in section 6.5 Use-Case Roadmap. In addition, we have aligned these with the Centre for Digital Built Britain Gemini Principles: proposed principles to guide the national digital twin and the information management framework that will enable it.

The digital twin should:

- **Deliver public good**
  The digital twin should serve as digital asset for the city which generates benefit for its citizens long into the future and be designed with citizens in mind. (Gemini Purpose Principle)
- **Make use of Open Standards**
  Enabling 'software to interoperate through open protocols and data exchange to occur between software and data stores'[1], avoiding any data islands and maximising applicability and usage. (Gemini Trust Principle)
- **Be scalable and extensible**
  The solution should allow for a small initial starting point focused on a small number of use cases, but scale to many more use-cases over time as needs are identifies and investment is secured; it should grow with the city.
- **Be modular and federated**
  Acting as a framework and providing the underlying enablement for various functions or use-cases to be added as 'modules', making use of existing capabilities and data. Bringing together powerful technology components and linking into a landscape of existing systems and data. (Gemini Function Principle)
- **Ensure trust and accuracy**
  Users must be confident in the accuracy and quality of the data represented, to be sure that they are making decisions based on reliable information. Transparency around data sources, calculations and visualisations supports this. (Gemini Trust Principle)
- **Have a common ontology**
  Creating powerful insight by bringing together data from multiple sources and mapping the relationships between them, identifying patterns and interdependencies.
- **Utilise APIs**
  Enabling interoperability between systems, and simplified integration of data sources, also allowing export of information to other systems.
- **Support various 2D/3D visualisations**
  Displaying information, graphics, analytics outputs in engaging, intuitive and contextual visualisations, as required to support the use-cases
- **Support simulation and predictions**
  Delivering value by using historical and live data and trends to predict future outcomes or allow modelling of what-if scenarios, related to the use-cases.
- **Support powerful analytics**

The computing power should also be scalable to support a variety of demanding use-case driven analytics, from simple rule-based analysis through to bespoke data analytics and Machine Learning.

- **Support near real-time applications**
  Whilst not needed for all use-cases, the ability to work with critical information in near real-time where required is important, e.g., for events, alerts and automated processes.
- **Generate insight**
  Providing a new and powerful understanding or visibility into the built environment, with granularity from a city-wide to a single building level as relevant for use-cases. (Gemini Purpose Principle)
- **Be flexible and adaptable**
  It is not possible to determine all the needs and applications from the outset, or how requirements will evolve, so functionality will need to be changed and expanded over time. (Gemini Function Principle)
- **Enable collaboration**
  Allowing different stakeholders and parties to work together, both on developing the use-cases in the digital twin, but also on projects or initiatives enabled by it.
- **Contribute to a broader ecosystem**
  Across Birmingham, the West Midlands and nationally, there are a multitude of digital twin projects and initiatives; the solution should interact with, and build from, these wider developments to maximise synergies.
- **Enable value creation**
  The digital twin should support the creation of real value and performance improvement for organisations, groups and citizens; outcomes should also be tangible and trackable. (Gemini Purpose Principle)
- **Support role-based access**
  Different user groups should be able to access different levels of information and applications, based on access rights defined in the system, ensuring security whilst maximising openness.
- **Have an intuitive and user-friendly interface**
  Users of differing levels of digital skills, familiarity and contextual knowledge will use the system and it should therefore be easy and simple to navigate and adapt according to user type.
- **Enable transparency and audit trails**
  In a collaborative, multi-party system, it is important to be able to see the changes made by other users, to be able to trace the origins and transformation of information, also to build trust and enable governance.
- **Have clear ownership & governance**
  To ensure longevity of the solution and to realise the full potential value, whilst ensuring data quality and managing maintenance and further development into the future. (Gemini Function Principle)
- **Ensure privacy and GDPR compliance**
  Have mechanisms in place for classifying and handling sensitive data, ensuring it is kept secure and personally identifiable data is handled in accordance with GDPR regulations.
- **Be secure**
  Users must be able to trust the security of the solution and the integrity of the data and information within it. (Gemini Trust Principle)
- **Be regularly updated**
  Both in relation to the data contained within to ensure relevance, but also the software and applications to fix any bugs or vulnerabilities in the solution or any components.
- **Be maintainable and supportable**
  The long term-term operation and function of the digital twin should be ensured, making sure it is developed in a way that can be easily maintained by the original supplier or by others.
- **Be provided according to a flexible business model**
  The investment and revenue models for the digital twin are yet to be defined, therefore implementation of the solution may need to be split into separately funded parts, or support a number of revenue generation mechanisms e.g., licensing of features.

6.2. Defining an Open Solution Architecture

Based on the requirements described above and the use-cases currently defined for the digital twin, we propose the following concept architecture for the solution. This architecture describes the various elements needed to deliver the digital twin functionality, with a focus on reusability and scalability into the future. The architecture is vendor-independent, and each of the various elements and components can be provided in several ways, which would be decided later in a

detailed solution design. The architecture describes a modular and federated basis by which all digital twin functionality will be enabled. This section contains technical descriptions, which may not be relevant to all readers of this report.

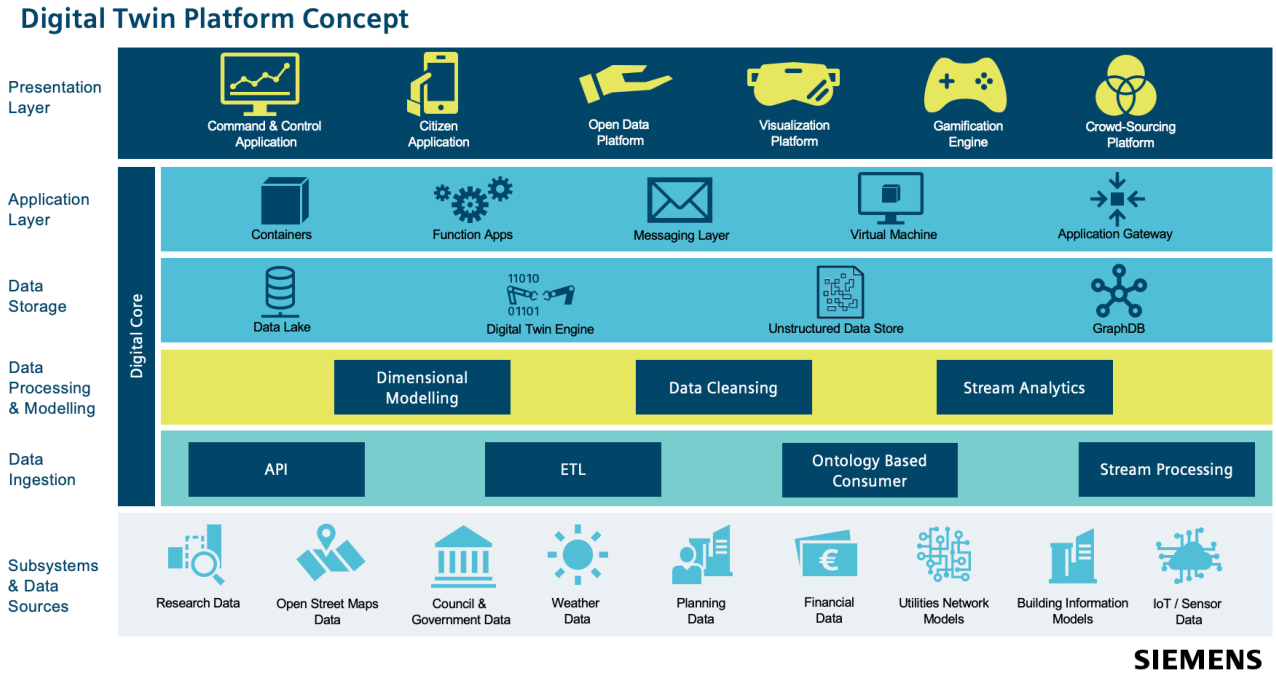


Figure 12 - High-level open solution architecture diagram for the digital twin.

We foresee connecting into an existing technical landscape, including existing on-premise hosted systems and solutions, third party systems and solutions, and the cloud hosted scalable environment to provide the compute and storage required for the newly developed use cases. It is our recommendation to connect the on-premise environment through a private link to the cloud where a consistent dependable bandwidth is required. This also keeps traffic segregated from the regular internet gateway and provides certainty of attainable transmission speeds. Coupled with the use of encryption, this provides a good level of data security while data is in transit.

To remove point to point integrations and create a repeatable scalable platform, we recommend that a Services Orientated Architecture (SOA) is deployed. This will provide many long-term benefits, such as: easier future integration changes or additions, the ability to scale different components of the solution independently, and enabling greater reuse of integration points data and capabilities. To support this SOA, we recommend the addition of a messaging layer, to enable the use of queues and to de-couple the components, enabling greater future flexibility. This will also enable the scaling of components, as additional computing instances can be added to assist with peaks in demand. The scaling can be based on the depth of these queues and can therefore be automated. The use of queues also has the benefit of increasing resilience of the solution, making it possible to allow initial components in the process flow to receive and start processing data, even when the next component is unavailable or busy processing a backlog.

