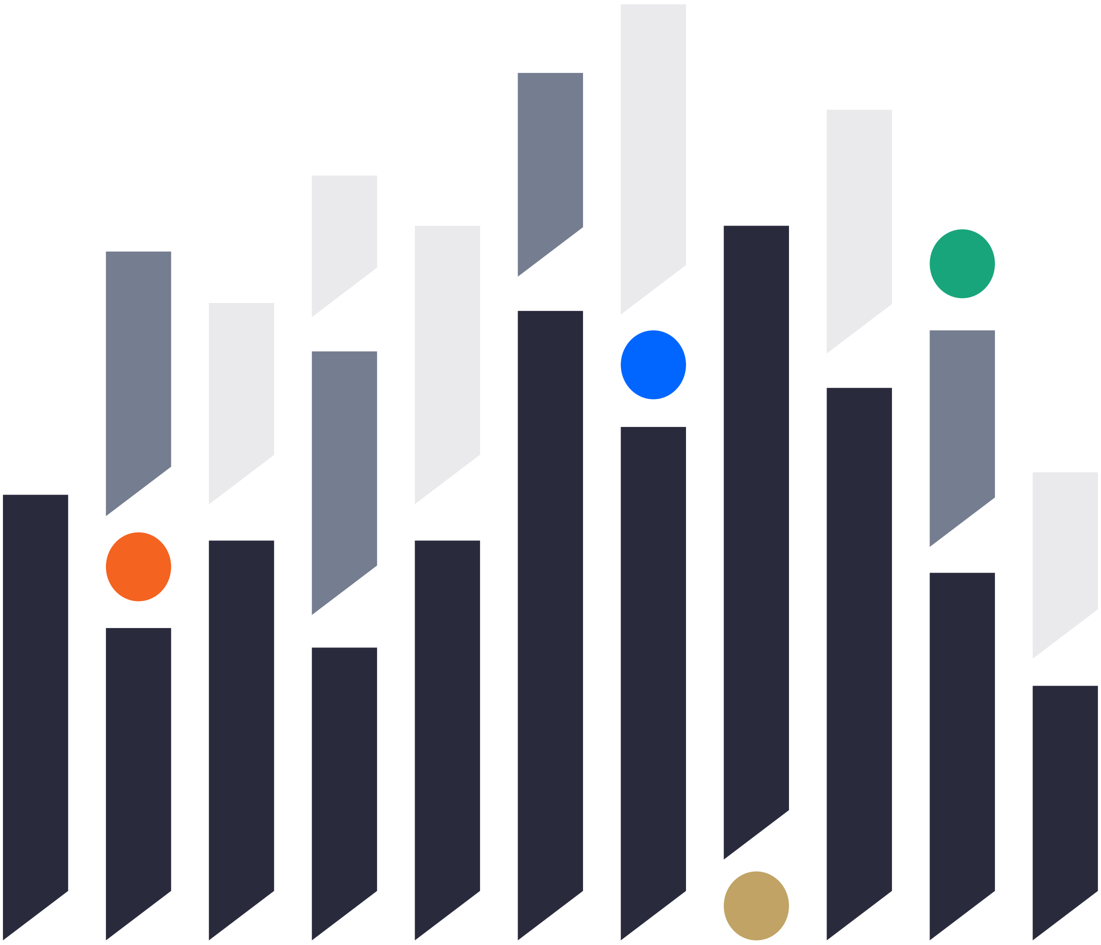
UNIVERSITY OF CAMBRIDGE
Centre for Digital Built Britain

CDBB L2C PROGRAMME

Standards landscape and information management systems



urban innovation labs

WP3 Information Pathways

Executive summary

This work package has introduced the theory of the information pathway approach. Information Pathways trace information about the service provision and asset requirements for the purpose of planning, designing, building, maintaining and/or operating the asset to fulfil the outcomes and performance objectives set out in the use case. It will trace the information and underpinning standards that describe a service that has a capability and capacity to provide economic or social benefit. This will illustrate how the information defined and captured during the design and build phase is critical to the asset maintenance and operation of the asset in the provision of a service that results in an outcome of economic or social impact, or vice versa.

Three use cases were selected, demand side regulation of electricity, integrated traffic management at a network (urban/extra-urban) level, and care of the elderly and the impact of hospital bed blocking. For each use case, a comprehensive standards assessment was undertaken. In all cases. even after careful key word selection to focus the search, identified in the order of 2,000 candidate applicable standards. After further detailed analysis was reduced to between 5-20 that describe information for the service and associated asset lifecycle. The pathways were established through the abstraction of the service layer and association of the assets required to provide the service throughout the assets lifecycle. The assets can be described using the existing IFC or COBie data structures and this will allow for easy migration to a future state.

For demand side regulation of electricity, the pathway was established with relative ease as the network is contained with a series of assets that are well defined. When the information required to describe the service was analysed, it was found at a transmission level information existed and is described by international standards. As you move from transmission to distribution to use, the information is contained within National Grid codes, the Distribution Network Operators or the smart meter data collection service, DCC. At a device level there is no definition for the purpose of demand regulation.

The transport pathway proved to be a challenge construct at an abstracted level due to the complexity in the network description, the actors, the probes and the interaction with other modes. That said, it was constructed, and the information needed for the service identified. This information was described in a range of standards that are focussed on a mixture of device and service.

The healthcare pathway was by far the most challenging as the association of the service and the asset was the most decoupled. The healthcare facility is governed by a range of well-defined rules and then execution of the service occurs within the confines of the facility with very little interaction with the direct outcome. The equipment within the facility is more closely coupled as it directly involved the service provision.

The hypothesis has been successfully tested to show Smart City standards and BIM standards can be linked, aligned and augmented with sectoral de jure and de facto standards, guidelines and codes of practice to enable these pathways to be established.

One of the key principles of the information pathways was the service providing the socioeconomic benefit could be described in terms of its capability and capacity, which is informed by its state and provide a measure of quality of service. This is key, as it allows for a consolidated catalogue of information to be surfaced at a service layer making it possible for different services to interact with the just the key information to describe what it does and much of it is available.

None of the use cases had de jure or de facto standards identified that described the capability of the assets associated with the service. Capacity was described, in engineering terms rather than the

amount of a capability available. The state is discoverable from analytics of available information and the quality of service is defined but would benefit from being associated with the capability and capacity. This approach where the service is abstracted to defining the capability, capacity, state and quality of service and identifying the associated information has been shown to provide a framework in which different standards can be assessed and gaps in functionality defined. It is suggested the approach is tested on further pathways to increase confidence in the approach. Then a guideline produce that can be used in the market to begin the process of advocacy and if applicable crystallised in the appropriate form of standard.

Table of Contents

1 Introduction

This work package will introduce the theory of the information pathway approach. Information Pathways trace information about the service provision (user requirements) and asset requirements for the purpose of planning, designing, building, maintaining and/or operating the asset to fulfil the outcomes and performance objectives set out in the use case.

It will explain how the pathways are rooted in control theory, linked to organisational science and in accordance with international standards. It will trace the information and underpinning standards that describe a service that has a capability and capacity to provide economic or social benefit. This will illustrate how the information defined and captured during the design and build phase is critical to the asset maintenance and operation of the asset in the provision of a service that results in an outcome of economic or social impact, or vice versa. This is in conjunction with how an outcome can be described, and how information about an asset is developed throughout the lifecycle, to the strategic planning stage.

It will seek to test the hypothesis whether the Smart City standards and the BIM standards can be linked, aligned or augmented to enable these pathways to be established and whether sectoral service capability and capacity can be determined. This is analogous to 'looking through the telescope from the other end' as illustrated in Figure 1.

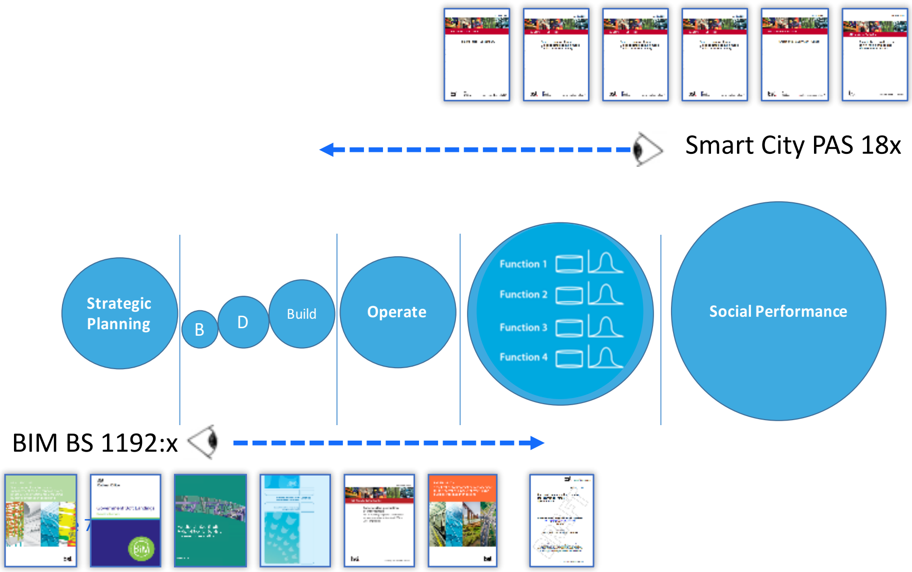


Figure 1 – Relationship between BIM and Smart City standards

2 Background

2.1 Strategic context

A key hypothesis of the Centre for Digital Built Britain (CDBB) is how the information defined and captured during the design and build phase is critical to the asset maintenance and operation of the asset in the provision of a service that results in an outcome of economic or social impact, this is known as feeding forward. When measurements of the asset performance or service outcome or socioeconomic impact are used to inform the strategic planning phase and make interventions to ensure the desired outcome is achieved, this is known as feedback. This process of feeding forward and feedback is core to control theory as illustrated by the closed-loop control diagram in Figure 2.

Using this analogy, CDBB is seeking to define a reference for what an asset should provide and develop closed loop control for the built and natural environment.

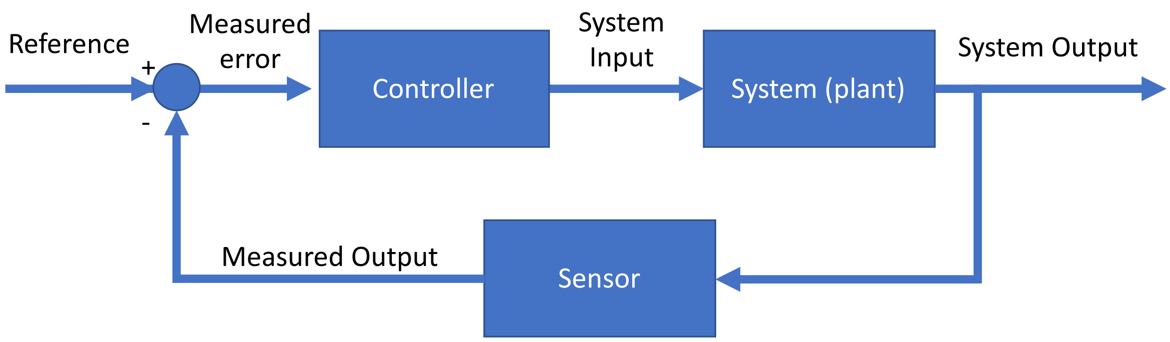


Figure 2 – Closed loop control

ISO9001[1], Quality Management System Requirements adopts a similar approach to have a closed loop control within a Deming cycle[2]. Here, the reference is the organisation and its context, with a series of activities that are evaluated to determine if the outcomes meet expectations with an improvement stage to make changes. This is illustrated in Figure 3.

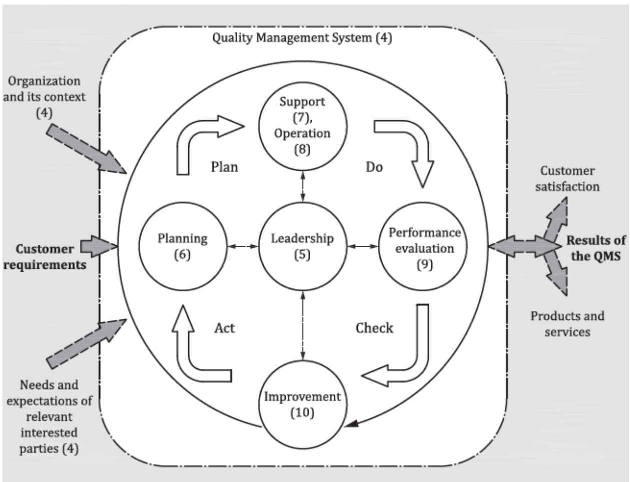


Figure 3 – ISO9001 represented in a Deming cycle

Using the same basic approach to control theory, in 2017 the work of Digital Built Britain proposed the hypothesis that socioeconomic impact would be improved if:

1. Information created during the asset plan, design and build phase is fed-forward into asset maintenance and asset operation, and into the use of the asset to provide services; and
2. Information created about impact, use and behaviour of the asset is fed-back to the planning phase

[1] https://www.iso.org/iso-9001-quality-management.html
[2] https://deming.org

This is illustrated in Figure 4 and also shows where the cost and impact throughout the asset lifecycle resides.

Figure 4 – Principle of feeding-forward and feeding-back information

To contextualise this within an organisation, where organisation could be a nation, city, local authority or campus, there should be a strategic framework linking the different aspects of the organisation together. An example is shown in Figure 5, built on experience and the basis of ISO9001[3]. This shows the relationship between an organisation's vision that explains the purpose, the mission that describes what is to be achieved, articulated through measurable outcomes, delivered through the application of strategy. This leads to the development of (products and) services that are governed by a variety of policy, process, procedures and tools.

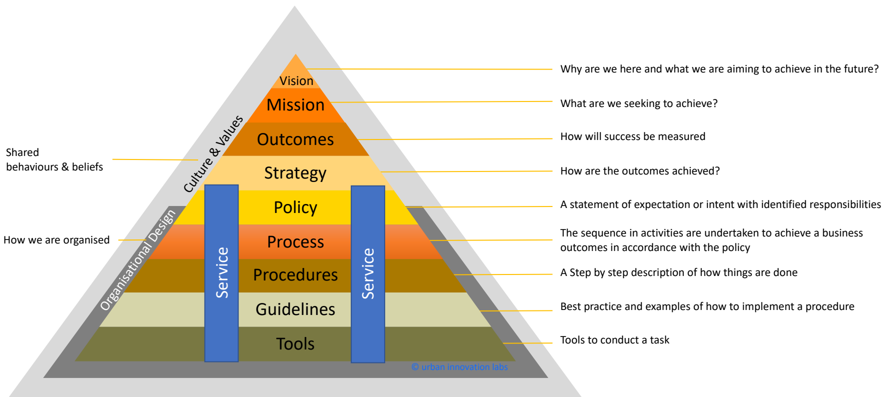


Figure 5 – Organisational Strategic Framework

Building on this approach, the Phase 1 DBB team put forward a Systems Engineering Framework that illustrated a model linking the vision and mission of an organisation, city or state to a series of outcomes and capabilities delivered by services, and the relationship to the underpinning information. This is illustrated in Figure 6.

[3] https://www.iso.org/iso-9001-quality-management.html

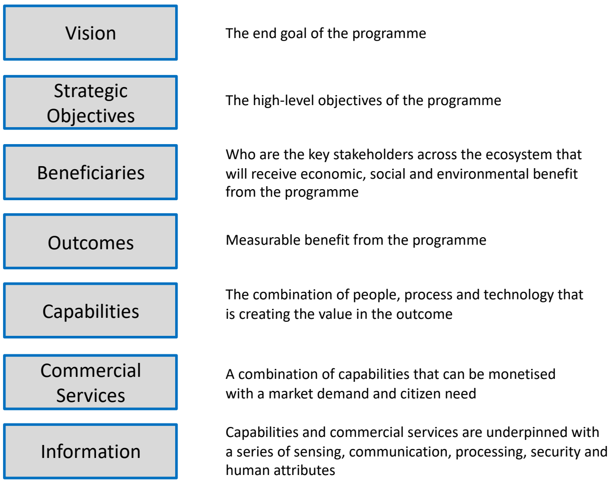


Figure 6 - Systems Engineering Framework

Using this approach within the context of the built environment and starting with the organisational purpose explained in the vision, this should be owned by the appropriate governing body: whether nation, city, region, local authority or parish. The approach to achieving this is explained in PAS181[4] and gives guidance on a framework for decision-makers in Smart Cities and communities (from the public, private and voluntary sectors) to develop, agree and deliver Smart City strategies that can transform their cities' ability to meet future challenges and deliver future aspirations. This is developed into the Smart City Framework (SCF), which distils current good practices into a set of consistent and repeatable patterns. Civic leaders can then use these to help them develop and deliver their own smart city strategies. This is shown in Figure 7.

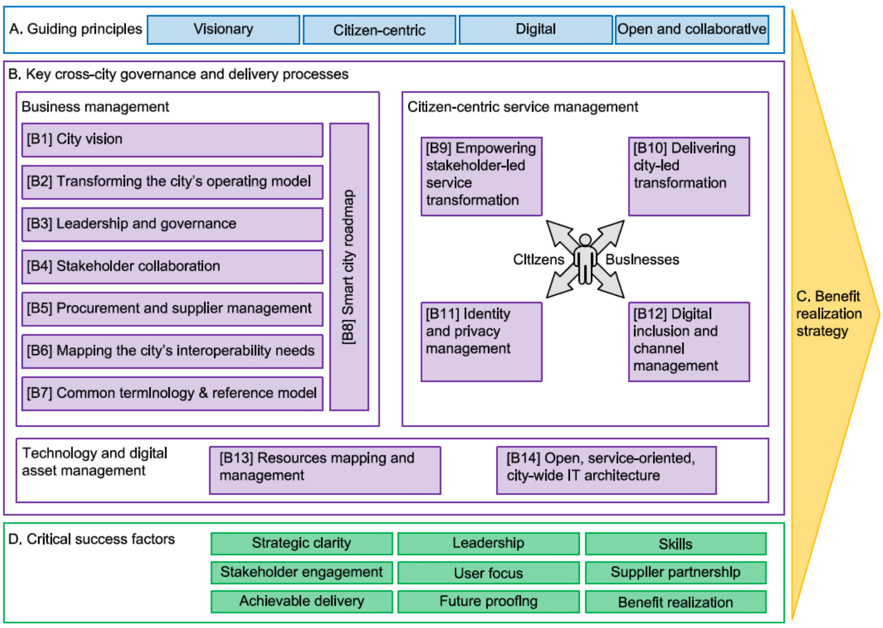


Figure 7 – Smart City Framework

4 https://www.bsigroup.com/en-GB/smart-cities/Smart-Cities-Standards-and-Publication/PAS-181-smart-cities-framework/

Other work by ISO and JCT[5] has summarised other conceptual models provided by a range of organisations. These are useful frameworks to reference, from ICT service layer or data layer perspectives, general statements of city challenges that may be addressed by the use of information, or whether similar to PAS181, identifying that a service management layer is needed.

2.2 Data model for information pathways

Using a combination of Organisational Strategic Framework, the Systems Engineering Framework and the Smart City Framework, it can be seen that the outcomes, the impact and measureable benefit from a service is described by capability. Our further research and experience has concluded that every service activity can and should be described by Capability and should be extended to include Capacity to demonstrate how much is available. This is supplemented by additional information about State and the resultant Quality of Service that provides an outcome. This is illustrated in Figure 8.

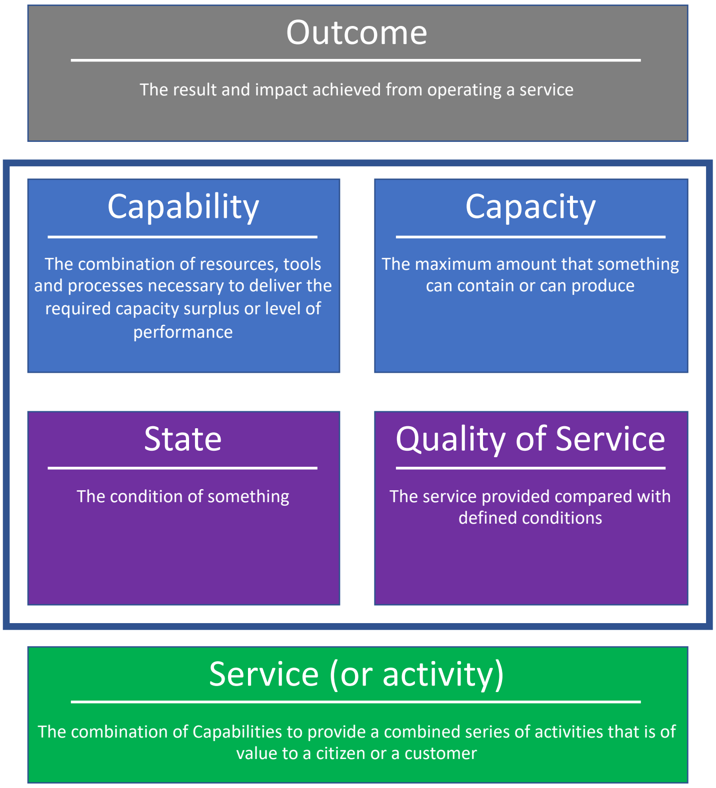


Figure 8 - Components of a service delivery

The Centre for Digital Built Britain has established that the majority of services provided are reliant on the built environment as shown earlier in Figure 4. We used this assumption to further develop our Asset and Activity & Asset information model[6]. Here, a service is provided by a series of activities using an asset that require or produce information in accordance with standards that sets out information needed to demonstrate or describe the capability, capacity, state or quality of service. Some of this

[5] https://www.iso.org/files/live/sites/isoorg/files/developing_standards/docs/en/smart_cities_report-jtc1.pdf

[6] UiI Activity and Asset data model, internal development project, 2016-2017

information is of a personal nature for the subject who is the recipient of the activity or service. An asset will have its own lifecycle, will consume and produce information pertaining to the service capability and capacity, which is described in a standard, guideline or code of practice. This is shown in Figure 9.

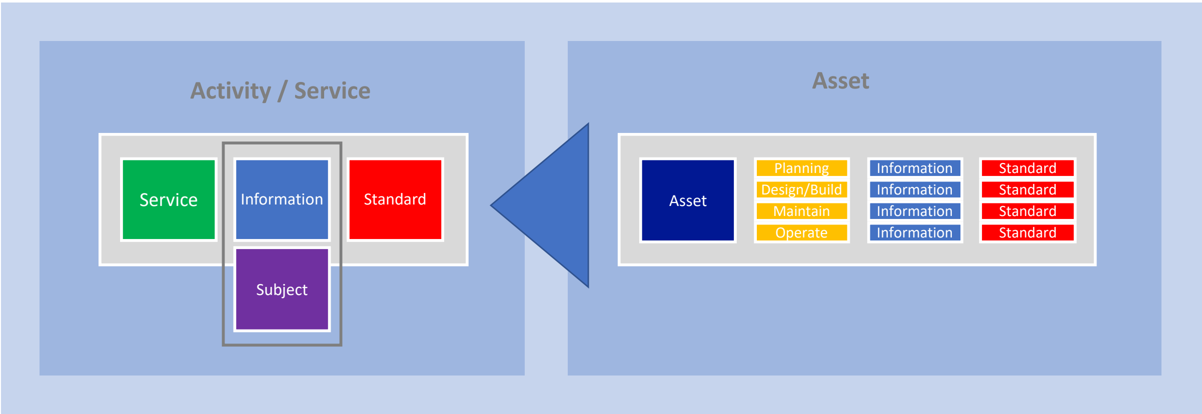


Figure 9 – Activity and Asset Information Model

The asset model can be extended to include all of the aspects required to provide a service, for example: equipment, resources or materials. This is shown in Figure 10.

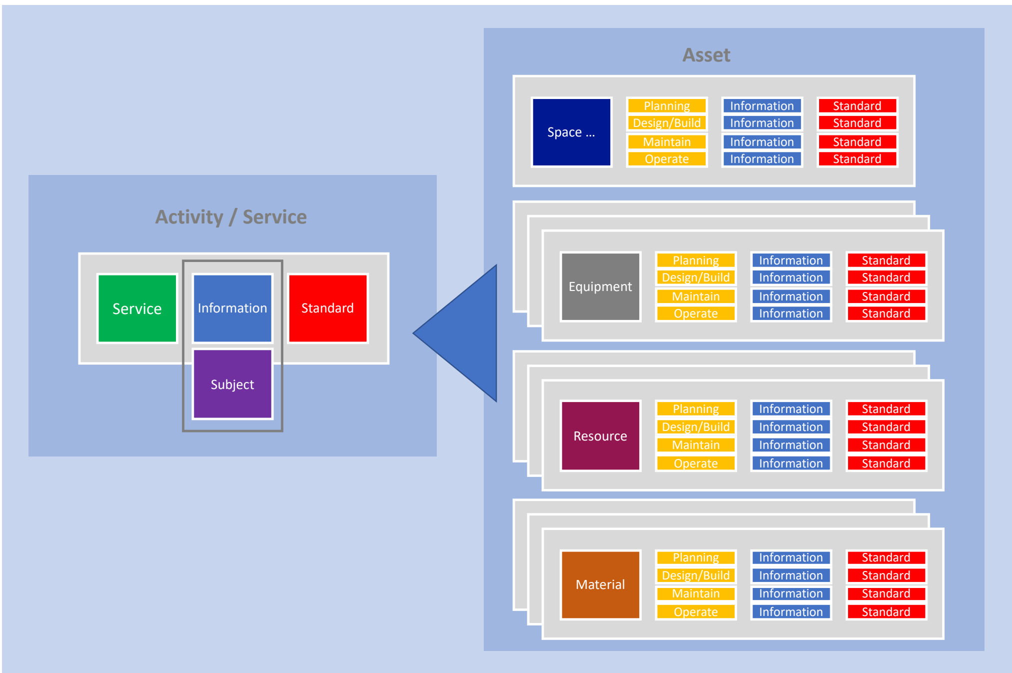


Figure 10 – Extended Asset and Activity Information Model

The structure of the asset definition is aligned to that of the Industry Foundation Class (IFC) and Construction Operate Building information exchange (COBie) formats as shown in Figure 11 and Figure

12. This will ensure that any of the information pathways created can be linked to recognised and established data structures and sources for future analysis.

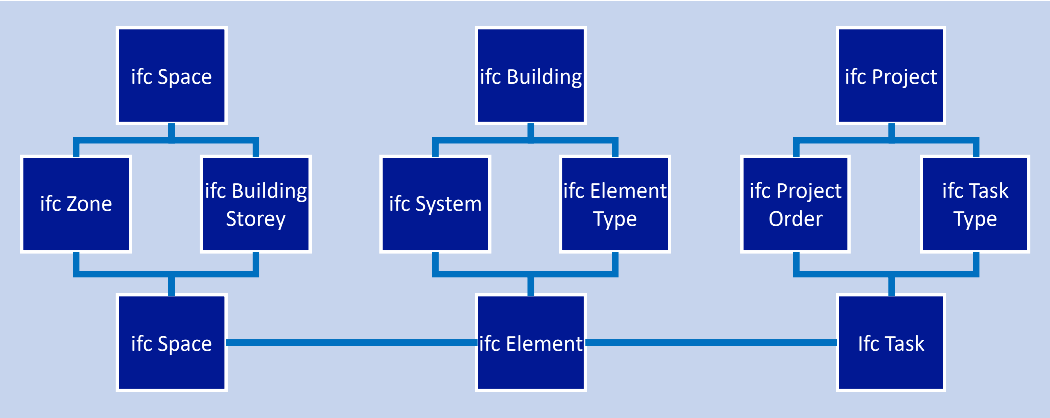


Figure 11 – IFC data model (reproduced)[7]

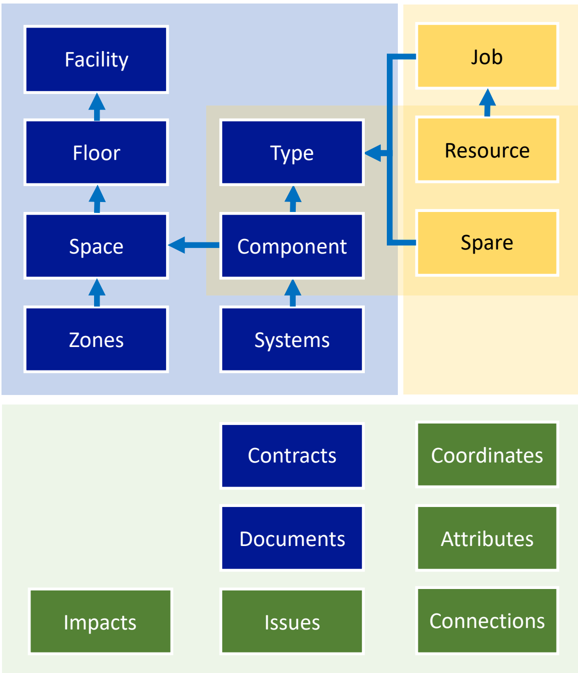


Figure 12 – COBie model

2.3 Creation of information pathways

Information Pathways trace information about the service provision (user requirements) and asset requirements for the purpose of planning, designing, building, maintaining and/or operating the asset to fulfil the outcomes and performance objectives set out in the use case.

[7] © Nick Nesbit, AEC 3

Information is either needed or created to undertake an activity and this capability or capacity may or may not be described by a standard. We have classified 4 use cases for the Activity model and this is illustrated in Figure 13.

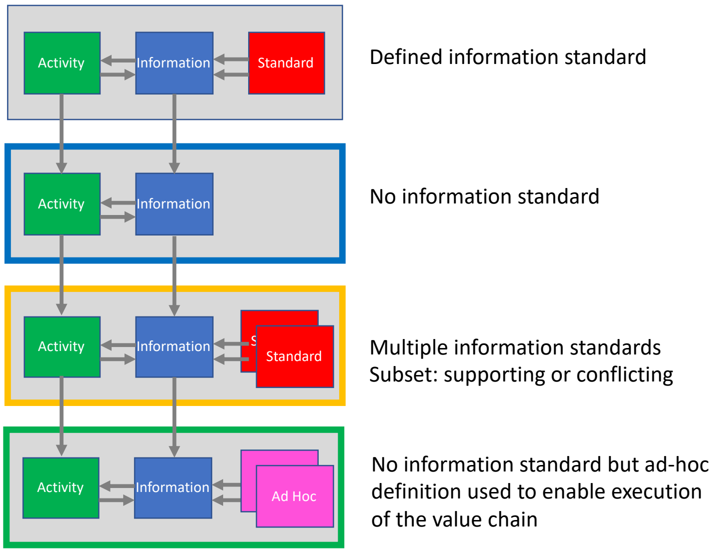


Figure 13 - Classes of Activity Information Model

Individual activities can be combined to create a service and the information models linked to illustrate how the information pathway is established throughout the value chain. This is illustrated in Figure 14. This shows the information pathway as the 'red-line' through the different Activity Information Model stages. The overall service of an organisation is likely to have many potential information pathways, and these are shown by the greyed-out boxes in the diagram. This also illustrates how the different classes of information definition may change throughout the information pathway. These individual Activity Information Models can be combined to create a service information pathway. Where a standard does not exist, someone in the process is making a decision based on their own experience or local custom and practice, in order to deliver a service. This happens, therefore, without necessarily understanding or being sighted on the impact of that decision on the fulfilment of the business objectives.

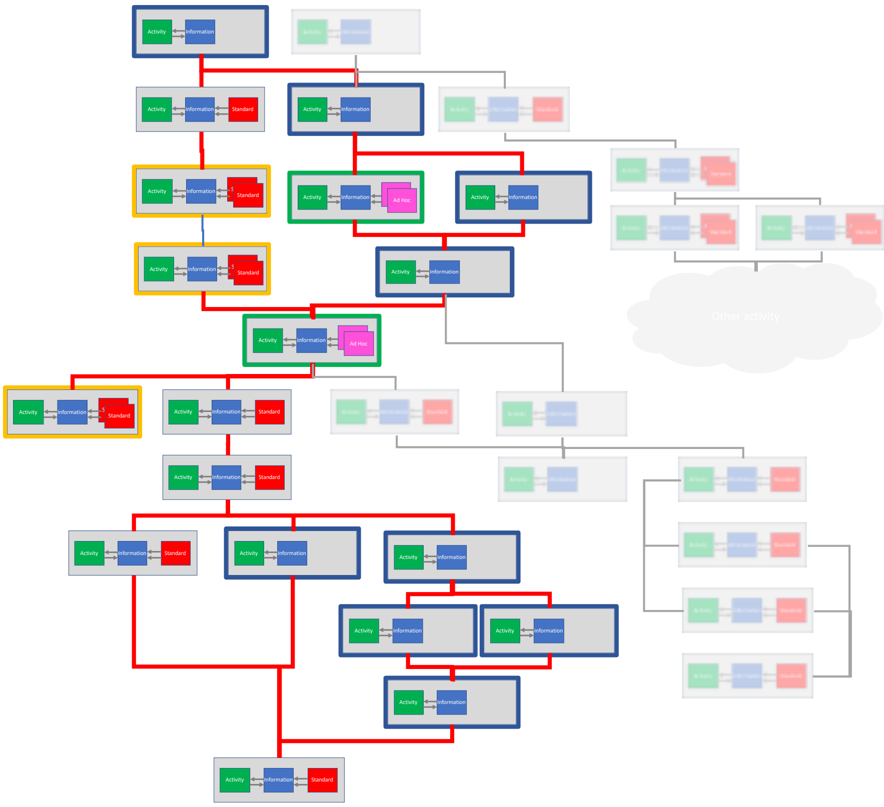


Figure 14 –Illustration of an information pathway

It is hypothesised that even if standards exist, it is likely that only part will be concerned with the service outcomes and that a number of standards will be required to describe the capability and capacity of the end-to-end service provided. It proposed that by highlighting the elements of these services, including descriptors where absent, and extracting to a layer that describes the capability and capacity of a service provision, a new meta-standard could be created that would describe the end to service provided in terms of capability, capacity, state and quality of service. This is shown in Figure 15. This approach is used in Work package 2, meta-standard.

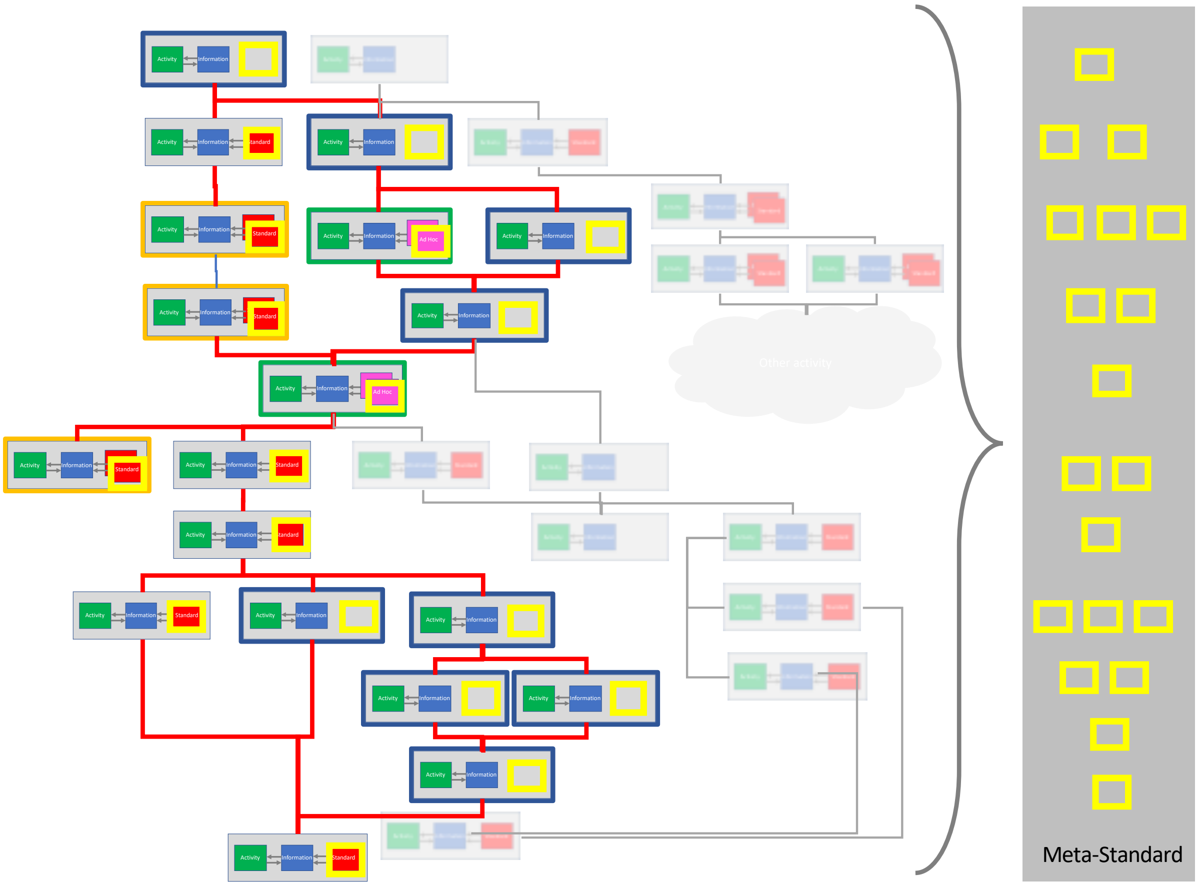


Figure 15 – Illustration of meta-standard creation from information pathway

The technique described in this section is applied to the use cases selected in the next section to create information pathways for services within 3 high value sectors later in the document.

