The Institution of Engineering and Technology

Digital Technology Adoption in the Smart Built Environment

Challenges and opportunities of data-driven systems for building, community and city-scale applications

Introduction

Data has always played an integral role in the decision-making and engineering management processes within the built environment, whether at the building-, community- or city-scale; and as information technology becomes more integrated into those environments, the importance of data will escalate; indeed, data has been described as now being the 'lifeblood' of the smart built environment, as we shall see.

Whilst there is a rapidly-changing landscape for digital technologies across these three domains, many organisations remain at an early stage of experimentation in their adoption of data-driven systems. One of the purposes of this Technical Briefing is to provide entry points for those seeking to understand the opportunities, challenges, and enablers for successful systems implementation: this is key to ensuring that appropriate levels of time and resources are invested in successful digital built environment projects.

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While technical and data-driven project considerations are a core focus for this Technical Briefing, many of the challenges faced in real-world projects lie in the balancing of co-existent interests and the scrutiny they will show toward proposed change:

- The user/stakeholder and wider societal interest will ask: is the proposal *desirable*?
- The technology/technical capability will ask: is the proposal *feasible*?
- The business/value case will ask: is the proposal *viable*?

Advances in information technology are a compelling factor here. Interest in the deployment of sensor devices and communication networks capable of collecting and publishing data from the physical environments, is growing apace. Such data is required to digitally represent and manage key aspects of the built environment: examples include congestion mapping, pollution monitoring and applying Building Information Modelling (BIM) tools within construction projects. To achieve these interests, organisations need to establish project objectives in the conceptual and design phases – they need to define what data harvesting is necessary for project delivery, information modelling and the derivation of ongoing benefits from project implementation.

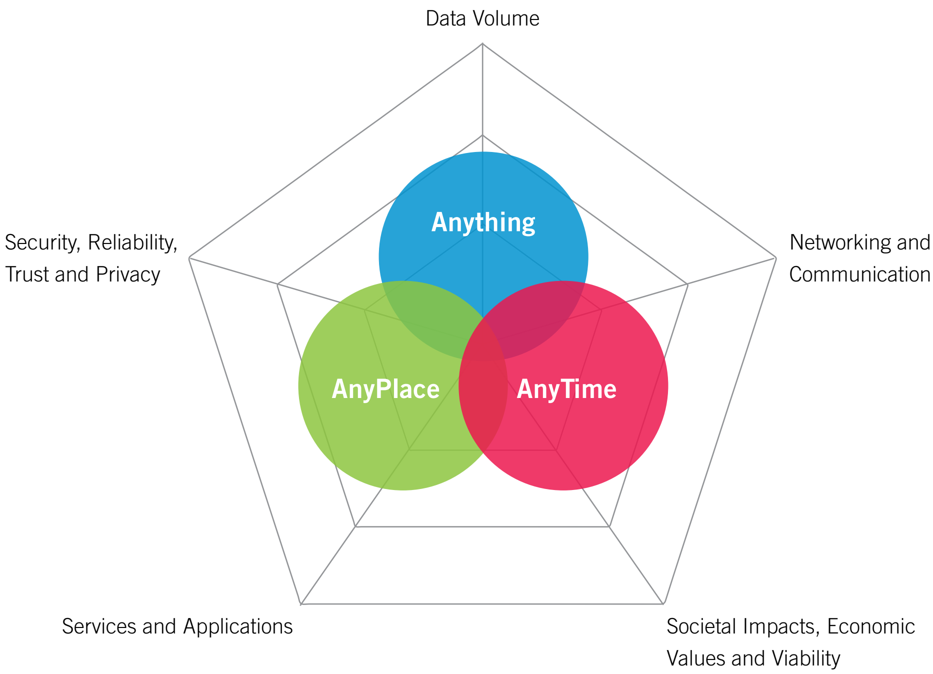
This Technical Briefing reviews the main challenges and opportunities for the application of digital technologies in the smart built environment, as a successor to the *IET Built Environment Thought Leadership Summit: Data as the Lifeblood of the Smart Built Environment* review that was published in August 2014.