The function and purpose of the layers in the above architecture diagram are described below, descriptions of each element within the proposed architecture diagram are show in Annex B: Solution Architecture Component Descriptions.

Subsystems and Data Sources – Data required for the digital twin use cases is generated across the city, contained in a wide array of different systems or repositories in various locations. These systems and sources need to be integrated to make the data available, either from a central location, or through a request to the relevant system as required. Data sources are discussed in more detail in section 6.4 Data and Systems Baselining.

Data Ingestion – These are the methods of bringing data into the digital twin; from static datasets (where the need is to load a large amount of data to support a use case such as energy network analysis), to APIs (where either a well-formed API is available such as weather forecasts or large datasets where only a subset is required for the use case). APIs can also be used to ingest fast moving data such as network states, GPS tracking, air quality sensors etc.

Data Processing & Modelling – data from multiple sources needs to be collated, standardised and modelled in order to be used effectively by the digital twin and the relevant use case applications. This layer ensures data quality and reliability of the data that exists in the overall solution.

Data Storage – not all data will be stored within the digital twin, only when it is required or preferable for the data in question. Data storage is used to hold relevant data, typically in cloud-based storage, or it may be stored in the system in which it was originally generated.

Application Layer – This is where the logic and intelligence relating to the use case applications reside. For each use case, app functionalities will be built to turn the data input into insight, actions, visualisations etc.

6.3. Data and Systems Baselining

Data is a key enabler for the Digital Twin. Through the Value Identification workshop, we discussed the data available across the city, which could be utilised, along with data sets that exist but are not currently available. The data sets discussed have been consolidated into several categories relevant across Birmingham.

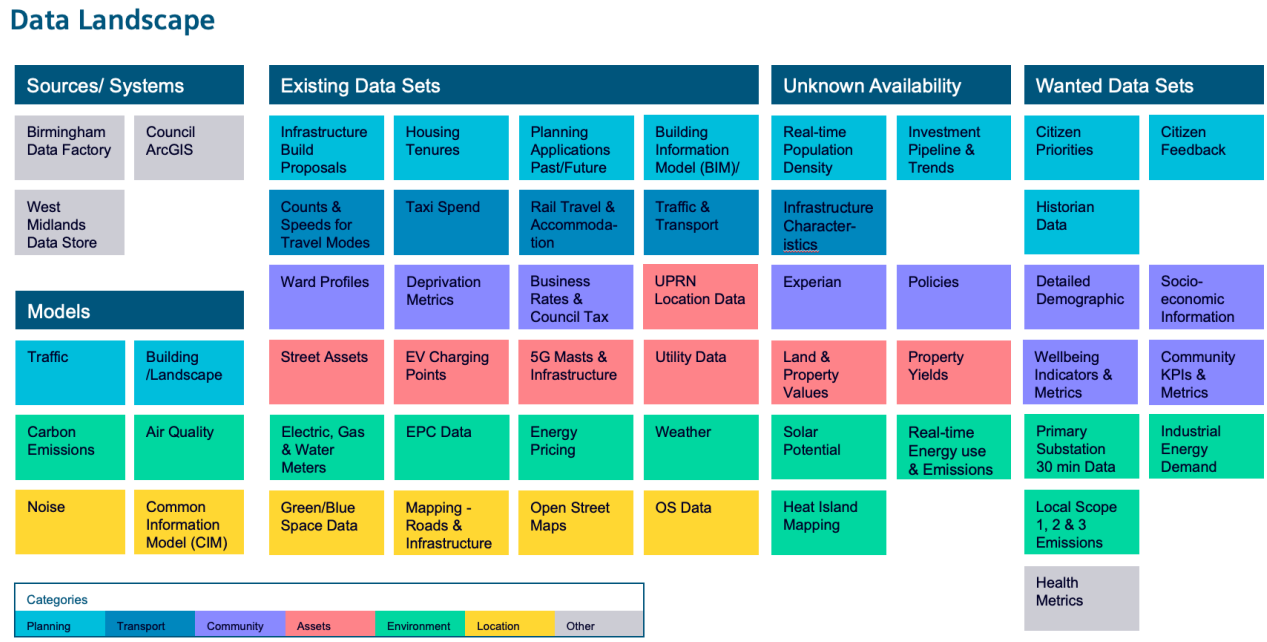


Figure 13 - High level data landscape for Birmingham, defined in the workshop

Data availability and quality plays a significant role in the selection of use cases to deploy in the digital twin, and in the ability to implement the chosen use cases. For all the required data sets, it is an important preparatory task to understand the availability and accessibility of data sets, along with the relevant sources and responsible parties that would need to be considered as part of the digital twin implementation. We have created a living document covering all these elements, as an annex to this report 'Data Discovery Table East Birmingham – V1.0'. This a table of collated data sets, categorised as above, with the detailed supplementary information.

6.4. Data considerations

Not all data required by the digital twin will be equally accessible and there may be some significant barriers in place that need to be overcome. Considering these as early as possible is an important success factor.

Data Best Practice Principles

Following the publication of the Energy Data Taskforce Report (EDTF) report BEIS, Ofgem and Innovate UK formed the Modernising Energy Data (MED) group to continue to push forward the recommendations of the EDTF. This group commissioned the development of Data Best Practice Guidance with the intention of providing the energy sector (and

beyond) a clear set of principles which describe data best practice accompanied by techniques and examples of how these principles could be implemented – Siemens supported this engagement throughout which culminated in a conceptual open-data platform for the energy sector. The twelve principles should be considered throughout the implementation of any digital twin, especially one which seeks to bring together the energy, transport, utility and built environment.

1. Identify the roles of stakeholders of the data
2. Use common terms within Data, Metadata and supporting information
3. Describe data accurately using industry standard metadata
4. Enable potential users to understand the data by providing supporting information
5. Make datasets discoverable for potential users
6. Learn and understand the needs of their current and prospective data users
7. Ensure data quality maintenance and improvement is prioritised by user needs
8. Ensure that data is interoperable with other data and digital services
9. Protect data and systems in accordance with Security, Privacy and Resilience best practice
10. Store, archive and provide access to data in ways that maximise sustaining value
11. Ensure that data relating to common assets is Presumed Open
12. Conduct Open Data Triage for Presumed Open data

Licensing

It is important to note that there are licensing agreements for each respective data source which is defined in a separate Data Discovery Table, a parallel living document for the city. There are a wealth of license types available depending on how the owner wishes to release the data, but also provides the data user with a clear understanding of what they are able to do with the data once it has been received.

We have categorised these into three groups:

- **Open** (Green) – This would be public domain data such as an OGL license where the data is accessible and be exploited for both commercial and non-commercial reasons.
- **Restricted** (Amber) – Data that is accessible and that has a specific set of terms regarding the use of data this can also include having to register to access the data.
- **Closed (Red)** – Data that is not accessible and not available to redistribute this can be accessed by contacting the owner of dataset however this would mean a special data exemption given to the person using the data and a change in license with terms needing to be agreed that can take a while to get traction on.

There are several standard licences which are already well understood which ensure that potential users know what they can and cannot do with data. The majority of these licences relate to open or permissive licences. See 'Data Licensing & Standardisation'[48] report by Siemens and Energy Systems Catapult for further detail.

Category	Description	Licence
Public Domain	Resource is dedicated to the public domain. Publisher is relinquishing all rights to the dataset	**PDDL:** This license is one of the open data commons licenses and is similar to public domain dedication. It allows you as a dataset owner to relinquish your rights in a dataset when you might otherwise not be able to dedicate your dataset to the public domain.
Creative Commons	A range of more permissive licences that make resources available to a wide audience with some limited restrictions	**CC-0 :** One of the most open creative commons licenses, similar to public domain and means the publisher has relinquished rights to the dataset, where they have not been able to dedicate to the public domain **CC-BY :** An open creative commons license, whereby the dataset user can share and adapt the dataset, but must give credit to publisher **CC-BY-SA :** Creative commons license where the user can share and adapt the data set, so long as they give credit to the publisher and distribute any additions, transformations or changes to the dataset under this license. Can be problematic, as user may decide not to use license as there is a risk that their work in the dataset will need to be shared also. **CC-BY-NC :** A more restrictive creative commons license, where the user can share and adapt the dataset, as long as they give credit to the publisher, but they may not use the dataset for any commercial purposes.