3 Selection of use cases for information pathway creation

This section will describe how the use cases are selected for the subsequent information pathway tracing.

3.1 Appraisal framework for high value sectors

The sectors for consideration were chosen based on a combination of the investment level stated in the National Infrastructure Delivery Plan[8] and the public spend[9] per year by Government department. It was decided that both an investment and public spend perspective was needed to ensure that a good balance was achieved for subsequent use case analysis, rather than biasing too heavily to investment and not recognising the service provided with the assets.

3.2 Identify high value sectors

The investment per sector is shown in Figure 16, here it can be seen that energy, transport and social infrastructure (hospitals, prisons, local community infrastructure) attract the greatest investment. Whilst looking to the public spend in Figure 17, the Department of Health was by far the greatest, driven by the staff cost of the NHS, with education following at around half of the amount of health.

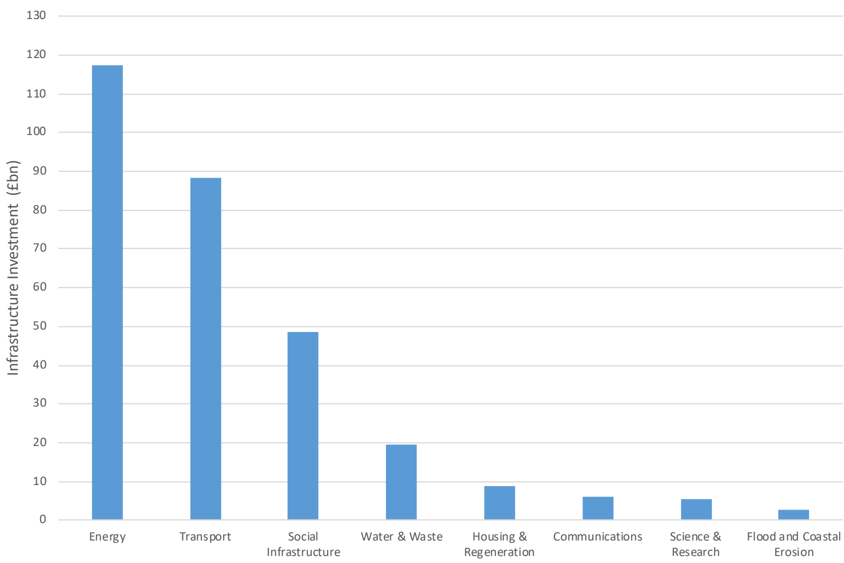


Figure 16 – Investment by sector

[8] https://www.gov.uk/government/publications/national-infrastructure-delivery-plan-2016-to-2021

[9] https://www.gov.uk/government/statistics/public-spending-statistics-release-february-2018

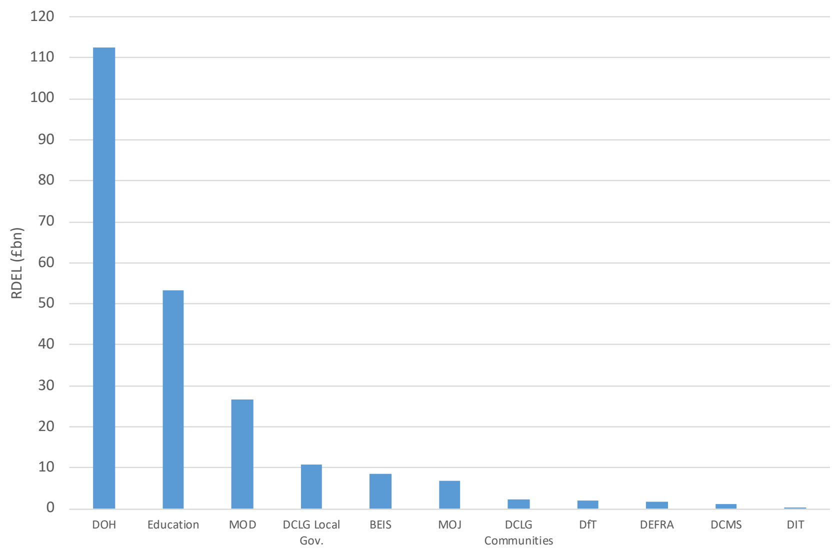


Figure 17 – Spend by department

Based on this analysis it was decided the use cases to be considered for further analysis were:

- Energy
- Transport
- Health Care

3.3 Determine candidate use cases

The use cases were developed using the Design Thinking model established by the Design Council[10], shown in Figure 18. As a product or service is not actually being developed in this instance, the process effectively stops ahead of the delivery phase, but the process of broad consideration and consolidation before developing a detailed solution stands.

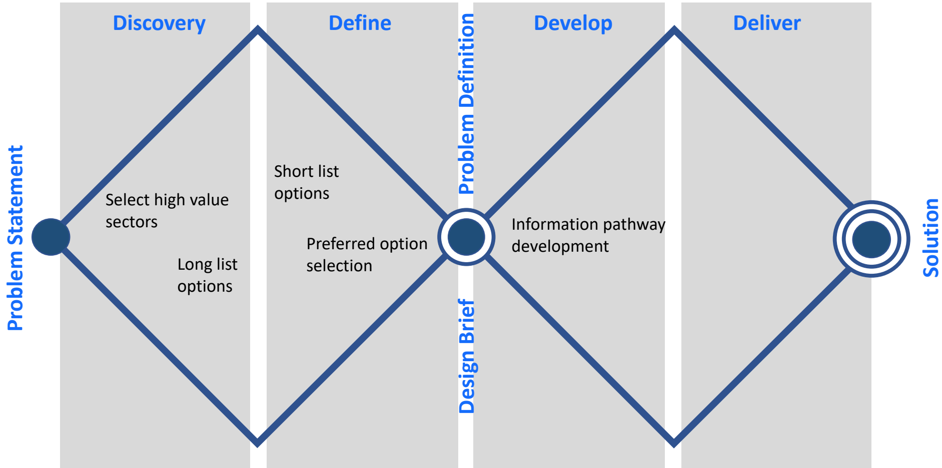


Figure 18 - Double diamond approach for identifying use cases

[10] https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond

This method uses a double diamond containing 4 elements:

Discovery: Identify the problem, opportunity or needs to be addressed. Define the solution space. Build a rich knowledge resource with inspiration and insights.

Define: Analyse the outputs of the Discover phase. Synthesise the findings into a reduced number of opportunities. Define a clear brief for sign off by all stakeholders.

Develop: Develop the initial brief into a product or service for implementation. Design service components in detail and as part of a holistic experience. Iteratively test concepts with end users.

Deliver: Taking product or service to launch. Ensure customer feedback mechanisms are in place. Share lessons from development process back into the organisation.

The discovery phase of qualitative research was undertaken to gain a better understanding of the market, current asset management challenges and priorities in the chosen high value sectors to inform the identification of outcome led services. Each use case section of this paper will provide an overview of the market considerations that have informed the use case. From here a long list is established for consideration.

The define phase is where the long list is appraised to create the short list, which in turn is appraised to define the preferred use case.

The develop phase is where the preferred use case is developed into an information pathway with the associated analysis.

3.4 Appraisal framework development for use cases

The appraisal frameworks were developed as a multi-stage process:

1. Creation of a long list of services through analysis of the selected high value sectors.
2. Review by the sectoral experts of the long list to produce a short list.
3. Establish a detailed appraisal framework and appraise.

3.4.1 Creation of long-list

A market analysis was undertaken for each of the high value sectors to understand what the challenges and opportunities were and to gain an insight into national and international policy. As the vision of CDBB seeks to exploit new and emerging technologies to enhance the natural and built environment, services were considered that deliberately pushed at the boundaries of current practice or where there was a particular compelling need to address. The market investigation undertaken by each of the use case teams is included later in this document for reference.

3.4.2 Review by the sectoral experts of the long list to produce a short list

The long list was short listed based on a round table discussion with the sectoral experts. The criteria used was experience based and focussed on:

Impact: will the use case have a significant contribution to the high value sector?

Service definition: is there a clear service definition?

Breadth: is the service provided by a succinct number of contributing factors that will enable a pragmatic evaluation?

3.4.3 Establish a detailed appraisal framework and appraise

Working with the sectoral experts, a series of criteria were established to assess the short list of the candidate use cases. These criteria reflected a balance between the impact and relevance of the different use cases and the practicality of having the necessary information available to develop the use case. The criteria selected were:

Scope: Looking at how far-reaching the challenge being addressed is, attested by the cross-system dependencies and number or variety of stakeholders sharing the ownership of the services.

Policy alignment: The challenge is clearly aligned with the current national policy landscape, as well as supported by relevant literature. There is strong evidence the services covered in the use case are attracting interest or investment from relevant stakeholders. The validation of the use case included peer review.

Relevance to the DBB: It is expected the findings will contribute to the generation of robust evidence highlighting the value of a whole lifecycle approach to information management. This will enable higher built environment productivity and efficiency levels.

Impact: The value of the services covered by the use case has been clearly established. There is sound evidence of the contribution of services to the identified outcomes and wider environmental and socio-economic impacts.

Replicability/Scalability: Extent to which the use case presents a challenge also recognised in other systems or sectors, and how applicable would the findings be in addressing it.

Innovation potential: Level of ambition of the use case translated by the ability of the services in addressing a well-recognised challenge whilst significantly progressing the state-of-the-art.

Data availability: The required information to successfully develop the research is accessible within a reasonable timeframe.

Clearly identifiable benefits: The benefits are identifiable and demonstrable.

Unfulfilled services contribute to use case: New intermediate or end services can be identified.

Pervasion through lifecycle: The extent the service impacts the lifecycle.

Each criteria is expanded upon to give fidelity to the assessment criteria and allow for individual rating for each sub-criteria where necessary. This is shown in Figure 19.

	Criteria	Descriptors	Transport					Energy					Health				
			Service 1	Service 2	Service 3	Service 4	Service 5	Service 1	Service 2	Service 3	Service 4	Service 5	Service 1	Service 2	Service 3	Service 4	Service 5
1	Scope	**Looking at how far-reaching is the challenge addressed, attested by the cross-system dependencies and number/variety of stakeholders sharing the ownership of the services.**															
	1.1	the challenge is clearly defined															
	1.2	the requirement for interoperability with other use cases is identified															
	1.3	the requirement for intergration with other use cases is identified															
	1.4	the relevant stakeholders have been identified															
2	Policy alignment	**The challenge is clearly aligned with the current national policy landscape, as well as supported by relevant literature. There is strong evidence the services covered in the use case are atracting interest/investment from relevant stakeholders. The validation of the use case included peer review.**															
	2.1	the challenge is clearly aligned with the current national policy landscape															
	2.2	there is strong evidence that services in the use case attract the interest and investment from regular stakeholders															
	2.3	the use case has been validated through peer review															
3	Relevance to the DBB	**It is expected the findings will contribute to the generation of robust evidence highlighting the value of a whole lifecycle approach to information management to enable higher built environment productivity and efficiency levels.**															
	3.1	the assets relevant to the use case are known and their requirements understood															
	3.2	the asset information requirements are clearly identified translating to the capability sought															
	3.3	the asset capacity requirements for the use case is identified															
	3.4	there is a relevant capability model developed															
	3.4	the information, and supporting standards, required is identified and understood															
4	Impact	**The value of the services covered by the use case has been clearly established. There is sound evidence of the contribution of services to the identified outcomes and wider environmental and socio-economic impacts.**															
	4.1	the business case has been devleoped															
	4.2	Key performance indicators have been identified															
	4.3	There is exisiting performance evidence base															
5	Replicability/Scalability	**Extent to which the use case presents a challenge also recognised in other systems/sectors, and how applicable would the findings be in addressing it.**															
	5.1	dependencies to other sectors clearly identified															
	5.2	point of integration recognised															
6	Innovation potential	**Level of ambition of the use case translated by the ability of the services in addressing a well recognised challenge whilst significantly progressing the state-of-the-art.**															
	6.1	the service has a clear business acase and linked to impact															
	6.2	the service has been implemented and is used															
7	Data availability	**The required information to successfully develop the research is accessible within a reasonable timeframe.**															
	7.1	information requrieemtns are identfied and sourced															
	7.2																
	7.3																
8	Clearly indentifiable benefits	**The benefits are indentifiable and demonstrable**															
	8.1	Information available from trusted sources															
	8.2	Research available															
9	Unfullilled services contribite to use case	**New intermediate or end services can be identified**															
	9.1	Service can be described															
	9.2	New services lines exist or are emerging															
	9.3	Established service need identified															
10	Pervasion through lifecycle	**The depth of pervasion the service impacts the lifecycle**															
	10.1	Understood and can be described															
	10.2	Has reasonable depth at all lifecycle stages															

Figure 19 - Appraisal framework for candidate service use cases

4 Standards analysis

A key component of the information pathways is the associated standards. The international standards database Perinorm[11] was used. This is the leading bibliographic database with national, European and international standards from more than 200 standards publishing organisations, in 23 countries, with a total of more than 1,400,000 records.

In order to interrogate the Perinorm database, a search is conducted in the English language on title, abstract and descriptors. The definition of the search criteria, the keywords, is the pivotal part of the overall analysis to ensure that a balance is reached between over inclusion of standards that would result in significant post processing, automatic and manual, and exclusion where a criterion is so narrow many standards that may be relevant are not included. It is a process that requires some expertise of the sector and how standards are described, and still takes many iterations to strike the right balance in returns.

Building on the work undertaken in Work package 2, the standards landscape, this section focused on the sectoral specific searches and relating these to the stages in the asset and data lifecycle as illustrated in Figure 20.

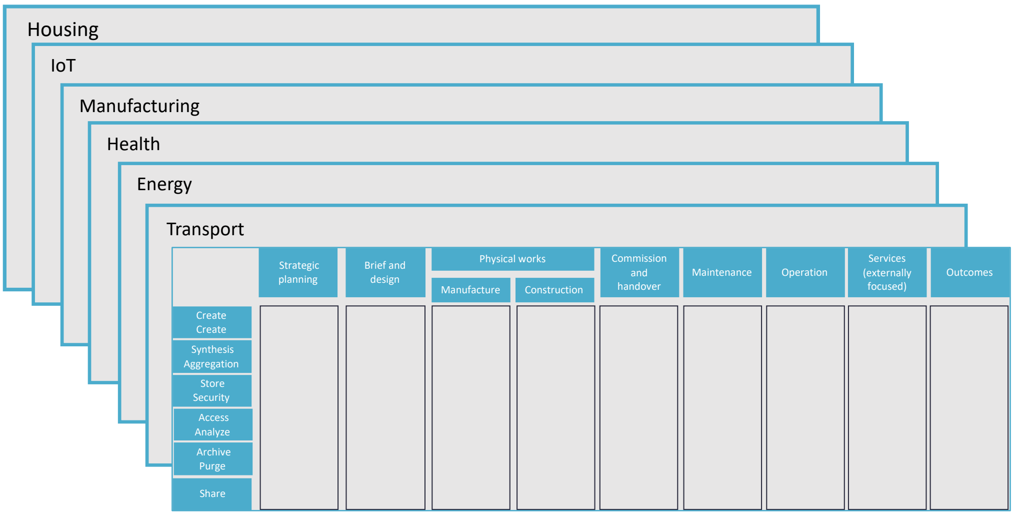


Figure 20 - Approach to sectoral standards analysis

The key words developed for the asset lifecycle and data lifecycle are described in Table 1, Table 2, Table 3 and Table 4.

[11] https://www.perinorm.com

Asset Lifecycle stage	Definition
Strategic Planning	Definition of capability and capacity required by an asset in relation to a wider system, to support service provision, and to achieve defined outcomes.
Brief and Design	Specification of the requirements for an asset to achieve the required outcomes.
Manufacture	Execution of activities and processes that deliver the asset (output) to the brief or specification.
Construction	Execution of activities and processes that deliver the asset (output) to the brief or specification.
Commission and handover	Confirmation the brief or specification has been met through assurance.
Maintenance	Activities to the asset so it continues to be available to meet brief or specification.
Operations	Activities to the asset to enable the service to be provided with the asset.
Service	Process (or combination of processes) provided to achieve the output.
Outcomes	The level of performance or achievement that occurred because of the activity or services. Outcome measures are a more appropriate indicator of effectiveness (perception of quality).

Table 1 - Definition of asset lifecycle

Asset Lifecycle stage	Keywords
Strategic Planning	strategic, define plan, client, brief, requirement, scope, outline, interdependencies, stakeholders, ecosystem, constraints, beneficiaries, user, business case, outcome
Brief and Design	brief, design, requirement, specification, aspiration, scope, objectives, plan, responsibility, feasibility, regulation
Manufacture	manufacture, make, produce, process, part, component, supply chain, deliver
Construction	construct, build, site, sequence, supply chain, deliver
Commission and handover	commission, handover, inspect, assess, assure, confirm, approve
Maintenance	maintain, fix, mend, prevent, predict, available, up time
Operations	operate, provide, asset owner

Asset Lifecycle stage	Keywords
Service	service, provide, customer, client, benefit, user, assist
Outcomes	outcome, quality, benefit , consequence, result, effect

Table 2 – Keywords for asset lifecycle

Data Lifecycle stage	Definition
Creation	The process of gathering, filtering and cleaning data.
Storage	The process of recording data in form that can be accessed for subsequent use.
Analysis	The activity to process raw data for operational decision-making or domain specific application.
Insight	The activity of interpreting the data to identify patterns, trends and opportunity.
Reuse	Where data created and analysed for one purpose has additional applications within an organisation.
Archive	The process of moving data that is no longer actively used to a separate storage device for long-term retention,
Deletion	The method of destroying data so that it no longer readable.

Table 3 - Definition of data lifecycle

Data Lifecycle stage	Definition
Creation	create, measure, acquire, cleaning, filtering
Storage	store, write, drive, recording
Analysis	analysis, process, decision, inspect, transform
Insight	insight, curation, interpretation, discovery, evaluate
Reuse	reuse, additional, extra, repurpose
Archive	archive, store, long term, retention
Deletion	delete, wipe, erase, remove, permanent

Table 4 – Keywords for data lifecycle

The development of sectoral specific keywords is described in the respective sections.

5 Utilities

5.1 Market analysis

The electricity energy market in UK can effectively be split into three areas: generation, transportation (transmission and distribution) and selling. Energy companies (privatised in the UK) can work in any of these different areas, and some operate across all three.

5.1.1 Generation

Electricity generation ranges from large power stations connected to the national transmission network, through to smaller scale power stations connected to the regional distribution networks. The decision on generating asset provision is a combination of energy company decisions, market signals and government policy. The number of companies in this sector, at the smaller end of the scale, is increasing. The breakdown by energy generation source is illustrated in Figure 21 [12] and shows the proportions in 2015 and 2016.

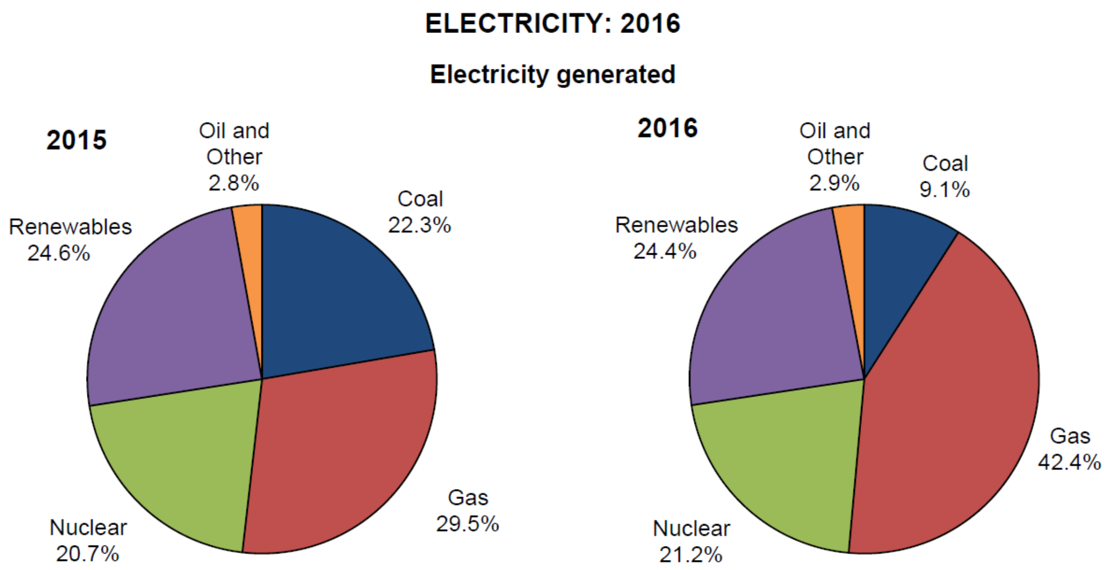


Figure 21 - Summary of UK electricity supply mix 2015 and Q4 2016

5.1.2 Transmission and Distribution

The transmission system is run by the National Grid and carries electricity long distances around the country at high voltages. The distribution network operates at a lower voltage and connects the Grid to homes and businesses. The National Grid is responsible for balancing the system and making sure that the supply of electricity meets the demand on a second-by-second basis. Currently there are 3 Transmission Network Operators (TNOs) and 14 Distribution Network Operators (DNOs).

[12] BEIS 2017 - UK Energy Statistics, 2016 & Q4 2016

5.1.3 Energy supply market

Suppliers buy energy in the wholesale market and sell it on to customers: the retail market. Suppliers work in a competitive market and customers can choose any supplier to provide them with electricity or gas. This is illustrated in Figure 22[13]:

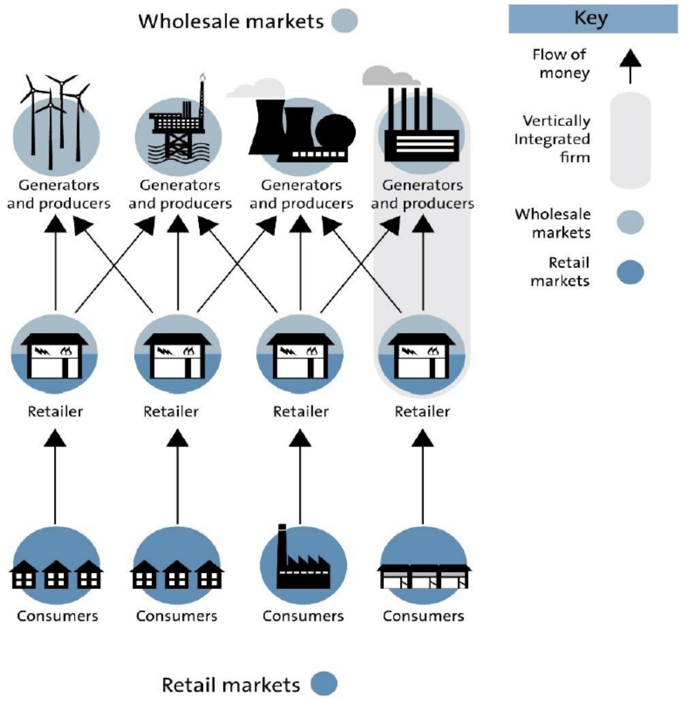


Figure 22 - Relationship between electricity wholesale and retail markets*

5.1.4 Energy regulation

The electricity (and gas) markets are regulated by the Gas and Electricity Markets Authority, operating through the Office of Gas and Electricity Markets (Ofgem). Ofgem issues companies with licences to carry out activities in the electricity and gas sectors, sets the levels of return which the monopoly networks companies can make, and decides on changes to market rules.

5.1.5 A market place in transition

The energy industry is undergoing significant change in response to changes in energy reserves and associated pricing and the policy drive toward the use of renewable resources and carbon reduction. This is impacting:

- The generation mix.

[13] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/531157/Energy-final-report-summary.pdf

- Flexibility and security of supply.
- Renewable deployment.
- Emissions reduction.

Electricity is a unique product that cannot currently be stored in large amounts. Supply and demand for electricity must be matched, or balanced, at all times. This balancing is primarily done by suppliers, generators, traders and customers trading in the competitive wholesale electricity market. Trading can take place bilaterally or on exchanges, and contracts for electricity can be struck over timescales ranging from several years ahead to on-the-day trading markets. Electricity can also be imported or exported through interconnectors. Currently there are electricity interconnectors between Britain and France, the Netherlands and Ireland.

National Grid Electricity Transmission (NGET) has overall responsibility as 'residual balancer' of the electricity system, and takes actions to ensure that electricity supply and demand match on a second-by-second basis. NGET has a number of tools that it can use to do this, including the Balancing Mechanism (BM). The Balancing Mechanism allows NGET to accept offers of electricity (generation increases and demand reductions) and bids for electricity (generation reductions and demand increases) at very short notice.

If a market participant generates or consumes more or less electricity than they have contracted for, they are exposed to the imbalance price, or 'cash-out', for the difference. The cash-out price is the incentive on market participants to ensure electricity consumers' demand is met, and the 'residual balancing role' of NGET is minimised. The cash-out price is based on NGET's costs of balancing the system.

5.1.6 Market Reform

Ofgem are responsible for monitoring developments in the electricity market and market arrangements where it is economic and efficient to do so. In addition, they have an important role in relation to the Reform Electricity Market (EMR) programme. It is estimated that over the next decade the UK will need around £100 billion of capital investment in its electricity infrastructure to accommodate projected future increases in electricity demand and to replace ageing power stations. EMR is a government policy to incentivise investment in secure, low-carbon electricity, improve the security of Great Britain's electricity supply, and improve affordability for consumers.

The Energy Act 2013[14] introduced a number of mechanisms. In particular:

- A Capacity Market (CM), helping ensure security of electricity supply at the least cost to the consumer.
- Contracts for Difference (CfD), providing long-term revenue stabilisation for new low carbon initiatives.

[14] http://www.legislation.gov.uk/ukpga/2013/32/contents/enacted

Both will be administered by delivery partners of the Department of Energy and Climate Change (DECC), now BEIS. This includes National Grid Electricity Transmission plc (NGET) as the EMR Delivery Body.

5.1.7 Drivers for Change

The forces for change acting on the electricity market will lead to large scale changes in both the way the network is operated, how supply is provisioned, and how and by whom demand is monitored and controlled.

Drivers for change include targets for the reduction of carbon emissions, incentives for the use of renewables and efficiencies in supply generation and use, and the mandate to roll out smart meters by 2020. Reinforcing the network to meet the peak demand has been the traditional way of ensuring supply. However, with the advent of renewables delivering power time skewed to demand, advances in storage technology, the increase in Electric Vehicles (EV) and the advent of smart automation in buildings and homes, a more comprehensive demand side data, analysis and management will need to be developed.

The Energy Network Association (ENA) [15] stated in the Opening Markets for Network Flexibility report: *"The complete evolution to a whole system approach and Distribution System Operation is a very large-scale business transformation which will require a substantial increase and change in capabilities in the networks over the next 10 years and beyond. Network companies are already evolving in response to the network challenges resulting from the decentralisation of energy production and the future challenges posed by the transition to a low carbon economy."*

Ofgem and BEIS have recently published their Smart Systems & Flexibility Plan placing an onus on ENA's Open Networks Project to "demonstrate how parties will deliver: the opening up of the delivery of network requirements to the market so new solutions such as storage or demand side response can compete directly with more traditional network solutions, including as an alternative to reinforcement."

Two approaches are being evaluated by ENA. The first is where the DSO coordinates - in this model, Distributed Energy Resources (DERs) and aggregators of DER services interact directly with local DSOs to provide services for distribution and transmission constraint management and for electricity system balancing. DSOs schedule the required DER services to deliver National Electricity Transmission System Operator (NETSO) and DSO requirements.

The second approach: joint procurement and dispatch - where DERs and aggregators of DER services interact either with the (NETSO) or with DSOs to provide services for distribution and transmission network constraint management and for electricity system balancing. The NETSO and DSO coordinate the secure scheduling of services.

A number of demonstration programmes run by ENA members, are underway. For example Scottish and Southern Electricity Networks (SSEN) is establishing agreements with suppliers for the provision of Constraint Managed Zone (CMZ) services. CMZs are geographic regions served by existing networks

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[15] Energy Networks Association- Open Networks Project -Opening Markets for Network Flexibility 2017 Achievements and Future Direction

where security of supply is met locally through the use of flexibility services, such as Demand Side Response, Energy Storage and stand-by generation. Innovation at the edge of the network rather than reinforcement more centrally is an increasing trend in the sector.

Ofgem in their report 'Creating the Right Environment'[16] for DSR identified two primary conclusions, the most urgent of which was stated as "*the need for a DSR framework that clearly formalises the interactions between different parties within the existing market model*." The report suggests the need for a DSR framework, which should include common standards for base lining, measuring and verifying DSR and Common communication standards and product definitions.

The development of analytics and greater control of supply and demand will be a key part of a future flexible and responsive smart grid. The financial benefits to the development of a smart grid and greater demand side response are variously estimated in the literature. As an indication of how much could be saved, it is estimated that between 20-30GW of unidentified energy is available within the electricity network, that there is around 6GW[17] of peak shifting potential and shifting this peak demand electricity supply would, in principle, remove the need for building grid generation capacity equivalent to Hinckley point C.

5.1.8 Who are the Stakeholders?

The electricity energy market is complex and has a wide range of actors from organisations, businesses, government departments, and regulatory bodies, through to consumers (who are increasingly generators in their own right) and new entrants. The main stakeholders are listed in Table 5.

Body	Descriptor
DECC (now BEIS)	Department for Energy and Climate change
Ofgem	Office of Gas and Electricity Markets
NETSO	National Electricity Transmission System Operator
TSO	Transmission System Operator
NGET	National Grid Electricity Transmission
DNO	Distribution Network Operator
IDNOs	Independent distribution System operators
OSO	Overseas System Operators
EMR	Electricity Market Reform delivery body
	Centralised generation providers

[16] Ofgem 2013 - Creating the right environment for demand-side response: next steps
[17] http://www.openenergi.com/uk-demand-side-flexibility-mapped/

Body	Descriptor
	Decentralised generation providers
	Energy suppliers
	Low carbon Contracts company
	Electricity Settlements Company
	Consumers
	Storage suppliers
	Home and building automation suppliers
	Aggregators
	Consumer product suppliers
	ICT and communications suppliers
	Community Energy Groups
	Smart City developers
	Smart Meters and associated Data and Communications Company (DCC)
	Balancing and settlement - Elexon

Table 5 - Electricity sector stakeholders

5.1.9 The Role of Demand Side Response (DSR)

DSR is a change in the power consumption of a customer to better match the demand for power with the supply. Operators have traditionally matched demand and supply by throttling the production rate by taking generating units on or off line, or importing power from other suppliers. There are limits to what can be achieved on the supply side, because some generating units can take a long time to come on line, may be expensive to operate, and demand can at times be greater than the capacity of all the available supply sources put together. Demand response seeks to adjust the demand for power instead of adjusting the supply. This approach will become more challenging as the percentage of renewable (availability time skewed) sources increases.

Demand side management is the ability of customers to have a greater role in load shifting their demand for electricity during peak periods and reducing electricity use overall. Load shifting or Demand Response (DR) allows transfer of customer loads to off peak periods of supply whilst energy efficiency and conservation encourage users to use less energy (through active monitoring) and through choosing more energy efficient appliances.

However, it is not just consumers that have a role to play. Large industrial and commercial customers, medium and small enterprises, and aggregators are part of a solution landscape increasingly providing on-site generation and storage and by reducing demand.

The figure below from the ofgem report - 'Creating the right environment for demand-side response: next steps'[18] - identifies a number of areas within the disaggregated supply chain that can be positively impacted by DSR.

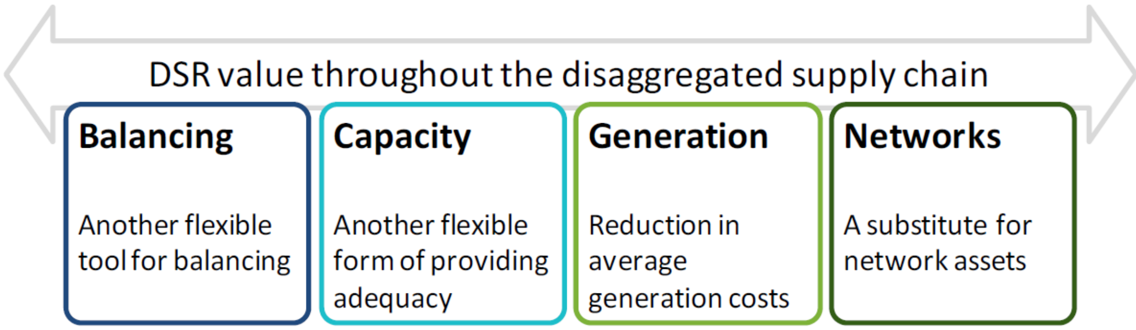


Figure 23 [18]: DSR disaggregated supply chain

The McKinsey report[19] - 'The Smart Grid and the promise of Demand Side Management' - identifies the following as key levers to an effective DSR:

- Tariffs – The ability to offer attractive tariffs which drive behaviour. For example, Time of Use (TOU), Critical Peak Pricing (CPP), or Real Time Pricing (RTP).
- Incentives – To encourage participation in demand side programs.
- Access to information – To inform energy use decision-making, real time and historical usage data, and so on.
- Automation systems – to directly control loads such as air conditioning during critical periods of peak demand or directly control energy storage and release.
- Education and marketing – making the case for DSM.
- Customer insight and verification – the ability to close the loop when operating DSR.

A key part of enabling effective DSR will also be the development and evolution of the Smart Grid. Ofgem's Smart Grid Vision and Route map[20] highlights increasing digitalisation of the network with ever greater use of smart technology in building and home automation and, as importantly, in monitoring both the grid edge, transmission, distribution, storage and generation elements.

A further key element to enabling DSR is effective and near real time exchange of large volumes of data. The report by the THEMA group – 'Data Exchange in Electric Power Systems: European State of Play and Perspectives'[21] – identifies that by far the most common approach to data exchange between TSOs and DNOs in Europe is currently decentralised. It seems likely that closer integration of both TSO's and DSO's data will be needed through the use of a Data Exchange Platforms (DEPs). Furthermore, this data will be needed to be securely shared with third party service providers such as aggregators and energy service companies.

[18] Ofgem 2013 - Creating the right environment for demand-side response: next steps
[19] McKinsey 2010 - Smart grid and the promise of demand side management
[20] Ofgem 2014 – Smart grid vision and route map
[21] Thema Consulting Group 2107 – Data exchange in electric power systems: European state of play perspectives

5.2 Use case selection for utilities

This section details how the High Value Sectors described earlier were decomposed to long list candidate areas within the utilities sectors. These were subsequently short listed and a preferred option for evaluation chosen for detailed pathway analysis.