Understanding challenges and opportunities

As explained in '*Data as the Lifeblood*' review, the built environment is experiencing an incremental expansion of the installation of data-generating sensor technology. The pace of such developments will show accelerated growth over the next 10 years, as the number of devices connected to the Internet exceeds the total number of the Earth's human population.

Sensors are enabling innovative new possibilities for practitioners to design digitally-connected experiences in private and public places. The different types of sensor technologies coming into the built environment have the capacity to feed almost unlimited quantities of data, so there is now an emerging need to be selective in what data is collected and aggregated, as 'harvesting' such huge quantities of data simply because it is possible, can prove counter-productive to projects predicated on their potential to derive value from that data.

Figure 1: Contextualising challenges for intelligent data processing



> “We need to know what the problem is before addressing the question of what dataset is going to solve it.”
>
> Dr David Evans, Chair of the IET Innovation and Emerging Technologies Policy Panel

Adding to this is the increasing interest in individual, citizen collectives and other constituencies of interest in logging descriptive data about their daily activities and life experiences – usually known as ‘self-tracking’. As noted in ‘*Data as the Lifeblood*’ review, some commentators foresee a situation where such personalised data, subject to aggregation processes, will become a tradable ‘commodity’, feeding back into smart city online products and services, and possibly acting as part of cyber-social projects.

Identifying the value dimensions

Pioneering projects often focus on topics such as resource efficiency or performance monitoring, with wider topics such as big data, open data, and data analytics featuring as common denominators across projects in different sectors. However, progress has been faster in some sectors, driven by agile value chains, novel business models or disruptive actors entering the sector. Examples of new digital offerings in different sectors include: e-mobility in the transport sector (such as BRIDJ, which describes itself as ‘the world’s first pop-up mass transit system’); appliance load monitoring in the energy sector (such as AlertMe, an ‘open platform to connect devices and appliances in the home’), and anonymised mobile data in the telecommunications sector (such as Telefonica Dynamic Insights, which collects ‘mobile data, anonymised and aggregated, to understand how segments of the population collectively behave’).

Other sectors, meanwhile, have not yet seen the same level of progress towards adoption of digital technologies. The reasons for this are diverse, but arguably, they usually come down to conventional mind-set and inflexible value chains; common barriers here include assurance of data privacy and security (found in the healthcare and defence sectors), or lack of technical capability and digital competency (such as the agricultural sector).

Technology is one pillar in constructing a successful data-driven project; management, planning, plus social and economic factors, also play important roles in defining and implementing an effective digital architecture. Several key issues should be considered when applying data-driven systems: this especially applies where data from multiple sources is required, potentially mediated by a mixture of different data interfaces and/ or separate points of data exchange, managed by different departments and/ or handled under separate third party agreements.

Table 1 outlines key considerations for the application of digital technologies in built environment projects. While each of the considerations listed here is individually important, there can be a wide variety of potential configurations in targeting of project goals and deriving appropriate data-driven technology solutions. These can lead to complexity and potential complications in the decision-making process for these projects.

> “We need people on the demand side to realise what is possible … who understand what questions to ask, what the tools can do for them without necessarily being hands-on with the tools.”
>
> Prof. Derek McAuley, School of Computer Science, University of Nottingham

Table 1: Key considerations for the application of digital technologies in built environment projects