Category	Description	Licence
		CC-BY-ND: Creative commons license where the user can share and adapt the dataset if they give credit to the publisher, but they cannot make any transformations, additions or changes to the dataset under this license. **CC-BY-NC-SA:** Creative commons license where user can share the dataset if they a) Give credit to the publisher, b) Do not use the data for commercial purposes and c) Distribute any additions and transformations or changes to the dataset under this license. Users will need to share their work under this license and any users of the adapted dataset and so on. **CC-BY-NC-ND:** A restrictive creative commons license, where users can share only the publishers unmodified dataset if they give credit to the publisher and do not share for any commercial purposes. Users can not make any transformations, additions or changes to the dataset under this license.
Community Data Licence	Collaborative licenses to enable access, sharing and use of data openly among individuals and organizations. A Linux Foundation project.	**CDLA-Permissive 1.0:** One of the community data license agreements, similar to the permissive open-source licenses. It allows the user to use, modify and adapt the dataset and the data within it, as long as they give credit to the publisher. **CDLA-Sharing 1.0:** One of the community data license agreement licenses and was designed to embody the principles of 'copyleft' in a data license. It allows users to use, modify and adapt the dataset and the data within it, and to share the dataset and data with their changes, as long as they do so under the CDLA-Sharing and give credit to the publisher.
Open Data Commons Licence	Open Data Commons exists to provide legal solutions for open data. An Open Knowledge Foundation project.	**ODC-BY:** One of the open data licenses and allows users to share and adapt the dataset, as long as they give credit to the publisher **ODC-ODbl:** One of the open data commons licenses and allows users to share and adapt the dataset, so long as they give credit to you and publish any additions, transformations or changes under this license. Problematic as there is a risk that any work done on the dataset will need to be shared under this license.
Other		MIT Licence Copyleft (e.g. GNU) Open Government Licence (OGL)

Table 1 – Extract of the Siemens & ESC Data Licensing & Standardisation Report[48]

Challenges

Many stakeholders hold data is a valuable commodity which in the current market and the digitalisation journey that each organisation is on can vary. In respect to data, this means that organisations' understanding of the use of the data can be complex and there can be a reluctancy to release data for use in the digital twin. Additionally, once a product has commercial success there can be organisations or individuals who may later wish to challenge the use of the data. Hence, it is important to have clear use cases with clear identification of the types of data being used, along with how and when these will be used. This can also support the compliance process if someone wishes to challenge the usage of the data by the digital twin. It would also be wise to have strong relationships with the organisations that are providing data for the solution, as the solution is ultimately reliant on the data available.

Compliance/ Citizen

There are a few datasets which will be required around the categories of planning, community and location. It is important to stay compliant with relevant legislation, namely GDPR (General Data Protection Regulation) and the Data Protection Act. Personal identifiable information should be used as sparingly as possible, and one should seek to use the minimum amount of personal information to achieve the solutions requirements. Where personal identifiable information is used, the purpose must be clear so that there is a lawful basis to process the data, but also that users are

informed accordingly. Additionally, users have the right to request their data and so systems should be in place for users to request any data held relating to them.

Scalability

Digital twins need to evolve with the physical world. One element of this is the data that is being processed and used for the twin. As the world uses more digital technology the ingest of data will increase. This means that the computing infrastructure and storage, that powers the twin environment, should have the ability or capacity to adapt to use cases and scale based of the size of data that is being processed and the number of users. To manage this, there should be a well-designed data architecture, this would be one that avoids data being siloed and is easy to integrate and manage, whilst being efficient in terms of power consumption and transmission of data.

6.5. Use Case Roadmap

The following roadmap shows the use-cases identified for the digital twin, and a suggestion for how these could be deployed over time; from those that are more easily achieved with currently available data and proven technology tools and capabilities, through to those which are more complex and ambitious, relying on new and developing technology. The goal of the digital twin is to be an exemplar for the city and a showcase for how this technology can add value, so it is important to consider ambitious and novel use cases, alongside those that provide more immediate value creation. This will help to engage stakeholders and provide credibility to the overall programme, demonstrating or testing elements of the strategy. Full descriptions are provided in Section 5 Use Case Descriptions, whilst the technical descriptions of the use cases is provided in Section 6.7 Use Case Technical Requirements below.

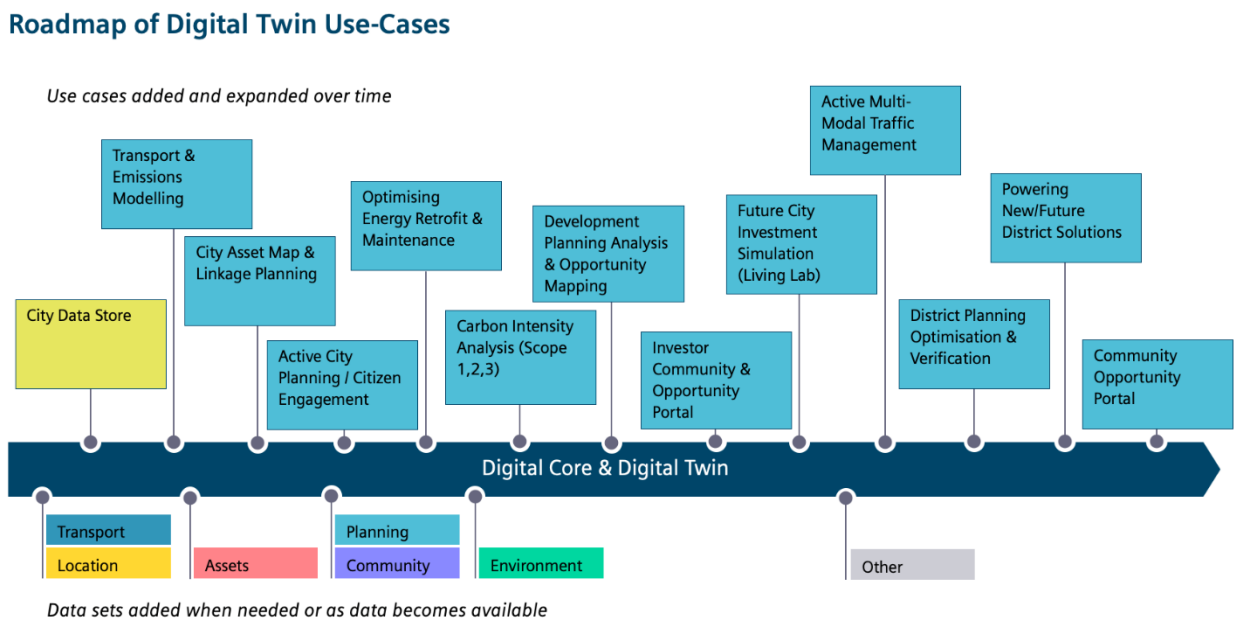


Figure 14 - Indicative roadmap of use cases for development in the digital twin

The proposed solution concept maximises repeatability and reusability across use cases, ensuring that an investment into the digital twin can be further utilised in subsequent use-cases. The scalable approach utilises a modular framework built around the concept of a 'Digital Core'. This core refers to the base platform, integrations, data management and intelligence that is built and added to over time. The Digital Core is the underlying enabling investment that powers the digital twin and all current and future applications, ensuring accurate, timely and usable data.

Data is collected from a variety of sources, spanning from Building systems and IoT Sensors, to city-wide data repositories, through to national databases and global external data sources. As each use case or set of use cases are funded, the efforts to implement the required integrations are undertaken and they are added to the digital twin solution. Further use cases can make use of data already present in the digital twin environment and can therefore benefit from lower implementation costs and a faster time to impact. The power of the digital twin continues to grow over time. Research

groups and other users are then given access to an ever-expanding set of data to experiment with, helping to conceptualise new use cases and grow new capabilities. This can also help to expedite new funding bids, for evidencing available data and supporting preliminary proof of concepts.

6.6. Base Platform Technical Requirements

To create the digital twin platform certain core requirements and functionalities must be realised. These are the base components which will enable the creation of the use cases.

Functional Requirements:

- **Identity & Access Management (IAM)**
  The creation of a federated Identity & Access Management layer which will allow Birmingham City Council and other partner organisations to access the provisioned environment using existing and trusted directories. The IAM must also be able to authenticate and authorise users where no federated service exists and can also scale for the open data platform use case.
- **Monitoring**
  Monitoring will be a crucial part of the platform and will enable active alerting and monitoring of the entire platform. Any alerts or events can then be directed to the relevant teams for resolution. The monitoring solution will also interact with cloud native services to flex the underlying services so that the platform serves the use cases it hosts, whilst being cost efficient.
- **Integration**
  To connect the various systems together and enable the sharing of information and capabilities a combination of a messaging layer alongside an API Layer/Gateway will be deployed. These two components will allow for the re-use of functions or messaging, utilising queues and topic threads from earlier use cases, to be quickly deployed later. The messaging layer also aids in de-coupling the solution components and so is fundamental in enabling the micro-services environment, which will allow the platform to flex components individually. It also provides an additional level of resilience into the system due to the ability to queue events/requests should a component suffer an outage.
- **Storage**
  The initial deployment of the platform should include storage in various forms such as databases, blob storage and virtual file systems/hard drives to support the core platform.
- **Compute**
  The creation of the API Gateway and the governance around code deployment will be a pre-cursor to the delivery of the initial use cases. The governance is tightly coupled with the version control & collaboration toolset and therefore this toolset will need to be deployed prior to code deployment/development.
- **Security**
  Alongside the IAM component the base platform will need a robust security design and governance model. The platform will not only host a vast amount of data, but also potentially provide prescriptive recommendations or actuate controls in the physical world. It is therefore crucial that the platform is protected against physical or digital security risks. These include components such network ACLs, Firewalls, resilience planning, disaster recovery planning.
- **Virtual Networking**
  The network connectivity between the existing systems is fundamental to enable data to flow from the on-premise solutions into the new platform. The design of which will need to provide the required Recovery Time Objective and align to other non-functional requirement metrics. It is envisaged that a private connection between the on-premise environments and the cloud will be required and so the configuration of a VPN Gateway will need to be undertaken, along with the various routing changes required to direct traffic into the new platform. Once in the platform a hub and spoke network topology will need to be defined so that a re-usable pattern can be used to allow future use cases to access virtual machines and Software-as-a-Service components via private endpoints can be utilised. At this stage administrative access will be implemented using patterns such as bastion hosts, which will be designed and deployed.