5.2.1 Long list for utilities

The market investigation showed that the utilities sector is at a point of transition as the traditional market structure changes with the introduction of new technologies. It also notes that demand side regulation has the potential to make massive change to our relationship with electricity and its usage. Within this area, the following long list was identified:

- Management of demand side data.
- Real time control of demand side energy assets.
- Peak load management.
- Data services (to other third parties) utilising aggregated consumer and small business demand and usage data.
- Provision or supply of smart home and industry appliances which support DSR.
- Provision of advanced analytics services to provide dynamic supply energy profiles.
- Management of micro grid operation and performance data.
- Data analysis of demand side data to optimise use of storage elements.
- Data acquisition and analytics provision to allow transmission and distribution network elements to be balanced more efficiently.
- Management of grid scale storage data.

5.2.2 Review by the utility experts of the long list to produce a short list

Using the criteria established, each of the items in the long list was appraised on a rating of 0-4, where 4 is the maximum value. The analysis for the utilities sector is shown in Table 6.

Option		Impact	Service definition	Breadth	Total
1	Management of demand side data.	4	3	4	11
2	Real time control of demand side energy assets.	4	3	3	10
3	Peak load management.	3	4	2	9
4	Data services (to other third parties) utilising aggregated consumer and small business demand and usage data.	3	3	3	9

Option		Impact	Service definition	Breadth	Total
5	Provision/supply of smart home and industry appliances which support DSR.	4	2	3	9
6	Provision of advanced analytics services to provide dynamic supply energy profiles.	3	3	3	9
7	Management of micro grid operation and performance data.	4	3	3	10
8	Data analysis of demand side data to optimise use of storage elements.	4	3	3	10
9	Data acquisition and analytics provision to allow transmission and distribution network elements to be balanced more efficiently.	3	2	3	8
10	Management of grid scale storage data.	4	3	3	10

Table 6 - Utilities long list appraisal

From this appraisal of the long list, a short list of 5 options have been selected:

Option 1: Management of demand side data.

Option 2: Real time control of demand side energy assets.

Option 7: Management of micro grid operation and performance data.

Option 8: Data analysis of demand side data to optimise use of storage elements.

Option 10: Management of grid scale storage data.

These options are then assessed using the detailed appraisal framework in the subsequent sections.

5.2.3 Establish a detailed appraisal framework and appraise

Working with the sectoral experts, a series of criteria were established to assess the short list of the candidate use cases. These criteria reflected a balance between the impact and relevance of the different use cases and the practicality of having the necessary information available to develop the use case. These were applied to the options short listed by the experts as shown in Table 7. This analysis resulted in the use case 'Option 1: Management of demand side data' being selected as the preferred option. This option will now be taken forward to develop the information pathway.

Criteria	Details	Management of demand side data Option 1	Real time control of demand side energy assets Option 2	Management of micro grid operation and performance data Option 7	Data analysis of demand side data to optimise use of storage elements Option 8	Management of grid scale storage data Option 10
Scope	How far-reaching is the challenge addressed, attested by the cross-system dependencies and number/variety of stakeholders sharing the ownership of the services	4	4	3	3	3
Policy alignment	The challenge is clearly aligned with the current national policy landscape, as well as supported by relevant literature. There is strong evidence the services covered in the use case are attracting interest/investment from relevant stakeholders. The validation of the use case included peer review.	4	3	4	4	4
Relevance to the DBB	It is expected the findings will contribute to the generation of robust evidence highlighting the value of a whole lifecycle approach to information management to enable higher built environment productivity and efficiency levels.	4	3	3	3	2
Impact	The value of the services covered by the use case has been clearly established. There is sound evidence of the contribution of services to the identified outcomes and wider environmental and socio-economic impacts.	4	4	3	3	2
Replicability / Scalability	Extent to which the use case presents a challenge also recognised in other systems/sectors, and how applicable would the findings be in addressing it.	4	4	3	3	2
Innovation potential:	Level of ambition of the use case translated by the ability of the services in addressing a well-recognised challenge whilst significantly progressing the state-of-the-art.	4	3	3	3	3
Data availability	The required information to successfully develop the research is accessible within a reasonable timeframe.	3	3	2	2	2
Clearly identifiable benefits	The benefits are identifiable and demonstrable.	3	3	3	3	3
Unfulfilled services	Contribute to use case: new intermediate or end services can be identified.	3	3	3	3	3
Pervasion	Through lifecycle: The extent the service impacts the lifecycle.	3	3	3	3	3
Total		36	33	30	30	27

Table 7 – Utilities short list appraisal

5.3 Standards analysis

A key component of the information pathways are the associated standards. In order to understand the specific standards landscape for the use case 'management of demand side data', this service is one of a number that would be required to form closed loop control and monitoring of demand generation and load elements. This would exist within the overall electricity network or within a smaller local micro grid, or perhaps as an energy aggregator.

5.3.1 Selection of keywords for standards analysis

In order to interrogate the BSI Perinorm standards database (searching in English language on the title and abstract) it was necessary to develop key words from the service. The initial approach was to disaggregate the service descriptor into component parts and brainstorm synonyms for the individual elements. Additionally, three further fields were added the first: the sector 'Utilities', the second 'Family' acting as an top level clarifier for the developed key words, and finally 'Other associations', designed to capture adjacent keywords not developed from individual parts of the part of the service but thought to be strong adjacent associated keywords. This is shown on Table 8.

Name of service: Management of (electricity) demand side data				
Sector	Utilities			
Family	Service specific			Other associations
	Management of	Demand side	Data	
Smart Grid	Control centre	DSR	Information	Demand management
Electricity	Management	Energy demand	Energy consumption	Demand side management
Micro Grid	Forecasting		Available capacity data	Behind the meter
Smart cities			Consumption profile data	Edge balancing
			Environmental data	

Table 8 - Utilities initial keyword selection

In a separate interactive session within the project team and BSI, the keywords above were further developed. The table of revised keywords has a number of features of note. Each of the family keyword is processes by logical AND with the consolidated service and associated OR 'ed' keywords below it. The same keywords are used for all family keywords with the exception on the last two 'smart home' and 'smart energy profile'. During testing with Perinorm, no results were surfaced when these two family keywords were used in logical association with the others so they were left as single keyword searches.

Extensive use has been made of the wild card operator '*' in the keywords to cover the use of plurals and continuous ending forms. The words 'data' and 'electricity' are not used singly but rather in combination since if used in isolation they generate too many hits. Care has also been taken in the use of the word 'centre' as both endings have been used to ensure that standards using either 'er' or 're' ending will be surfaced. This is shown in Table 9

Name of service: Management of (electricity) demand side data								
Sector: utilities								
Family association								
Micro grid	Smart Cities	Smart Grid	Electricity OR "Power transmission" OR "distribution network*"	Micro grid	Smart buildings	Renewable energy	Smart home	Smart energy profile
"energy manag*" OR "load management" OR "load forecasting" OR "load control*" OR "control centre*" OR "control center*" OR "forecasting" OR "energy demand" OR "load" OR "energy" OR " level of service" OR "information" OR "energy consumption data" OR "available capacity data" OR "consumption profile data" OR "environmental data" OR "demand management" OR "demand-side response" OR "edge balancing" OR "management of DSR data" OR "telematics" OR "building automation" OR "photovoltaic" OR "energy storage" OR "electric vehicles"	<-	<-	<-	<-	<-	<-	blank	blank

Table 9 - Utilities final keyword selection

5.3.2 Results from standards analysis

The keywords generated 2185 separate standards. This baseline data set was further processed to introduce a data cut specifically based on keywords associated with the asset life cycle and the data life cycle. This reduced the number to 1710 standards. This resultant list was then reviewed manually, looking at the title, abstract and descriptors to identify which would be relevant, thus reducing the number to 15.

This search was extended by a manual search to include the de-facto standards: the International Electrotechnical Commission (IEC) Specifications, National Grid codes of practice, the Advanced Metering Infrastructure (AMI) guidelines and those of the Data Communications Company (DCC).

The relevant standards identified include 15 standards from BSI/Perinorm, 7 standards from the IEC list and 3 standards from the adjacent standards or codes list.

Of the Standards identified from the Perinorm search, the following initially down selected (abridged descriptions) give an indication of applicability. These are shown in Table 10.

Standard	Title
PAS 183:2017	Smart cities. Guide to establishing a decision-making framework for sharing data and information services.
BS EN 62939-3.	Smart grid user interface. Part 3. Energy interoperation services.
BS EN 50491-12-1.	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS). Smart grid. Application specification. Interface and framework for customer. Part 12-1. Interface between the CEM and Home/Building Resource manager. General Requirements and Architecture.
ANSI/ASHRAE/NEMA 201	Facility Smart Grid Information Model.
CTA-2045	Modular Communications Interface for Energy Management.
BS EN 50491-12	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS). Part 12.
BS EN 62056-6-2	Electricity metering data exchange. The DLMS/COSEM suite. Part 6-2. COSEM interface classes.
BS IEC 62325-301.	Framework for energy market communications. Part 301. Common Information Model (CIM) extensions for markets.
GB/T 32127	Guide for monitoring effect and comprehensive benefit evaluation of demand response.
SATS 62056-6-9:2017	Electricity metering data exchange - The DLMS/COSEM suite - Part 6-9: Mapping between the Common Information Model message profiles (IEC 61968-9) and DLMS/COSEM (IEC 62056) data models and protocols.
SATR 62056-41:2015	Electricity metering-Data exchange for meter reading, tariff and load control-Part 41: Data exchange using wide area networks: Public switched telephone network (PSTN) with LINK+ protocol.
EU directive 2014/724/ EUEmpf	Commission Recommendation of 10 October 2014 on the Data Protection Impact Assessment Template for Smart Grid and Smart Metering Systems.
GB/T 32127	Guide for monitoring effect and comprehensive benefit evaluation of demand response.
GB/T 35681	Function specification of power demand response system.
IEEE 2030.6	IEEE Guide for the Benefit Evaluation of Electric Power Grid Customer Demand Response.

Table 10 - Relevant de jure standards

The IEC review surfaced a number of specifications, as shown in Table 11.

Standard	Title
IEC 60870-5-101	Telecontrol equipment and systems - Part 5- 101: Transmission protocols. Telecontrol of equipment and systems with coded bit serial data transmission and control of geographically wide processes.
IEC 61850-6	Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs. Specifies a file format for describing communications related IED (Intelligent electronic Device).
IEC 61850-7-420	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes. Defines IEC information models to be used in the exchange of information with Distributed Energy Resources (DER).
IEC 61850-8-1	Communication networks and systems for power utility automation - Part 8-1: Specifies a methodology for exchanging time critical and non time critical data across local area networks.
IEC 62056-1-0	Electricity metering data exchange – The DLMS/COSEM suite – Part 1-0: Smart metering standardisation framework.
IEC 62457	Industrial communication networks – Network and system security – Part 2-1: Establishing an industrial automation and control system security program. Defines the elements necessary to establish a Cyber Security Management system (CSMS) for Industrial Automation and Control Systems (IACS).
IEC 62325 series	Framework for energy market communications: Specifies the common information model (CIM) for energy market communications. The CIM is an abstract model that represents all the major objects in a electricity utility enterprise typically involved in the utility market and operations and electricity market management.Provides a standard way of representing power systems resources as object classes and attributes along with their relationships. The CIM facilitates the integration of Market Management Systems (MSSs) applications developed independently by different vendors between entire MMS systems developed independently, or between an MMS system and other systems concerned with aspects of market management such as Capacity allocation, Day ahead management, Balancing , settlement etc.

Table 11 - Relevant IEC de-facto standards

Adjacent standards – The Distribution Code 'DOC1', concerned with Demand forecasting for operational purposes, and DOC6 with demand control are both identified as relevant for demand side management. The DCC SMETs 2 V1.58 standard for smart meters from the DCC is also key for customer demand measurement. These standards are shown in Table 12.

Standard	Title
Distribution Code DOC1	Demand forecast
Distribution Code DOC6	Demand control
DCC SMETs V1.58	Smart meter technical specification

Table 12 - Relevant NG/DCC de-facto standards

5.4 Information pathway development

To develop the information pathway enabling the service 'the management of demand side data' the existing landscape of the electricity supply and demand system must be identified. The literature has many views of the electricity system and in all cases some simplification in representation has been employed. The picture below strikes a good balance, identifying many of the key elements that will be present in both the existing and future system. In particular it identifies where renewables and storage may be connected at grid scale and where renewables and storage would be connected at a commercial and residential scale. Not shown on this diagram is the Electric Vehicle (EV) element, which would provide a geographically dispersed demand on the system.

One of the key distinctions to make is that the physical topology of the electricity system, whilst useful for gaining an understanding of the individual elements and interconnections, does not represent the way data flows in the system now or in the future.

In order to assess the pathways it has been necessary to provide some level of abstraction that maintains the key physical elements, such a sources of generation and sources of load, whilst presenting some degree of hierarchy linked to the physical network.

The diagram in Figure 24 shows a simplified electricity network model[22] identifying core network generation elements (for example, power stations), the transmission network, the distribution network, generation and storage local (to the distribution grid), and commercial and domestic elements. This developed into simplified network model shown in Figure 25, with salmon areas in between these various elements is shown to highlight potential points of data exchange, all of which are considered to interact with the retail energy market.

[22] https://www.nationalgrid.com/uk/about-grid/our-role-industry/about-electricity

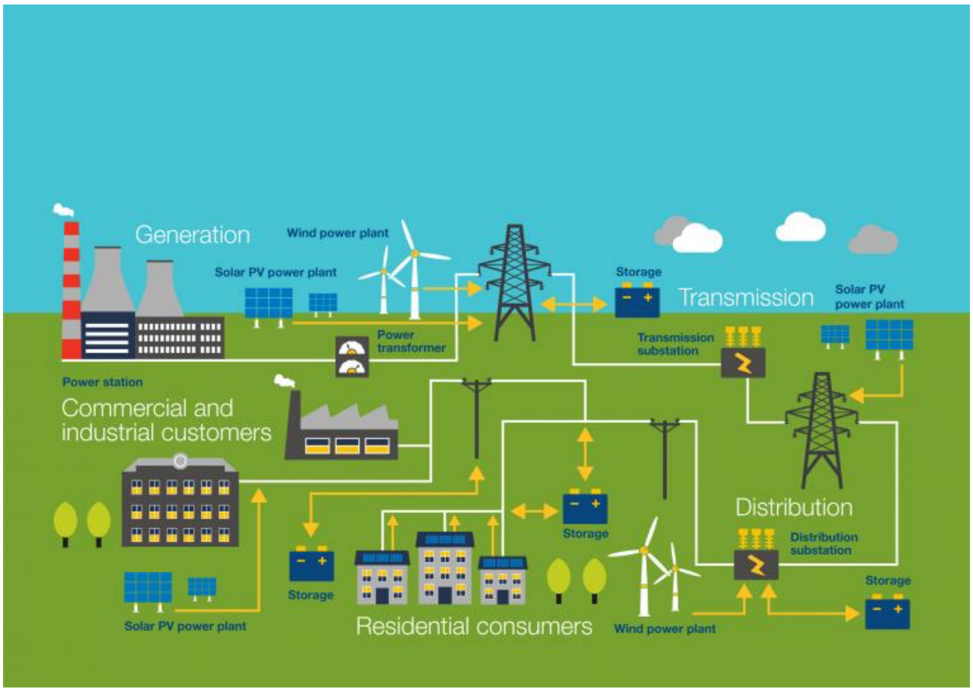


Figure 24 - Simplified electricity network

To aid analysis, the remainder of this section addresses the following individual layers considered to be core to the service provision:

- District layer.
- Neighbourhood layer.
- Building layer.
- Individual building element layer.

This is shown in Figure 25.

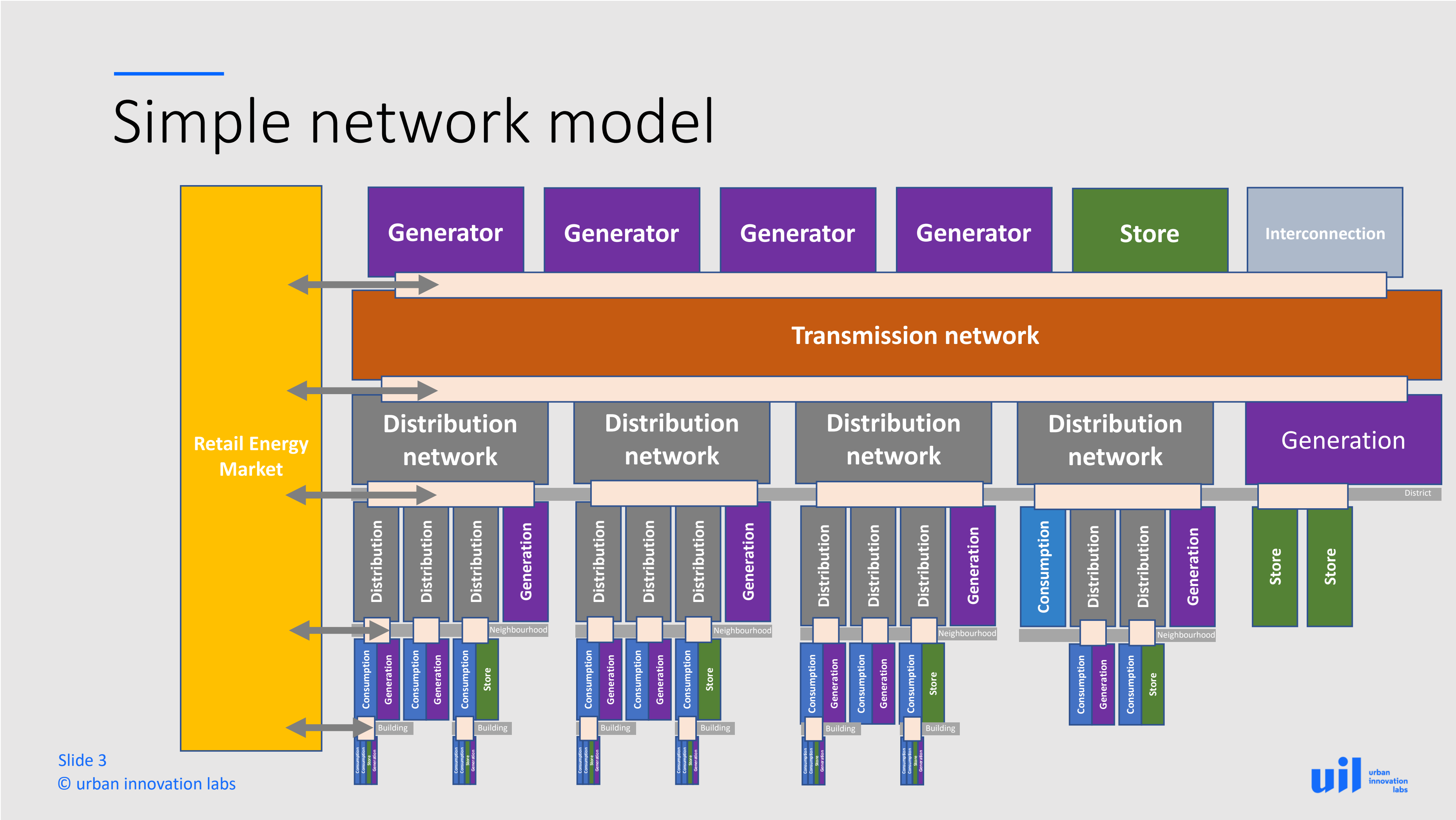


Figure 25 - Simplified model of electricity network

Figure 26 shows the District Layer. At this layer the distribution grid is connected to distributed medium scale supply generation and storage and to commercial buildings.

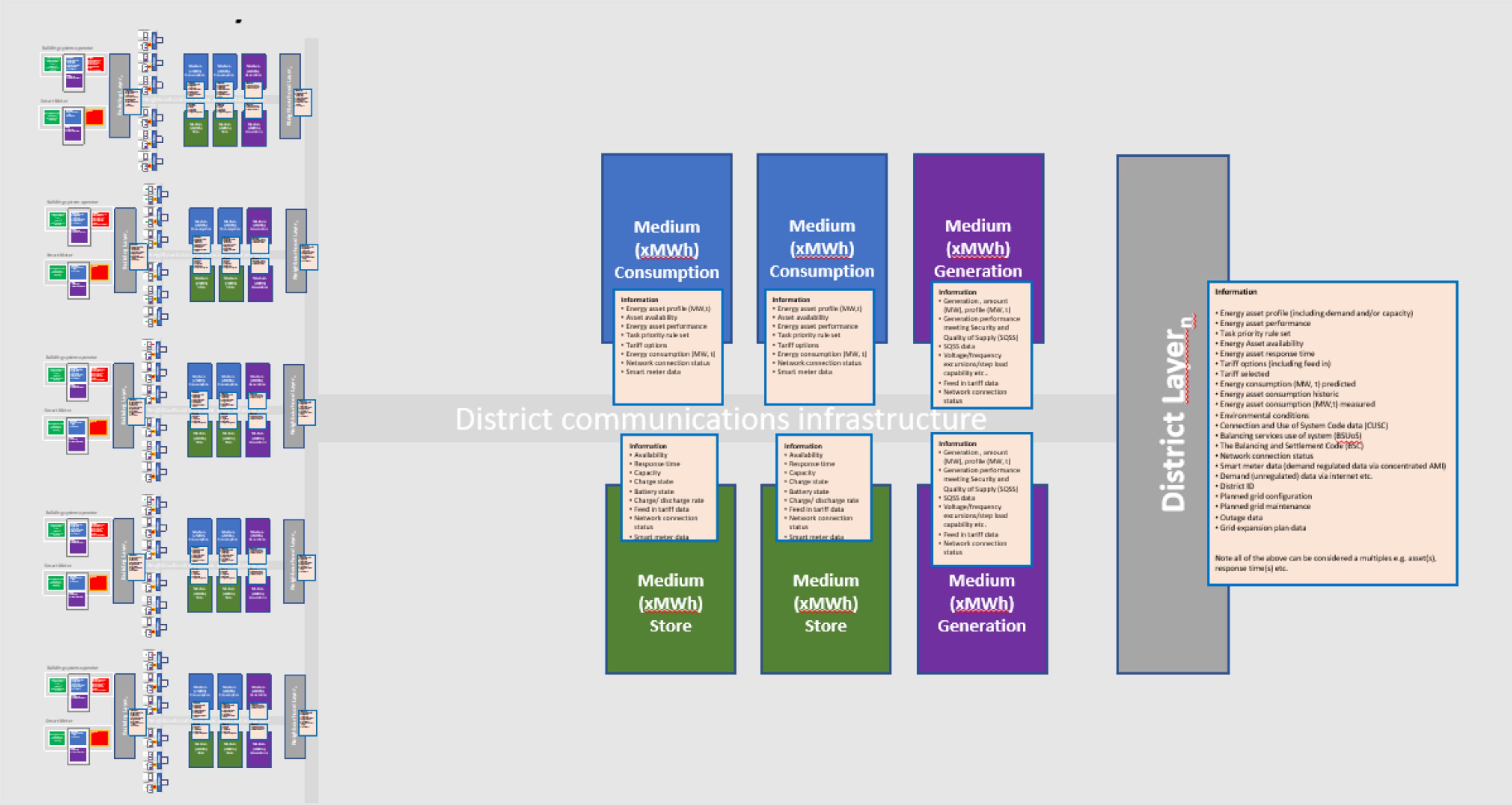


Figure 26 - District Layer

Figure 27 shows the Neighbourhood Layer. At this layer the distribution grid is connected to medium scale supply generation and storage and to large scale commercial buildings. The left-hand side of the figure shows a representation of a commercial building with its own building automation and smart metering systems. This element of the figure is repeated in reduced scale to represent many buildings or a campus.

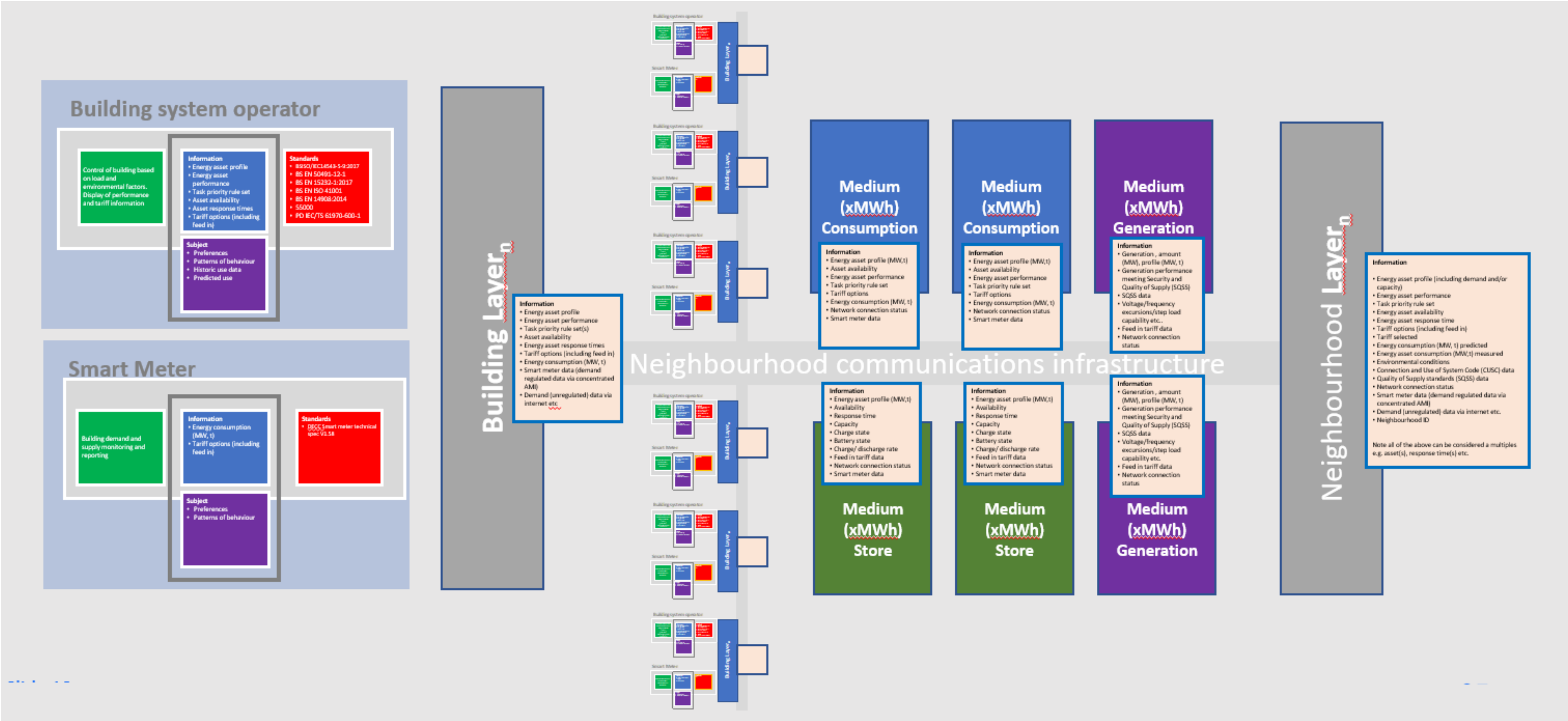


Figure 27 - Neighbourhood Layer

Figure 28 shows the Building Layer. This layer shows the individual elements that may be present in a commercial building.

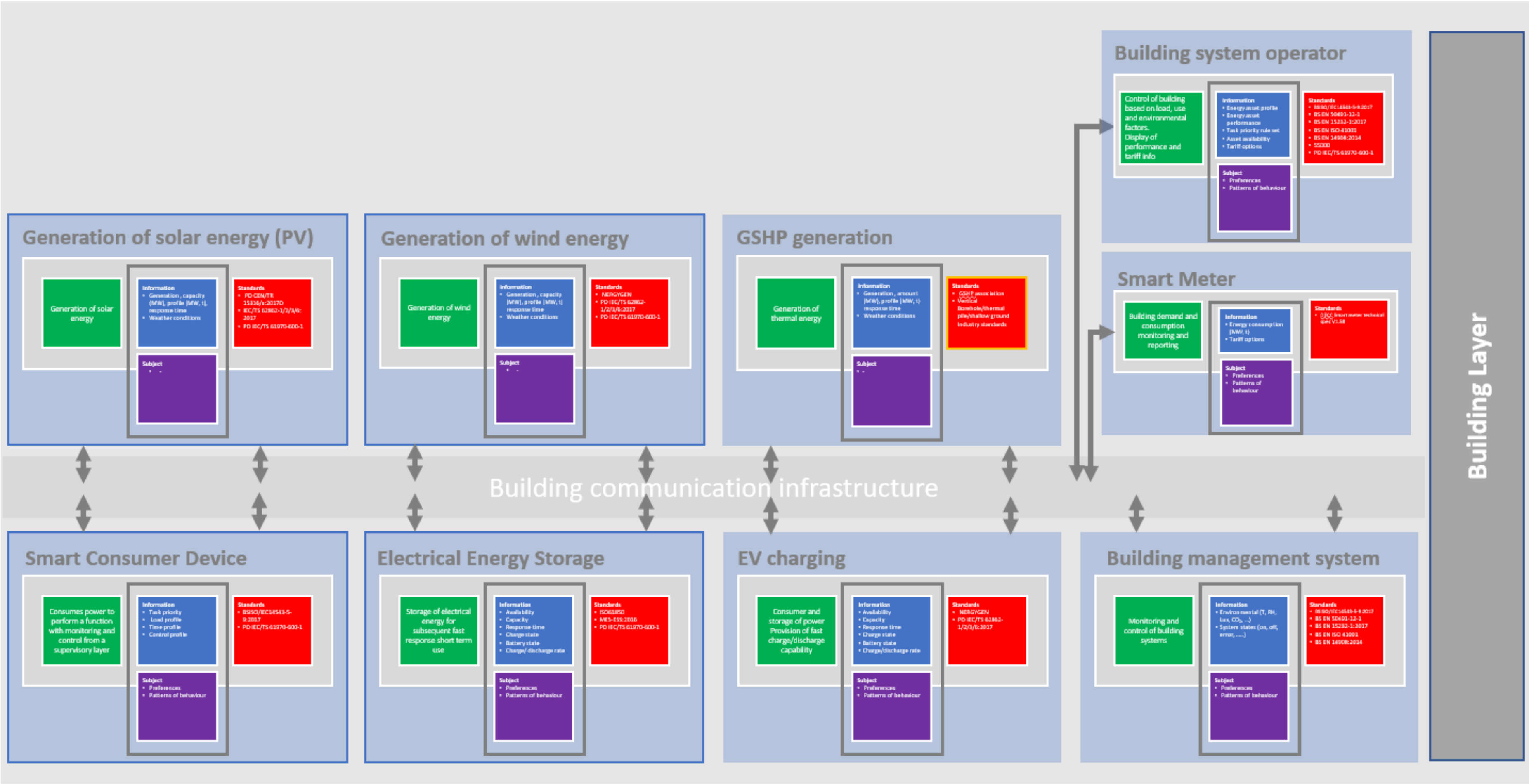


Figure 28 - Building Layer

Figure 29 shows an individual consumer device within the Building Layer and its associated decomposition into its associated services and build lifecycle elements.

Figure 29 – Example of Consumer Device within Building Layer

The diagram in Figure 30 is the application of the Activity and Asset information model described earlier in Figure 9. This example of Electrical Energy Storage, which in practice might be an array of batteries capable of providing power to a building due periods of supply outage and potentially in a smart flexible network, could be called upon as short term demand balancing.

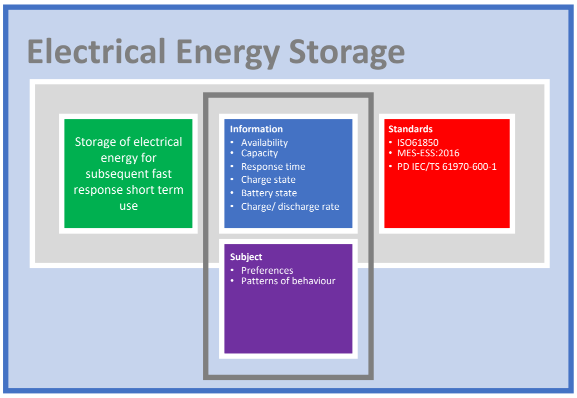


Figure 30 – Service and activity model for Electrical Energy Storage

The boxes represent the following:

- The green box describes the service being provided at a high level.
- The blue box is the information needed to provide the service.
- The purple box represents the subject; in this case identifying that there is an element of personal data.
- The red box identifies associated standards.

In determining the information needed to provide the top-level service 'the management of demand data' it is to some extent a roll up of the individual data or information streams from individual elements (such as those within a commercial building) and other network elements. When aggregated, these provide sufficient input data to allow analysis and ultimately control of demand. It is worth drawing attention to the fact that such control could be exercised down to the consumer device level in the future (consumer acceptance provided), however typically the control at present is indirect by providing tariff signals to encourage time shifting demand.

The data or information needed to describe the capability, capacity, state and quality of service at any layer in the pathway map can be found in the salmon coloured boxes. Examples of these are given in

Figure 31 showing building, neighbourhood and district data and information interfaces respectively.

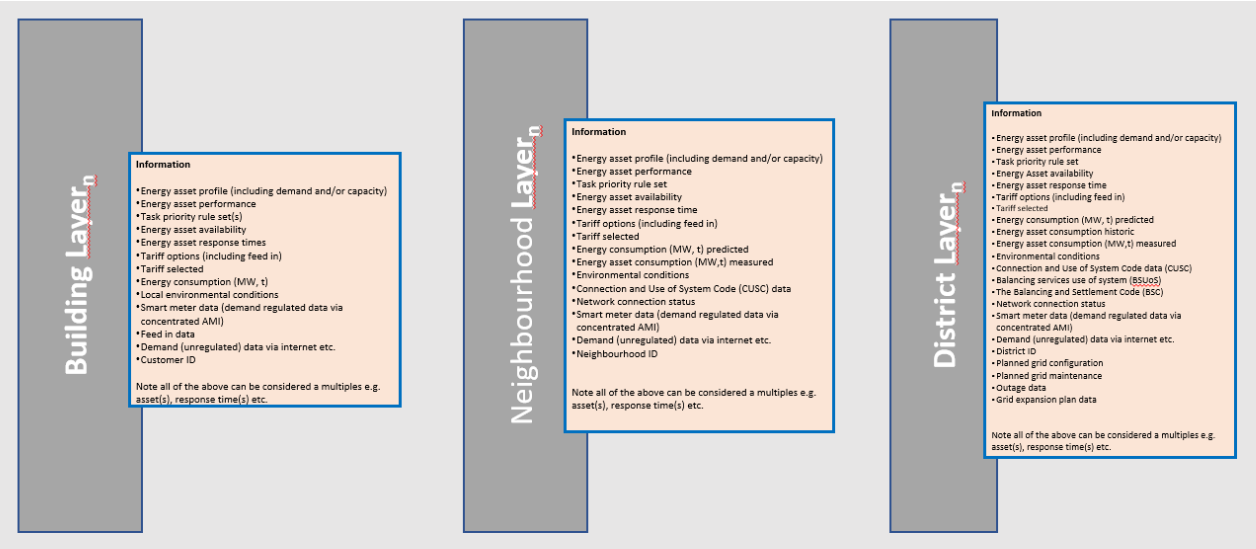


Figure 31 – Data and information present at the layer interfaces

5.5 Information pathway

Based on the data collected from the service development, the standards work and the simplified network model developed earlier, it is now possible to trace a pathway. This section covers the tracing of this pathway, its associated data and standards. During the course of this part of the work additional relevant standards were surfaced these have been included and listed in the standards tables.

5.5.1 High level use case

Taking the high level use case below as a starting point:

- Use Case: Manage the electricity demand to a consumer level. A fuller description of demand side management can be found in section 5.1.9.
- Target: Reduction in peak demand by 5% would reduce the need for Hinckley Point C.
- Hypothesis: Reduction in the peak demand could be achieved if the demand at a distributed or federated level could be managed.