Key consideration	Specification requirements
User context and consent needs	■ Are we able to clearly articulate and communicate the requirements and boundaries in an understandable way to users/data providers? ■ Has consent/support been secured for all intended uses of data? ■ Have users been informed who will access and use their data, and how their data will be captured/stored/processed/updated/disposed of? ■ What data privacy and cyber-security requirements exist, both for project stakeholders and for the wider end user base? ■ What is the context for sharing data (mission critical versus non-essential/elective requirements)? ■ Who are the stakeholders? And what are their requirements?
Ethical/regulatory/ security/legal position	■ Has the letter and spirit of relevant regulations been applied (e.g., data protection, opt-ins/opt-outs)? ■ Is the proposed use of data ethically justified (including user consent, risks of data being de-anonymised)? ■ What are the potential security risks? And what solutions are considered for the system and wider network interactions? ■ What potential risks and/or liabilities might such a data-driven project face?
Monetisation	■ Have the long-term resource and maintenance requirements been fully considered for both technical infrastructure and data management? ■ What existing processes are being challenged and how will short-term budget/financial constraints be suitably balanced against potential long-term benefits? ■ What is the business case for investment and how will it be measured? ■ What types of value will the project bring (cost saving, efficiency, revenue generation)?
Quality, consistency, and scale of data	■ How do we assure the continuing utility of the data when systems and/or sensors change? ■ How do we bridge/fill gaps and compensate for missing entries in data sets? ■ What are the implications for storage, processing, and pooling of large data sets? ■ What are the requirements for data collection frequency and aggregation at relevant scale? ■ What is the duration for data retention? And what are the requirements for deletion? ■ What levels of data granularity of detail and structure; data quality; and consistency are required?
Engineering/ technology approach	■ Are there systems in place that are compatible and capable of supporting project delivery? ■ What are the common optimisation goals (e.g., energy efficiency, latency, accuracy)? ■ What are the hardware, software, communication, and networking requirements? ■ What are the scale, velocity and dynamic utilisation requirements of the data handling system? ■ What processes are in place for management, security and resilient operation of project-specific technologies? ■ What tools/techniques are most appropriate for the project tasks?

Establishing project purpose and vision

The first and foremost challenge in the application of digital technologies in the built environment is to establish a clear purpose and vision for the project, aligned with the aims and needs of the relevant constituency and scale of the system (city/community/ building level). This decision will lie with the project funder – typically a local group, civic authority, community organisation or building owner/operator. However, increasingly the funder is acting as the 'first among equals' in a diverse set of stakeholders, who can materially impact on the success of the project. Policy and strategy alignments are key to ensuring defined goals are achieved and objectives are pulling in the same direction. The complete project/system/ infrastructure lifecycles require consideration at an early stage to ensure that upfront investment in effort, cost and time delivers the optimum solution against brief and requirements. Context is key in defining purpose and vision as the first step in strategic decision-making for a project. Both ongoing challenges in the built environment (e.g. population density concerns from increasing urbanisation) and feasible technical solutions (e.g. utilising cyber-physical or cyber-social systems need to be identified and balanced against one another.

> "In a home, you have to convince the owner that data can be beneficial to them. In a business, you have to think about how that data can be recognised. If people are actually going to do it, they have to understand why it is helpful."
>
> Simon Robinson, Technical Director, WSP Parsons Brinckerhoff

A good example of context is provided by Innovate UK's Future Cities Demonstrator, OPEN Glasgow, where the strategic benefits are summarised as follows:

- *Transparency* – an opportunity to adopt a more collaborative (and cross-sector) approach to policy, planning and design of the built environment and interaction with the built environment.
- *Insight* – an opportunity to combine datasets in new ways and to analyse the built environment in ways previously not possible.
- *Smarter engagement* – an opportunity to improve engagement and participants with users (particularly at a community level).
- *Smarter operation* – an opportunity to deliver efficiency improvements for the operational management of the built environment through improved partnership working, service optimisation (targeting services more effectively) and proactive management (e.g., using predictive analytics).

Engaging with key stakeholders

Social, contextual and other domain dependent information should also be available and utilised within in a project. Take this as an example: if a built environment project provides incentives for energy usage in non-peak times for households in a district, other factors – such as family size, working hours, special needs and types of devices used in a household – should also be considered. This will allow for non-discriminatory incentives for different groups of users with different needs.

In some cases, before starting a project, an analysis should be made on barriers to adoption, in order to identify whether the different aspects of a project are clearly defined – for example:

- Are data sources identified and available, and are data providers informed/on board?
- Are the team trying to adopt technology for adoption's sake?
- Have key end user requirements been fully addressed by the project?

A people-centric approach is key to building stakeholder engagement and support. Without listening to and understanding user needs, a project could carry risks from professional culture clash due to lack of confidence in digital technology adoption, or even from a more personal fear of loss of control undermining motivation for stakeholders to participate. Such an eventuality could, of course, potentially lead to a wasted asset.