Initial System Integrations:

- Cloud integration via VPN
- On premise service bus to cloud service bus instance

6.7. Use Case Technical Requirements

For the eleven use cases described in Section 5 Digital Twin Use Cases, each has been further analysed below to determine the potential functional requirements for the digital twin solution. Additionally, we have indicated the likely relevant systems which would likely need to be integrated to support the digital twin use case in question. Finally, the data required from these (and other) systems to enable the use case. A follow up step, typically done as part of the detailed solution design phase, would be to agree on which of these functional requirements are must have capabilities. The remainder could be considered as future expansions to the use case.

Transport & Emissions Modelling

Functional Requirements:

- Combined map of city/regional spaces and transport infrastructure
- Map view with overlaid data e.g., heatmaps of emissions or traffic, motion trials for route analysis, POIs for major transport nodes, colour-coded points for alerts and issues
- Combining multiple layers/modes of transport data (bus, rail, car, active) from different sources
- Analysis of energy use and emissions from transport, filterable by period, mode, emissions
- Modelling of relationships between modes of transport, including interdependencies
- Simulation of impacts of interventions across transport network

System Integrations:

- Transportation management systems from public transport providers
- City CCTV platform
- Clean air congestion charging system
- OpenStreetMap

Data required:

- Road network data
- Air quality sensor data
- Traffic congestion information
- Public transport occupancy information
- Road works locations
- Public transport vehicle tracking

Investor Community & Opportunity Portal

Functional Requirements:

- Portal User Interface, allowing users to create an account or log in, role-bases access to areas in the portal
- User profiles, perhaps imported from another platform e.g., LinkedIn
- User interaction mechanism e.g., internal messaging
- Free to use portal, but support for additional revenue models e.g., premium elements may be needed
- Submission form for new opportunities, with possible workflows for moderation and governance
- Data catalogue/repository access (role-based)
- Modelling and scoring of new investment opportunities against defined criteria (from own data input or validated data in twin) – e.g., enter high level details of opportunity which are converted to KPIs and mapped against city data to give impact score and allow filtering of opportunities
- Homepage view with engaging presentation of investment opportunities and KPI
- Tailored news feed and adjustable notification preferences for users

System Integrations:

- Identity Access Management system
- Social Media platforms
- OpenStreetMap

Data required:

1. Investment opportunity data
2. Land mapping/OS Data
3. Investment norms and standards
4. Utility/transport infrastructure data
5. City KPIs

Future City Investment Simulation (Living Lab)

Functional Requirements:

- Map with overlay of multiple sources of data, relating to buildings, land areas, organisations etc.
- Ability to create new investment opportunity in Twin, uploading relevant data e.g., plans, BIM
- Option to create a new investment scenario, inputting parameters that the project will impact, with projections over a time period, to simulate impact.
- Ability to select existing assets, land areas etc. to submit investment opportunity against, or to compare multiple investment opportunities against these.
- Modelling of impacts across layers in the twin e.g., building is proposed with X people capacity Y projected energy load profile and Z on-site generation, the twin models the impact on energy network, transport, jobs...
- Modelling of investment scenarios, based on CAD plans, BIM data, manually inputted data around projected outcomes.
- Simulation of impacts of developments based on historical city data, agreed standards or regulations, and development plans.
- Automatic generation of high-level business case, with editable sections pre-filled with suggestions from available data (with traceable sources and calculations), based on standards
- Ability to compare multiple simulated investment scenarios
- Monitoring and measurement of KPIs detailed in the business plan once investment has been done, to validate actual versus projected outcomes of any investments made, with feedback loop within the model

System Integrations:

- Identity Access Management system
- BIM Repository/Viewer
- Planning Portal/ Database
- Investment news feeds
- OpenStreetMap

Data required:

1. Investment opportunity data
2. Land mapping/OS Data (land boundaries)
3. Investment norms and standards
4. Financial/economic projections (rates)
5. Utility/transport capacity and infrastructure data
6. Location-relevant data

City Asset Map & Linkage Planning

Functional Requirements:

- Common ontology to identify relationships between different asset-related data sets
- Network and infrastructure mapping, showing current connectivity, energy assets and major loads
- Mapping of different types of city assets in layers, with the ability to toggle visibility
- Ability to select energy assets to see further detailed information, data visualisation
- Modelling to identify possible optimisations, or linkages required
- Simulation of different linkage scenarios, to understand how proposals would impact the wider network

System Integrations:

- OpenStreetMap

Data required:

1. CIM
2. Energy Asset information

Optimising Energy Retrofit & Maintenance

Functional Requirements:

- Database linking various properties and parameters to housing stock, e.g., EPC data, asset information
- Overlay on map of detailed information to allow selection/filtering/simulation by geographical area
- Address tagging and parameters to enable identification of suitable candidates for retrofit initiatives
- Linkage to maintenance schedules, with logging of required and completed activities
- Ability to create new complex filters to select buildings for retrofit, with export of results

- Gap analysis to identify missing data
- Ability to add additional external data sources or sensors to capture missing data
- Rollout planning tool to optimise rollout by impact, need, available funding etc.
- Automatic notifications to subscribed users on status and progress of retrofit activities
- Simulation of various rollout scenarios; ability to create new intervention with a set of parameters and apply selectively to filtered areas/buildings to understand impact.

System Integrations:

- OpenStreetMap
- Address database

Data required:

1. Housing stock information/categorisation
2. Land mapping/OS
3. Retrofit cost standards/variables
4. EPCs
5. Resident contact details

Carbon Intensity Analysis (Scope 1,2,3)

Functional Requirements:

- Combined database of emissions data, with resolution.
- Mapping of emissions data against geographical zones, showing if data has been collected at the required granularity or interpolated for the given area
- Traceable audit trail for data e.g., supplier or end user generated data
- Categorisation of emissions data from multiple sources, aligned with the scope 1,2,3 categories
- Ability to filter by category/area/emissions type/data source etc. for investigation
- Visualisation and graphing across adjustable timescales with ability to overlay different sets of data
- Historical, current and projected emissions data representation
- Monitoring against set KPIs or a roadmap, with validation of progress to see if targets have been met
- Analysis to highlight key areas for concern or focus
- Gap analysis to identify missing data

System Integrations:

- National databases for emissions data
- Utility operator metering systems
- MDM systems
- Environmental monitoring systems
- OpenStreetMap

Data required:

1. Utility consumption data (aggregated and granular)
2. National emissions data (local allocation)
3. Energy consumption data from major consumers
4. Known emissions data (direct/supply chain/consumer)
5. Adjacent data sets for emissions calculation (e.g., transport)
6. Environmental data (temp, air quality)

Development Planning, Analysis & Opportunity Mapping

Functional Requirements:

- Access to planning database to view and work with live or past applications, utilise submitted information and upload additional supporting material e.g., BIM.
- Mapping to link land, building proposals, energy networks, transport infrastructure, services, green spaces etc. modelling interactions and relationships between these and opportunity costs.
- Translation of planning objectives into a set of criteria to analyse development opportunities against
- Filtering of all opportunities, by project size, risk, timeline, local outcomes, sustainability, payback period, relevant policy etc.
- Comparative capability, selecting multiple development plans and review a matrix of options against chosen criteria
- Allow collaboration between multiple parties on a single development opportunity

System Integrations:

- Identity Access Management system
- CAD and BIM Repository/Viewer
- Planning Portal/ Database
- OpenStreetMap

Data required:

1. Development-specific data (planning/supplementary)
2. Land mapping/OS Data
3. Utility/transport capacity and infrastructure data
4. Local amenities/services (schools, healthcare, green space

City Statistics & Policy Impact Analysis

Description: Analyse the overall impact of policy decisions at a city, region or hyper-local level, especially related to levelling up and regeneration. This forms a tool to communicate the reasoning behind policy decisions and desired outcomes, creating engagement and transparency with citizens, and providing a feedback loop to gather input to shape policymaking. Assessment of policy outcomes can be achieved by analysing data sets relating to measurable outcomes and direct qualitative assessment from citizens.