In order to tackle a reduction in peak demand of say 5%, there would have to be a step change in control of the demand side and in the acquisition of the associated near real time (demand) data. We adopt a working assumption that such activities are co-ordinated at a district level (perhaps by a DNO), and then translate this into a set of descriptors for overall system Capability, Capacity, State and Quality of Service (QoS - the CCSQs). These descriptors would apply at the district level interface to a control centre, and could therefore result in the following:

Capability (that is what the service would need to do):

- Assess aggregated consumption (MW,t) measured data.
- Assess aggregated consumption historic data.
- Assess current and near future environmental conditions.
- Predict consumption (MW,t).
- Evaluate load shedding profiles.
- Select district load shedding options.
- Command network load shedding of industrial plant (where possible).
- Command network load shedding of domestic plant (where possible).
- Command network storage dispatch (where possible).
- Update and communicate dynamic tariffs to alter consumer behaviour.
- Access to regulated and unregulated time stamped near real time data.

Capacity (The maximum amount that something can contain or produce):

- Analyse medium to long term district demand profile (MW,t) to drive provision decisions.
- Invest in generation and storage (or contract with) district level suppliers and aggregators.
- Model district level electricity supply mix and potential failure modes.

State (the condition of something):

- Amount of load to be shed (MW,t).
- Use of aggregated and anonymised commercial, personal, or location data.

QoS (The service provided compared to defined conditions):

- Maintenance of frequency, voltage, and response time specifications.
- Compliance with Balancing and settlement code (BSC).
- Compliance with the Grid code.

The process of tracing the information pathway is aided by inspection of the salmon boxes present at each level of the simplified network model and whether the contents of those boxes supports the use case and the service in question. By inspection, this can be done as either a forward or backward pass. In this case, from a consumer appliance perspective moving up through the layers, or from the district control level moving down through the layers. The following description is based on traversing from the district to the device layer.

5.5.2 District Layer

At the district level, data is aggregated from a number of sources via a number of communications channels. It is important to note that although this is represented by the district communications infrastructure in the diagram this will be made up of a number of discrete feeds. For example, dedicated backhaul links, wide area communications, or data exchange platforms. A good example of a separate data feed is consumer demand, assumed to come via the Advanced Metering Infrastructure (AMI) from the Data Communications Company (DCC). This is not a point-to-point delivery mechanism as the data is acquired from domestic smart meters and transmitted via the mobile infrastructure network, then aggregated, anonymised and delivered as output by the DCC.

The district layer will potentially form a control element of a DSO in a future smart grid. The diagram shows that at this level there will almost certainly be medium scale (industrial) consumers, generators and storage assets. The aggregated information present at a district layer control element is shown Figure 32

Information

- Energy asset profile (including demand and/or capacity)
- Energy asset performance
- Task priority rule set
- Energy Asset availability
- Energy asset response time
- Tariff options (including feed in)
- Tariff selected
- Energy consumption (MW, t) predicted
- Energy asset consumption historic
- Energy asset consumption (MW,t) measured
- Environmental conditions
- Connection and Use of System Code data (CUSC)
- Balancing services use of system (BSUoS)
- The Balancing and Settlement Code (BSC)
- Network connection status
- Smart meter data (demand regulated data via concentrated AMI)
- Demand (unregulated) data via internet etc.
- District ID
- Planned grid configuration
- Planned grid maintenance
- Outage data
- Grid expansion plan data

Note all of the above can be considered a multiples e.g. asset(s), response time(s) etc.

Figure 32 - Data and information located at the district interface

For the use case the key element is managing peak demand. There are a number of possible strategies that could be employed to achieve local balancing:

- Dispatching of additional generating resource.
- Load Shedding (control of flexible demand).

The first employs the use of stored energy previously generated in period of oversupply and/or bringing on line discrete generation assets. The provision of this service could be as part of the distribution owned asset base or via independent provision. This then is one path (Path 1 in blue) that could be drawn at the district level from the District control centre to a medium store and generator. In practice, there would be a choice of which one (or more) of the stores or generators at a district (or potentially at a neighbourhood) level are dispatched. This sort of dispatching usually falls under the catch all of Distributed Energy Resources (DER) management.

The second (Path 2 in red) has a more complex pathway whereby the control of load may be by both direct and indirect means. An indirect approach would be by the use of Tariffs to encourage load shedding to periods of oversupply, whereas a direct approach would be to task individual elements in the system (perhaps down to consumer device level) to load shed. In either case, a pathway for tariff data and control could be drawn through all the layers from the district control centre through to the consumer device within the building layer. However, in practice, in this use case, it is more likely that the control interaction may be abstracted to the building systems operator.

Load shedding at a district level is more likely to be achieved via tariffs and contractual agreements to optimise and smooth base load away from peaks of demand. This is shown in Figure 33.

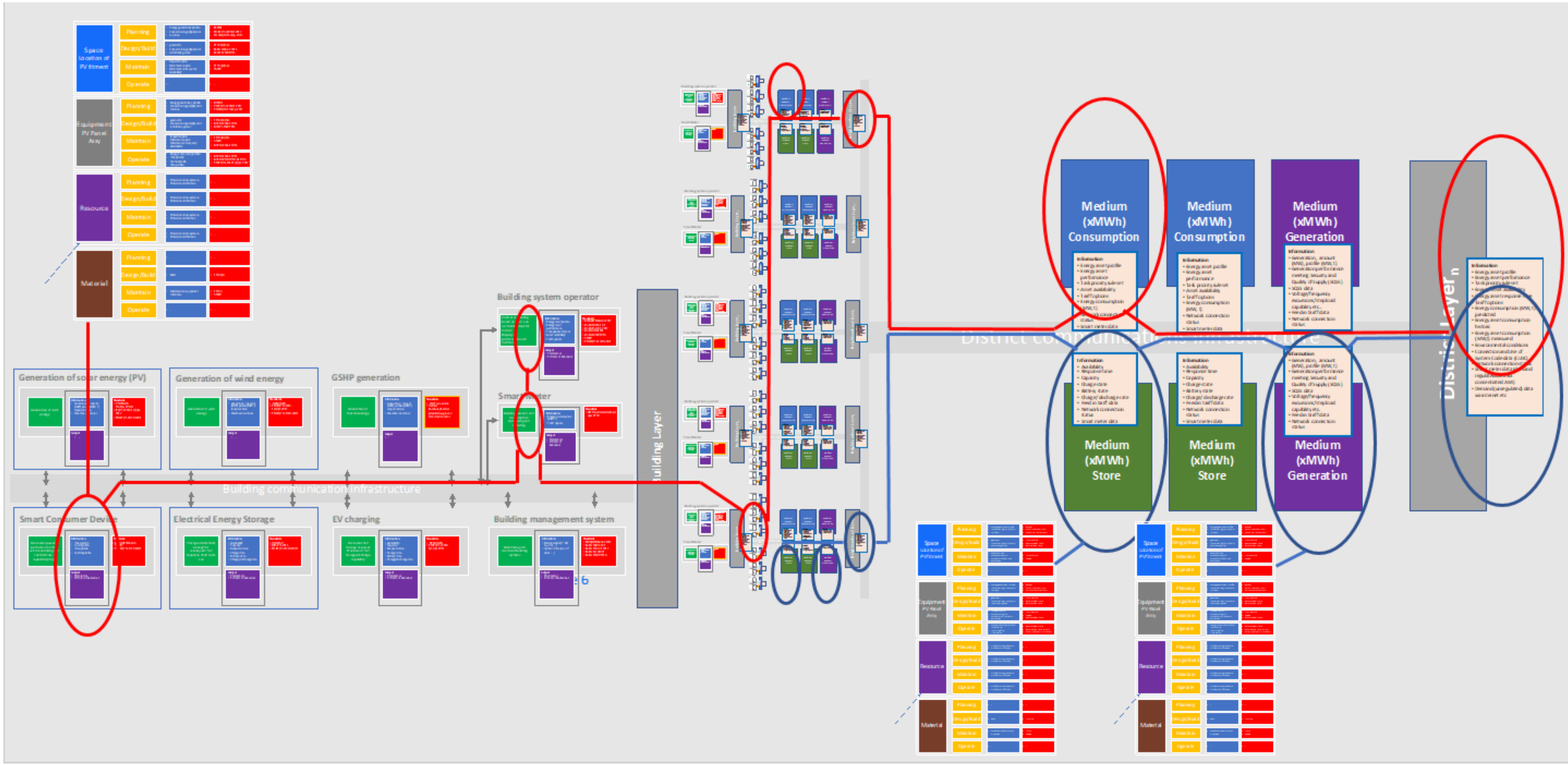


Figure 33 - Overall pathway

The salmon box examples in Figure 34 below, are taken from the overall pathways and illustrate the likely data interchange at the boundary between the Store and Demand district elements. It can be seen from the lists in the salmon boxes that while there are a number of common information types, the energy asset profile will be specific to the device itself. For example, the storage asset will have specific data on charge state and discharge rates. Smart meters associated with each asset will monitor both demand and feed in performance.

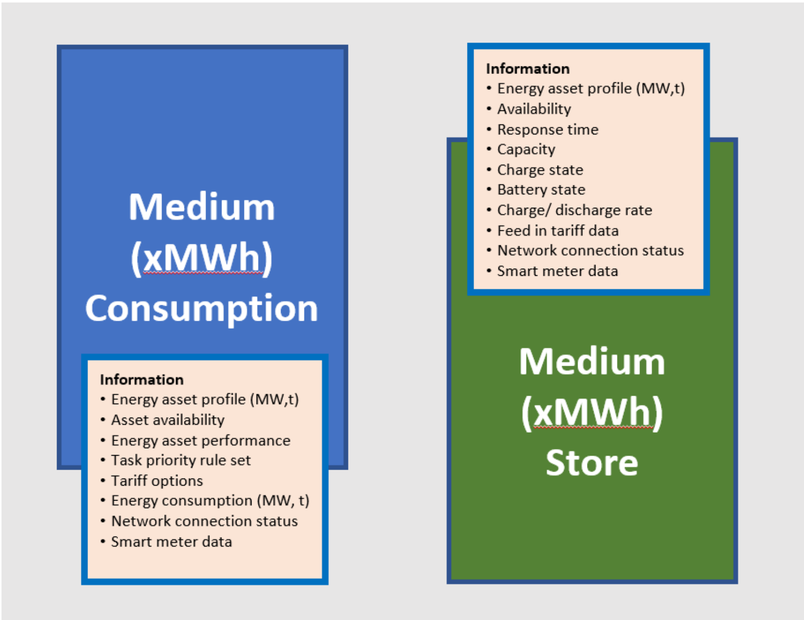


Figure 34 - Data and information located at the store and demand interfaces

The use cases for the consumption and store elements and their associated system Capability, Capacity, State and Quality of Service (QoS) descriptors are detailed in the following sections

Medium consumption:

- Use case: smart demand management of a significant load. In this case, it is assumed that this is a medium scale industrial plant which will contract with the energy provider to move time of use of demand heavy processes away from peak times. To do this in a smart dynamic way, knowledge of load schedules and impacts would need to shared.
- Target: reduction in peak demand in line with agreed tariff and control profile.
- Hypothesis: reduction in the peak demand could be achieved if the demand at a distributed or federated level could be managed.

At the demand/district interface the CCSQs with respect to the industrial plant will is shown in Figure 35

Capability (that is what the service would need to do):

- Provided contracted load shed (xMW,t).
- Provide consumption (MW,t) data.
- Provide consumption historic data.
- Provide future consumption (MW,t) schedules.
- Provide local environmental conditions.
- Respond to load shedding command requests.
- Interact with dynamic tariffs.
- Provide future industrial process planning data (including maintenance down time).
- Access to regulated and unregulated time stamped near real time data.

Capacity (the maximum amount that something can contain or produce):

- Provide contracted load reduction (xMW,t).
- Provide exceptional load reduction margin (xMW,t).

State (the condition of something):

- Amount of load to be shed (xMW,t).
- Use of process, plant, and schedule data.

QoS (the service provided compared to defined conditions):

- Maintenance of frequency, voltage, and response time specifications.
- Performance against tariff and contract for load shedding (xMW,t).

Figure 35 - Industrial plant CCSQS

Medium Store:

- Use case: smart demand management of a storage facility. In this case, it is assumed that this is a medium scale storage plant. Such a plant might be collocated with, and fed by, PV or wind energy generation systems. The store will contract with the energy provider to provide peak demand reinforcement of the supply and store charging. Such a store allows time shifting of the charge function to periods of low supply demand. Additionally, such a store and its associated inverter technology may have a role to play frequency control.
- Target: reinforcement of peak supply in line with agreed tariff and control profile.
- Hypothesis: reduction in the peak demand could be achieved if the demand at a distributed or federated level could be managed

At the demand/district interface the CCSQs with respect to the storage plant is shown in Figure 36.

Capability (that is what the service would need to do):

- Provide contracted supply (xMW,t).
- Provide supply (MW,t) data.
- Provide supply (MW,t) historic data.
- Provide local environmental conditions.
- Respond to supply command requests.
- Interact with dynamic tariffs.
- Provide plant condition data (including, charge state, battery condition and maintenance down time).
- Access to regulated and unregulated time stamped near real time data.

Capacity (the maximum amount that something can contain or produce):

- Provide contracted supply (xMW,t).
- Provide exceptional supply (xMW,t).

State (the condition of something):

- Amount demand supplied (xMW,t).
- Use of process and plant data.

QoS (the service provided compared to defined conditions):

- Performance against tariff and contract.
- Performance against tariff and contract for supply provision (xMW,t).

Figure 36 – Medium Store CCSQS

5.5.3 Neighbourhood layer

At the neighbourhood level the same load balancing options are available, so for Path 1, dispatch of small to medium storage elements could be tasked by the district level control centre.

Demand and load shedding Path 2 has the same interactions with the consumption elements at a neighbourhood level. The salmon boxes for the Store and Demand neighbourhood elements are similar to those district elements shown above.

The interactions at a neighbourhood level in a future smart grid could be held directly with energy aggregators rather than with discrete suppliers. Such aggregators will be contracted directly with distribution operators to provide balancing services. It is possible that some asset data aggregation is performed at the neighbourhood level and passed to the district level control; some of the data will have already undergone processing by aggregators.

The types of data exchanged at this level are similar to those for the district level and are therefore not repeated here.

5.5.4 Building layer

At the building level the types of data exchanged at the interface are slightly reduced. Load shedding (path 2) interacts with two Building elements/services: the Building Systems Operator (BSO) and the Smart Meter System. Services provided by these two elements are captured in the activity/service diagrams in Figure 37.

Information

- Energy asset profile (including demand and/or capacity)
- Energy asset performance
- Task priority rule set(s)
- Energy asset availability
- Energy asset response times
- Tariff options (including feed in)
- Tariff selected
- Energy consumption (MW, t)
- Local environmental conditions
- Smart meter data (demand regulated data via concentrated AMI)
- Feed in data
- Demand (unregulated) data via internet etc.
- Customer ID

Note all of the above can be considered a multiples e.g. asset(s), response time(s) etc.

Figure 37 - Data and information located at the building interface

Building System Operator:

- Use case: smart demand management of building. In this case, it is assumed this is a large apartment block with a range of energy generation options. The BSO will contract with the energy provider on behalf of the occupants to optimise energy use and energy costs. Part of such and optimisation could be done within the boundaries of the building, for example, using storage to manage. However, for this use it is assumed that the district control centre has direct control of some elements of demand case, for example, smart consumer devices.
- Target: reduction in peak demand in line with agreed tariff and control profile.
- Hypothesis: reduction in the peak demand could be achieved if the demand at a distributed or federated level could be managed.

At the demand/district interface the CCSQs with respect to the Building systems operator is shown in Figure 38

Capability (that is what the service would need to do):

- Provide contracted load shed (xkW,t).
- Provide consumption (xkW,t) data.
- Provide consumption historic data.
- Provide future consumption (xkW,t) schedules.
- Provide local environmental conditions.
- Respond to load shedding command requests.
- Interact with dynamic tariffs and end consumers.
- Access to regulated and unregulated time stamped near real time data.

Capacity (the maximum amount that something can contain or produce):

- Provide contracted load reduction (xkW,t).

State (the condition of something):

- Amount of load to be shed (xkW,t).
- Use of behavioural data.

QoS (the service provided compared to defined conditions):

- Performance against tariff and contract (xKw,t).

Figure 38 – Building System Operator CCSQS

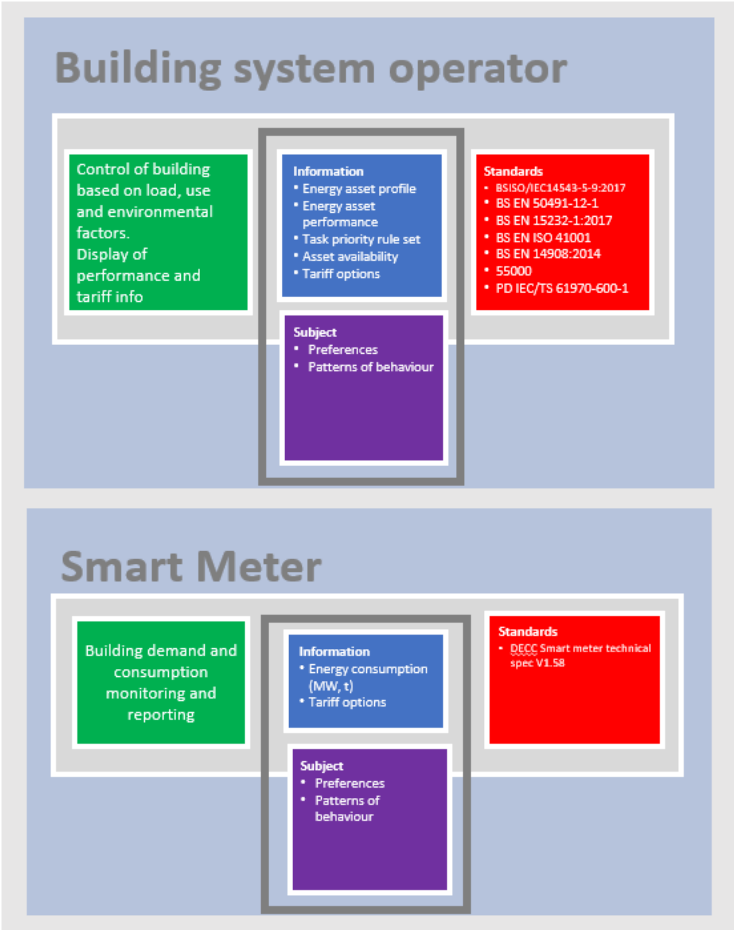


Figure 39 - Service and activity models for the BSO and smart meter

For this example, it has been assumed that the BSO Figure 39 has control over a range of generation and storage assets. This allows optimisation of local energy management and supports local load dispatch (path 1), for example, use of the storage asset at the request of the remote district operations control centre.

The smart meter in this case is assumed to be monitoring the feed in energy based on a previously agreed tariff. In principle, the BSO could meter the resource directly using independent metering and unregulated data, or could request AMI data from the DCC.

5.5.5 Device (smart consumer device)

Load shedding (path 2) is assumed to be controlled by the BSO interacting with a smart consumer device(s). Taking an apartment block as the building example, there would be many such devices operating within a number of individual customer premises. The BSO could optimise local energy consumption, but could also act as an aggregator of data and control to support local load shedding at the request of the remote district operations control centre. This would be done via standard communications linking the district and building systems, for example, WAN or internet.

A common method of control for such a smart consumer device is unclear. It is likely that such devices will be connected through a Home Area Network (HAN). In the apartment block example, individual HANs would be connected to the Building Area Network (BAN), serviced by the building energy management system. Alternatively, devices could be connected and controlled through the smart meter interface. This approach would allow load shedding to be performed via the AMI interface, in which case the data path is via the DCC.

The Smart consumer device service/activity profile is shown in Figure 40. This is shown at a high level of abstraction. However, if the device was a washing machine it would be straight forward to characterise its function. More interestingly, remote control of this device, be it the by the BSO or the District Operations Centre, raises a number of practical and data management issues.

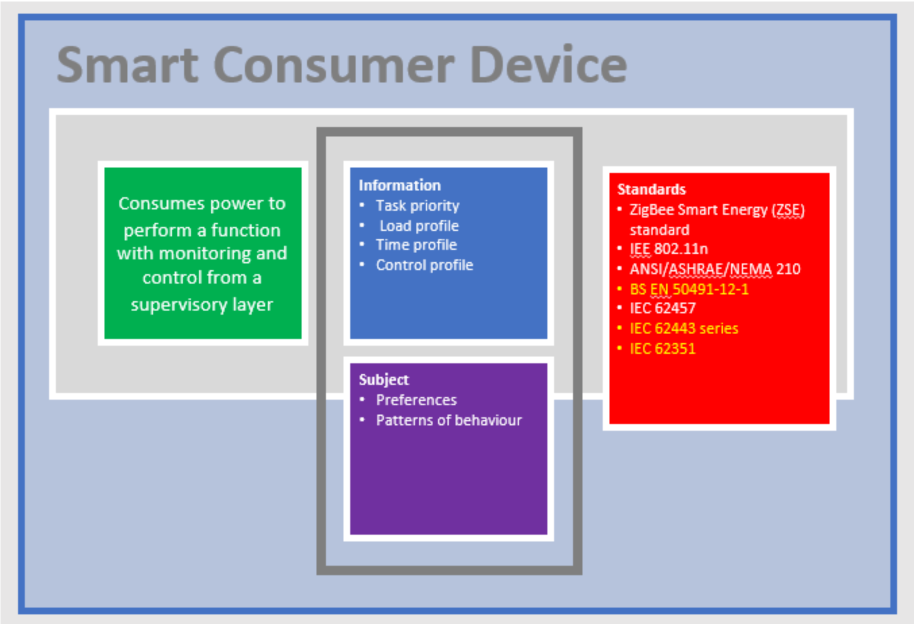


Figure 40 - Service and activity models for the smart consumer device

The Device profile would need to have:

- A prior knowledge of a load shedding tariffs (or more correctly load shifting, Time of Day (ToD)).
- Knowledge of patterns of use.
- Task priority rules to prevent remote override operations when in normal use.
- Device specific rule set and associated data.
- Two-way communications functions.

The activity and service model can be extended to include all of the aspects required to provide a service, for example: equipment, resource or material. This is shown in Figure 41.

The red boxes in the right-hand column give an expanded view of the standards currently available that support the Smart Consumer Device.

The standards most relevant to demand side management fall into two broad categories: firstly, those that provide communications pathways (air interfaces) in this case ZigBee (ZSE) and WiFi (802.11), and secondly those standards that relate to function. BS EN 5049-12-1, for example, covers the general requirements for home and building electronic systems, building automation and control systems and interfaces to the CEM and home and building resource management systems.

IEC 62457 also has relevance in that specifies the requirements for the interface between Home Network lower layer and household appliances and the application of TCP/IP between these nodes.

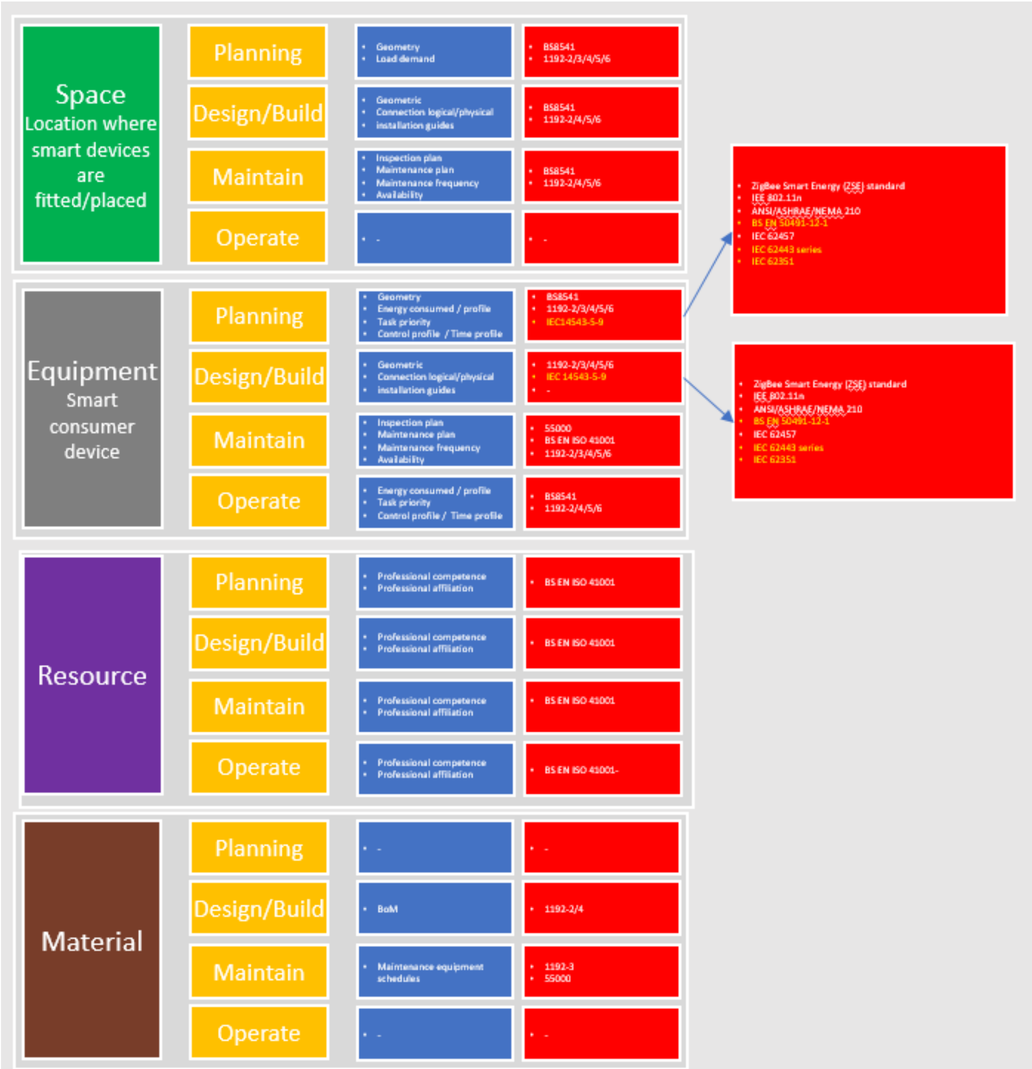


Figure 41 - Extended activity and service model for a smart consumer device

Secondly, those standards such ANSI/ASHRAE/NEMA 201, which provides guidance on abstract object-oriented information models to enable appliances and control systems in homes, buildings and industrial facilities. The standard also covers a Modular Communications Interface (MCI), which provides a standard interface for energy management and signals.

BS-EN 50941-12-1 details the requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS). In particular this part of the standard deals with the interface between the Customer Energy Management systems (CEMs) and Home/Building

Resource managers. The different types of smart devices in the home/building are likely to use different communications protocols and/or different data/function models this is also likely to be true for smart grid entities. The CEM described (and shown in figure 5) of the specification acts as an interpreter between them.

The need for data security and the potential for personal preferences and behavioural data to be generated also mean that standards such as the IEC 62443 and IEC 62351, which covers cyber security, may apply.

It is understood that additional standards development being coordinated by the BSI in the area of smart consumer devices which will inform the some of the functions and data requirements of future smart consumer devices.

Taking the more detailed analysis done for the smart consumer device, two further district system elements are evaluated in the following sections. This has been done to explore the standards applicability and because these system elements are a key part of the future smart grid and the demand side story. The first is a generator of medium power (in this case a remote EV system), and the second in a medium store.

5.5.6 Generation (grid scale solar energy)

One lever of managing demand in a smart grid is the despatch of additional generating resource, in this case assumed to be managed as a Distributed Energy Resource (DER) element. In the example in Figure 42, the grid scale PV system and its associated inverters does not have local storage. Such Solar farms may produce 1-5 MW but there are examples in the 100s of MW.

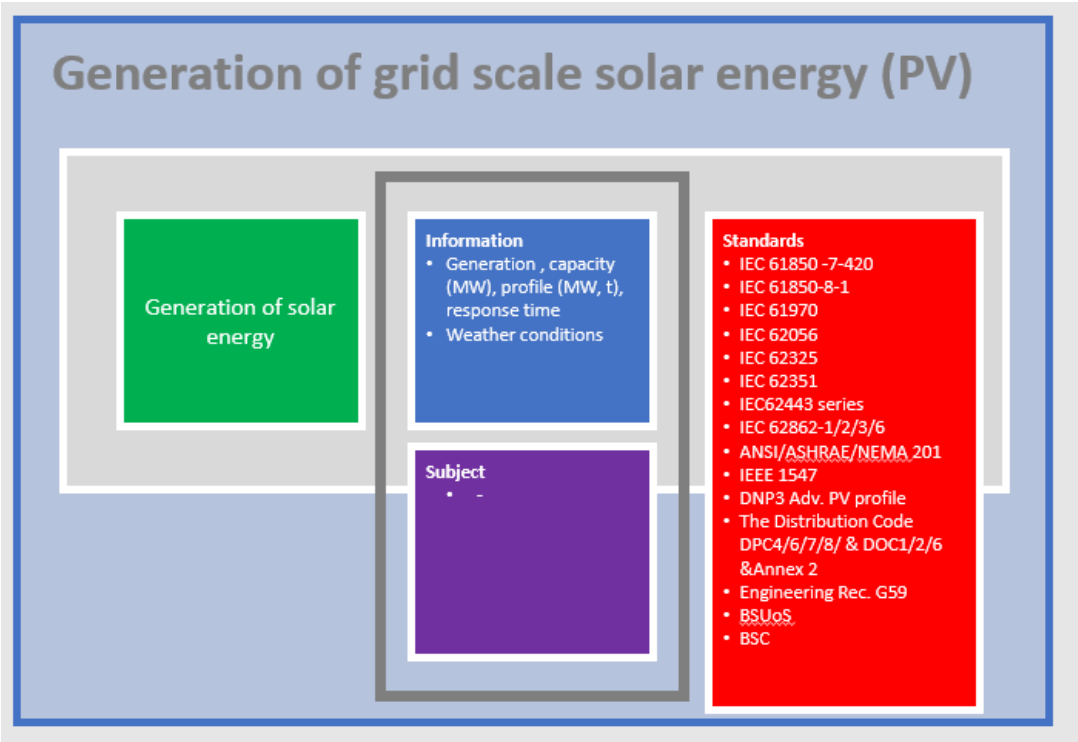


Figure 42 - Service and activity model for grid scale EV

The activity and service model can be extended to include all of the aspects required to provide a service, for example, equipment, resource or material. This is shown in Figure 43.

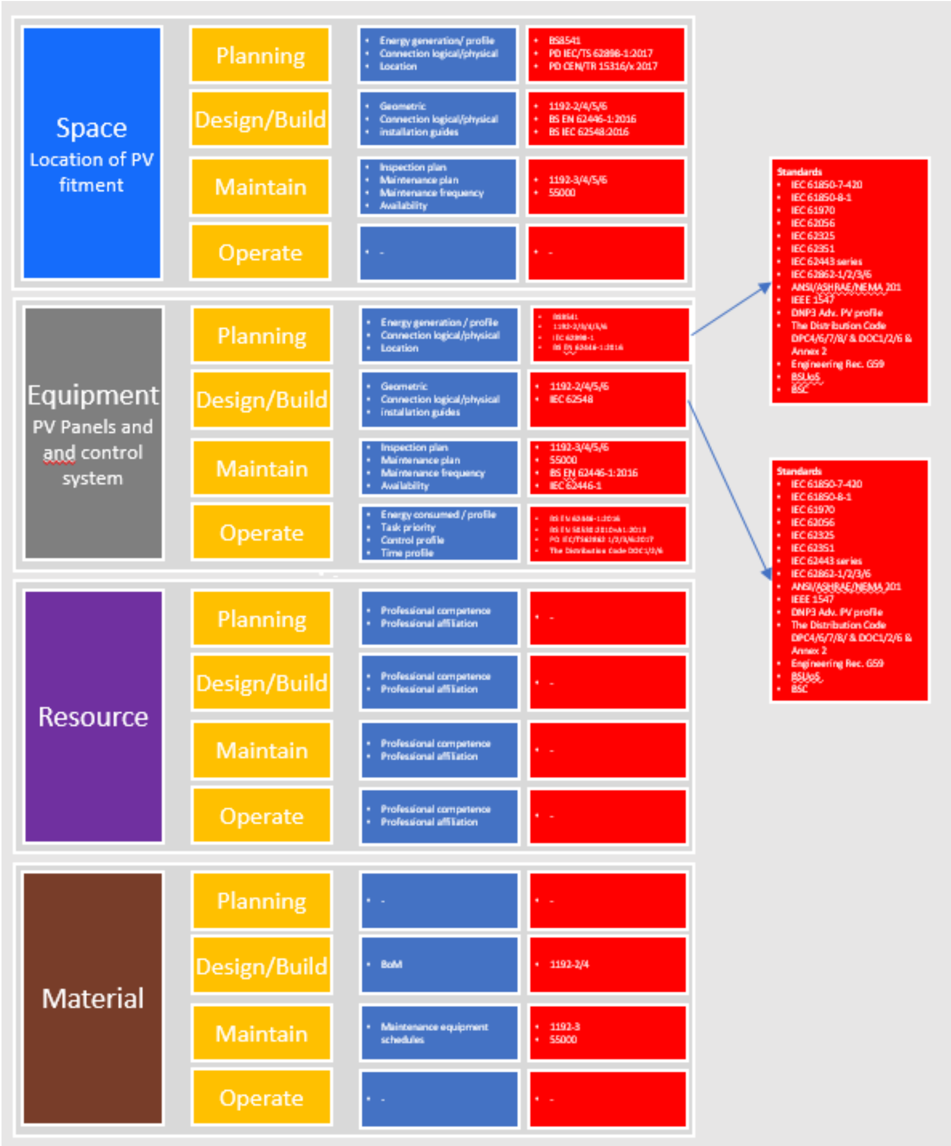


Figure 43 - Extended activity and service model for grid scale PV

The standards most relevant to enabling or supporting demand side management fall into four broad categories:

- Models.
- Data Exchange.
- Security.
- Distribution or Grid specific.

It should be noted that at this level of the model, all the possible communication interconnect modes such as WAN, leased line, fibre and dedicated SCADA links are not covered but assumed available. In some cases, the standards listed in Table 13 form parts of series, elements of which may also be applicable.

Category	Spec. Ref.	Description
Models	IEC 62325 series	Specifies a common information model (CIM) for energy market communications utility market. It provides a standard way of representing power systems as object classes and attributes. As an example 62325-301 section 6, table 1 details max/min resource capacity as elements of a common attribute. Section 6 also covers a range of topics/attributes including market management, operation and environmental.
	IEC 61970 series	Common Information Model/Energy management. This standard deals with the application program interfaces for energy management systems (EMS).
	IEC 61850-7-420	Defines information models to be used in the exchange of information with Distributed Energy Resources (DERs).
Data Exchange	IEC 61850	Defines communication protocols for intelligent electronic devices at electrical substations.
	ANSI/ASHRAE/NEMA 201	Provides guidance on an abstract object-oriented information models to enable appliances and control systems in homes, buildings and industrial facilities. It covers a Modular Communications Interface (MCI) providing a standard interface for energy management and signals.
	IEC 62056-1-1	Electricity smart metering data exchange DLMS/COSEM suite, part 1 smart metering standardisation framework. Detailed specification covering communications physical and MAC layers, messaging, security measures, service mapping, registration and connection etc.
	DPN3	Advanced PV profile - defines a standard data point configuration, set of protocol services and settings (the profile) for communicating with photovoltaic (PV) generation and storage systems using DNP3.
Security	IEC 62443	Defines the elements necessary to establish a cyber security management system for industrial automation and control systems.
	IEC 62351 series	Power systems management and associated information exchange - Data and communications security.62351-6 covers securing of algorithms based on IEC 61850 and 62351-12 covers the security and resilience of distributed energy resources and their management systems.
Distribution/ Grid specific	The Distribution Code	The Distribution Planning and Connection Code specifies the planning, design and connection requirements for Distribution Systems owned by the DNO and for connections to those Systems. Areas of applicability include DPC4/6/7/8 covering design principles and standards, general requirements for connections,

Category	Spec. Ref.	Description
		requirements for embedded generators and transfer of planning data respectively. Also DOC1/2/6 and Annex 2 covering demand forecasts, operational planning, demand control and qualifying standards.
	IEC 62898-1	Microgrids, guidelines for microgrid planning and operation. The standard covers for example, resource analysis, generation forecast, load forecasts, DER planning, microgrid power system planning, in sections 6,7,8,9 respectively
	Eng. Rec G59	Engineering Recommendation G59 - Ref from Annex 1/2 of the Distribution code - Recommendations for the connection of generating plant to the distribution systems of licenced Distribution Network Operators.
	BUCoS	Balancing services use of system BSUoS charges - The BSUoS charge recovers the cost of day-to-day operation of the transmission system. Generators and suppliers are liable for these charges, which are calculated daily as a flat tariff for all users. BSUoS charges depend on the balancing actions that we take each day, but we provide a monthly forecast of BSUoS. You can also consult historical BSUoS charges.
	BSC	The Balancing and Settlement Code (BSC) contains the rules and governance arrangements for electricity balancing and settlement in Great Britain. The code covers aspects relating to metering of the physical production and demand for electricity from generators, suppliers and interconnectors against their contracted positions; and calculating and settling the resulting imbalances when the delivery or off take does not match contractual positions.
	IEEE 1547	Standard for Interconnecting Distributed Resources with Electric Power Systems. This is a standard of the Institute of Electrical and Electronics Engineers is intended provide a set of criteria and requirements for the interconnection of distributed generation resources into the power grid.