> "Relying merely on data from sources that are unevenly distributed, without considering background information or social context, can lead to imbalanced interpretations and decisions."
>
> Dr Payam Barnaghi, Institute for Communication Systems, University of Surrey

Aligning policy and processes

The challenges of digital technology adoption projects can be described in the context of management, from relationships between different stakeholder groups, links between external data sources and organisations, and technical and skills capabilities within project teams. The management team at different levels within an organisation should be clear, aligned and consistent in their articulation in relation to the value, cost and various requirements of a data-driven project.

The expectations and enhancement goals of the project – such as productivity, competence, time-to-market, prediction and forecast – should be realistic and well-defined, with appropriate oversight and governance applied to ensure these can be delivered according to project vision and scope. Table 2 outlines key roles and responsibilities for digital technology adoption in the smart built environment.

> “Not all data is equal... If you get the right quality of data and the right business process, you can really make progress.”
>
> Adrian Furner, Managing Director, Kommercialize Ltd

Sometimes different groups have access to datasets that need to be made available to other internal and external beneficiaries to drive a project. This requirement can present a range of questions around policy issues, cultural barriers, and value incentives for data use and reuse, as well as potential security, privacy, and business risks from sharing data. These issues have to be investigated, identified and resolved before the project starts, optimising selection of technical solutions and minimising potential barriers to development or cost implications as a consequence of incompatible systems in future. Key roles and responsibilities for digital technology adoption are outlined in Table 2.

Table 2: Key roles and responsibilities for digital technology adoption projects

Role	Responsibility	Sample considerations
Senior manager/ board/sponsor	Setting organisational strategy and context, and defining the benefits/ business case	■ Developing and communicating the value case ■ Policy development including legal/ ethical oversight (e.g., data protection) ■ Programme/project governance, ownership and lifecycle management
Professional/ business unit manager	Specifying, processes and procedures, planning and resourcing projects	■ Aggregation/filtering tools, reporting/ profiling solutions ■ Systems architecture, business rules, standards and compliance ■ Technical/data quality assurance, benchmarking/control
Project manager/ technical operative	Detailing technical practices, addressing tasks with appropriate technological implementations	■ Data storage, computing, profiling/ reporting platforms ■ Task characteristics, format, range, metadata, action/feedback ■ Technology specification, selection, application

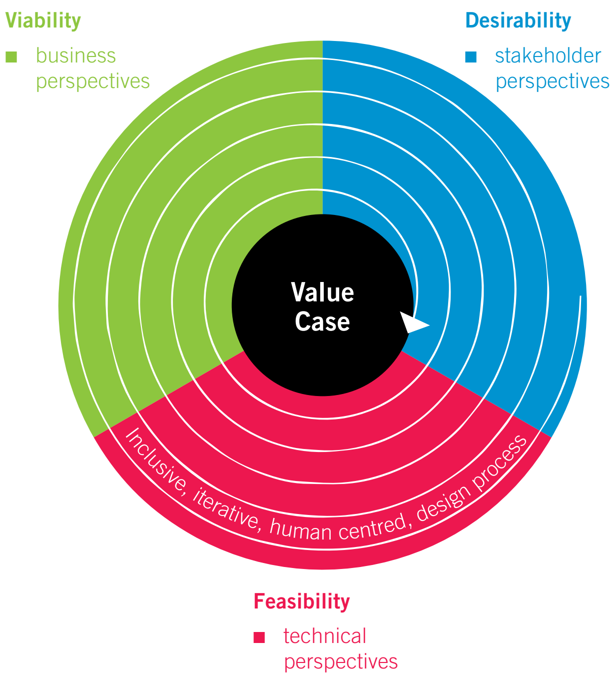
Putting together the 'value case'

The 'value case' is a key consideration for digital technology adoption, with definition and communication challenges, including aspects such as:

- Applying a multi-dimensional approach, noting that engineering and technology by themselves are not sufficient to provide enduring value.
- Gaining buy-in from a diverse set of stakeholders; and with it, building clarity and relevance to all parties.
- Generating outcomes through a combination of data and technical systems, management and project participation as part of a whole-systems approach.
- Identifying a baseline for success, with project objectives as a primary requirement, while mapping the future path for an evolving opportunity.