Functional Requirements:

- Monitoring of a broad set of defined city measures and KPIs which can be impacted by policy changes, with relationships mapped between them
- Statistics dashboards for various city themes, with filterable/sortable views, with timeline adjustment
- Translation of policy changes into impacts against measures to allow analysis
- Tool/form to allow new policies to be added with impact on KPIs adjusted manually (absolute/percentage)
- Adjustable variables, e.g., by sliders, to show varying impacts on KPIs
- Dashboards to represent impacts of policies, with clear visualisation and supporting information
- Feedback form to gather direct citizen input on measures proposed or to be sent out as a feedback request
- Display relevant KPIs depending on user type (resident, business, investor)

Data required:

1. City KPIs and strategic objectives
2. Citizen generated data
3. Relevant data for monitoring factors

Active Multi-Modal Traffic Management

Functional Requirements:

- Combined map of city/regional spaces and transport infrastructure including active travel
- Map view with overlaid data e.g., heatmaps of emissions or traffic, motion trials for route analysis, POIs for major transport nodes, colour-coded points for alerts and issues
- Combining multiple layers/modes of transport data (bus, rail, car, active) from different sources
- Carbon intensity insights of different travel methods as factor to optimise
- Modelling of relationships/interdependencies between modes of transport to identify issues/interventions
- Simulation of impacts of interventions across transport network
- Crowd behaviour simulation, based on multiple factors e.g. weather, disruptions, time of day
- Pro-active notifications of projected capacity issues or congestion across transport network to subscribed users

System Integrations:

- Transportation management systems from public transport providers
- City CCTV platform
- Traffic data for road networks
- OpenStreetMap

Data required:

- Road network data
- Air quality sensor data
- Traffic congestion information
- Public transport occupancy information
- Construction works locations/closures
- Public transport vehicle tracking

- 3rd party services (e.g., e-mobility)
- Environmental/weather data

Powering New/Future District Solutions

Functional Requirements:

- Open portal to allow citizens to virtually explore areas e.g., in 2D/3D map with overlaid POIs and data
- Ability for users to add their own tags, information, identified issues, ideas etc. through community features
- For people to submit ideas and view existing submissions, with some kind of community engagement mechanism e.g., voting, comments, likes etc. to crowdsource ideas for improvements to the city
- Capture of new possibilities explored as a city, with the impact to residents detailed e.g., 5G+ comms
- Linking of actions and outcomes against logged issues/ideas to show progress
- Data portal, allowing export for further analysis by partner companies
- Linked data and information sources from ideas and solutions logged in the Digital Twin
- Enable parties to build new proposals as a later, which can be turned on/off e.g., eV charging network
- Ability to get automatic suggestions about the proposed solution (potential reach, rating against objectives)

System Integrations:

- Identity Access Management system
- Operational management/ticketing systems
- Social Media platforms
- OpenStreetMap

Data required:

- Road network data
- Relevant city data e.g., energy, transport, infrastructure
- Population numbers, distribution, demographics
- 3rd party service data and proposals (e.g., e-mobility)
- Environmental data
- Point of Interest information and linked data

Active City Planning & Citizen Engagement

Functional Requirements:

- Open portal to allow citizens to virtually explore their city and local area to view city planning information
- Ability for citizens to create a profile and set preference and rank their priorities related to city development and regeneration goals.
- Filterable list of planning activities, proposals and decisions, which citizens can curate to their preferences
- Ability to open proposal for consultation, allowing citizens (even selected group) to submit direct feedback, ratings and informal voting developments
- Clear visualisation of impacts of proposal and options, with ability to compare multiple proposals
- Reporting on decisions that have been made, along with reasoning and demonstration of projected impacts
- Possible gamification engine to allow citizens to run a simulation, trying to balance the overall objectives of the city and residents by choosing the best development opportunities
- 'Suggestion box' allowing citizens, groups or community organisations to propose new ideas and opportunities

System Integrations:

- Identity Access Management system
- Planning portal
- Social Media platforms
- OpenStreetMap

Data required:

- Planning/development data
- Policy and regeneration objectives
- City planning KPIs
- Environmental KPIs
- Relevant city and local data
- User-generated, qualitative
- Citizen details for verification

6.8. Establishing a Sustainable Future for the Digital Twin

To create a lasting and operational digital asset that can scale and grow in the future we must create and consider potential enduring business models to ensure the sustainability of the twin and ensure that a global exemplar innovation project can evolve into a working sustainable asset for all its users. It is assumed that an initial model will be developed as a funded innovation project. To avoid the 'deploy and forget' trap that befalls so many of this type of project we need to explore what avenues exist to ensure a sustainable and scalable operational and commercial model for the twin, post-implementation.

Definition and deployment of a sustainable, enduring business model is critical for Birmingham City Council to achieve the compelling and ambitious goals set, delivering for all the city residents and communities on the levelling up strategy, based around people-powered change in an economically and commercially stable way.

Ensuring the appropriate technical and commercial foundations are laid from the outset is imperative, to create an environment which supports lasting growth and impact for the digital twin and its stakeholders. Furthermore, this approach underpins the goal of a having a digital twin that will evolve alongside the city and citizens it is there to serve; establishing a model to support the ongoing development and evolution of the digital twin as it grows according to the long-term roadmap. This evolution will be underpinned by a robust 'base build' and the digital twin is designed to be consistently iterated with new use cases and applications to support the city into the future.

Critically, the digital twin can be considered as both a key 6th digitalisation pillar for levelling up, and as a horizontal integrator between these five strategic pillars, to maximise value within the various independent initiatives.

1. Inclusive, sustainable growth
2. People and places
3. Empowering communications
4. Improving public services
5. Addressing structural inequalities

Creating a compelling rationale to develop, implement and operate a digital twin, developed around the needs of key stakeholder groups, is an important first step on the journey to creating a sustainable and lasting digital asset for Birmingham. Such an endeavour inevitably brings associated challenges and risk.

For example, the availability of capital and operational resource and investment required to deploy, and subsequently maintain, the digital twin – considering the evolving ecosystem of data, systems and assets that need to be iteratively integrated to maintain a consistent and valuable data set.

The data model itself will need to be refined, based on data and system updates, whilst the data feeds themselves must remain appropriate and consistent quality to be of value to the twin. This evolving landscape of technology integration introduces a level uncertainty and potential cost; topics which must be addressed to maintain a robust data model.

Additionally, determining the value of such a digital asset for the communities it will serve is a worthwhile aim, but can prove challenging due to the lack of well-defined mechanisms for valuing assets of this kind. It is also challenging to determine a model by which to create steady revenue streams (and even to consider if there is need for the digital twin to be a revenue generating asset). Stakeholders themselves will evolve over time, bringing new perspectives and challenges to the programme. These points, amongst others, increase the uncertainty surrounding such a long-term project, and thus the perceived risk.

Therefore, taking steps to outline feasible operational models for the digital twin, from the outset, will support productive conversation about the ongoing management of the digital twin and the respective commercial models which could be implemented. Such insight will offer an important perspective towards subsequent funding bids for the twin, considering the operational and implementation requirements.

As outlined within section 6.5 Use Case Roadmap, the digital twin is intended to be developed iteratively, addressing new use cases over time. As each of the use cases are realised and deployed, the services within the digital twin will grow; this increasing capability can be converted to perceived value and can even be monetised as the platform grows.

Providing an ecosystem of use cases within the digital twin delivered on a secure and scalable platform enables opportunities for value creation underpinned by a flexible digital asset.

Figure outlines how linking the increasingly complex and potentially valuable functionalities of the digital twin (derived directly from the twin use cases), with an expanding user base coverage, can support the growth of a self-sustaining environment for the twin's future operation. Illustrating how additional users can be drawn to and integrated within the twin, attracted to additional features which support their needs and operations. Note, this is an illustration framed around the personas discussed earlier: citizens, SME owners and investors.

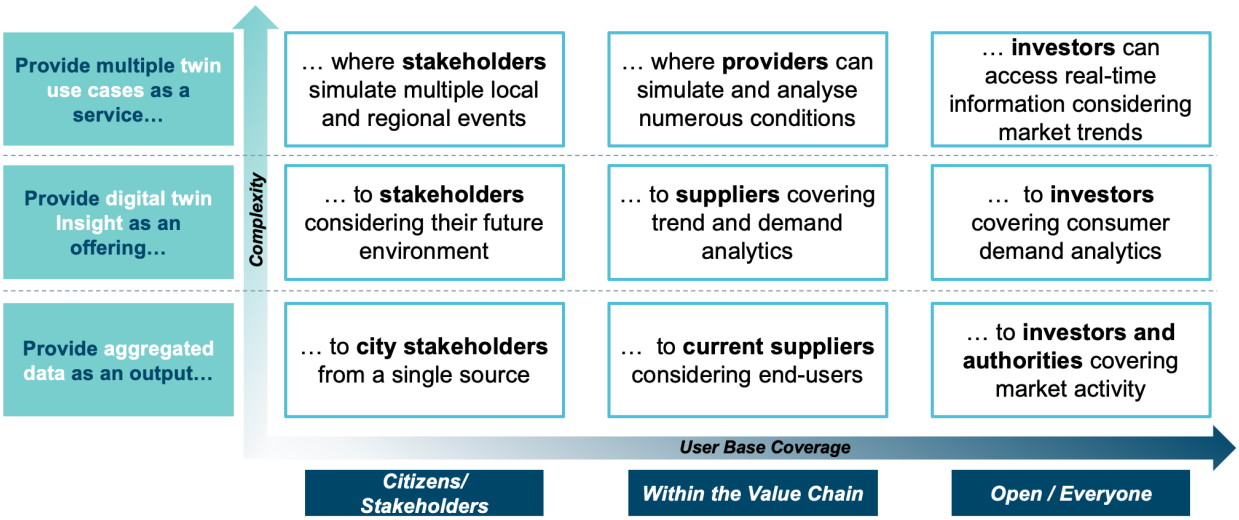


Figure 15 - Creating an ecosystem of choice within a growing user base within the digital twin

Opportunities for growth come from the very complexity of what the twin is trying to achieve as well as the innovation in both digital technology and data This complexity is described in Figure which outlines how the increasingly complex and functionality-rich digital twin environment will, over time, support customisation and packaging of multiple offerings, each of which can be offered to existing and future customers thus opening potential revenue models in turn.