Table 13 - Standards most relevant to enabling or supporting demand side management

5.5.7 Store (grid scale storage)

Another lever for demand side management, complementary to EV generation, is energy storage, shown in Figure 44. This allows excess generation to be stored when demand is lower and accessed during periods of peak demand. As previously mentioned, this resource is assumed to be managed as a Distributed Energy Resource (DER) element of a smart grid. The recently commissioned Blackburn Meadows energy storage plant has a 10WM capacity and is capable of meeting demanding response time and Enhanced Frequency Response (EFR) targets.

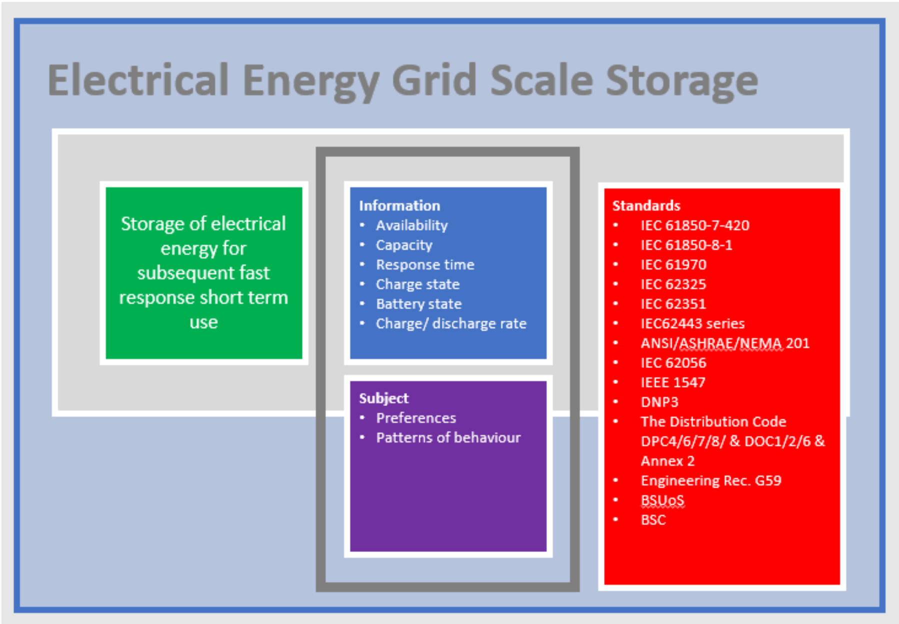


Figure 44 - Service and activity model for grid scale storage

The activity and service model can be extended to include all of the aspects required to provide a service, for example, equipment, resource or material. This is shown in Figure 46.

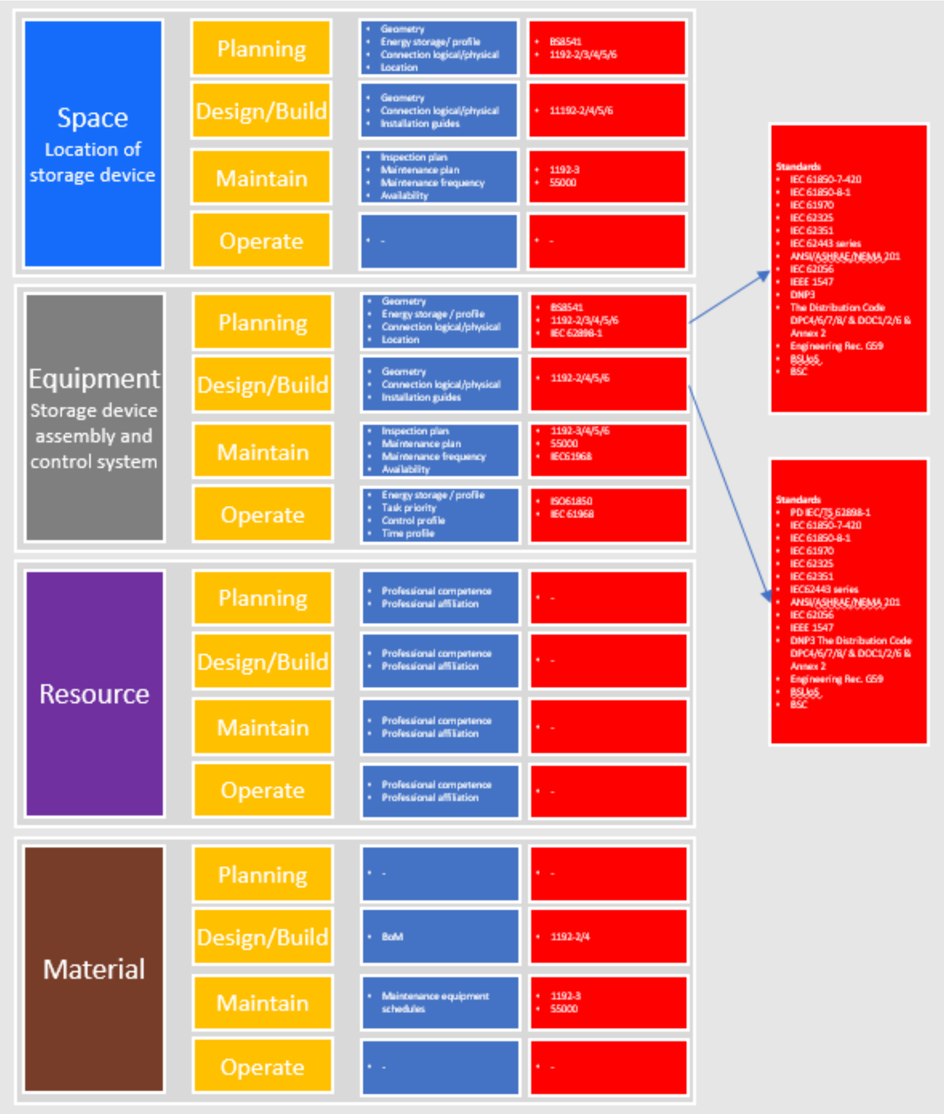


Figure 46 - Extended Service and activity model for grid scale storage

The standards most relevant to enabling or supporting demand side are listed in Table 14. It should be noted that at this level of the model that all the possible communication interconnect modes such as WAN, leased line, fibre and dedicated SCADA links are not covered but assumed available.

Category	Spec. Ref.	Description
Models	IEC 62325 series	Specifies a common information model (CIM) for energy market communications utility market. It provides a standard way of representing power systems as object classes and attributes. As an example 62325-301 section 6, table 1 details max/min resource capacity as elements of a common attribute. Section 6 also covers a range of topics/attributes including market management, operation and environmental.
	IEC 61970 series	Common Information Model / Energy management. This standard deals with the application program interfaces for energy management systems (EMS).
	IEC 61850-7-420	Defines information models to be used in the exchange of information with Distributed Energy Resources (DERs).
Data Exchange	IEC 61850	Defines communication protocols for intelligent electronic devices and electrical substations.
	ANSI/ASHRAE/NEMA 201	Provides guidance on an abstract object-oriented information models to enable appliances and control systems in homes, buildings and industrial facilities. It covers a Modular Communications Interface (MCI), providing a standard interface for energy management and signals.
	IEC 62056-1-1	Electricity smart metering data exchange DLMS/COSEM suite, part 1 smart metering standardisation framework. Detailed specification covering communications physical and MAC layers, messaging, security measures, service mapping, registration and connection etc.
	DPN3	DNP3 (Distributed Network Protocol) is a set of communications protocols used between components in process automation systems.
Security	IEC 62443	Defines the elements necessary to establish a cyber security management system for industrial automation and control systems.
	IEC 62351 series	Power systems management and associated information exchange - data and communications security.62351-6 covers securing of algorithms based on IEC 61850 and 62351-12 covers the security and resilience of distributed energy resources and their management systems.
Distribution/ Grid specific	The Distribution Code	The Distribution Planning and Connection Code specifies the planning, design and connection requirements for Distribution Systems owned by the DNO and for connections to those Systems. Areas of applicability include DPC4/6/7/8 covering design principles and standards, general requirements for connections,

Category	Spec. Ref.	Description
		requirements for embedded generators and transfer of planning data respectively. Also, DOC1/2/6 and Annex 2 covering demand forecasts, operational planning, demand control and qualifying standards.
	IEC 62898-1	Microgrids, guidelines for microgrid planning and operation. The standard covers for example, resource analysis, generation forecast, load forecasts, DER planning, microgrid power system planning, in sections 6,7,8,9 respectively
	Eng. Rec G59	Engineering Recommendation G59 - Ref from Annex 1/2 of the Distribution code - recommendations for the connection of generating plant to the distribution systems of licenced Distribution Network Operators. 13.8.5.2 (C1.2) Solar specific.
	BUCoS	Balancing services use of system BSUoS charges - The BSUoS[23] charge recovers the cost of day-to-day operation of the transmission system. Generators and suppliers are liable for these charges, which are calculated daily as a flat tariff for all users. BSUoS charges depend on the balancing actions that we take each day, but we provide a monthly forecast of BSUoS. You can also consult historical BSUoS charges.
	BSC	The Balancing and Settlement Code (BSC) contains the rules and governance arrangements for electricity balancing and settlement in Great Britain. The code covers aspects relating to metering of the physical production and demand for electricity from generators, suppliers and interconnectors against their contracted positions; and calculating and settling the resulting imbalances when the delivery or off take does not match contractual positions.
	IEEE 1547	Standard for Interconnecting Distributed Resources with Electric Power Systems. This is a standard of the Institute of Electrical and Electronics Engineers is intended provide a set of criteria and requirements for the interconnection of distributed generation resources into the power grid.

Table 14 - Standards most relevant to enabling or supporting demand side

5.5.8 Commentary

Standards

The standards analysis work has shown that the selection of keywords used for the service did not surface all of the relevant standards. There are several possible reasons for this. The first is that the keyword selection needed further optimisation. This could be done by adopting a more systematic

[23] https://www.nationalgrid.com/uk/electricity/charging-and-methodology/balancing-services-use-system-bsuos-charges

and interactive use of Perinorm. This however is a significant task and may not yield improved results. The search engine is looking for keywords in the titles and the abstracts, the latter are a significant resource but are only present for 20% of database entries.

A separate manual search was required to surface a significant number of relevant IEC specifications and standards that exist within the Transmission and Distribution operators organisations. The Perinorm database is a very good standards repository and, more importantly, it is curated and regularly updated. The ability to query the database, however, is not particularly user friendly and requires significant user knowledge and experience to compile a good quality search and hence achieve good quality search results. Search strings cannot be assembled off line and loaded directly.

A further observation is that, with few exceptions, in the standards reviewed (notably within the Grid Distribution and transmission codes) there are few direct references to operate and maintain building phases.

There are key standards principally internal to energy organisations such as TSOs and the DNOs, that do not appear in Perinorm.

Pathways

It is possible to draw a pathway path 1 (shown in red) and path 2 (shown in blue) for elements of demand side management, as shown in Figure 33

- Dispatching of additional generating resource.
- Load Shedding (control of flexible demand).

Path 1 follows the demand side action of dispatch of small to medium storage, and generation elements tasked by district level control centre, assumed to be coordinated by, for example, a DNO.

Path 2 has a more complex pathway in that the control of load may be by both direct and indirect means. An indirect approach would be by the use of Tariffs to encourage load shedding to periods of oversupply, whereas a direct approach would be to task individual elements in the system (perhaps down to consumer device level) to load shed. In either case, a pathway for tariff data and control could be drawn through all the layers from the district control centre through to the consumer device within the building layer. However, in practice, in this use case, it is more likely that the controlling interaction may be abstracted to the building systems operator.

From a standards viewpoint, Path 1, the control of energy assets by a district control centre, appears to be well supported by the standards landscape. However, it is not clear whether the controls of these Distributed Energy Resources (DERs) are currently enacted in a consistent way. Further work would need to be carried out, particularly with respect to assessing the consistent use of IEC61970, IEC 61968, IEC 62325, covering the use of Common Information Models (CIMs) for information, energy management and energy market communications. Discussions with industry experts suggest they may not.

Path 2 is more problematic since there are more interface boundaries and the potential for control more diffuse. Indeed, direct control of consumer load is not covered well in the standards landscape. It is unlikely that Common Information Models are applied down to this level. However, there is the clear potential for such control using the Advanced Metering Infrastructure (AMI) in association with a Home Area Network. Such interchange of control and data is supported in principle by the AMI directly using what is considered as regulated data. It would also be possible to achieve the same effect using data pathways that bypass the AMI, using existing communication channels to either the Building System Operator (local control) and then onto the District Control Centre. This route uses what might be termed unregulated data.

Discussions with industry experts have indicated that there is early work being undertaken in the development of standards for load control in smart consumer devices. Further investigation would be required to evaluate their projected impact.

It is clear that that both the energy market, and the roles of the TSOs and the DSOs, is undergoing a period of change. The DSO is moving from managing a largely passive network to becoming a Distribution System Operator with responsibilities over local balancing and system optimisation of a very dynamic grid edge. The standards landscape appears to be missing a consistent systems architectural overlay, which supports the operation of a highly dynamic future smart grid.

The knock-on impact of an evolving system is that from a data management viewpoint the data paths and associated guiding specification framework necessary to provide a flexible smart grid with flexible demand side data acquisition analysis and management may not fully exist at a system level for some time. However, local level trials are in progress, which is likely to lead to islands of local DSM and supply. Data pathways do exist, for example, those provided by Electralink (the data transfer company for the TSOs and DSOs) along with traditional SCADA and other control system for grid asset and switchgear control and modelling, however, these have developed over time to serve a more traditional network generation and distribution topology.

It is noted that if DSR is to be more pervasive down to consumer level then there is need to have demand data which is meaningful at the level at which it is to be used. This is particularly difficult when the needs of data protection and data anonymisation come into play. This problem has been tackled for the Advanced metering Infrastructure, using what is identified as 'regulated data', but many business bypass services will likely be based around 'unregulated data', using more traditional methods of standardised wide area communication and applications reaching directly into the office or home.

Electricity sector

The electricity sector and, in particular, the digitisation of the sector is at a very early stage. The core element, the TSOs and the DNOs, are still relatively siloed from an operational point of view and not yet best placed to take advantage or control of the innovations in the industry, particularly at the edge of the network.

The question of how a demand side data management system could be architected has two difficult areas to overcome.

Firstly, clarity of roles and responsibilities for a future smart grid and the evolution of the TSO and DSOs remits to match the changing needs of CNI provision and operating a network with significant renewable assets. In particular, there is a good case for a systems architect function. This was discussed recently in an IEE publication 'Transforming the electricity systems' [24]which proposed 3

[24] Ref IET – Transforming the Electricity system- How other sectors have met the challenge of whole system integration

possible models for achieving this function within the electricity sector. One of these model highlighted the use of a Technical Architecture Group responsible for developing architecture principles and associated technical standards.

Secondly, is the need to have demand data, which is meaningful at the level at which it is to be used. This is particularly difficult when the needs of data protection and data anonymisation come into play. This problem has been tackled for the advanced metering infrastructure, using what might be identified as 'regulated data', but many business bypass services will likely be based around 'unregulated data', using more traditional methods of wide area communication reaching directly into the office or home. In either case, maintaining consumer confidence and engagement will be key to maximising the potential of demand side management at both local and system level.

6 Transport

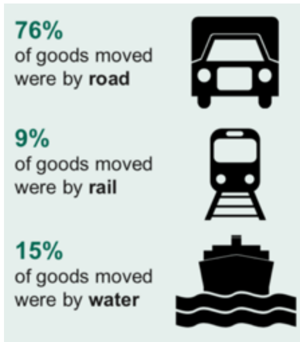
6.1 Market analysis

6.1.1 Background

Transport connects people, businesses and services. It enables people to access schools, jobs, food stores, hospitals and businesses to get their goods to market. But along with economic and population growth comes additional demand for transport.

In 2016, passenger transport in the UK recorded the highest volume ever ,with 801 billion passenger-kilometres and 201 billion tonne-kilometres of domestic freight moved within the UK in 2015[25]. Road has been the predominant mode in both passenger and freight transport for over 60 years and urban road freight movements (in van) increased at an average rate of 2% a year for the past 5 years[26]. The rise in internet shopping and home deliveries is likely to be one of the contributing factors to such trend.

As for air transport, in 2016, UK airports handled a total of 268 million terminal passengers and 2.4 million tonnes of freight. Heathrow Airport is one of the busiest airport in the world with 76 million terminal passengers and 481 air transport movements[27].



But despite all the challenges it presents, the role of transport as an engine of the UK economy is undeniable. Just in 2015 alone, the transport and storage industry added gross value of £75,174 million[28] (4.5% of total GVA) and transport related taxes accounted for over 6% of all public sector receipts in 2016[29].

As set out in the Industrial Strategy[30], infrastructure is one of the five foundations of productivity. Maintaining and upgrading the transport infrastructure can play a key role in enabling the delivery of the government's plan[31], and the Government is already acting on this priority, having allocated over £61 billion in capital investment for transport infrastructure up to 2020/21[32]. In fact, in 2016, transport represented 4% of total UK public expenditure (of which more than half was on capital)[33].

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[25] Department for Transport: *Transport Statistics Great Britain: 2017*
[26] Data computed by the authors from Department for Transport (2017): *Road Traffic Statistics*
[27] Department for Transport: *Transport Statistics Great Britain: 2017*
[28] Office for National Statistics: *United Kingdom National Accounts: The Blue Book 2017*
[29] Data computed by the authors from Office for National Statistics: *Budget 2016*
[30] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf [last accessed 11 April 2018]
[31] Department for Transport (2017): *Transport Investment Strategy*
[32] Department for Transport (2017): *Proposals for the Creation of a Major Road Network Consultation*
[33] HM Treasury: *Budget 2016*

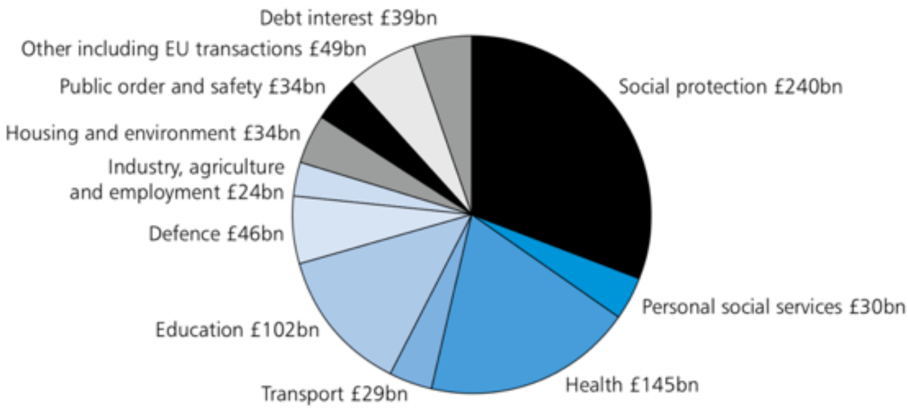

Figure 47 - Public sector spending 2016-17[34]

6.1.2 Challenges

However, the multiple negative impacts associated to current levels of transport activity are too well-known. A multi-departmental report of 2009[35] referred to excess delays having the biggest economic cost of all transport externalities, followed by physical inactivity and the growing level of obesity, road accidents and poor air quality. Currently, it is estimated that congestion costs the UK economy around £31 billion a year, £6 billion in London alone[36].

For 2017, on average, 67.7% of additional time was required compared to free flow on the SRN. On local 'A' urban roads it was 77.5% [11]

In 2015, 13.7% of the household weekly expenditure in the UK was spent on transport (ONS, 2017)

Moreover, according to official BEIS data[37], transport accounts for the largest proportion of final energy consumption, and has done since 1988. At around 40% of total energy consumed in the UK, road transport accounted for the largest share of transport consumption representing 74% of energy consumption in transport in 2016[38] and a quarter of UK domestic greenhouse gas emissions.

Alongside socio-economic and environmental challenges, ongoing changes in the administration of transport infrastructure will present new challenges to the way the infrastructure will be managed and maintained. Notably, the devolution of transport powers, a process that intends to give more control to English local authorities by transferring powers historically centralised to local government, will enable the latter to have more say over strategic transport investment on their local transport network. And, if on one hand, it will enable integration at the local level, for instance through smart

[34] HM Treasury: *Budget 2016*
[35] Cabinet Office et al: *The wider costs of transport in English urban areas 2009*
[36] INRIX: *INRIX 2016 Traffic Scorecard – U.K.;* http://inrix.com/resources/inrix-2016-traffic-scorecard-uk/ [last accessed 28 March 2018]
[37] Department for Transport: *Transport Statistics Great Britain: 2017*
[38] Data computed by the authors from Department for Business, Energy & Industrial Strategy: *Energy Consumption in the UK* (2017)

ticketing, the risk is that this decentralisation will hinder an integrated approach to infrastructure and data management at network level.

At the same time, while the Government has announced that from 2020-21 all Vehicle Excise Duty in England (generating around £6 billion in 2016[39]) will be allocated to a new National Roads Fund and invested directly back into the road network[40], it is unclear how the expected reduction in the revenue raised due to current policies promoting ultra-low emission vehicles will provide a stable funding stream to maintain the necessary levels of investment to improve and upgrade critical road infrastructure under the management of local authorities.

Lastly, given the increasing pressure on existing transport networks as a consequence of the additional demand for transport that comes from economic and population growth, it is of utmost importance to understand how to achieve higher levels of performance of the existing and future transport infrastructure.

6.1.3 Sector operation

The transport network in the UK includes all 5 modes: road, rail, (inland and maritime) waterway and air transport.

The road network has a total length of 246,500 miles, and of these 31,357 miles are major roads (motorways, urban A roads and rural A roads). Motorways account for 2,268 miles: 1,896 miles located in England, 283 miles in Scotland and 88 miles in Wales[41]. Trunk roads are nationally important routes and are managed by the national highway authority of each country; all other public roads are under the responsibility of local authorities (in England alone, the responsibility is split between 153 LAs). Roads in Northern Ireland are all maintained by the Northern Ireland Roads Service.

Figure 48: Strategic Road Network Map [9]

England's existing road network consists of the Strategic Road Network (SRN) and the Local Road Network (LRN). The SRN has over 4,400 miles of roads, amounting to 2% of the country's road network but carrying a third of traffic and two-thirds heavy-duty traffic[42]. It comprises all motorways (apart from the privately owned and operated M6 Toll) and major A-roads in England, providing access to major ports, airports and inter-modal freight terminals and the main cross-border routes to Scotland and Wales. The SRN is managed, operated and maintained by Highways England.

[39] Data computed by the authors from Office for National Statistics: *Budget 2016*
[40] Department for Transport (2017): *Transport Investment Strategy*
[41] Department for Transport: *Transport Statistics Great Britain: 2017*
[42] Department for Transport (2017): *Proposals for the Creation of a Major Road Network Consultation*

More recently, as part of the Transport Investment Strategy, the Government committed to creating a Major Road Network (MRN) across England - a middle tier of the busiest and most economically important local authority A-roads, sitting between the SRN and the rest of the local road network[43].

As for the railway infrastructure, in 2016-17 the length of the route open to traffic in Great Britain was 9,825 miles (corresponding to 19,400 miles of track), 34% of which electrified. The network was supported by 2,560 mainline stations[44]. The rail network in Northern Ireland is not part of the network of Great Britain and follows a different operation model.

The network consists of five main lines (the West Coast, East Coast, Midland, Great Western and Great Eastern), which radiate from London to the rest of the country, complemented by regional rail lines and dense commuter networks within the major cities, including Glasgow, Liverpool and London.

The Railways Act 1993[45] introduced a new regulatory regime for the railway sector, with the establishment of a regulatory body (the current Office of Rail and Road, ORR) and a new (privatised) model for passenger railway services that consisted in two main types:

- Franchise: train operating companies (TOCs) run specified services within a particular part of the rail network for a specified period of time through a contracted service. This is through a track access agreement with the government, and licence granted by the rail regulator. A special case is the format concession, where services are contracted out (e.g. London Overground and Manchester Metrolink).
- Open access: when companies identify an opportunity to run a service not being provided through a franchise are able to apply separately to the regulator for access to routes in a purely commercial way (for example, the London Underground, Eurostar and the Heathrow Express).

Ownership and operation of the infrastructure (tracks, signals, stations, tunnels and level crossings) falls under the responsibility of Network Rail, although often TOCs lease stations on their network. Presently, Network Rail owns and operates 19 of the biggest stations, namely the ones that different train operators run services on.

Rolling stock in the UK is generally privately owned by Rolling Stock Companies (ROSCOs) who lease the rolling stock to passenger and freight train operators to then deploy it on their services. Typically, the train companies procure the rolling stock directly from the rolling stock companies as part of the franchising process. The average age of rolling stock for franchised passenger operators is 21.1 years[46].

The key stakeholder groups and relationships within the rail sector are illustrated in Figure 49.

It is worth noting that the Office of Rail and Road (ORR) was set up to regulate the rail industry's health and safety performance, making sure that the rail industry is competitive and fair, as well as to monitor the performance of Highways England. ORR also has economic regulatory functions in the railway sector in Northern Ireland and for the northern half of the Channel Tunnel, situated in the UK.

[43] Department for Transport (2017): *Transport Investment Strategy*

[44] Office of Rail and Road (2017): *Rail infrastructure, assets and environmental: 2016-17 Annual Statistical Release*

[45] Railways Act 1993; https://www.legislation.gov.uk/ukpga/1993/43/contents[last accessed 28 March 2018]

[46] Office of Rail and Road (2017): *Rail infrastructure, assets and environmental: 2016-17 Annual Statistical Release*

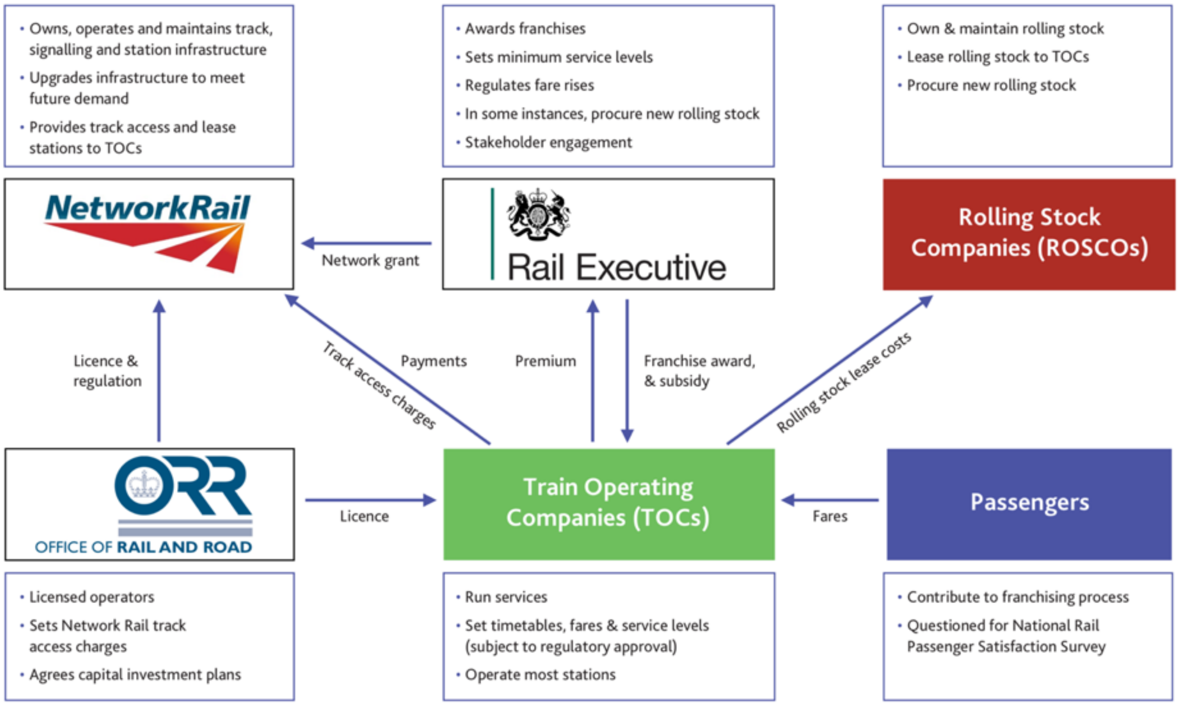

Figure 49 - Relationships within rail sector

6.1.4 Stakeholders

The transport sector is extremely complex and has a wide range of actors from government departments, regulatory bodies, transport operators, local authorities, watchdogs, to market watchdogs. For reference, the key stakeholders are shown in Table 15.

Body	Descriptor
Department for Transport	The Department for Transport is the government department responsible for the English transport network and a limited number of transport matters in Scotland, Wales and Northern Ireland that have not been devolved.
Highways England	Highways England is the government-owned company charged with operating, maintaining and improving England's motorways and major A roads
Transport for London	Transport for London is a local government body responsible for the transport system in Greater London, England.
Transport Focus	Transport Focus is a watchdog for transport passengers and road users in the United Kingdom. It was known as Passenger Focus until March 2015
TravelWatch	Travel Watch is a social enterprise company which acts as an advocate for passengers to lobby for the improvement of public transport working closely with local authorities, business organisations, partnerships and other stakeholder groups.
Rolling Stock Operating Company	A rolling stock operating company (ROSCO) owns and maintains railway engines and carriages which are leased to train operating companies who operate the trains.
Train Operating Company	A train operating company (TOC) is a business operating passenger trains on the railway system of Great Britain under the collective National Rail brand. TOCs have existed since the privatisation of the network under the Railways Act 1993

Body	Descriptor
Network Rail	Network Rail is the owner and infrastructure manager of most of the rail network in England, Scotland and Wales. It is owned by the Government
Office of Rail and Road	The Office of Rail and Road is a non-ministerial government department responsible for the economic and safety regulation of Britain's railways, and the economic monitoring of Highways England
Rail Delivery Group	The Rail Delivery Group is a membership body in the British railway system, bringing together the companies that run Britain's railway into a single team with one goal - to deliver a better railway for Britain, its businesses and communities

Table 15 - Transport sector stakeholders

6.2 Use case selection for transport

This section details how the High Value Sectors described earlier were decomposed to long list candidate areas within the transport sectors. These sectors were subsequently short listed and a preferred option for evaluation chosen for detailed pathway analysis.

6.2.1 Long list for transport

The market investigation showed that the transport sector is highly fragmented with a variety of actors and service providers at all levels in the value chain and throughout the lifecycle. Our analysis has shown the complexity of the relationships between asset owners, service providers, regulators, policy makers, and the variety of sectoral challenges. The landscape is extremely challenging and tackling traffic congestion is pivotal to achieve a more sustainable sector from all dimensions: economic, social and environmental. Within this area, the following long list of potential use cases was identified:

- Management of traffic in the Strategic Road Network.
- Management of road traffic in urban areas (including dedicated cycle paths and footpaths).
- Coordinated management of traffic with neighbouring networks (the case of the future Major Road Network).
- Management of last mile logistics.
- Demand management through the provision of integrated multi-modal public transport services in urban areas.
- Integrated traffic management at network level.
- Provision of digital technologies in the rail network.
- Management of waterway traffic.
- Demand management of personal mobility.

6.2.2 Review by the transport experts of the long list to produce a short list

Using the criteria established, each of the items in the long list was appraised on a rating of 0-4, where 4 is the maximum value. The analysis for the utilities sector is shown Table 16.

Option		Impact	Service definition	Breadth	Total
1	Management of traffic in the SRN	4	3	4	11
2	Management of road traffic in urban areas	4	3	3	10

Option		Impact	Service definition	Breadth	Total
3	Coordinated management of traffic with neighbouring networks (MRN)	3	2	4	9
4	Management of last mile logistics	2	3	3	8
5	Demand management through the provision of integrated multi-modal public transport services	3	3	3	9
6	Integrated traffic management at network level	4	3	4	11
7	Provision of digital technologies in the rail network	3	2	4	9
8	Management of waterway traffic	3	2	2	7
9	Demand management of personal mobility	4	2	4	10

Table 16 - Long list of transport use case appraisal

From this appraisal of the long list, a short list of 4 options was selected:

- Management of traffic in the Strategic Road Network.
- Management of road traffic in urban areas.
- Integrated traffic management at network level.
- Demand management of personal mobility.

This long list was then assessed using the detailed appraisal framework shown in *Table 17*.

6.2.3 Establish a detailed appraisal framework and appraise

Working with sectoral experts, a series of criteria were established to assess the short list of the candidate use cases. These criteria reflected a balance between the impact and relevance of the different use cases and the practicality of having the necessary information available to develop the use case. These were applied to the options short listed by the experts as shown in *Table 16*. This analysis resulted in the use case Option 6 (Integrated traffic management at network level): the option that will now be taken forward to develop the information pathway.

Criteria	Details	Management of traffic in the SRN 1	Management of road traffic in urban areas 2	Integrated traffic management at network level 6	Demand management of personal mobility 8
Scope	How far-reaching is the challenge addressed, attested by the cross-system dependencies and number/variety of stakeholders sharing the ownership of the services.	2	3	4	3
Policy alignment	The challenge is clearly aligned with the current national policy landscape, as well as supported by relevant literature. There is strong evidence the services covered in the use case are attracting interest/investment from relevant stakeholders. The validation of the use case included peer review.	4	5	3	4
Relevance to the DBB	It is expected the findings will contribute to the generation of robust evidence highlighting the value of a whole lifecycle approach to information management to enable higher built environment productivity and efficiency levels.	4	4	4	2
Impact	The value of the services covered by the use case has been clearly established. There is sound evidence of the contribution of services to the identified outcomes and wider environmental and socio-economic impacts.	4	4	2	3
Replicability / Scalability	Extent to which the use case presents a challenge also recognised in other systems/sectors, and how applicable would the findings be in addressing it.	4	4	5	3
Innovation potential:	Level of ambition of the use case translated by the ability of the services in addressing a well-recognised challenge whilst significantly progressing the state-of-the-art.	4	4	5	3
Data availability	The required information to successfully develop the research is accessible within a reasonable timeframe.	3	3	3	2
Clearly identifiable benefits	The benefits are identifiable and demonstrable.	3	3	3	2
Unfulfilled services	Contribute to use case: new intermediate or end services can be identified.	3	3	5	2
Pervasion	Through lifecycle: The extent the service impacts the lifecycle.	3	3	4	2
Total		34	36	38	26

Table 17 - Transport short list appraisal

6.3 Standards analysis

The standards analysis is a key element of the information pathways. It will identify where the description of the information assets needed for a use case are described in standard forms. There many thousands of standards, de jure and de facto, that are attributable to the transport sector and potentially applicable for this use case.