The opportunities can be significant, but if stakeholder groups – often made up of disparate and diverse perspectives – do not buy into the project outcomes and their proposed benefits, then it is unlikely that the project will achieve success if progressed; or, at very best, the outcomes would be sub-optimal. A true benefits-led approach which not only identifies individual and societal benefits for all stakeholders, but also prioritises them and quantifies them in both financial and non-financial terms, is key to project success.

Figure 2: Developing the Value Case



It is likely that the technological 'art of the possible', so to speak, may not be the constraining factor here. Often non-technical considerations such as regulation, data usage rights, and end-user perception will lag the pace of technical options. Only by taking a blended, multi-disciplinary, approach will a realistic value-case that maps to the purpose, is inclusive, iterative, and human-centred, be created.

> "You have to start with the lens of who is valuing the asset"
>
> Mike Short, Vice President, Telefonica

Time is a key dimension in building-out a scalable solution. Because of this it is important that, in addition to constructing an initial baseline of value cases, a project should also plot a future roadmap for investment, in which alignment of both technical and non-technical issues would unlock opportunities for services/functions that further enhance the value case.

While these key issues are similar for other non-data centric opportunities – due to the nature of data systems – we need to ensure that we get a better balance between the customer perspective (desirability), the technical perspective (feasibility) and the business perspective (viability). The value case is a key lynchpin for this, and for the trade-offs required. A key trend that underlines these opportunities is resource efficiency, but as this Technical Briefing highlights, new systems will have their own resource dependencies to consider, from governance and financial implications, to management and technical investments.

Managing technical infrastructure

Having access to large volumes of data will not be sufficient for an effective data-driven project unless resilient management procedures, roles and responsibilities and secure access policies, processing approaches and methodologies are also defined at a systems level. Defining appropriate hardware and software components, data storage, cloud computing and communications platforms, along with infrastructure deployment, test, integration and maintenance regimes, are also essential parts of a data-driven project.

> “In any data-driven project addressing the security and privacy issues requires a holistic approach from the outset, which addresses people, process, physical and technological aspects of the solution.”
>
> Hugh Boyes, IET Cyber Security Lead

The criteria for evaluation of the use of data aggregation and analytics should also be clearly defined, with project goals measured against these criteria as the project progresses. Additionally, projects where value cases employ actuation of systems or notification of users will need to consider feedback, interaction and control mechanisms as part of an end-to-end approach based on real world information and situational awareness.

In distributed, multi-source and multi-provider projects, interoperability, quality, security, sharing, exchange, methods and interfaces are key issues to project success. Understanding the value of data, how information and insights can be extracted, and what benefits are realistic to expect, are all vital considerations for the successful definition, running, and handling of a data-driven project within an organisation.

As previously noted, future development should also be considered, as potential uses and benefits from a project may not be predictable at the outset. The additional cost of including a few extra sensors and devices when equipment is installed will probably be minimal, and will certainly be a lot less than the cost of retrofitting sensors to existing equipment once ‘clear purposes’ have been identified. However, it is important not to get carried-away with fitting sensors and devices – it should be predictable through appropriate contextual survey, as to what information and signals may be of use in times ahead.

Handling data flows

Underlying the purpose and business case, the need to apply appropriate data management is paramount to achieving the desired outcomes through robust technical implementation. Accumulating data from different sources will not be helpful unless the goal, requirements and procedures of publishing, accessing, handling and processing of the data (in addition to approaches and methodologies for extracting new information from them) are clearly defined. Understanding data requirements is largely a question of structure:

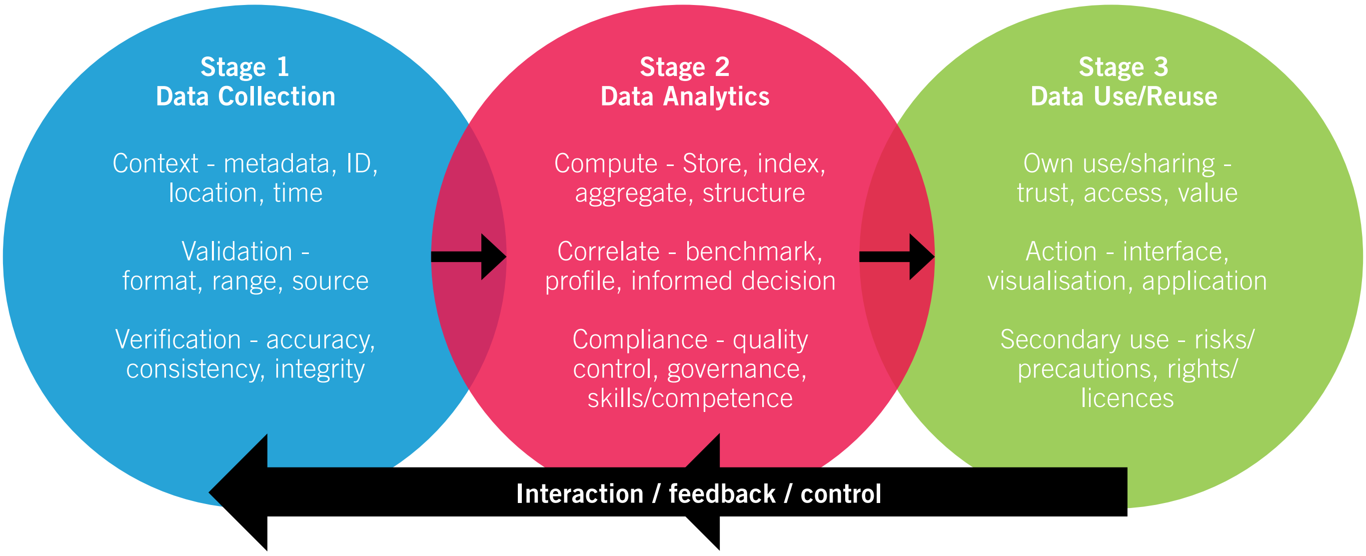
- What reference architectures and technological solutions are suitable to the purpose of the project?
- How do they align with available data sources in terms of quality, format and metadata structure?
- What are the dynamicity, velocity, consistency and volume related issues?

Awareness of these issues is crucial, because it is impossible to get ‘perfect’ data, and so certain insights might be more easily yielded through the use of smaller, discoverable samples with focused tools, rather than application of big data alone. A key challenge is to ascertain domain-specifics in terms of what levels of data granularity and quality, and what degree of tooling will be necessary, to deliver in line with the scale and complexity of the project outputs.

Planning of a data-driven project should also consider the risks and issues of accessing the data, security, communications, collection, and handling policies of pre-, current, and post- project data handling procedures. Figure 3 details the overall data lifecycle, wherein data is collected from sensor readings or other data sources, analysed to provide specific informational insights and transformed into actionable information (use/reuse and feedback/control).

> “There is a strong argument to suggest that how we handle data will affect the speed of the development of the Internet of Things.”
>
> Stephen Pattison, Vice President for Public Affairs, ARM Holdings

Figure 3: Data Lifecycle: Collection, Analytics, Use/Reuse and Feedback/Control



The potential for larger-scale data-driven systems is that via iteration and abundance of data, the systems can be 'tuned' to find new aggregate patterns and to extract new insights and co-relations that were not known before. This opens-up the potential for design and development of more intelligent systems with higher learning capabilities, the prospect of which brings interoperability forward as a key challenge to projects.

With emerging data systems moving away from 'vertical' silos (e.g. those integrated in proprietary systems) towards 'horizontal' systems utilising common data formats and protocols for shared information, there is a need to address data and service interoperability within projects to ensure overall approaches can be scaled or adapted for new purposes, new data sources, or wider ranges of input. For example, while internal data structures and architectures may need to provide information views to support operation as a primary goal, further definition of structures may be required for wider data integration and information interfaces with secondary services.