Further work is required to establish a definitive or combination of potential revenue and service models to build an investment case for continuous and scalable operation. An initial view on potential service models is provided in Figure 16 (below) these bundled service offerings and clustered revenue models are outlined. Based on previous work Five indicative but feasible services have been defined:

Offered Service: Data Broker
Service Description: For successful operation the digital twin will need to incorporate multiple data sets from numerous data providers. The digital twin could feasibly surface such data, or act as a route to the source, as part of a free brokerage service for any user following registration with the twin.
Commercial Model: Global free service

Offered Service: Solution Developer
Service Description: Creating an open SDK for developers to use within the digital twin, allowing access to the raw, unfiltered data whilst offering a sandbox for development and innovation based on this city digital asset.
Commercial Model: Global free service

Offered Service: Single Use Case Access
Service Description: With a feasibly broad functional capability of the twin in the future, incorporating multiple use cases, a community-led service could be developed to give specific access based on the use case(s) which are directly related to the stakeholders in question.
Commercial Model: Free service for local citizens

Offered Service: Limited Trial Access

Service Description: As part of a time-bounded free trial access for the system, users can temporarily access the Data Broker and a pre-defined use case / functional offering within the twin.
Commercial Model: Predefined free trial period followed by auto-enrolment into the monthly 'premium subscription'.

Offered Service: Premium Subscription
Service Description: Full, unencumbered access to the digital twin and its library of use cases/ functionality, as well as the Data Broker and developer services. A premium subscription can be at a single user level and evolved within a commercial context to offer multiple-business licenses as part of a bundled subscription.
Commercial Model: Monthly rolling subscription

Offered Service: Pay-per-Service
Service Description: Bespoke access based on pre-defined user access blocks and timing restrictions. Offering a one-time pay as you go arrangement, providing flexibility for alternate stakeholders.
Commercial Model: One off fee for services accessed

Offered Services	Revenue Models				
	Free Community Services	*Community / Developers*	*Limited Trial Access*	*Premium Subscription*	*Pay per access / service*
Data Broker	✓	✓	✓	✓	✓
SDK (Software Development Kit)		✓	✓	✓	✓
Single Use case Access	✓		✓	✓	✓
Marketplace (Data, Apps)					✓
Enabled Services (IoT, Process optimization)			✓	✓	✓

Figure 16 - Digital twin revenue models based on bundled service offerings

For a digital twin to operate and scale successfully, the question is not just about technology, but also one of stakeholders, finance, operations, and an ongoing need to innovate. The offered services and revenue models outlined above are indicative, designed to encourage discussion and further thorough analysis is needed as a follow-up activity, to mitigate risk and maximise the opportunity.

In the future, we may see evolving organisations develop, to take on the role of custodian for both Birmingham-centric data and the digital twin itself. For example, establishing a 'Birmingham Data Company' to manage such digital assets; a potentially crucial step towards establishing a sustainable environment, and growing ecosystem, of many stakeholders, partners, and suppliers.

7. CONCLUSIONS

This report has delivered some tangible requirements as a starting point for the development of a new digital twin for East Birmingham.

7.1. Framing the Benefits Case for East Birmingham and TEED

Rapid urbanisation has long been recognised as a global megatrend. The data underpinning this assessment demonstrates the shift towards urban living is vast and growing. Over half of the existing global population lives within urban areas, a figure which is expanding by over 1.5 million people additional people every week. This growth is concentrated in African and Asian countries [50]. Nevertheless, the challenges associated with rapid urbanisation, concerning the infrastructure, services, job creation, quality of life, environment and climate will be common across global urban centres and growing economies.

Alongside urbanisation, cities and the assets and systems within which support urban life, are increasingly vulnerable to rising demand and climate-related forces. Cities therefore must find solutions to help raise the quality of life for citizens but also tackle the chronic stress on assets and infrastructure. They must mitigate the growing and evolving risks associated with climate impacts, delivering upon net zero commitments or aspirations.

In parallel, technology continues to be an increasingly present in the lives of people globally, with a growing and diversifying user base for digital technology of all kinds. Infrastructure, buildings, and services are increasing the focus of digital transformation. The ecosystem of existing and evolving technologies continues to grow, with communications mediums (5G et al), devices and applications (smart phones, wearables, drones) and technology-orientated service enablers (cloud services, embedded sensors). These continue to enhance the opportunity and feasibility of new client-orientated solutions within the modern evolving city.

Digital twins have taken a central role in advancing efficiency and improvement within many industries; integrating data and information from individual assets, applications, and enterprise systems to create a digital representation of process, system, asset or place. Bringing together disparate information within a twin, alongside the respective operational and engineering systems and data, creates a holistic view of critical assets and the opportunity to visualise and analyse assets and systems in an increasingly immersive, open and secure manner.

Within East Birmingham and TEED a digital twin can become a catalyst for change, advancing digitalisation throughout the city and region. Below we explore some of the feasible benefits of a holistic twin for the region.

Creating a basis for an extensible digital asset
As outlined in chapter 6.3 there is no shortage of current data flowing throughout city systems. These systems and data sources vary significantly, as do their owners, operators, workflows, data quality, data format. Such breadth of applications and constantly changing data – BIM, CAD, GIS, CIM, databases, spreadsheets, documents, photos and more – means that access to a common and consistent data stream incorporating even some of the above is highly challenging. Often the effort to sanitise such volumes of data is equally overlooked, in both importance and complexity.

Therefore, within the twin it is important to build upon a scalable and sustainable base. One which creates the infrastructure of the twin whilst supporting a federated approach to data from the multiple systems, which provide and manage the data sets themselves. Only when the twin, and city stakeholders, have access to a repeatable and consistent set of data can any of the use cases we have identified be realised. This sits at the core of all use cases.

For East Birmingham and TEED, an area with perceived frustrations from citizens as to the quality of digital connectivity, alongside the varied digital skills within the general population, creating a digital framework to support the twin within the region could act as a catalyst for engagement and skills development. Empowering community groups, providing a framework and access to learn and develop their understanding of a complex landscape of city data, to act as champions within focus areas (such as TEED) will support the development of a strong and scalable community-driven digital transformation over the medium term.

The twin could provide a vehicle for those in the community to continually iterate and (re)frame the focus of the twin, considering what it should deliver for the community and why, to ensure the roadmap of the twin is citizen and outcome centric. Considering the twin to not only be a citizen 'owned' digital asset, but also a vehicle for people-powered

change, can deliver a strong community legacy for generations to come. City planners, investors and businesses can also benefit from standardised and accessible data and tools in many tangible and intangible ways. In essence the twin will provide a reason and framework, to progress an increasingly open approach to data with city stakeholders; one that is respective of the relevant privacy and security concerns of data providers but is driven by unlocking un-tapped value for all within the city.

Improving collaboration, and visibility, between city stakeholders
When considering the city is a living and breathing ecosystem, with assets and infrastructure owned by many different actors each with their own ambitions and expectations, the twin provides both the opportunity to visualise how and where these assets or services are co-located. Moreover, the twin will enable focussed dialogue around how individual assets and systems are managed, considering the wider ecosystem (system of systems) of which they form a part. From rail, highways, transit, utilities, there are many tangible benefits; from effective collaboration and sharing to enhanced planning, safer and more resilient city operations and enhancing economic development.

A holistic approach to sharing data and information, enabled by the digital twin, will ensure that infrastructure owners and operators are equipped with the latest insights to support individual, and collective, project and investment planning. Accessing such current data will support proactive citizen outreach, advising of where and how interruptions will impact them, informing of alternate options available to avoid areas of significant disruption. These analyses would support a wider campaign for the acceleration towards low carbon transportation within the area.

For those living and working within TEED, who currently face challenges of poorly accessible infrastructure, alongside disruption from potential redevelopment, would see value from the twin as it enhances the city's ability to realise its strategic visions and promises, also driving greater transparency and communicating the vision and benefits of key infrastructure improvements. This type of proactive engagement supports not only the citizen but also the SME / supply chains operating within the area. Furthermore, integrating the twins of individual buildings into a region-wide twin will enable a pro-investment landscape, using digital twins to engage developers and building owners both during planning and operations. They can showcase where and how investments can drive city-wide value and demonstrating the business case of investing to this region and community.