6.3.1 Selection of keywords for standards analysis

The methodology adopted for the identification of keywords followed the same approach as in the utilities use case: the original activity descriptor was decomposed to its key descriptive components and keywords were identified under the three broad categories of Family, Service Specific and Other Associations. For the transport use case, 2 services were selected to ensure enough coverage of results yield. These searches are shown in *Table 18* and *Table 19*.

Name of service: Managing real-time traffic flow intelligence					
Sector	Transport				
Family	**Service specific**				**Other associations**
	management	real-time	traffic flow	intelligence	
ITS	control centre	in-trip	traffic data	information	traffic classification
Intelligent Transport Systems		dynamic	traffic statistics	data	traveller information service
smart motorways			traffic monitoring		travel information system
smart cities			traffic condition		
			level of service		

Table 18 - Transport initial keyword selection: service 1

Name of service: Dynamic management of traffic signals (based on real-time information)				
Sector	Transport			
Family	**Service specific**			**Other associations**
	dynamic	management	traffic signals	
ITS	real-time	control	traffic signals	MIDAS
Intelligent Transport Systems	telematics	routing	traffic	Traffic technology
smart motorways		journey	VMS	
smart cities			road vehicles	
			messages	

Table 19 - Transport initial keyword selection: service 2

Through a workshop between the project team and BSI, the initial keyword list was further refined to provide a more focussed output from the standard searches. This is shown in Table 25:

Name of service 1: Managing real-time traffic flow intelligence **Name of service 2:** Dynamic management of traffic signals (based on real-time information)								
Sector: Transport								
Family association								
"Intelligent Transport Systems"	"Smart motorways"	"motorway*"	"Smart cit*"	Road				
"road" OR "real time" OR "traffic flow" OR "control centre*" OR "control center*" OR "on-trip" OR "traffic data" OR "dynamic" OR "traffic statistics" OR "traffic monitor*" OR "traffic condition*" OR "level of service" OR "traffic classification" OR "traveller information service*" OR "travel information system*" OR "traveler information service*"	<-	<-	<-	<-				

Table 20 - Transport final keyword selection

6.3.2 Results from standards analysis

These keywords generated an initial return of 693 standards. Following an initial filtering of the results on the basis of the title, abstract and descriptors correlation with the asset and data life cycles, the list was further refined through an expert sense-check comprising an assessment of the standards relevance to the four service descriptors: capability, capacity, state and quality of service for the use case in question.

Alongside the Perinorm search, this exercise included a manual review of standards produced by sectoral technical committees such as ISO/TC 204 (intelligent transport systems) and CEN/TC 278/WG3 (public transport), as well as the compilation of de facto standards, either produced by national bodies, namely Highways England, or internationally renowned organisations such as the Transportation Research Board.

The relevant standards identified include 30 standards from BSI/Perinorm, 15 standards from the additional search list and 11 de facto family standards or guidance. This is shown in Table 21, *Table 22* and *Table 23*.

Standard	Title
GB/T 29107	Road traffic information service - Traffic condition description.
UNE 135460-1-2:2006	Road equipment. Traffic control centres. Part 1-2: Remote stations, services management. Real time and historical data services.
UNE 135490-1:2006 IN	Road equipment. Exchange of information between zonal control centres and the centre of centres. Part 1: General requirements.
UNE 199152-1:2016	Road traffic management equipment. Data quality. Data analysis. Part 1: Interurban Traffic data.
EN 12896	Road transport and traffic telematics. Public transport. Reference data model.

Standard	Title
BS ISO 15638-12	Intelligent transport systems. Framework for cooperative telematics applications for regulated commercial freight vehicles (TARV). Part 12. Vehicle mass monitoring.
BS ISO 24102-6	Intelligent transport systems. Communications access for land mobiles (CALM). ITS station management. Part 6. Path and flow management.
BS EN ISO 17427-1	Intelligent transport systems. Cooperative ITS. Part 1. Roles and responsibilities in the context of co-operative ITS architecture(s).
BS ISO 15638-21	Intelligent transport systems. Framework for cooperative telematics applications for regulated commercial freight vehicles (TARV). Part 21. Monitoring of regulated vehicles using roadside sensors and data collected from the vehicle
BS EN ISO 18750	Intelligent transport systems. Co-operative ITS. Local dynamic map
BS EN 16157-2	Intelligent transport systems. DATEX II data exchange specifications for traffic management and information. Part 2. Location referencing. Part 2: Location referencing.
BS ISO 14813-5	Intelligent transport systems. Reference model architecture(s) for the ITS sector. Part 5. Requirements for architecture description in ITS standards.
ASTM E 2300	Standard Specification for Highway Traffic Monitoring Devices.
ASTM E 2665	Standard Specification for Archiving ITS-Generated Traffic Monitoring Data.
ASTM E 2759	Standard Practice for Highway Traffic Monitoring Truth-in-Data.
DIN SPEC 91340	Terminology of intelligent individual urban mobility.
DS/ENV 12896	Road Transport and Traffic Telematics - Public Transport - Reference Data Model.
GB/T 20607	Intelligent transport systems - Architecture – Services.
GB/T 21379	Classification and coding of the attribute of traffic management information - City road.
GB/T 28788	Road geography data collection and quality control.
GB/T 29101	Road traffic information service - Specification for data services quality.
GB/T 29746	Data structure of real time traffic information services.
GOST R 56351	Intelligent transport systems. Indirect management of traffic flows. Requirements for technology for road users information by means of variable message signs.
GOST R 56675	Intellectual transportation system. City's highways and roads state control using telematics data of road machines.
NF P99-300	Road traffic data. Development, storing, distribution. Measurement and processing units. Type, accuracy of traffic data and metrological sequentially.
NF P99-330	Road Traffic Data: development, storing, distribution - Measurement and processing units - Type, accuracy of traffic data and metrological sequentially.
SANS 52896:2008	Road transport and traffic telematics - Public transport - Reference data model.
SANS 53998:2008	Road transport and traffic telematics - Public transport - Non-interactive dynamic passenger information on ground.
SANS 55531-1:2008	Public transport - Service interface for real-time information relating to public transport operations Part 1: Context and framework.
UNE 178101-3:2016	Smart cities. Infrastructures. Public Service Networks. Part 3: Transport Networks.

Table 21 - Relevant de jure standards from Perinorm

Standard	Title
PAS 183	Smart cities. Guide to establishing a decision-making framework for sharing data and information services.
CEN/TS 16614	Exchanging Public Transport schedules and related data.
BS ISO 10711	Intelligent Transport Systems -- Interface Protocol and Message Set Definition between Traffic Signal Controllers and Detectors.
BS ISO 13111	The use of personal ITS station to support ITS service provision for travellers..
EN ISO 14825	Intelligent transport systems -- Geographic Data Files (GDF) -- GDF5.0.
ISO 17185	Public transport user information.
ISO/TR 17427	Cooperative ITS.
ISO/TR 17465	Cooperative ITS.
ISO/TR 20529-1	Intelligent transport systems -- Framework for green ITS (G-ITS) standards.
ISO/TS 17187	Electronic information exchange to facilitate the movement of freight and its intermodal transfer.
ISO/TS 17426	Cooperative systems -- Contextual speeds.
ISO/TS 17427	Cooperative systems -- Roles and responsibilities in the context of cooperative ITS based on architecture(s) for cooperative systems.
EN 15531	Public transport. Service interface for real-time information relating to public transport operations.
CEN/TS 17118	Intelligent transport systems - Public transport - Open API for distributed journey planning.
Directive 2010/40/EU	Deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

Table 22 - Relevant de jure standards from additional analysis

Standard	Title
DMRB	Design Manual for Roads and Bridges
MCHW	Manual of Contract Documents for Highway Works
RWSC	Routine and Winter Service Code
NMM	Network Management Manual
TMMM	Technology Management and Maintenance Manual
TCRP Report 165	Transit Capacity and Quality of Service Manual
HCM	Highway Capacity Manual: A Guide for Multimodal Mobility Analysis
UTMC-TS003.003	UTMC Framework Technical Specification
UTMC-TS004.0064	UTMC Objects Registry: Traffic signal interface
TIS-DG*	Family of Traffic Information Systems standards
TMS-DG*	Family of Traffic Management Systems standards

Table 23 - Relevant de facto standards or guidance

6.4 Information pathway development

We adopted a two-layered model:

1. **Physical layout view:** a first step consisted with the definition of a system architecture based on key physical components and the main interactions with the activities putting pressure in the system (in other words, generators and attractors of traffic) as shown in Figure 50.
2. **Functional layout view:** captures the asset owners' perspective of what is needed to achieve the desired performance gains (what we call 'services').

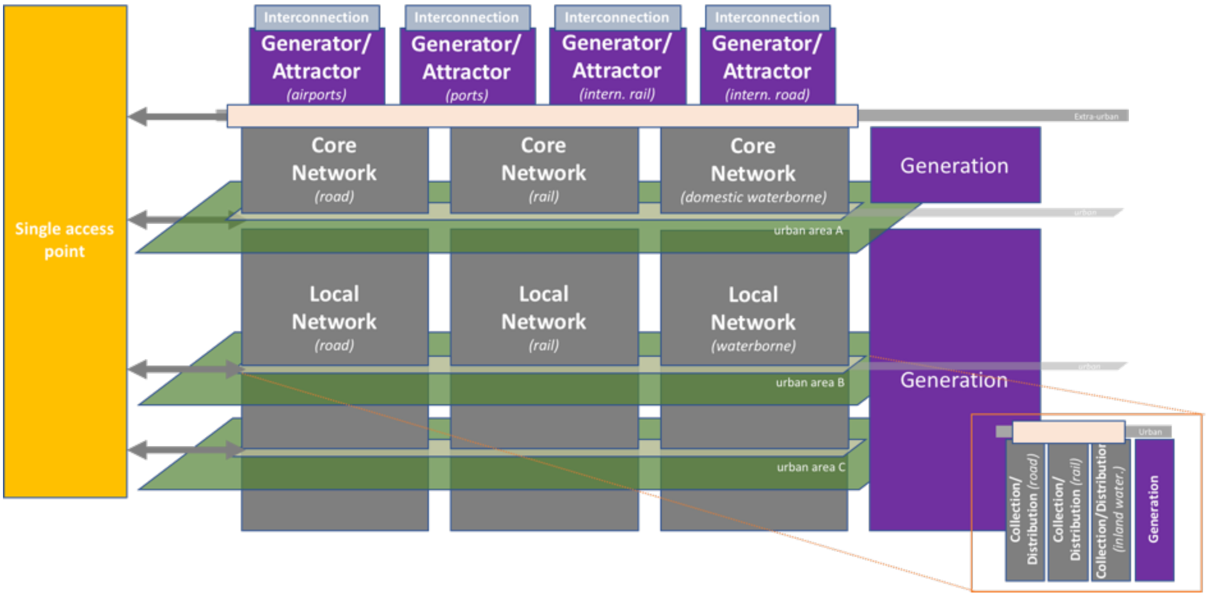

Figure 50: Physical layout view of the transport sector

- **Large generators and attractors** of traffic located at the boundaries of the system, whether an internal border (for example, England/Scotland) or a political/administrative border (UK/Continental Europe), where bottlenecks such as interoperability and eRoaming[47] need to be sorted to ensure adequate connection across systems.
- **Core network:** high-capacity primary transport network (road, railway or waterway) that ensures medium to long distance journeys between strategically important places, not necessarily comprised by sections of the same hierarchy but which are under the administration of a single agent. For instance, in the case of England, one of the core networks is the SRN, which includes motorways and major A-roads, managed exclusively by Highways England.
- **Local network:** provides access from and within urban areas. It might be managed by the same or different agent as the core network. In the case of the road network it includes A-roads not covered by the SRN and all other paved roads (including dedicated cycle paths and footpaths). Given the complexity of the transport network, each urban area is illustrated through a

[47] As with roaming for mobile communications, eRoaming refers to the capability of EV drivers to charge their vehicles at any charging station, even in a foreign country, regardless of the contractual agreement they have with a specific operator.

sectional cut of the entire network, and there are *n* number of local networks corresponding to the *n* number of urban areas.

- **Single access point (SAP)** is a market place that ensures accessibility to transport data through a common a digital interface. It is an extension of the requirements set in the Directive 2010/40/EU[48] to the entire transport network.

The functional view entailed a comprehensive mapping of the activities that address specific needs that fulfil the delivery of the intended outcome: the reduction of traffic congestion through integrated traffic management at network level. Given the foresight nature of this exercise, the definition of the service required an educated guess on what will be the activities or modules required to improve traffic flow in the future. This includes the creation of new ones such as the ‘inter-app cooperative navigation service’ aimed at addressing the unintended consequences of currently concurrent navigation applications by imposing capacity ceilings to the network while still respecting the principles of distributed journey planning.

As for the information flows, at a high level of abstraction it is established that a package of information will be exchanged between an urban layer and an extra-urban layer (the salmon boxes) through a single access point that will enable the description of capability, capacity, state or QoS of the service. The specific information exchanged between layers required to describe an end-to-end service (in other words, parameters contained in the salmon boxes) will vary depending on the transport mode and activity in question. Given the use case in question, the analysis of the information pathway will be limited the road transport, although, in a real life situation, there would be an additional level of integration: the multimodal one.

The following diagrams illustrate the functional layout views for the selected services (integrated traffic management at network level):

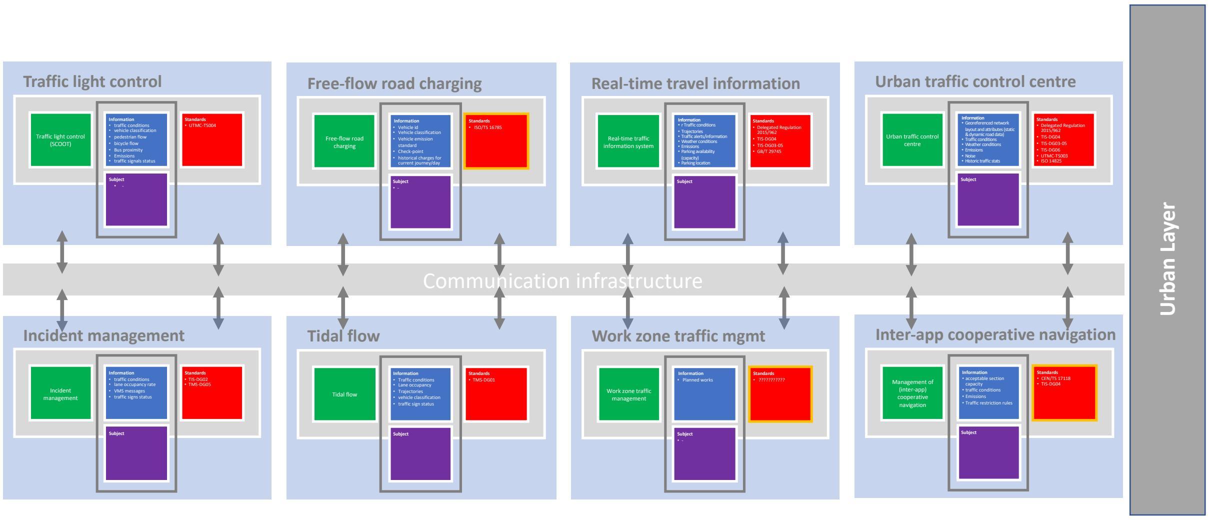

Figure 51 - Ecosystem of activities (or modules) in the urban layer

[48] Which focuses on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport

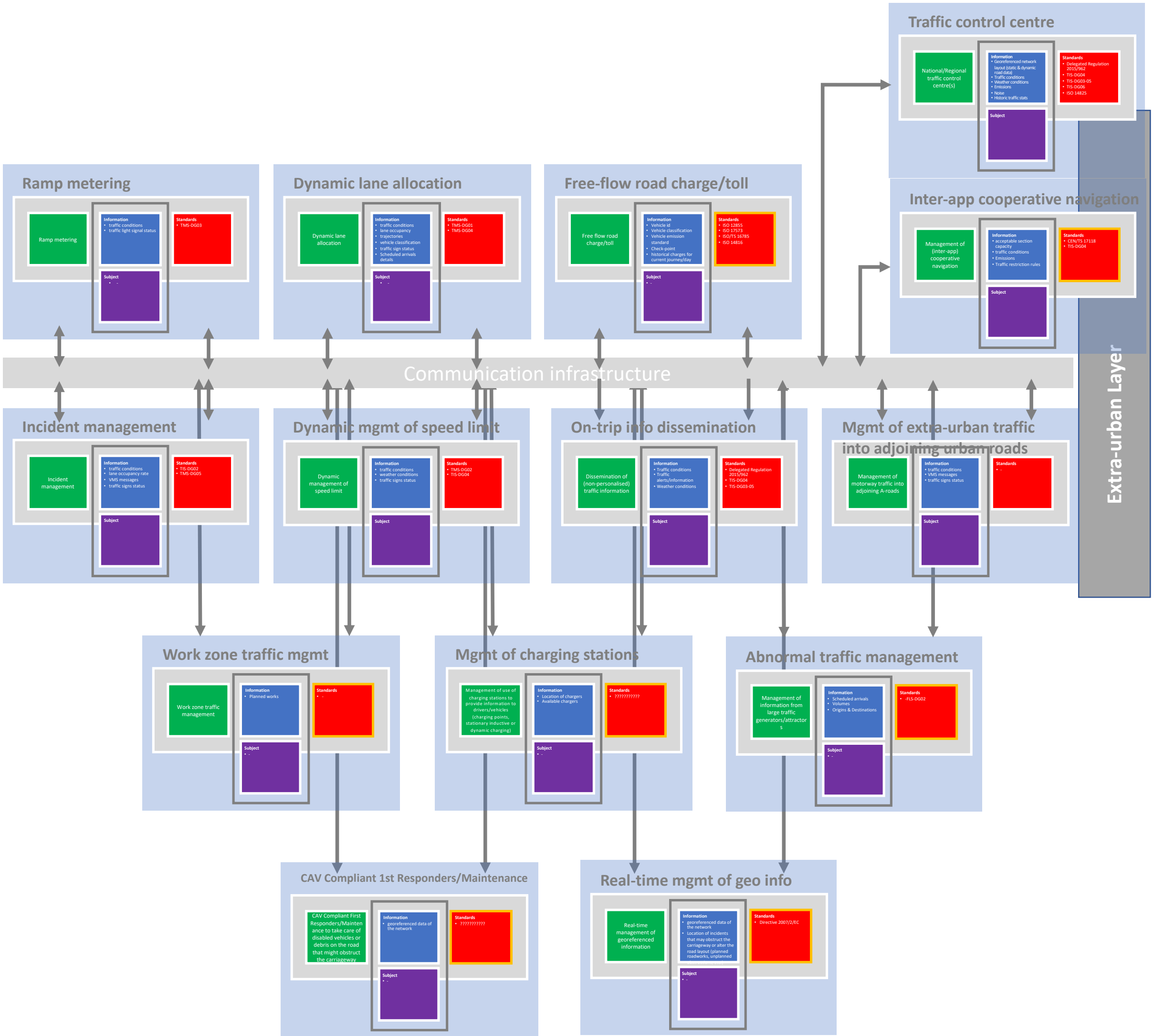

Figure 52 - Ecosystem of activities (or modules) in the extra-urban layer

6.5 Information pathway

The analysis of the information pathway was developed by tracing the data required to deliver the services, as mapped in the functional view related to the use case selected:

> **Headline:** £31 billion economic cost a year due to current levels of vehicle delay[49].
>
> **Hypothesis:** integrated (extra-urban and urban) traffic management can help reduce congestion significantly by using data at network level and integrated information measures to manage traffic within each system[50].
>
> **Use case:** integrated traffic management at network level.

Historically, traffic management systems have been either planned for single networks or with some degree of integration along strategic corridors or sections (essentially, the underlying principle of the Major Road Network). The hypothesis put forward advances the state-of-the-art as it not only

[49] INRIX: *INRIX 2016 Traffic Scorecard – U.K.;* http://inrix.com/resources/inrix-2016-traffic-scorecard-uk/ [last accessed28 March 2018]
[50] *Written evidence from Intelligent Transport Systems (ITS UK) (ETM 06);* https://publications.parliament.uk/pa/cm201011/cmselect/cmtran/writev/etm/m06.htm [last accessed5 April 2018]

promotes a seamless transition between neighbouring systems (for example, through on-ramp and off-ramp metering), but it optimises capacity by adopting a network approach to the integration of existing infrastructure through cooperative information management. This ultimately ensures the end-to-end transport of people or goods:

- In a safe manner.
- Within predictable and reliable journey times.
- With no disruptions and at constant flow.
- Having the minimum negative environmental impact.

To that end, at network level, the service would need to have the ability to:

- Gather information about the whole network capacity, state and QoS, by interrelating capacity, state and QoS of the different network layers.
- Manage the supply of network capacity based on the information and a series of priorities and policies including maintenance needs, balancing capacity across the network and user type.
- Keeping users informed of navigation options, traffic conditions and any relevant events occurred while on trip.
- Equitably charging for road usage on the basis of negative externalities.

In order to realise such capabilities, the asset owner or operator requires access to regular and reliable information on available capacity: to relate the acceptable section capacity at a certain moment, to inform dynamic system status and quality of service (QoS) variables, and to describe service performance (the CCSQs). The corollary is that exchange of information must be ensured at the interconnection of each level of the network (salmon boxes in Figure 50) to inform each layer on the upstream or downstream conditions. For the particular use case in question, the information requirements translated into capacity, state and QoS would resemble:

Capacity:

- Maximum number of vehicles within a given layer of the network (urban, extra-urban) per unit of time.
- Maximum free-flow speeds.
- Minimum journey times.
- Maximum cost of externalities.

State:

- Georeferenced network layout and attributes.
- Safety rating of EuroRAP.
- Network availability.

QoS:

- Vehicle-miles travelled.
- Traffic profile (average vehicle speed, flow, density, delay).
- Journey profile (speed profile, journey times, planning time index).
- Degree of saturation (ratio of demand to capacity).
- Number of casualties by severity.
- Energy consumed and GHG by vehicle type and vehicle-miles travelled.

- Air quality levels.
- Noise exposure levels.
- Net loss reduction of biodiversity.
- User satisfaction score.
- Cost savings.

The different elements (or activities) in each layer required to deliver the above-mentioned capabilities at network level are described in the next sections, along with the identified information interdependencies and specific CCSQ descriptors at system service level (in other words, within each network layer), following an illustrative information pathway starting from the urban traffic centre (Figure 53):

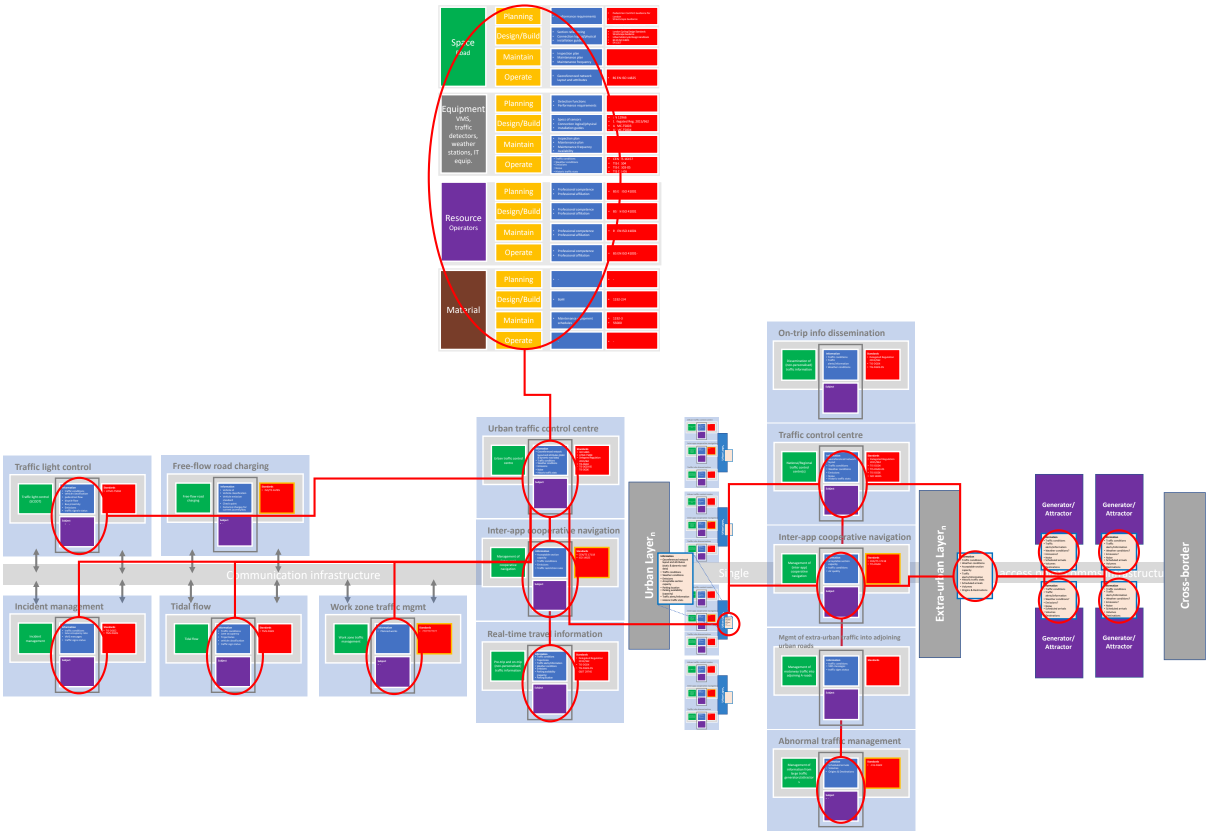

Figure 53 - Illustration of an information pathway (UTC)

It is, however, important to note that a number of assumptions have been made. Firstly, whilst each layer contains a considerable number of activities (or modules) to collectively manage traffic within the layer and that may benefit from having information from a different system, direct communication between layers is limited to a small number of these activities to ensure effective coordination of instructions. Hence, inter-layer communication is restricted to activities that have end-to-end functionalities and directly support the integration of traffic management at network level (such as passenger information systems and inter-app cooperative navigation). This would also apply to traffic control centres that work as gateways of information to enable the assessment of the overall system performance and make decisions regarding actions that should be taken by inward-looking services to improve their individual performance.

At the same time, it is considered that all 'front-end' activities exchange information through the single access point and each layer has its own closed system of communication channels. For example, 'traffic light control', an autonomous module that controls traffic signals based on the traffic conditions in the urban network, is a critical component to the urban layer and serves this system only: automatic decisions to control the signals are informed by data sourced in the urban area and its boundaries (at the interconnection of A-roads and motorways), but regular service does not have direct access to information on the traffic conditions in the extra-urban layer. Exceptionally, automatic decisions may be overridden on the basis of information received from the extra-urban layer in the urban traffic control (UTC) centre. Information on CCSQs follows the same principle.

Urban layer

At the urban level, inter-layer information is provided by three different system activities through the single access point: (on-trip) real-time traffic information system (RTTI), inter-app cooperative navigation (IACN) and the urban traffic control (UTC) system. The aggregated information at the interconnection of the urban and extra-urban layers is represented Figure 54 and Figure 55.

Information

- Georeferenced urban network layout and attributes (static & dynamic road data)
- Traffic conditions
- Weather conditions
- Emissions
- Acceptable section capacity
- Parking location
- Parking availability (capacity)
- Traffic alerts/information
- Historic traffic stats

Figure 54 - Information at Urban Layer

Information

- Traffic conditions
- Weather conditions
- Acceptable section capacity
- Traffic alerts/information
- Historic traffic stats
- Scheduled arrivals
- Volumes
- Origins & Destinations

Figure 55 - Information at Extra-urban Layer

The UTC is one of the core systems in an urban area, providing a central control and monitoring point to network controllers such as the traffic light control system (commonly known as SCOOT) to manage vehicles, bicycles and pedestrian flows. This also enables the assessment of the performance of the entire local network. (Note that the transport network model, depicted in Figure 50, presumes the existence of a UTC for each urban layer). The UTC aggregates information on static network data (for example, road geometry, traffic signs, speed limits, location of parking places) and data generated by internal services as dynamic road status (road/lane closures, dynamic speed limits, availability of parking places, weather conditions affecting road surface and visibility, for example). This information is then shared with the extra-urban traffic control centre through the SAP.

In its turn, the UTC receives data from the extra-urban traffic control centre and, together with the information processed by the extra-urban inter-app cooperative navigation, processes new information that is then forwarded to associated urban modules such as the traffic light control system and tidal flow.

Capability, Capacity, State and Quality of Service (CCSQ) descriptors at the UTC level would be translated as shown in Figure 56:

Capability:

- Manage information from the different urban services.
- Aggregate data to relate capacity, state and QoS of the local network.
- Provide consolidated information to other layers and users.
- Gather information on the extra-urban layer's capacity, state and QoS of the core network to support local services.

Capacity:

- Maximum traffic density within a given section of the network per unit of time.
- Maximum free-flow speed within a given section of the network.
- Minimum journey times.
- Number and location of parking facilities.

State:

- Number of modules/% network covered by the UTC.
- Number and % of signal controlled junctions using adaptive traffic control or prioritisation.
- Number of active controllers (outstations, junctions controllers, pedestrian & bicycle controllers, traffic counters, for example).
- Network availability.
- Weather conditions.

QoS:

- Vehicle-miles travelled.
- Traffic profile (for example, average vehicle speed, flow, density, delay) within a given section of the network.
- Journey profile (speed profile, journey times, planning time index).
- Degree of saturation (ratio of demand to capacity) per section of the network.
- Performance of queues (length and time) in network layer intersections.
- Number of casualties by severity.
- Delays induced by accidents and incidents.
- Delays induced by roadworks.
- Time spent looking for parking.
- Energy consumed and GHG by vehicle type and vehicle-miles travelled.
- Air quality levels.
- Noise exposure levels.
- Net loss reduction of biodiversity.
- User satisfaction score.
- Cost savings.

Figure 56 - CCSQ for UTC

Real-time traffic information allows the communication of information to users in the system by providing real-time or close to real-time road traffic conditions, travel alerts and information on network capacity. (This is not to be confused with the service 'personal mobility management' in the public transport layer that provides personalised multimodal journey planning). This information is also shared across the system (through the traffic control centre of the extra-urban layer) to inform incoming users of key factors that might affect their journey and make them take a different route.

While this is a front-end activity, the model considers data is aggregated from a number of different sources by the UTC (for example, traffic loops from the traffic light control system, tidal flow information on trajectories), and then processed and disseminated by this module.

In terms of CCSQ descriptors, these are shown in Figure 57.

Capability:

- Manage traffic data.
- Provide information to local network users on traffic conditions and network availability.
- Provide navigation guidance to park the vehicle.

Capacity:

- Maximum traffic density within a given section of the network per unit of time.
- Number and location of parking facilities (off-street) and parking spaces (on-street).

State:

- Length and % of road network covered by the service.
- Number of variable message signs (VMS).
- Number of operational VMS.
- State of parking facilities (open/closed).
- Network availability (to infer on-street parking availability).

QoS:

- Traffic profile (for example, average vehicle speed, flow, density, or delay) within a given section of the network.
- Journey profile (speed profile, journey times, planning time index).
- Travel time reliability.
- Performance of queues (length and time).
- Parking search time.
- Parking occupancy rate.

Figure 57 - CCSQ for Real-time traffic information

Lastly, the inter-app cooperative navigation module was designed to enable cooperation between the infrastructure and the multiple navigation systems currently offered in an uncoordinated manner (Waze, Google Maps, Citymapper, and so on). By dynamically managing road capacity according to real-time traffic conditions and pre-established rules (for instance, restricting through traffic in residential areas, avoid highly polluted sections, or limit circulation to a particular vehicle class), IACN helps balancing loads across the local network and prevent gridlock situations.

In order to calculate routes, each navigation system interrogates the network on the available capacity and the network responds with boundary conditions determined by the maximum traffic volume allowed in each road section. All information used by this module comes from the UTC. The same principle applies between layers: the urban network communicates the available capacity to the extra-urban layer so the latter can use that information to control traffic across the core network and potentially redirect users to improve the smoothness of traffic transitions between systems. (The reverse process is also considered in the extra-urban layer.)

The translation of this activity into CCSQ is shown in Figure 58

Capability:

- Manage local road capacity by dynamically determining acceptable road capacity based on traffic conditions and pre-defined rules.
- Negotiate allowed capacity with multiple navigation applications requesting capacity to the same sections simultaneously.

Capacity:

- Maximum traffic density within a given section of the network per unit of time.
- Minimum vehicle speed within a given section of the network.
- Maximum air quality level within a given section of the network.
- Restrictions to circulation.

State:

- Network availability.
- Time of day.
- Air quality levels.

QoS:

- % of answered or unanswered requests by navigation apps.
- Traffic density and speed.
- Degree of saturation (ratio of demand to acceptable capacity).
- Air quality levels.
- Fleet profile (vehicle class) circulating within areas with restrictive conditions.

Figure 58 - CCSQ for inter-app cooperative navigation module

Extra-urban layer

The extra-urban level is effectively a middle layer between the urban layer and cross-border large traffic generators where administrative powers end, therefore presenting a completely different set of interconnection challenges.

At the extra-urban layer, information is exchanged both ways by the means of five different activities: management of traffic in major interconnections (MTI), (on-trip) real-time traffic information dissemination system (RTTI), inter-app cooperative navigation, abnormal traffic management (ATM) and the traffic control centre (TCC) as shown in Figure 59:

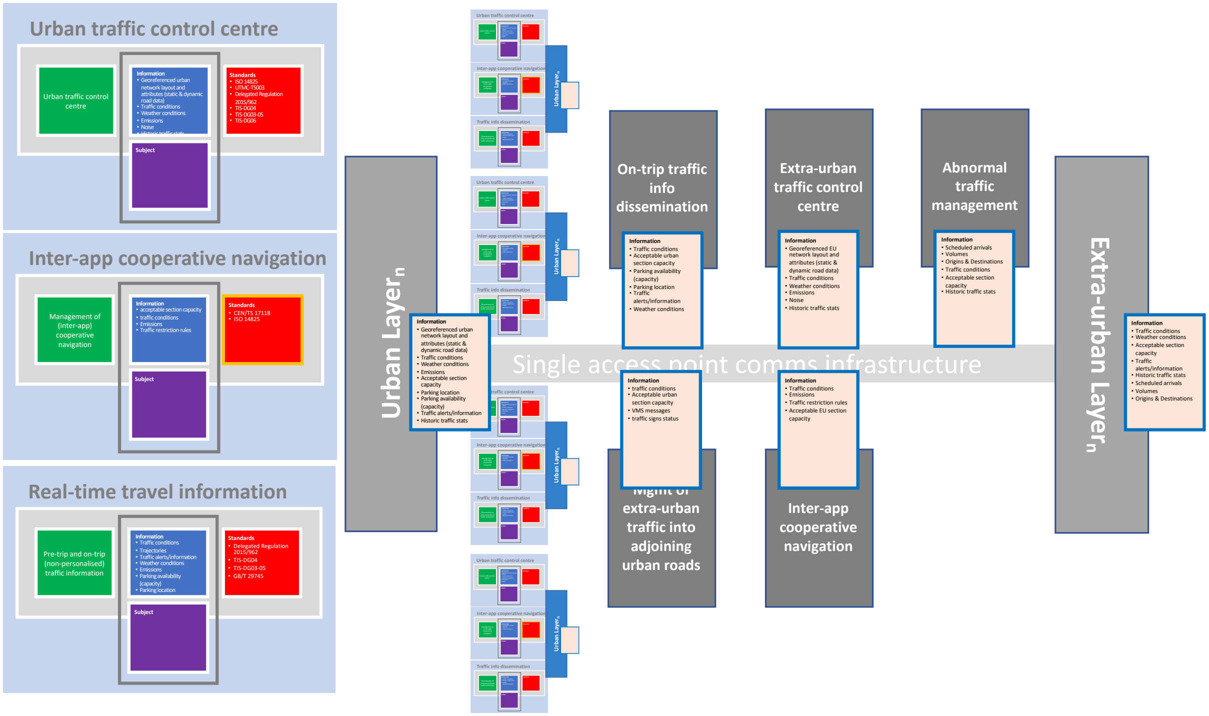

Figure 59 - Extra Urban layer

As in the urban layer, the extra-urban TCC (whether of regional or national reach) aggregates information from internal network modules. This is essentially an upgraded version of a Highways England regional/national traffic control centre as it also receives information from the urban layer. Information from UTC is then processed together with information coming from the urban IACN module and forwarded to other associated activities such as the dynamic management of speed limit and management of extra-urban traffic in major intersections with adjoining urban roads. At the same time, at the other end the extra-urban traffic control centre shares information with large traffic generators via SAP.