Developing organisational capability

Both the public and private sectors need to gain more awareness on the value and importance of data, the technical, social and cultural considerations to deal with large-scale data projects and to train and prepare their people with the right skills to drive the related projects. Prior to applying big data and/or data analytics methods, a more immediate question is whether the concepts of data management, ICT systems, analytical tools and contextual requirements for using data, are well-defined and understood within the organisation by all key team-members involved in the project.

An additional requirement is to ensure that both the requirements and approval processes for new assets and systems supports the incremental extra cost of additional sensors and devices whose benefit cannot perhaps be clearly articulated at the procurement stage. For example, projects requiring near real-time processing and analysis of data would be poorly suited to organisational environments with constrained resources and limited ability to deploy sufficient technical know-how to support the task. Some of the key organisational capability issues include awareness and understanding of:

- Adequacy of digital technologies and related internal systems for the project purpose.
- Appropriate use of data sharing and open data ('give-to-get' model) as part of the project.
- Development, articulation and evolution, of benefits-led, multi-stakeholder business cases.
- Requirements for project scale – e.g. are big data and large-scale data analytics imperative?
- Security and privacy risks and dependencies – e.g. have cases such as crowd-source data or contracted third party IT management been assured? Does the exposing of data introduce security risks to the systems concerned?

- Whole systems value – i.e. how to quantify a project, measure payback and qualify success?

The architects of digital projects for the built environment should have clear goals in mind, to identify required datasets and to specify key criteria and restriction to the management of data. Designers and developers can then define the fit-for-purpose software and hardware solutions – from data handling rules and processing methods to technical components and infrastructure –managing the (often distributed and heterogeneous) data sources based on project specific criteria. Looking beyond an organisation's internal processes, there is also a benefit to considering how outputs from data projects can be shared or openly published, with external open-data sources utilised to advance an organisation's own asset base.

Architecture of data-driven projects in closed systems can be totally different to that in open systems. Understanding how to value a data-driven project may also vary among different domains and groups. A city council might take different views on smart cities, some of which may be influenced by their regulatory responsibilities. In the smart city context, for example, different cities might look at projects from such diverse points of view as job creation, environmental management, cleanliness, healthcare, public safety or informed citizenship.

One set of data is often insufficient to derive insight into such wider issues – particularly if data collection has not been designed with this purpose in mind. Multiple data sources and complimentary datasets might need to be utilised in order to extract useful information and insights from that environment. However, without common industry standards for interoperability of data sources, and given the range of processing tools organisations may prefer to support for bringing datasets together, it is unlikely that one set of skills alone will be sufficient to handle the complexity of managing such data projects.

> "The challenge is to make sure that the projects … are done with enough level of aspiration such that resources are not wasted in designing things that are never quite fit for purpose."
>
> Heather Savory, Independent Chair, Open Data User Group

It is also important to note that in some cases, data providing resources can be constrained devices that rely on a limited source of energy (e.g. battery powered), computation or low bandwidth communications. The resource cost of data collection, processing and communication in such constrained environments will also be a key factor in designing efficient data analytics solutions and applications.

Addressing knowledge, skills and training

In planning-out data and technical infrastructure implementations for a project, supporting knowledge, competences and experience of employees, should be reviewed to identify any skills gaps. Individual digital skills development is a key step towards building organisational capability for digital technology projects, though it is only through effective team-working that a culture embracing principles of data-driven decision-making can be established.

The key challenges to matching project purpose with the functional skills sets and relevant competencies to deliver upon objectives can broadly be summarised as follows:

- Assessment and evaluation of planning, integration, adoption and operation for digital technologies (key to continuous improvement).
- Definition of procedures, project roles and responsibilities (who should own what aspects, and how collaboration can be facilitated between different roles).
- Identification of gaps in current infrastructure, skills, expertise and required knowledge and approaches, to deal with these issues.
- Identification of realistic goals and targets in bringing a benefits-led value-proposition for digital technology deployment into the organisation.
- Risk analysis in accessing, collecting and using data, and defining contingency plans.
- Strategy definition, supporting policy development and compliance management (including privacy, security, governance, and quality assurance).

Awareness-raising and two-way project communication with the wider user-base is also key to consolidating a people-centric approach that sustains stakeholder engagement and support.