Creating a climate resilient city
Visualising a building, street, postcode, city, or district is all possible with a digital twin. Providing the ability to deliver analytical insight at a property or street level, whilst allowing a macro-city perspective, will be key in planning mitigations for emerging climate challenges. Assessing the infrastructure of the city at each level, testing approaches to harden individual elements before considering the holistic, whole-system, performance is no small feat, but one that will be vital in addressing environmental change within planning and operations.

Naturally, the type of changes and their impact, will vary depending on location and geography, but cities such as Birmingham will need to understand and plan how to deal with the consequential factors of environmental change directly, alongside the broader human and population effects.

Developing a twin which provides modelling and simulation capability will support East Birmingham and TEED in enhancing its ability to plan and operate within an uncertain future environment. City stakeholders including planners and policy makers will feel direct benefit in de-risking decision-making, based on available data and agreed parameters. Investors and SME owners/ managers will translate such insight into a viable, and risk appropriate, business plan. Citizens equally can benefit, with associated outreach and learning to support their awareness of wider climate challenges and feasible impact to their location, along with the potential behavioural changes they can implement to reduce their carbon footprint. The digital twin can drive positive change for the city throughout all key personas.

7.2. Reflecting on the aspirations

The aspirations, defined from the outset of this activity, have ensured that a future digital twin for East Birmingham and TEED will be geared towards scaling growth in investment, stakeholder and community engagement, and the cities global reputation. Success in each of the three factors is possible, and success will be measured both with accessing the correct scale of funding to advance these aspirations within a tangible solution, but also with the governance and operational models which sit around the twin itself.

Targeting East Birmingham and TEED sets a tone which is aligned with the levelling up agenda, driving 'people powered change', scaling investment in the region to enhance the lives of the citizens and create previously inaccessible value for those who stand to benefit the most.

As defined by UK Government and BEIS[51], the UK is targeting the rapid enablement of Cyber-Physical Infrastructure to directly support innovation, resilience in complex systems-of-systems, climate change and levelling up. Each of these four key areas align neatly with the aspirations of this initiative and that of Birmingham City Council and West Midlands Combined Authority.

The digital twin for East Birmingham and TEED can directly support and inform this critical national dialogue. A twin which is tasked with realising challenging use cases, unlocking investment, enabling a pathway towards net zero, evolving and enhancing city-wide planning, policy and engagement can operate as a lighthouse for BEIS and other key Governmental/ central stakeholders to engage with, and learn from.

There is an opportunity to inform and advance the development and application of applying shared building blocks created with interoperability at its heart to provide Birmingham with a fantastic opportunity to maximise their national and global presence, advancing the shared-learning and demonstrating thought-leadership with the application of an innovative digital twin to create increased understanding of, and targeted solutions to, some of the global challenges which face societies today.

Figure 17 – The goals and aspirations of the Digital Twin

As the UK's 2nd city, Birmingham is uniquely positioned to drive the international dialogue in this area. Developing a targeted and extensible twin which is created collaboratively with city stakeholders, showcasing innovation and creating opportunity for the inhabitants is a novel, challenging, yet attainable end-state. The mix of engaged stakeholders, from the citizen to city to partners, will enable access to all the inputs and tools which realise many of these topics. Ensuring the development and application of a forward-looking governance and operational model for the digital asset for Birmingham will also ensure success and a legacy of impact.

Birmingham is looking forward with a desire to change for the better. The twin will be a key underlying enabler for this positive change.

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Annex A: Activity and Project Synopses

Built environment

The digital twin should provide visibility into the built environment of the city, allowing user to explore insights around existing housing, commercial buildings, utility facilities and infrastructure, as well as simulate potential policies, initiatives and developments to reach the overarching goals of the city to make data-driven decisions. The digital twin can support existing projects across the built environment by providing a holistic view of all development activities, mapping the interplay between these and potential synergies or opportunity costs between them.

Birmingham Development Plan: The City's statutory planning framework guiding decision making on all development and regeneration activity to 2031. A long-term strategy for Birmingham to be celebrated as an enterprising, innovative, and green City delivering sustainable growth in line with the future needs of citizens.

3 Cities Retrofit: West Midlands Combined Authority initiative to advance net zero ambitions across Birmingham, Coventry and Wolverhampton. More than 165,000 social homes to be improved in terms of energy efficiency, green energy generation and green heating.

300-Home Whole House Retrofit Pilot: Project to lift some of Birmingham's poorest households out of fuel poverty with a 300-home whole house retrofit across Coventry and Solihull. Retrofitting with super-efficient insulation and low carbon heating technology to reduce energy consumption and greenhouse emissions.

TEED Local Development Order: Allowing the Local Planning Authority to grant automatic planning permission for certain types of development. Seeks to simplify the planning process and stimulate new economic development in the area.

Natural environment

Green and blue space is a critical asset for the city and one that has a marked impact of the health and wellbeing of citizens, whilst also a key pillar in tackling climate related issues such as air quality, wildlife and carbon emissions/ sequestration. The digital twin could be utilised to monitor, protect and improve the green and blue spaces across the city, incorporating these into Net Zero Carbon master planning and interventions. In a broader sense, improvements in sustainability and emissions reductions are a major focus of the digital twin use-cases and capabilities.

Route to Zero Action Plan / R20 Community Assembly: A Taskforce of representatives from key stakeholder groups that worked in collaboration with the council to produce the Call-to-Action report.

Net Zero Neighbourhoods: West Midlands Combined Authority project to create low carbon neighbourhoods, retrofitting homes with insulation and green heating, alongside other low carbon infrastructure including on-street electrical vehicle charging points.

National Centre for Decarbonised Heat: University of Birmingham-led alongside the Manufacturing Technology Centre, Energy Systems Catapult and the Energy Research Accelerator to meet carbon reduction targets by enabling the rapid scaling up of manufacturing, skills, and deployment of heat solutions.

Birmingham's Carbon Roadmap: Sets an ambitious target to reduce total CO_2 emissions by 60% by 2027 against 1990 levels. Priorities to address fuel poverty, improve energy security, and decarbonisation.

Tyseley Community Commons Project / Love your River Cole: University of Birmingham-led programme delivering green and blue infrastructure improvement interventions in the Tyseley area of the River Cole Valley. Strong community interface.

Places for People: Introducing new schemes to create Low Traffic Neighbourhoods across Birmingham making it harder or impossible to drive through the area other than by residents, their visitors, or for deliveries.

Clean Air Zones: Targeted action in an area to improve air quality by discouraging the most-polluting vehicles from entering the area with daily charges.

Green Infrastructure Masterplan: A plan demonstrating the benefits of green infrastructure in addressing global challenges. To reinstate the city and region as a driver of commercial, creative, scientific, political and cultural life with influence beyond its borders. Aim for the council to change the way it manages green assets to deliver a „Bolder Greener Birmingham ".

Digital Environment

Digitalisation is widely recognised as a fundamental part of the city's future and therefore there are a wide array of activities underway which contribute to this. There are several projects or organisations aiming to gather and make usable the wealth of data being generated across the region and collect additional data sets to enhance this picture. The digital twin will benefit from and support these digital initiatives, through the sharing of data, provision of tolls and

functionality which is aligned to achieve the same or similar outcomes. The digital twin provides an opportunity to map these different existing programmes and repositories and their linkages.

Birmingham's Smart City Roadmap: A Roadmap of actions which embrace smart city technologies and access to data to empower citizens and ensure the future resilience of the city. Many actions are being delivered in collaboration with business, community and the public sector to tackle low economic performance and unemployment, health and wellbeing inequalities, mobility, and achieving a low carbon economy. Activities are centred around the Smart City Principles of Integration, Digital, Data and Citizen Engagement.

Combined Authority Smart City Regional Bid: Pushing for a regional, combined data platform bringing together all data sets.

Digital Birmingham – Insight Programme: To make better use of customer insights and business intelligence for informed decision making and efficient resource allocation. The Insight Programme enables the council to become more data driven by supporting Data Lifecycle Management, Insight Data Platform and Analytics, Business Intelligence and Data skills training.

BT Street Hubs: To capture carbon emissions enabling a potential carbon trading capability. Used for planning purposes.

Digitization of Traffic Systems: Looking at how Traffic Junctions can be digitized to carry out capabilities such as remote monitoring and change sequencing.

Birmingham Urban Observatory (City Observatory): A system of research platforms that observe urban events such, but not limited to, heat waves, flooding, traffic flow, air pollution and biodiversity. These events are observed in the context of critical networks and the interconnected impact on each.

Birmingham Intervention Programme: Looking at how data sets can be used to assess the need for early intervention. To be piloted in East Birmingham.

ArcGIS System: Main mapping tool containing lots of data. Public version available.

Birmingham Data Factory: A 'one-stop shop' for open data in the Greater Birmingham Region. Administered by Digital Birmingham and Birmingham City Council.

Digital Neighbourhoods: Early-stage work to gain a common understanding of what a Digital Neighbourhood would mean to citizens. To be trialled in Northwood.