The types of data exchanged at this level are similar to those in the UTC, and so are the CCSQ descriptors shown in Figure 60

Capability:

- Manage information from the different extra-urban services.
- Aggregate data to relate capacity, state and QoS of the core network.
- Coordinate information with large traffic generators or attractors.
- Provide consolidated information to other layers and users.
- Gather information on capacity, state and QoS of local networks to support local services.

Capacity:

- Maximum traffic density within a given section of the network per unit of time.
- Maximum free-flow speed within a given section of the network.
- Minimum journey times.

State:

- Number of modules/% network covered by the TCC.
- Number of controllers connected to the TCC (for example, regional stations or MIDAS).
- Network availability.
- Weather conditions.
- Safety rating EuroRAP.

QoS:

- Vehicle-miles travelled.
- Traffic profile (for example, average vehicle speed, flow, density, delay) within a given section of the network.
- Journey profile (speed profile, journey times, planning time index).
- Degree of saturation (ratio of demand to capacity) per section of the network.
- Performance of queues (length and time) in network layer intersections.
- Number of casualties by severity.
- Delays induced by accidents and incidents.
- Delays induced by roadworks.
- Energy consumed and GHG by vehicle type and vehicle-miles travelled.
- Air quality levels.
- Noise exposure levels.
- Net loss reduction of biodiversity.
- User satisfaction score.
- Cost savings.

Figure 60 - CCSQ for extra-urban layer

One of the main bottlenecks in a network approach to traffic management is the management of vehicle flow at major intersections of motorways, and major trunk roads with urban roads. When downstream traffic is free-flowing and volumes in the mainline carriageway are not substantial, the problem is contained to the typical capacity decrease by carriageway narrowing. In this case, a regular off-ramp metering system or enhanced interchange design can be sufficient as shockwaves are localised. However, in the event of congested traffic in the adjacent local roads, a drastic capacity drop can lead to uncontrolled shockwave propagation, resulting in long queues and severe congestion in upstream motorway sections. To that end, the module considered in this particular use case entails the management of traffic along influence areas of major intersections according to the capacity, quality of service and state of the urban network. This allows diverging traffic to be redirected to alternate exits by instructing the on-trip information dissemination system to update drivers on best routes. This would occur whenever the urban inter-app cooperative navigation system sends through information on limited available capacity at the local network, and the UTC communicates a heavy traffic situation or other types of disruptions. The CCSQ for this is shown in Figure 61

Capability:

- Gather traffic information in the urban network.
- Control traffic along influence areas of major intersections according to the capacity, QoS and state of the urban network.

Capacity:

- Maximum traffic density at major intersections per unit of time.

State:

- Traffic conditions in the urban and core network.
- Available capacity and network availability in the urban network.
- Network availability.

QoS:

- Traffic conditions (flow, density) in the proximity of major intersections (upstream and downstream),
- Performance of queues (length and time) in the proximity of major intersections.
- Delay induced by major intersections.

Figure 61 - CCSQ for major intersection control

Similarly to the real-time traffic information service in the urban network, the extra-urban traffic information dissemination system provides non-personalised traffic information through variable message signs and, eventually, by infrastructure-to-vehicle (I2V) communication with network users. Information communicated includes: traffic conditions as to the location and length of traffic queues, travel alerts (accidents, roadworks and weather conditions affecting road surface and visibility) and information on alternate routes or exits (as described in the previous service). This service is limited to on-trip information as pre-trip information (personalised and non-personalised) is provided by the traffic control centre via the single access point. Information used by this activity comes from multiple traffic sensors and information processed by other internal services, communicated via the extra-urban traffic centre.

Figure 62 shows the CCSQ of this module:

Capability:

- Manage traffic data.
- Provide information to local network users on traffic conditions, network availability, variable speed limit, and so on.
- Provide navigation guidance to core network users based on conditions from the service management of traffic into adjoining urban roads.

Capacity:

- Maximum traffic density within a given section of the network per unit of time.
- Maximum traffic density at major intersections per unit of time.

State:

- Number of operational variable message signs (VMS) and traffic signs.
- Length and % of road network covered by the service.
- Network availability.

QoS:

- Traffic profile (for example, average vehicle speed, flow, density, delay) within a given section of the network.
- Journey profile (speed profile, journey times, planning time index).
- Travel time reliability.
- Performance of queues (length and time).
- Cost savings.

Figure 62 - CCSQ for infrastructure to vehicle and driver messaging

The inter-app cooperative navigation module in the core network works in an identical way to the urban inter-app cooperative navigation system: it dynamically adjusts available capacity based current traffic conditions and pre-established rules with the purpose of balancing traffic across the network. For that reason, the CCSQ descriptors are not repeated here.

Another activity added to the model was the abnormal traffic management module consisting of the advance communication of expected substantial traffic volumes from large traffic generators to the network (for example, a port or a stadium), allowing the asset owner to plan ahead and manage capacity before the abnormal traffic enters the system. When receiving the information from the large traffic generator, the ATM responds with the available capacity (provided by the inter-app cooperative navigation) and informs other inward-looking activities such as dynamic lane allocation and ramp metering so they can control traffic accordingly (for instance, by temporarily assigning dedicated lanes to heavy goods vehicles to create freight corridors and thus enabling truck platooning). Once information has been received from large traffic generators, the module forwards it to the TCC, making it available through the single access point to the urban layer. This is shown in Figure 63.

Capability:

- Anticipate abnormal traffic flows based on traffic conditions.
- Control traffic by prioritizing and managing vehicles by class.

Capacity:

- Maximum traffic density within a given section of the network per unit of time.
- Minimum vehicle speed within a given section of the network.
- Rules or priorities for circulation (for example, allowed vehicle classes by time of day).

State:

- Network availability.
- Scheduled arrivals and volumes (passengers and goods), and origins and destinations.

QoS:

- Vehicle-miles travelled of abnormal passenger or goods loads.
- Traffic profile (for example, average vehicle speed, flow, delay) within a given section of the network.
- Journey profile (speed profile, journey times, planning time index) of abnormal passenger or goods loads.
- Energy consumed and GHG by vehicle type and vehicle-miles travelled.
- Cost savings.
- Response rate.

Figure 63 - CCSQ for inter-app navigation module

Generators

Even though these are not a layer of the network per se, large traffic generators or attractors are nonetheless treated as a system as they are a key variable to the network; any abnormal traffic volume might have a significant impact on the available capacity of the network and its performance. Notwithstanding, information exchanged with this layer is relatively slim, as the model considers there is information sent to the network to inform of expected large volumes of traffic and the network responds with the available capacity through the inter-app cooperative navigation module. This therefore informs decisions on how to manage traffic such as when and which mode will be the most efficient. As for the specific CCSQ descriptors, these could be related as shown in Figure 64.

Capability:

- Provide efficient and effective transport of passengers or goods from its facilities.

Capacity:

- Maximum tonnage or passengers handled.
- Maximum unitized traffic (for example, containers or roll on - roll off cargo)
- Maximum number of parking places.

State:

- Scheduled arrivals and volumes (passengers and goods), and origins & destinations.
- State of parking facilities (open/closed).

QoS:

- Tonne-miles travelled and passenger-miles travelled.
- Dwell time.
- Journey time.

Figure 64 - CCSQ for traffic generators

The analysis of the information pathway was followed by a more refined analysis of the previously list of relevant standards *Table 21*, *Table 22*, *Table 23* to determine the extent to which they cover the information requirements of the use case, and in particular their applicability to the CCSQ descriptors data model.

Given the similarities of the activities that enable the delivery of integrated traffic management at network level across layers, for the avoidance of repetition, the results are presented in a consolidated format in *Table 24*. Notwithstanding, all standards or guidance (both de jure and de facto) identified for the individual system components are listed in the specific activity or module.

The standards can be grouped in four broad categories according to their main scope:

- **System architecture**: when looking at conceptual or functional models.
- **Service requirements**: when specifying the needs at service level.
- **Data exchange**: when covering procedures for the communication of data.
- **Information specification**: when focusing on metrics and indicators.

Category	Standard	Geographic reach	Brief description	Applicability
System architecture	ISO 14813	International (adopted in the UK)	Reference model architecture(s) for the ITS sector, including the definition of primary 'ITS service groups' and domains within which the Service Groups reside in order to establish the relationship and interdependencies of the various ITS services.	local and core network service model
	ISO/TR 26999	International (adopted in the UK)	Advocates for the use process-oriented method (POM) in the development of high-level system architecture for ITS (functional, physical and communications viewpoints).	local and core network service model
	ISO/TS 17427	International	Defines technology agnostic roles and responsibilities required to deploy and operate Cooperative-ITS (V2V, V2I and I2I) in all types of road traffic.	local and core network service model
Data exchange	UNE 135490-1 IN	Spain	Establishes the procedures for the exchange of traffic management information (current and historic) between regional control centres and centralised control centres (centre of centres).	Extra-urban traffic control centre
	GB/T 29746	China	Establishes the framework for the exchange of urban real-time traffic information and data structures. It applies to traffic information centres and application terminal.	UTC
	CEN/TS 16157	EU (adopted in the UK)	Common set of data exchange specifications for traffic management and information (DATEX II) across boundaries (for example, national, regional, urban), including data content, data structure and relationships and communications specification for: - Location referencing - Variable Message Signs - Situation - Parking	local and core network services
	ASTM E 2759-10	International	Standard Practice for Highway Traffic Monitoring Truth-in-Data about the disclosure of how data are managed from field data collection through evaluation, acceptance, summarisation and reporting.	core network services

Category	Standard	Geographic reach	Brief description	Applicability
Service Requirements	UNE 135460-1-2	Spain	Requirements for real time and historical data service management in the scope of traffic control centres and on-trip information systems (for example, remote stations, VMS, weather stations)	UTC, TCC and (urban and extra-urban) RTTI
	CEN/TS 17118	EU (adopted in the UK)	Specifies the requirements for an open API for distributed journey planning service.	IACN
	ISO/TR 20529-1	International	Framework guideline for identifying cost-effective technologies and related standards required to deploy, manage and operate sustainable 'green' ITS technologies in surface transportation with eco-mobility. It includes a gap analysis of existing ITS standards and guidance documents to facilitate the practical implementation of identified standards.	local and core network services
Information specification	GB/T 29107	China	Guidance aiming at regulating urban road traffic information services in the description of traffic conditions, in particular traffic flow indicators (vehicle queuing, traffic volume, travel time reliability, and so on).	UTC, IACN, TCC, ATM, MTI and (urban and extra-urban) RTTI
	GB/T 29746	China	Urban real-time traffic information service data transfer application framework and data structures.	Urban RTTI
	UNE 199152-1	Spain	Specification of data quality and data analysis of interurban traffic data, in particular the definition of error detection procedure and reconstruction of traffic data in the interurban area.	core network services
	ASTM E 2665	International	Describes data elements and schema for an archiving ITS-generated traffic monitoring data, including conventional traffic monitoring data, data collected directly from ITS systems, and travel-time data from probe vehicles. It establishes the names of the data elements, their interrelationships, and their procedural definitions such as data collection instrumentation and methodology as well as recommended procedures for calculating traffic statistics.	local and core network services

Table 24 - Standards relevant to the delivery of integrated traffic management at network level, according to the established information pathway requirements

6.6 Commentary

This section examines two types of findings: the ones related to form, looking at the methodology adopted with a critical eye to understand future areas for improvement in the hypotheses and assumptions, and the findings associated to the content and what has emerged when testing the hypotheses. Regardless of potential limitations in the methodology, it is nonetheless valuable to inform policy recommendations.

Despite the significant investment made in the transport sector and strong evidence on the benefits of system integration, research shows stakeholders are still operating in semi-closed sub-systems (either by geographic coverage or mode) and information exchange across stakeholders and systems tends to be established in an ad hoc manner.

Research also reveals that typically data is collected and processed to run individual or small sets of activities but little account is taken of potential uses beyond those services at the planning stage, and even less how these can bring system benefits at network level. Information pathways appear to emerge in an incremental way, as a response to specific needs of the asset owner(s). To some extent some are accidental as historically the priority was on the integration at the physical level and digital integration ended up being an afterthought.

Nonetheless, findings of the information pathway exercise support that it is possible to trace the information required to deliver an end-to-end service by linking the already existing information in the individual activities. However, the way this information relates capability, capacity, state and quality of service has proven to be fragmented. Notwithstanding, discussions with experts have indicated stakeholders are very mindful of the value of data in a lifecycle approach to asset management.

From a standards viewpoint, progress has also been unbalanced and remains siloed. While certain topics have been subject to thorough standardisation processes (typically industry-led), as is the case for cross-border transport and cooperative-ITS (and even digital rail), the integration element (of different layers and modes) is still at an early stage. However, research suggests there is an enormous potential benefit in the adoption of principles and concepts explored in particular use cases (for instance, in TEN-T corridors) at a network level (as the assumption taken of expanding the single access point concept to the entire transport network). In fact, there are clear signs the sector is starting to evolve in its approach. For instance, recognising the benefit in expanding the scope of ITS beyond road traffic management, traveller information and electronic payment systems, ISO 14813 explores thirteen different ITS service domains including data management and performance management.

There were several challenges in the standards mapping exercise which resulted in an iterative, very resource intensive process overall. Firstly, the large number of standards obtained by selecting keywords and using Perinorm (693) was not easily manageable and required additional steps to assess their effective relevance. And while the keywords could be further optimised, it is unclear to what extent narrowing the keywords would significantly improve the quality of the results given that the search is typically limited to the information contained in titles and descriptors.

On the other hand, a particularly good feature of Perinorm is its extensive current database and geographic coverage. The results yielded included country specific standards, such as from Germany, Spain and China. However, very few standardisation bodies translate to English more than the titles and descriptors, which once again restricts the process of assessing the relevance of these standards beyond ‘in principle’.

As with the utilities use case, another valuable finding was that despite the large number of standards obtained, not all the relevant ones were captured. This reinforces the argument that a search limited to titles and descriptors is fairly simplistic and a more sophisticated method would not only bring efficiency to the process but also be more effective.

7 Healthcare

The UK NHS employs 1.7 million staff, making it the fifth largest employer in the World. It has over 3,500 buildings[51] with millions of equipment assets within. All of this exists to provide health care to over 1 million patients seen every 24 hours. It is an enormous service that has many sub-services providing the different lines of care.

7.1 Market analysis

The UK health care system is now really comprised of four separate health care systems: National Health Service (England), Health, Social Services and Public Safety in Northern Ireland, NHS Scotland and NHS Wales. The national system was first established in 1946 under the National Health Service Act and in 1947, in Scotland under the National Health Service (Scotland) Act, but launched to the public on 5th July, 1948. The national system was devolved into four separate systems in the late 1990s during the wider devolution process. The UK government sets the overall budget available to the NHS in England, while providing block grants to the other three countries, under which their legislatures determine how much of that block grant is spent on health care.

The UK system is a mainly publicly-funded system where individuals also have access to certain private health service providers, if they wish to do so for elective treatment. All systems provide preventive medicine, primary care and hospital services to all those ordinarily resident. This includes primary care, in-patient care, outpatient care, mental health services, ophthalmology, and dentistry. Users must pay a user fee or part of the following services: dental, optometry, and prescriptions (only in England and only for 15% of the prescriptions dispensed.)

The social care system is different in each country, and is designed to support children or adults in need or at risk, or adults with needs arising from illness, disability, old age or poverty through social services programs. It is integrated with the health care system in Northern Ireland but is delivered by local government social services in the other three countries.

NHS Wales was partially devolved in 1969, when powers over the NHS in Wales were given for the Secretary of State for Wales. It was further devolved in 1999 when powers were transferred to the Welsh Government, under the Welsh Minister for Health and Social Services. In 2009, NHS Wales underwent a change in structure, whereby there are currently seven Local Health Boards (LHBs) in Wales, delivering NHS services on a geographic basis, as well as three national trusts, operating services such as cancer care or the ambulance service.

NHS Scotland. Universal health care coverage came into effect in Scotland in 1947 under the National Health Service (Scotland) Act, and was revised in 1972 and 1978. Previous to this, half of Scotland was provided state-funded health coverage by the Highlands and Islands Medical Service, established in 1913. Today, NHS Scotland is comprised of 14 regional NHS Boards, seven Special NHS Boards, and one public health body.

Health, Social Services and Public Safety in Northern Ireland. The Health, Social Services and Public Safety department is responsible for both health care and social care, which differentiates it from the other three national systems responsible for only health care. The department is organised under a Permanent Secretary, with five business groups, five medical professional groups and one agency.

[51] https://www.property.nhs.uk/about-us/

There are also five regional trusts responsible for their own budgets and the management of front-line staff, health and social care services.

National Health Service (England) was accountable to the UK Parliament until 2013, through the Secretary of State for Health and the Department of Health. In 2012, the UK's Coalition government introduced substantial reforms to the NHS in England, with the introduction of a new clinically led commissioning model called the Health and Social Care Act. Although it was also designed to bring more patient involvement and local clinical knowledge to the NHS, the reality is there is no more patient involvement and possibly less local clinical representation than before. The Act has an explicit goal to create a competitive market in health care where there once had been an integrated public service, which has been extremely controversial.

A new organisation, known as NHS England, is now responsible for day-to-day operations. It is responsible for overseeing the 211 Clinical Commissioning Groups (CCGs), as well as commissioning specialist services and the national contracts for general practice, dentists, and so on. CCGs controlled approximately half of the NHS' total budget in 2013-2014. These CCGs receive funding from NHS England and can purchase health care services from within the NHS or from independent sources that are known as providers, such as for-profit businesses or non-profit organisations. CCGs are made up of GP practices in their geographic area, but are governed by a board designed to be clinically led, but including two lay members. They are responsible for purchasing the following services:

- Urgent and emergency care (for example, A&E).
- Elective hospital care (for example, outpatient services and elective surgery).
- Community health services (services that go beyond the GP level).
- Maternity and newborn,
- Mental health and learning disabilities.

Primary health care is commissioned directly by NHS England, as is some specialised secondary care, health care for military personnel and their families, individuals in prison and victims of sexual assault. Public health care is now handled by a new organisation, Public Health England, with local public health switched from the NHS to the responsibility of local health authorities. This is illustrated in Figure 59:

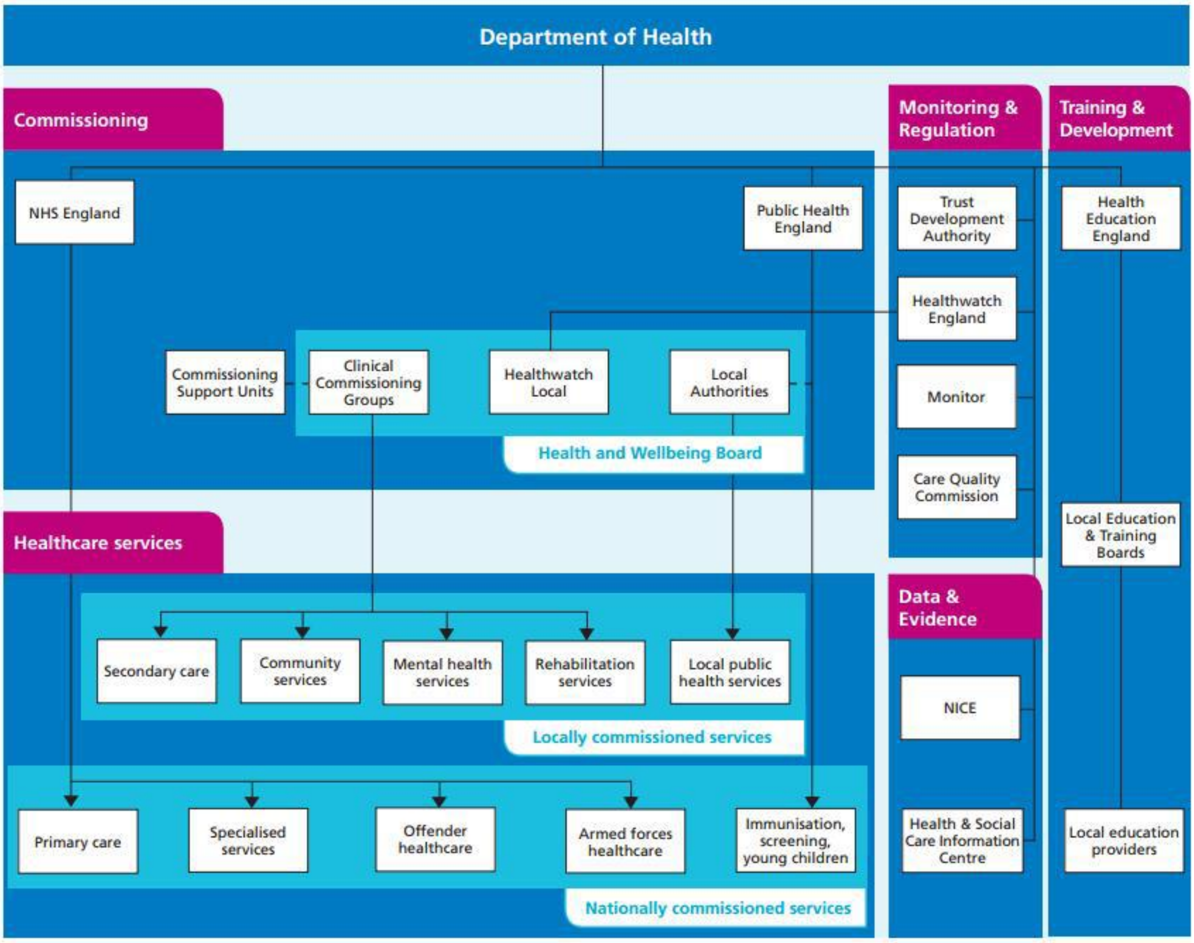

Figure 65 - Structure of the NHS

Trusts and Foundations. NHS trusts are organisational entities that serve a geographical area (usually anchored by a hospital service area) or a specialised service, such as the ambulance service or mental health. Since the 2012 Health and Social Care Act, trusts have been mandated to transform into foundation trusts, which are more independent and allow for more locally-based decision-making. This has not been universally successful. In a controversial move, the 2012 Act also abolished the private patient income cap for foundation trusts and allowed them to raise up to 50% of their revenue from private work. Many worry that this will lead to private patients being prioritised over NHS patients.

Funding:

As a publicly-funded system, health care costs are included in taxation received from the four countries. NHS England is funded directly from the UK Treasury, while the three other countries fund health care out of the block grants they receive from the UK Treasury.

NHS England funds the CCGs on a weighted capitation basis, which means they are funded on the basis of the lists of the GPs in the CCG, weighted by the lists' age profile, the health of the population and where the CCG is located. The complex flow of money into UK and social care in 2016 is shown in the illustration produced by the BMJ[52] in Figure 66. Even though the absolute values have changes the distribution is broadly similar.

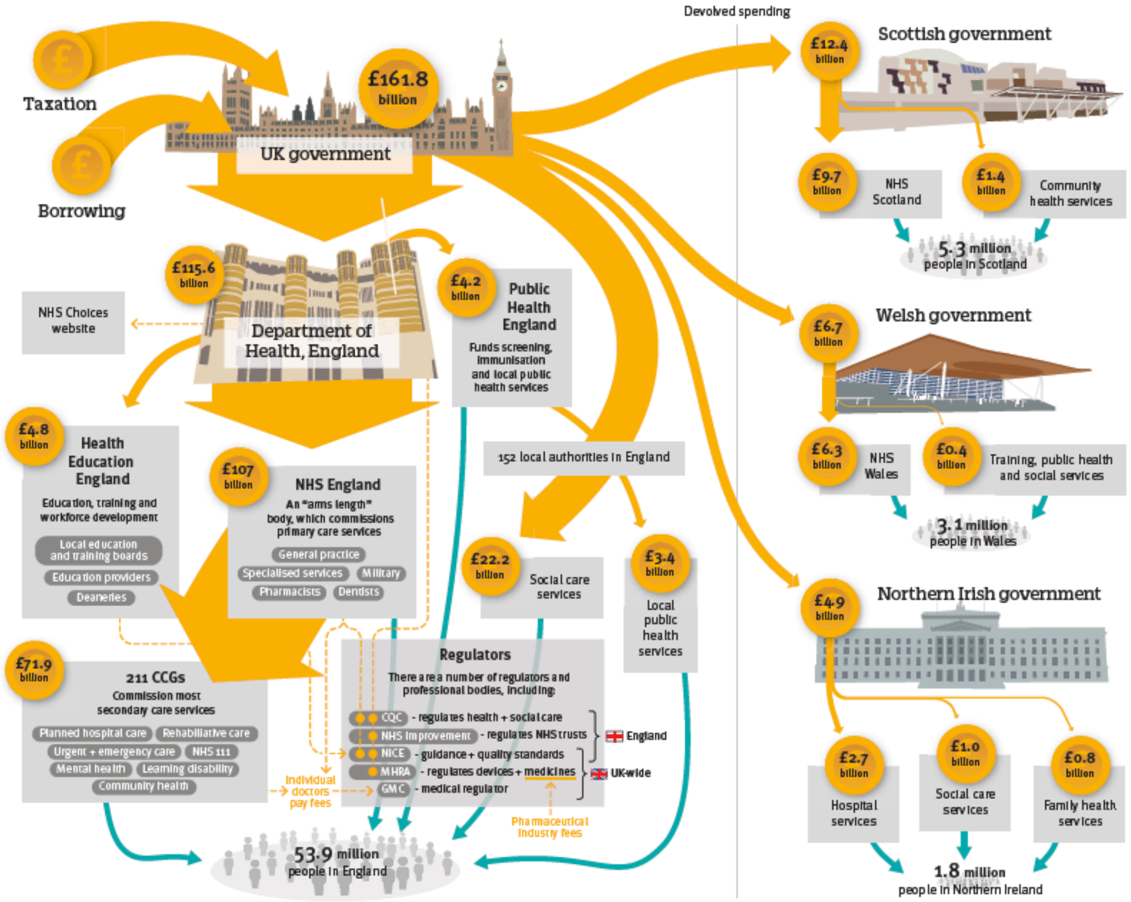

Figure 66 - UK Health and social funding on 2016

In the 2017 budget[53] extra funding for health care was announced to give a total of £126.4bn for 18/19 rising to £127.2bn for 19/20, shown in Figure 67. Although this increase in funding was appreciated by health care professionals, it still falls short of the historic levels leaving many CCGs with a deficit and tough decisions to be made. A recent report by The Kings Fund[54] produced the diagram shown in Figure 68 indicating the start realities of the funding for the CCG.

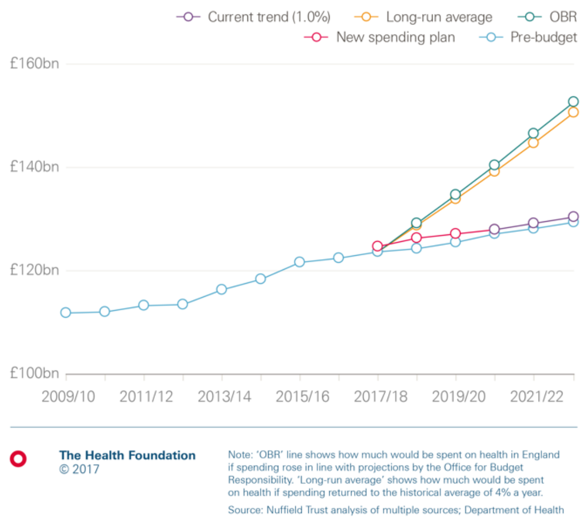

Figure 67 - Health spending in England projections

52 https://www.bmj.com/content/bmj/suppl/2017/01/13/bmj.j41.DC1/nhsfinances46.ww1.pdf

53 https://www.health.org.uk/new-money-nhs-announced-november-budget

54 https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/Understanding%20NHS%20financial%20pressures%20-%20full%20report.pdf

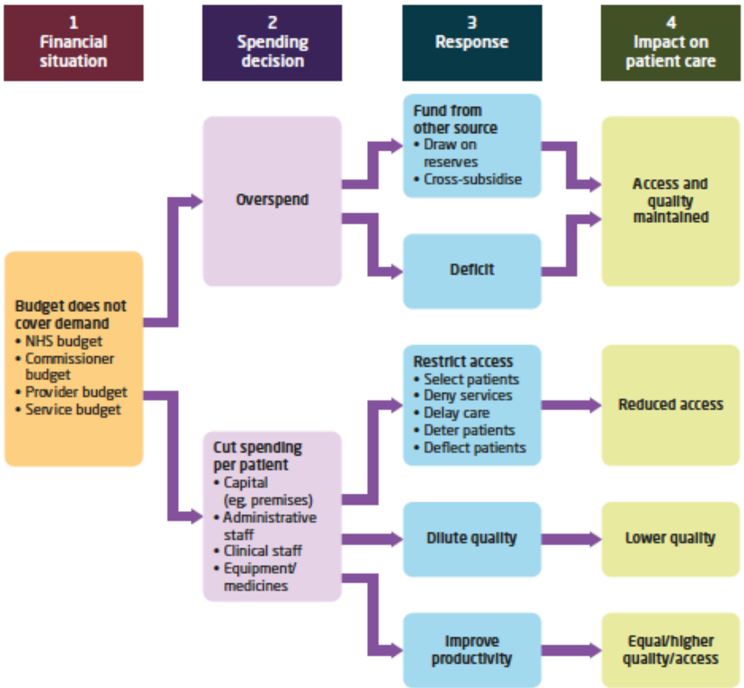

Figure 68 - Simplified model of possible responses to funding pressures

Social care: Northern Ireland has an integrated system whereby social care is part of Health, Social Services and Public Safety. Social care in the other three countries is provided through local councils. Scotland offers free personal care for seniors.

In England, social care is delivered by local councils and is a separate, though related, system. As it is almost always underfunded, this impacts the health care system by stressing hospitals, as those needing sub-acute care may not be able to find a place in the social care system and remain in hospital. It is means and needs tested, so that an individual's financial situation (including assets) and health condition are considered before they receive publicly-financed care. There are both public and private providers in the social care system, and more than half of services are delivered by private providers and paid for privately. There is some discussion to integrate both the social care and health care systems, so that both can be commissioned by the same entity, and budgets can be contained. Typically the local council social care budget is around 10% of the primary care budget.

In 2014, the Coalition government passed the Care Act, which introduced personal budgets, whereby individuals have more control over choosing their own personal care services. This has also been a controversial reform, as research has indicated it could cost the system more with worse patient outcomes, although many patients found the personal control to be positive. It also introduced a national threshold for minimum availability for care, which replaced the previous local system of varied thresholds. It has also increased the means testing level, so that more people will be able to access state-funded care. Even if individuals pay for their own care, there is now a proposal to set a maximum to save people from catastrophic care costs, after which point state funding will commence.

Performance evaluation: As part of the NHS England system, there are numerous organisations that are designed to evaluate performance and ensure compliance. The Care Quality Commission inspects hospitals, care homes, dental and general practices and other care services as per the basic standards of safety and quality. It monitors, inspects and regulates care and health services to ensure they meet basic standards of quality and safety, and publishes performance ratings.

Monitor is the sector regulator for the NHS in England, tasked with ensuring both competition and regulation in the health care system. As part of its mandate, it is responsible to ensure that foundation trusts are properly governed and that they are acting in the best interests of patients. It maintains a publicly-available directory of foundation trusts and their ratings to help achieve this. Monitor also ensures services are maintained if a provider fails.

Healthwatch England and its local members are designed to provide consumer oversight to the NHS England system and act as a champion for consumers while integrating local knowledge of issues to form national trends in consumer concerns. It was established under the 2012 Health and Social Care Act, replacing Local Involvement Networks, which in turn replaced the Community Health Councils in 2003. These Councils had statutory power and rights that Healthwatch does not have. There are concerns that Healthwatch suffers from a low profile and that it is poorly integrated into the health care system.

The National Institute for Health and Clinical Excellence (NICE) develops quality standards for the most common conditions that occur in primary, secondary and social care. It has developed national strategies for numerous conditions, including cancer, trauma and stroke. NICE has developed a very useful website known as NHS Evidence to provides open access to current clinical guidelines.

7.2 Use case selection for health care

The NHS is currently facing the biggest challenge in its existence. On a day-to-day basis most areas of the service are running perfectly well at present, but we are already seeing signs of the strain the system is under in areas such as hospital care, A&E and GP services. The reasons for the service reaching this crisis point are many, but here are the main ones[55]:

An ageing population: The NHS was set up to treat people with diseases. Many of the diseases that would have killed people 65 years ago, have been cured. While that means people are living for longer, it also means that they are, probably, living with one or more illnesses (long-term complex conditions) such as diabetes, heart and kidney disease. In turn, that means ongoing treatment and specialist care.

Lifestyle factors: The way we live now is also having a negative impact on our health. Drinking too much alcohol, smoking, a poor diet with not enough fruit and vegetables, and not doing enough exercise are all major reasons for becoming unwell and needing to rely on our health services. Increasing numbers of overweight children show this problem is currently set to continue.

The change in public expectations: Originally, tackling disease was the main job of the NHS. Today we all expect more. From advice on healthcare management through to mental health and social care, contraception, antenatal and maternity services, vaccination programmes and the fast, efficient processing of our medication and appointments. All of this with a growing population due to living longer and higher birth rates with lower infant mortality.

Accident and Emergency departments: More and more people are visiting A&E departments and minor injury units, stretching the ability of the departments to cope. It is suggested that many of the

[55] https://www.myhealth.london.nhs.uk/help/nhs-today

visits are unavoidable, but some are visiting because of inconsistent management of their long-term health conditions, the inability to get a GP appointment or insufficient information on where to go with a particular complaint. Winter sees an even bigger rise in visitor numbers with staff finding it harder by the year to cope.

Rising costs: The current financial crisis, rising costs of services, energy and supplies; innovations and technological breakthroughs that require more investment, along with higher numbers of people to cater for, all spell out a huge economic disaster for the NHS. It is estimated that without radical changes to the way the system works, as demand rises, and costs rise, the NHS will become unsustainable, with huge financial pressures and debts. If we make no changes there will be a £20bn-£30bn funding gap for the NHS nationally by 2020.

Advances in medicine and technology: Huge advancements in medicine and surgery, alongside IT and technological innovations mean that there is a wealth of ideas and efficiencies that could potentially be implemented to make the NHS meet the needs of us all in the 21st Century. Utilising these new approaches within a major restructure, the NHS could go on to be a reassuring source of health care and wellbeing well into the future.

A health care article by the BBC[56] includes the graphs from the IFS and ONS shown in Figure 69 and Figure 70. These clearly show that when you look at the budget commitments and the expected health care costs, we are on a rising incline of a challenge that will impact some of the most vulnerable members of society.