> *"A lot of graduates coming through are very numerate and able to work with data. The problem they have is not a lack of pure technical skills, but a lack of understanding about the business domain and the context."*
>
> Harvey Lewis, Research Director – Analytics, Deloitte LLPp

Taking next steps

Many of the concepts related to adopting digital technologies are not new. Established organisations will already recognise that service delivery relies not only on technical infrastructure and data systems, but also on their management and wider organisational support.

With projects now moving away from 'pure' engineering systems and bridging out into non-technical fields, a key focus is rising on the need to address end-user benefits and acceptance criteria; and so it is equally as important to clarify the purpose, benefits and risks of such projects. It is up to key stakeholders and decision-makers to engage at critical stages to establish confidence boundaries and forge trust in the project.

Some projects will require a champion. All projects need clear vision and good leadership. For complex projects, teams will rely on multi-disciplinary approaches and strong teamwork to deliver according to expectations upon key requirements – from the minimum viable product-phase upwards. Assessment and evaluation across the project lifecycle will also serve to move projects forwards from fundamental proof of concept, towards achieving additional scale.

An organisation adopting digital technology in the built environment should apply their efforts in a smart way: they should leverage what data, technology and skills are available, and identify what else may be needed in order to deliver in a reliable, dependable, and timely solution – and with that, a successful project. While the technological 'art of the possible' may be constrained by non-technical considerations – such as regulation, data usage rights and end-user perception – the adoption of digital technologies in the smart built environment can yield real-time, real-world intelligence; it can also enable both local control and remote interactions that offer new opportunities in business, industry and society.

The key challenges to doing so are founded both on engineering principles and on interacting with key stakeholders and end users – where relevant barriers to adoption are appropriately overcome, the end result can represent a truly transformative solution.

Best practice case studies

Digital technology adoption case studies published in association with this Technical Briefing and reviewing applications at the building-, community- and city-scale, include:

- City-scale Internet of Things (IoT) infrastructure: Applying a collaborative, people-centric approach
- An open data platform for integrated city services: Open Glasgow
- Integrating building services data for energy efficiency and cost saving investment: Glasgow City Council
- Data Integration Approaches for Smarter Operation of Large Commercial Buildings
- Smart Buildings in Action - Real-Time Structural Monitoring: Barcelona's Olympic Venue 'Palau Sant Jordi'
- Digital Engineering and Project Controls in the Construction Industry
- Accelerating the Adoption of Building Information Modelling (BIM) in the Built Environment

Key terminology

Big data is a generic term that refers to a large collection of datasets that are usually from multiple sources. Big data is considered too large or too complex for traditional data processing methods and applications. Velocity, volume, and variety are among the key issues in handling big data.

Cyber-physical systems are a system of collaborating computational elements controlling physical entities.

Cyber-social projects present increased potential benefits from integration of user data (e.g., from 'citizen-sensors') into behavioural profiles, but also present complex challenges in terms of balancing potential advantages against privacy and security requirements, as well as perceptions of trust.

Data analytics refers to a set of processing mechanisms, techniques and methods that are used to analyse and interpret the datasets for extracting information and meaningful value from them, and the visualisation of data.

Data harvesting, also sometimes known as Web scraping, Web harvesting or Web data extraction. This software technique extracts information from websites. Harvesting focuses on the transformation of unstructured data on the Web into structured data that can be stored and analysed in a central dataset.

Data sharing refers to the approach and methodology for making the data available to other users. Data sharing may require interoperable and flexible ways for providing access to the data.

Data sources in the built environment tend, as a minimum, to include cyber (i.e. Internet-, wireless-, analogue-, state-based data) and physical (i.e. real-world sensor-based) systems, extending at times to the use of social data (i.e. personal information, or data derived from social media or user devices).

Internet of Things (IoT) is an umbrella term that refers to a sub-set of cyber-physical systems wherein real-world objects and systems (often consumer-related products) are interconnected via the internet protocol (IP) to enable data flows and internet-based feedback, interaction and control capabilities.

Open data refers to the idea of enabling everyone to publish and use the data on the Internet and the Web. Open data is usually available for use, sharing, linking and distribution for commercial or non-commercial purposes.

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