Multi-sector

These are broader national initiatives which impact the city across several different sectors and stakeholder groups. Government schemes such as these can provide necessary impetus to tackle major, systemic issues faces by the city and its citizens. Aligning the digital twin use-cases and capabilities to these, gives credibility, relevance and increased visibility and potentially funding to the development. The goals of these have a broader citizen engagement and wellbeing angle which is reflected heavily in the approach and goals for the digital twin.

Birmingham's Trailblazer Devolution (Devo Deal): Building upon the East Birmingham Inclusive Growth Strategy, the 'Devo Deal', has a proposed key focus on East Birmingham to include different funding sources, 'Levelling Up' Zones, Net Zero, large-scale housing retrofit, green energy, early intervention & prevention around poverty, employment and education, greater local housing powers and improved local transport.

Levelling Up: People-powered change with inclusive growth to deliver improved outcomes on key measures of economic and human development. Committed to addressing the high levels of deprivation and persistent inequalities between people, place and communities in the city. Key indicators rooted in addressing the following integrated challenges: Boosting skills employment and the local economy, promoting health and wellbeing, strengthening community resilience and cohesion, addressing the Climate Emergency and Creating fairer and better opportunities for children and young people.

Transport

In Birmingham, as a busy metropolitan city and a major transport node within the UK, the transport network/s are a major asset for the city and bring huge operational challenges. Significant changes are coming in future years with ambitious and transformative transport plans such as HS2. East Birmingham and TEED has been recognised as a major area for improvement, with the ability to improve the connectivity of the area and the outcomes and prospects for its residents and businesses. Transport organisations across Birmingham and the West Midlands are already working on many initiatives to improve the efficiency, sustainability and provision of transport and the digital twin can bot enable and benefit from these adjacent activities.

Birmingham Transport Plan: Details the changes required to meet the demands of the future. Measures are designed to reduce impact to the environment, eliminate road danger, reconnect communities, revitalise city and local centres, and connect people with job and training opportunities.

Arcadis Transport Study: Focus on transport. Proposals for funding packages.
East Birmingham and North Solihull Transport Study: Being delivered by Arcadis on behalf of Transport for West Midlands and Birmingham and Solihull Councils.
The Integrated Rail Plan: Co-ordinating and integrating investment in rail across the country and setting out how the Government delivers rail investments.
Proposed East Birmingham to North Solihull Metro: A transport element of a regeneration plan for the area. An extension to the route from Birmingham Eastside further east to serve North Solihull, terminating at the High Speed 2 interchange.
Integrated transport and micro mobility: West Midlands Combined Authority key focus area. Current initiatives include E-Scooter trial zones across Birmingham.

Community

East Birmingham has been identified as one of the most deprived areas in the UK and improving this situation for citizens is one of the major drivers of the City Council activities in the area. There are initiatives in place across this area focused on improving the lives of citizens and some of the digital twin use cases also aim to tackle these, empowering the community through community groups, citizen action and better communication and resident interaction.

East Birmingham Inclusive Growth Strategy: Sets out Birmingham Council's approach to ensure a full benefit to the local community in the context of major planned infrastructural investments. Themes are Employment and Skill, Transport and Infrastructure, Health and Wellbeing and Local Centres and Green Spaces.
Neighbourhood Networks: Asset-based communication building on the capacity of community with a focus on early intervention. Each constituency receives funding initially to support the elderly, but this is expanding into young people.
East Birmingham Locality Forum: Network supporting community organisations to be strong and successful. Offering peer learning and connection, specialist advice and support, influencing campaigns, and supporting local community projects. Connection to integration of healthcare within wider public sector services.
Community Economic Development Plans / Community Economic Planning Policy Lab: A process of economic development within a specific geographic area to make the economy in the area work well for that community. Emphasis on reshaping the underlying economic systems, economic development which generates human wellbeing within environmental levels, and is community led.

Commercial

Driving up investment into East Birmingham, and TEED specifically, in high growth and high social value areas (such as green technology), is critically important. TEED is designated as an Environmental Enterprise District and therefore there is a big driver to attract, retain and support businesses in this field in the area. Existing organisations set up to generate value in these areas are a key asset for the city. The digital twin can be used by these organisations and the important work that they are doing also feeds into the definition and development of the digital twin itself.

Birmingham Energy Innovation Centre: Funded by the Greater Birmingham and Solihull LEP, BEIC helps to deliver a greener and cleaner ecosystem for Birmingham and the West Midlands. Promoting innovation in waste, energy and low carbon vehicles.
Tyseley Energy Park: Energy Park harnesses the capability of industry, academics, and local government to deliver low and zero carbon power, transport, heat, waste and recycling solutions for a greener, cleaner, healthier Birmingham.
City Region Economic and Development Institute (City-REDI): Created in response to the increasing need for a multidisciplinary approach to region challenged. Based at the University of Birmingham Business School with a team spanning a range of disciplines.

Annex B: Solution Architecture Component Descriptions

Data Ingestion

APIs – Application Programming Interfaces will be used for the scenarios mentioned in the 3rd party data / systems section. These APIs can be hosted on traditional machines, app services, containers or function-as-a-service options like Azure Function Apps.

When utilising APIs for data ingestion from remote systems there may be scenarios where the incoming data velocity is so great that it exhausts the provisioned capability of the receiving APIs. In order to counteract this risk, we would recommend the use of dynamically scaling APIs; some form of event broker to handle the messages into a queue for processing, or both. Utilising this architectural pattern will reduce the risk that your APIs will be overloaded and that the system experiences losses of data or downtime.

ETL – Extract-Transform-Load tools such as Azure Data Factory will be used to load larger and more static datasets. During the load processing we can batch tasks to run at the optimum time and a scripted restructuring of the data can be undertaken including merging different datasets.

Challenges

As the platform grows and starts to ingest more and more information the ETL process may come under increasing load and its pipelines will need to be monitored to ensure that data arrives into the system within the required timescales for its dependant use cases. A combination of monitoring and the use of scalable ETL tools will aid in managing this risk.

Ontology Based Consumption – Ontology Based Consumption will take standardized dataset formats from various sources such as CIM models from Energy Utilities companies, or BIM models from tech park operators and consume these into digital twins and merge the twins to create a federated model of interconnected twins where pertinent information can be shared where the boundaries of the twins intersect such as a buildings connection to the energy network via transformer or HV metering unit.

Stream processing – Stream processing will be used where fast-moving data is coming in from things such as sensor networks, SCADA systems or video feeds from CCTV networks. Where there is a need to process video data it may be necessary to take into consideration data privacy and employ some AI processes to mask individuals' identities, face masking etc.

Data Processing & Modelling

Dimensional Modelling will be used to create a multi-dimensional model of data and creating data vaults. Here we will use tools to create HUB, LINK and SATELLITE tables. These will be used to store metadata around processing, to catalogue the various datasets, how they link to each other and then the data itself.

Data Cleansing – these techniques will be used to look for anomalies within the data, potentially reframe data and storing the data

Stream Analytics tools will be used to look for insight in fast moving data as it is received. This could be related to data coming in from SCADA systems for example looking at predictive analysis around faults etc.

Data Storage

Data Lake will store the structured (tables for example) and unstructured data (plans, documents). This could be a combination of database services and storage services.

Digital Twin Engine will store the data models which are a digital representation of a real-world process or object. Generally, these are stored within a graph database consisting of nodes and their relationships between one-another.

Unstructured Data Store ability to handle datasets (typical large collections of files) that are not stored in a structured database format

GraphDB Graph databases are purpose-built to store and navigate relationships between data.

Application Layer

Containers can be used to package up software and its dependencies so that it can run on multiple environments quickly and reliably. It also provides isolation between different services and can be useful when creating a Services Orientated Architecture. These are used in conjunction with containerization platforms such as Docker or Kubernetes and can be run on premise or in the cloud

Function Apps –These are small applications which are generally event triggered and accessed through an API gateway. They allow for small stateless applications to interconnect together creating a highly scalable and resilient microservice environment.

Virtual Machines – Can be used to host legacy applications either on premise or in the cloud.

Presentation Layer

Command and Control application will provide an operating centre application for monitoring the city and will stitch together various data and functions to provide oversight to city operations

Citizen Applications - will provide citizens with access to a host of information from air quality data to planning permission applications or key topics for their community

Open Data Platform - will expose publicly shareable data catalogues for the entire system, so that it can be used for the common good of future projects or initiatives. Strict governance will be required here to ensure that the platform does not share data which is deemed in any way private to users who are not authorised to view it. The use of data masking and redaction alongside row and column-based access controls is strongly recommended. These permissions can be linked to personas and then applied to groups of users or APIs.

Visualisation platform - can be used to view the data in new ways, to promote engagement, or to provide detailed information to non-technical users. This can be in the form of mapping, 2D, 3D, Augmented Reality or VR applications

Gamification Engine - this will facilitate the gamification of data retrieval or cleansing tasks. It can be used to create fun and interesting ways of gaining crowdsourced data or effort for various tasks such as map enhancement, texture mapping for 3D building models, pothole reporting, rubbish tipping reporting, etc. It can drive user engagement and digital upskilling.

Siemens Advanta

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