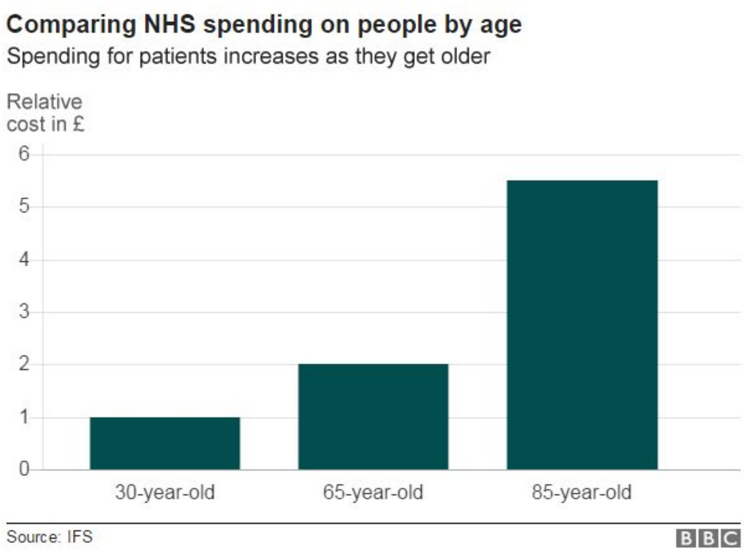

Figure 69 - UKs aging population

[56] http://www.bbc.co.uk/news/health-38887694

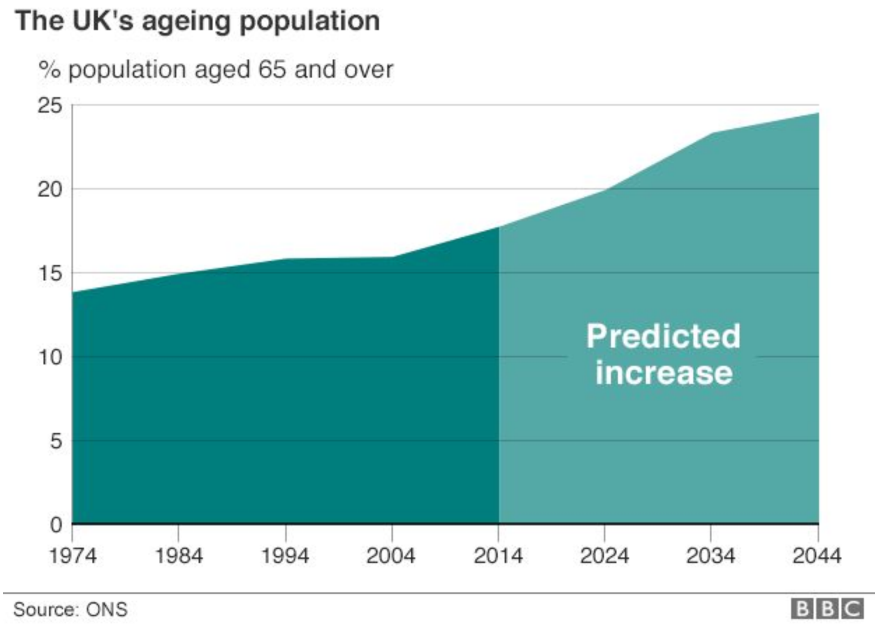

Figure 70 - NHS costs on people by age

7.2.1 Care of the elderly and the impact of 'bed blocking'

During period of this assignment there was an all-too-familiar press report[57] showing a former nurse, aged 93, who received an MBE for her services to the NHS, who spent six days in a hospital corridor because of a bed shortage, as shown in Figure 71. The hospital commented she was cared for in a 'non-designated bed space' for longer than is acceptable. Or, to put it in other terms: a demand that has outstripped the capability or capacity of the asset.

Figure 71 - Former nurse cared for in a 'non-designated bed space'

The uil team believe that this is exactly the type of social challenge that CDBB should be seeking to address and was the basis for the selected use case: Care of the elderly and the impact of 'bed blocking'. However, as we begin the analysis we are conscious that this is a very complex issue where the asset may or may not be one of the primary levers in the service delivery.

The term 'bed blocking' has found its way into common parlance and is considered derogatory with negative connotations towards the most vulnerable members of society. It is fair assumption that

[57] https://www.metro.news/six-days-on-a-corridor/981793/

most people do not wish to be in hospital any longer than they need be. For the purpose of this work package we define bed blocking as the 'inability to match supply with demand'.

The cost to the NHS and government of bed blocking is in excess of £900m[58] per year. This money could be better spent elsewhere in the NHS, such as research into the three main causes of premature death in the UK: Cancer, Heart Problems and Obesity.

The cost to the local council and the taxpayer is also rising, and having a negative effect on the economy. People are not spending their hard earned money as they are worried about rising costs in daily living and the potential to have to fund themselves or parents for long term healthcare in care homes as the government is becoming more strapped for cash, and funding is becoming harder and harder to obtain or be awarded. Gone are the days when a person who entered a care home was automatically awarded funded nursing care. Now, formal assessment only occurs after a wait of 28 days, and only then is money for the nursing element of care awarded, providing you meet the strict criteria. If you do not meet the criteria then you are classed as residential and the local council pay even less for these rooms. People are wanting more and more for their money; relatives, compliance and government expect homes to meet very strict guidelines as set by CQC, CCG and government legislation, all costing money. The higher national minimum wage and increase in pension costs all brings down the profit that care homes were previously assumed to have made.

In June 2017, the House of Commons drafted a briefing paper on 'Delayed Transfers of Care in the NHS[59]; this paper details the cost to the government and the individual of how delayed discharge affects the country as a whole. The evidence indicates the cause of these delays is both social and NHS, which prompts the questions why this has been allowed to happen and what intervention will be made. The report indicates that 45.3% of hospital delays are due to people waiting for a package of care for them to go home, either into their own home or into a care home setting. This is due to a combination of factors that cross jurisdictions, including the ability to administer the care needed in other environments, the reduction of trained personnel such as social workers and discharge coordinators, and a reduction in available care home beds.

The Care Act 2014[60] was introduced whereby people are given more choice about where they want to be discharge to and have the right to have services available to them. This highlights a challenge. Taking a person who has had a Cerebral Vascular Accident, for example: they have had treatment, rehabilitation whilst in hospital and are ready to go home. Before they go home, an Occupational Therapist has to ensure their home is fit for them to to. They may need specialist equipment such as beds or hoists. they may need additional physiotherapy, district nurses to attend to wounds or medication and specialist equipment such as profiling beds or pressure relief mattresses. Those who want to go into a care home have to wait to be assessed for government funding, (as detailed before, NHS Continuing Health Care Funding, or social care funding). The amount of coordination and information exchange for this one case is extraordinary and there are thousands of cases like this being managed every day.

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[58] http://nhsproviders.org/media/2175/lc-report-briefing-v5_12082016.pdf

[59] http://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-7415

[60] http://www.legislation.gov.uk/ukpga/2014/23/contents/enacted

It is now worth looking to the individual and how bed blocking affects them. NICE (the National Institute for Health and Clinical Excellence) wrote a paper and provided subsequent guidance[61] on the transition between inpatient hospital and community care home setting for those with social needs. When a person is ready for discharge, they are in the mindset of going home, and their mood lifts, as they look forward to going home. Every person, in accordance to the Care Act, have a right to choose where they want to reside, therefore the process begins when they are informed that discharge will take place.

Any delay in discharge will affect this individual's wellbeing: their health can deteriorate and the longer they are in hospital the greater the risk of developing hospital acquired infections such as MRSA, C Diff, pneumonia and urine infections. There is evidence[62] to support that delay in hospital discharge increased the hospital mortality rates and therefore more delay in discharge as a result of further illness developing as a result of staying in hospital.

Investigations into the major reasons for delays in discharge are shown in Figure 66. This shows the four highest reasons are due to waiting for assessment for home care package, further care not needed from a hospital, patient assessment before discharge or confirmation of space at a nursing home.[63]

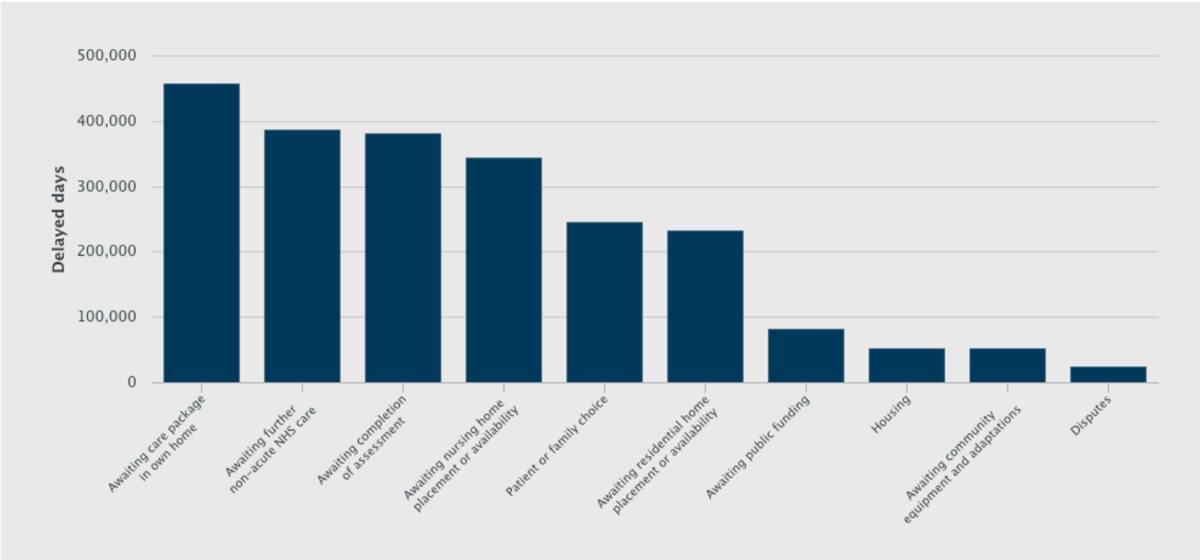

Figure 72 - Comparison of reasons for discharge delay

Building on the statistics from NHS England, discussion with experts in care for the elderly identified a number of areas with the potential to improve the issue of bed blocking.

- Reduce the amount of unnecessary hospital admissions – increase the amount of trained personnel who can give medical advice or treatment in their own homes. For example, if a person has a chest infection, often they need intravenous antibiotics and they have to go to

[61] https://www.nice.org.uk/guidance/ng27

[62] https://www.bmj.com/company/newsroom/delayed-hospital-discharges-could-be-linked-to-rise-in-population-deaths/

[63] https://www.england.nhs.uk/statistics/statistical-work-areas/delayed-transfers-of-care/

hospital to have this treatment. If this service can be carried out in the individual’s home, then this would be one person less in hospital. For those who reside in care homes, plan for care in advance. If an individual’s health is deteriorating, it is usually due to previous complication. The individual has the right to have treatment or pass away in a place of their choice: by asking the right questions on admission and implementing a Do Not Attempt Resuscitation (DNAR) protocol and defining their preferred place of care, can mean all systems are in place such as medication, equipment, facilities and resources and the person can either be treated or pass away with dignity in their own home with people around them rather than on a hospital trolley in a corridor.

- Training more effective social workers, the fundamental building blocks of the system, as they help source funding, homes and care packages for the individuals.
- Reduce people from unnecessary calling for 999, by utilising the 111 service, or increase support for those with mental health problems who often use the 999 service for crisis management when they need community support.
- Make the system work quicker, give care homes the facilities and funding to be able to block out beds for short term assessment or discharge. This will be good for the economy as well as the group or owners of the homes as they will have the facilities to be able to make improvements to the homes as well as being able to offer a service to those who want to stay in a care home for short or long term care.
- Training and development, a key area which needs to be addressed for social care workers, nurses, managers and those who fund the services.
- Improved communication from hospital to place of home.
- Reduction in the "bid for beds" or the use of costed care plans to identify the amount of money which would need to be spent to place a person in a care home. Costed Care Plans are used to identify the amount of hours needed to offer a standard of care to any resident who comes into a home, the cost also includes the running costs of the home as well as the amount of hours or nursing care a person requires. Continuing health care have this ethos and this delays homes from supporting people to be effectively discharged into their services as they have to wait to see if their bid has been accepted for a room, when this room could have been accessed by another individual. Not all Commissioning groups following this ethos, some have set room prices dependent on the home and what has been agreed in their contract
- Increase funding from the government.
- Increase the funding or make the system easier for people to access additional funding to enable them to go to care homes or have care at home.
- Better training in hospital and care homes for staff to access funding.

There is a clear and understandable focus on funding in any of these discussions and the earlier evidence supports that a funding issue does is exists, but it is not just money, it using what is available better and making better use of the information to make better and swifter decisions. However, very few of these factors are directly attributable or have primary causal linkages to the built or natural environment for this use case. Intermediate benefits could be foreseen, such as reducing the cost of operation and maintenance of the asset would release funds to be used elsewhere for clinical needs. Other very specific use cases such as reduction in air borne infection could be selected and the HVAC design and operation would have a direct impact.

7.3 Standards analysis

The standards analysis is a key element of the information pathways. It will identify where the description of the information assets needed for a use case are described in standard forms. There many thousands of standards, both de jure and de facto, that are attributable to the health care sector and potentially applicable for this use case.

7.3.1 Selection of keywords for standards analysis

The methodology adopted for the identification of keywords followed the same approach as in the other use case: the original service descriptor was decomposed to its key descriptive components and keywords were identified. Through a workshop between the project team and BSI, the initial keyword list was further refined to provide a more focussed output from the standard searches. This is shown in Table 25.

Name of service 1: Care of the elderly **Name of service 2:** Hospital bed allocation								
Sector: Health care								
Family association								
“Care of the elderly	“ Health care”	“ Health”	“ Assisted Living”	“ Hospital”	“ Bed”			
elderly OR outcome* OR benefit* OR care OR caring OR plan* OR deliver* OR triag* OR Convales* OR patient* OR acute OR framework* OR rehabilitat* OR chronic* OR social* OR communit* OR capacit* OR capabilit* OR discharge* OR administ* OR admit* OR emergenc* OR assist* OR "Ambient Assisted Living" OR Sanatorium OR "nursing home OR block* OR discharg*	<-	<-	<-	<-	<-			

Table 25 – Health care final keyword selection

These keywords generated an initial return of 825 standards. Following an initial filtering of the results on the basis of the title, abstract and descriptors, and correlation with the asset and data life cycles, the list was further refined through an expert sense-check comprising an assessment of the standards relevance to the four service qualifiers: capability, capacity, state and quality of service for the use case in question. This reduced the number of standards to 16, analysis of these highlighted the 6 key standards highlighted in bold in Table 26. Further analysis was undertaken of the Department of Health and Social Care (DoHSC) NHS Digital, National Institute for Health and Care Excellence (NICE), Care Quality Commission (CQC) and Royal College of Physicians (RCP), and .this surfaced another 15 guidelines applicable for the use case. This is summarised in Table 27.

Standard	Title
DIN SPEC 91280	Ambient Assisted Living (AAL) - Classification of Ambient Assistant Living services in the home environment and immediate vicinity of the home.
VDE-AR-E 2757-4	Staying at home service - Quality criteria for providers, services and products of Ambient Assisted Living (AAL).
VDE-AR-E 2757-5	Ambient Assisted Living (AAL) - Requirements for the qualification of person working in the field of AAL.
VDE-AR-E 2757-6-1	Ambient Assisted Living (AAL) - Representation of integration profiles - System planning point of view.
VDE-AR-E 2757-6-2	Ambient Assisted Living (AAL) - Conceptualisation of integration profiles.
VDE-AR-E 2757-7	Ambient Assisted Living (AAL) - Classification scheme for assistive solutions in everyday life.
VDE-AR-E 2757-8	Ambient Assisted Living (AAL) - Process support for the technical implementation of assistant systems (ambient assisted technology) in homes and residential buildings.
VDE-AR-E 2757-9	Ambient Assisted Living (AAL) - Mobility in the AAL environment.
VDE-AR-E 2757-10	Ambient Assisted Living (AAL) - Requirements for mobile terminals for use in the field of AAL.
VDE-AR-E 2757-100	Ambient Assisted Living (AAL) - Guideline for the development of AAL products.
ENV 12443	Healthcare Information Framework (HIF).
ENV 12612	Messages for the exchange of healthcare administrative information.
CEN ISO/TS 13972:2015	Detailed clinical models, characteristics and processes.
CEN ISO/TS 14265:2013	Classification of purposes for processing personal health information.
EN ISO 10781:2015	Electronic Health Records-System Functional Model, Release 2.
EN ISO 13606-1:2012	Electronic health record communication.

Table 26 - Relevant de jure standards

Guidance	Title
PH16	Mental wellbeing in over 65s: occupational therapy and physical activity interventions[64].
NG32	Older people: independence and mental wellbeing[65].
SG1	Safe staffing for nursing in adult inpatient wards in acute hospital[66].
05871	Discharge to assess[67]. NHS England Publications Gateway Reference.
CCQ KLOE	Key lines of enquiry for adult social care services[68].
	NHS and independent acute hospital regulation handbook[69].
	Royal College of Physicians: Example records[70].
KH03	Bed Availability and Occupancy[71].

64 https://www.nice.org.uk/guidance/ph16
65 https://www.nice.org.uk/guidance/ng32
66 https://www.nice.org.uk/guidance/sg1
67 https://www.nhs.uk/NHSEngland/keogh-review/Documents/quick-guides/Quick-Guide-discharge-to-access.pdf
68 http://www.cqc.org.uk/sites/default/files/20171020-adult-social-care-kloes-prompts-and-characteristics-showing-changes-final.pdf
69 http://www.cqc.org.uk/sites/default/files/20150326_acute_hospital_provider_handbook_appendices_march_15_update.pdf
70 https://www.rcplondon.ac.uk/guidelines-policy/example-record-templates
71 https://www.datadictionary.nhs.uk/data_dictionary/messages/central_return_data_sets/data_sets/quarterly_bed_availability_and_occupancy_data_set_(kh03)_fr.asp?shownav=1

Guidance	Title
ISB0092	Commissioning Data Sets (CDS)[72].
HBN00-01	General design guidance for healthcare buildings[73].
HBN00-03	Designing generic clinical and clinical support spaces[74].
HBN00-08	The efficient management of healthcare estates and facilities[75].
HBN08-02	Dementia friendly health and social care environments[76].
RCP	Standards for the clinical structure and content of patient records[77].
RCP	Standards for the clinical structure and content of patient records – part 2[78].

Table 27 - Relevant de facto standards

7.3.2 Results from standards analysis

As with the other use cases, there are hundreds of sectoral de jure and de facto standards. Most of the standards or guidelines are addressing very discreet and specific topics with just a handful providing an overarching framework from which the others can be associated or provide linkages to other standards. One such example is ISO13972[79]: 'Detailed clinical models, characteristics and processes'. This is aligned to ISO 9001 and provides the framework for which clinical models can be developed, used and monitored. This framework is illustrated in Figure 73:

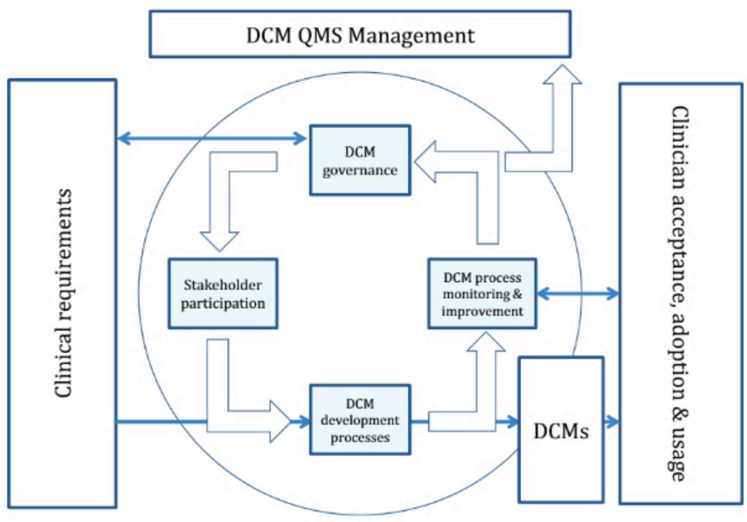

Figure 73 - ISO 13972 framework

[72] https://digital.nhs.uk/isce/publication/isb0092
[73] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/316247/HBN_00-01-2.pdf
[74] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/147845/HBN_00-03_Final.pdf
[75] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/370592/HBN_08_Part_A.pdf
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[77] https://www.rcplondon.ac.uk/projects/outputs/standards-clinical-structure-and-content-patient-records
[78] https://www.rcoa.ac.uk/sites/default/files/FPM-clinicians-guide2.pdf
[79] https://www.iso.org/standard/62416.html

This analysis has shown there is a range of regulation, standards and guidelines applicable to this use case. However, the focus is predominately about the provision of the individual services and elements of that service, rather than the association of the asset to the provision of the care. Furthermore, the health infomatics standards focussed on the transport and message structure at a device level. Where service information is specified, this appears to be retrospective slow time base performance information, rather than dynamic service operational information. The experts advised there is a number of proprietary systems[80] developed to assist in the allocation of beds and record occupancy but these do not necessarily link with the care management or provision. Where asset related standards do exist, they tend to focus on the function rather than the purpose or the outcome they seek to support.

7.4 Information pathway development

The information pathway, which enables a service to mitigate against 'bed blocking' particularly for care of the elderly, is to be developed. The literature reviews and analysis of the NICE pathways demonstrated a number of models of varying degrees of coverage and detail for the healthcare services. When detail about care of the elderly or bed blocking is considered, this leads to the development of a simple model inspired and developed from the work of Abo-Hamad et al[81] and is illustrated in Figure 74. This shows the service layer for care of the elderly:

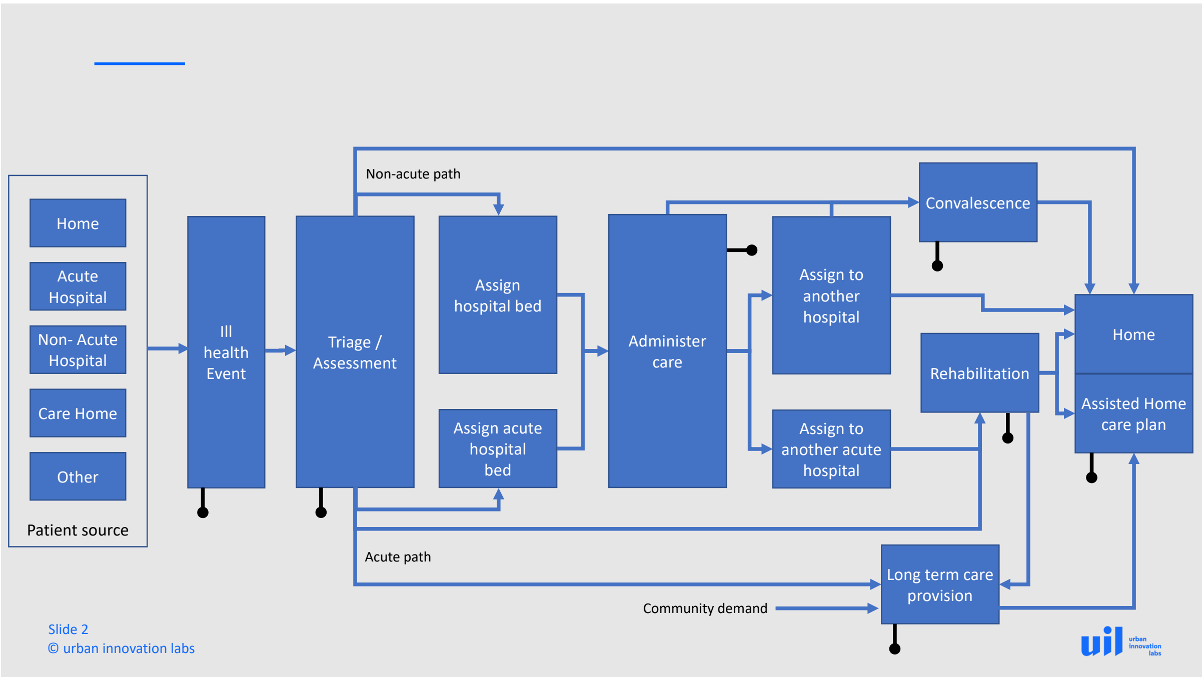

Figure 74 - Simple care of the elderly model

[80] https://www.emishealth.com/products/bed-management-app/

[81] Abo-Hamad, W., Rashwan, W., & Arisha, A. (2015). A system dynamics view of the acute bed blockage problem in the Irish healthcare system. European Journal of Operational Research, 247(1), 276-293. doi:10.1016/j.ejor.2015.05.043

Figure 69 shows when the type of service, and therefore the analogue to the assets involved, are overlaid. This shows the service provided with a hospital, social care provision and the individual's home:

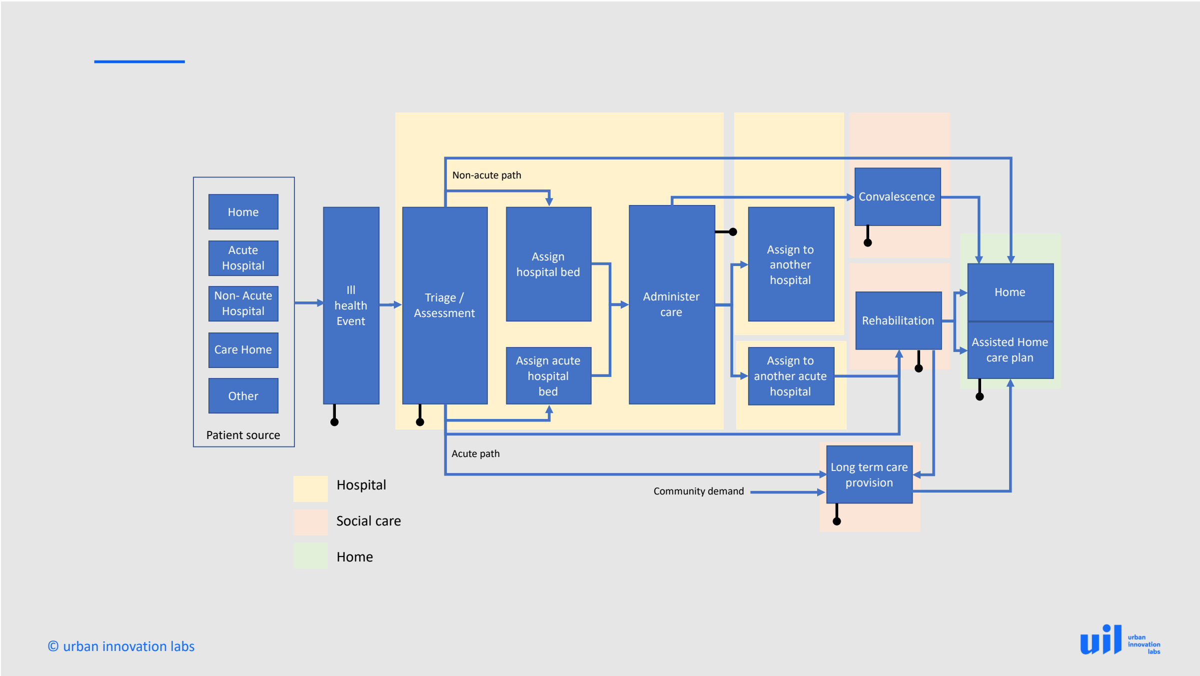

Figure 75 - Simple care model with service delivery types

7.5 Information pathway

This section traces the information pathway throughout this service layer, identifying the information needed by performing the service, any standards associated and how the capability, capacity, state and quality of service is defined. The diagram in Figure 75 is used as a guide with a red box indicating the stage of subsequent pathways.

The first stage of the pathway, shown in Figure 76, illustrates the triggering of an ill health event. Here it can be seen, as expected, that the majority of the information is personal in nature and related to the individual as indicated by the purple box. It is only the basic metadata about location and time that is non-personal. The standards that are related to this pathway are all associated with the description of patient data. For the purposes of simplification, the pathway through primary care is omitted.

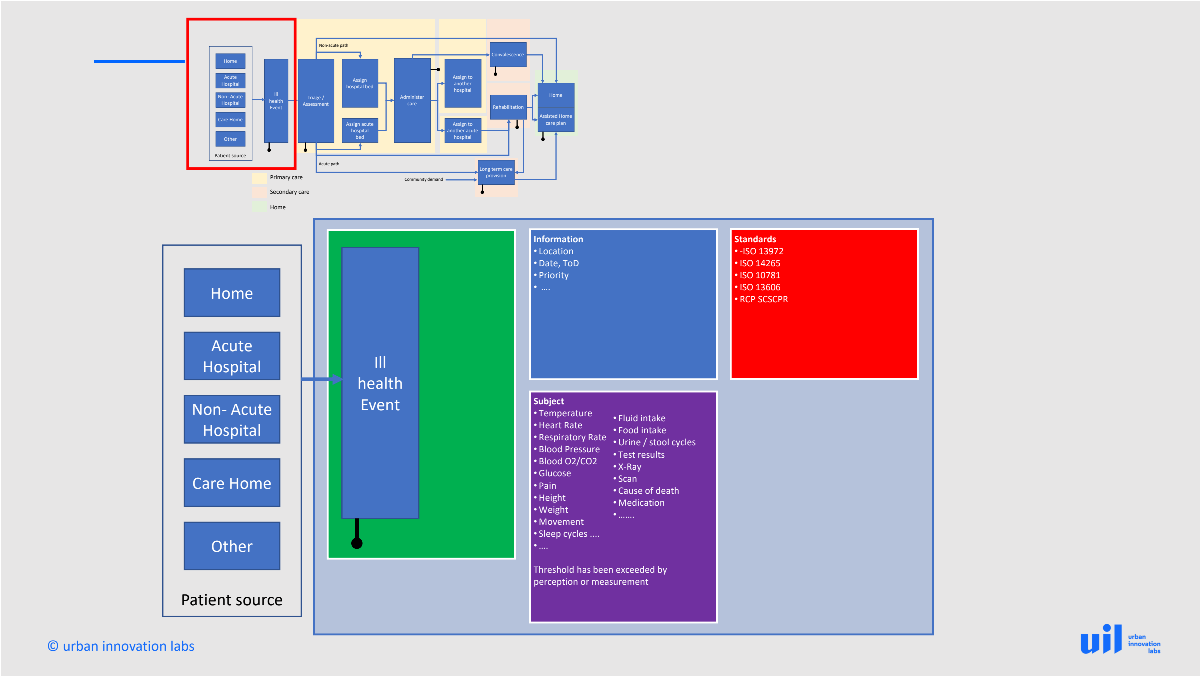

Figure 76 - Ill health event pathway section

The next pathway section is when triage occurs at a hospital. Here, the patient's records are needed as a basis for a triage or assessment of their health condition. This is shown in Figure 77. Information about the available staff and their competencies is required, along with the facilities needed to provide care, such as the number of beds, to help assess the most appropriate route of care. The same standards apply as highlighted in the previous section. This section is where the capability, capacity, state and quality of service can be measured. This is indicated in the blue box.

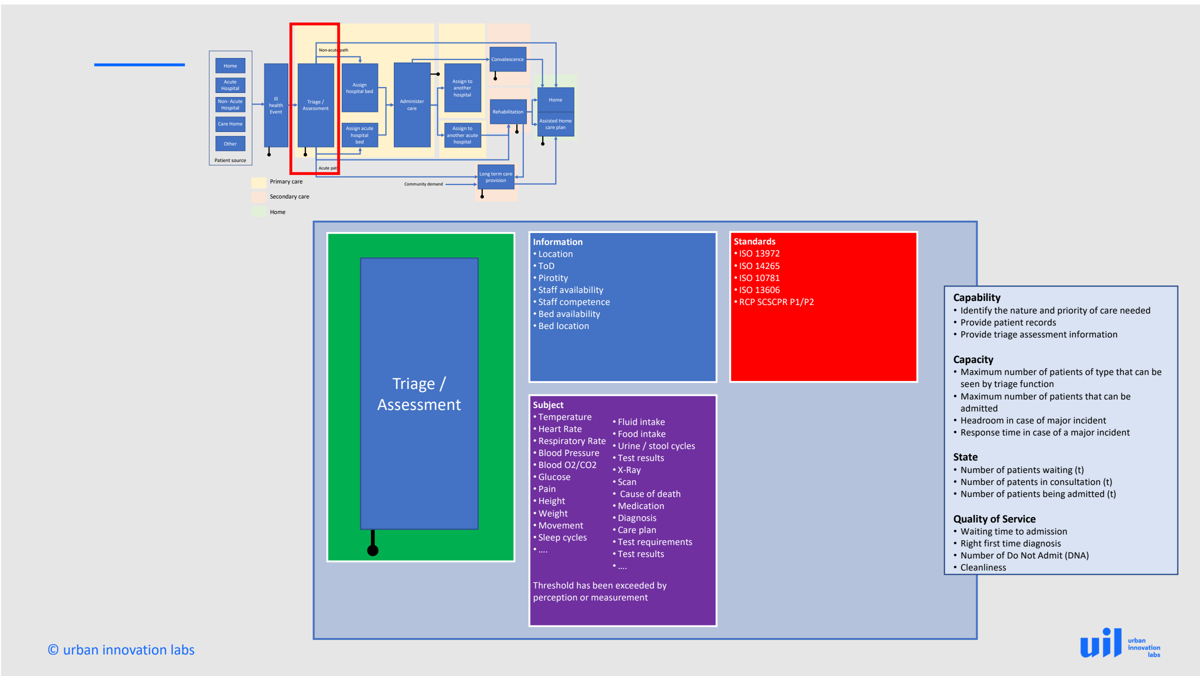

Figure 77 - Triage / Assessment pathway section

Figure 72 shows the completion of triage and the decision that a bed is to be assigned. The information needed shifts from that of the patient, to the nature of the care needed, and the allocation of the correct assets in the provision of that care. The standards describing the information types are persistent through the pathway with the addition of bed allocation guidance. The capability, capacity, state and quality of service can be measured and indicated in the light blue box.

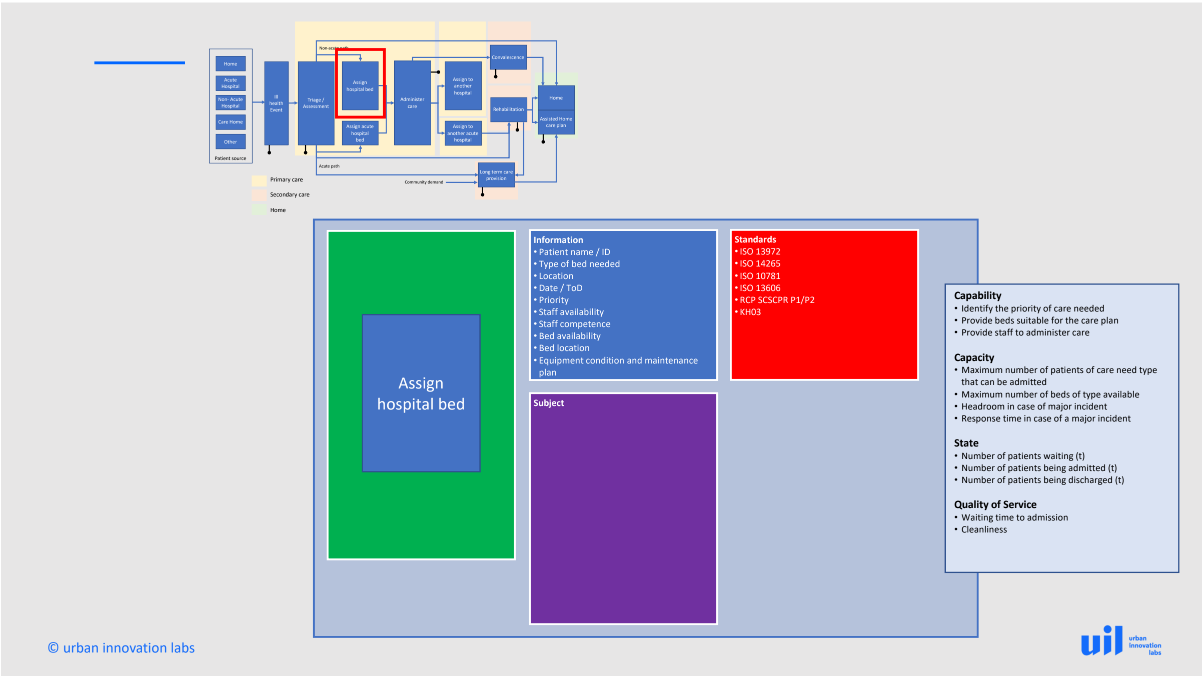

Figure 78 - Assign hospital bed pathway section

Once assigned a bed, care can be administered according to the diagnostic and care plan, as shown in Figure 79. This patient record and care information is of a personal nature and shown in the purple box. The information needed to provide the care increases as included in the blue box, and here the focus on the interface between the patient and the hospital is described and includes the requirements of staff, medicines, equipment and facilities to administer the care plan. In addition to the information standards, guidance on care provision is detailed. The capability, capacity, state and quality of service for care provision can be measured and indicated in the light blue box.

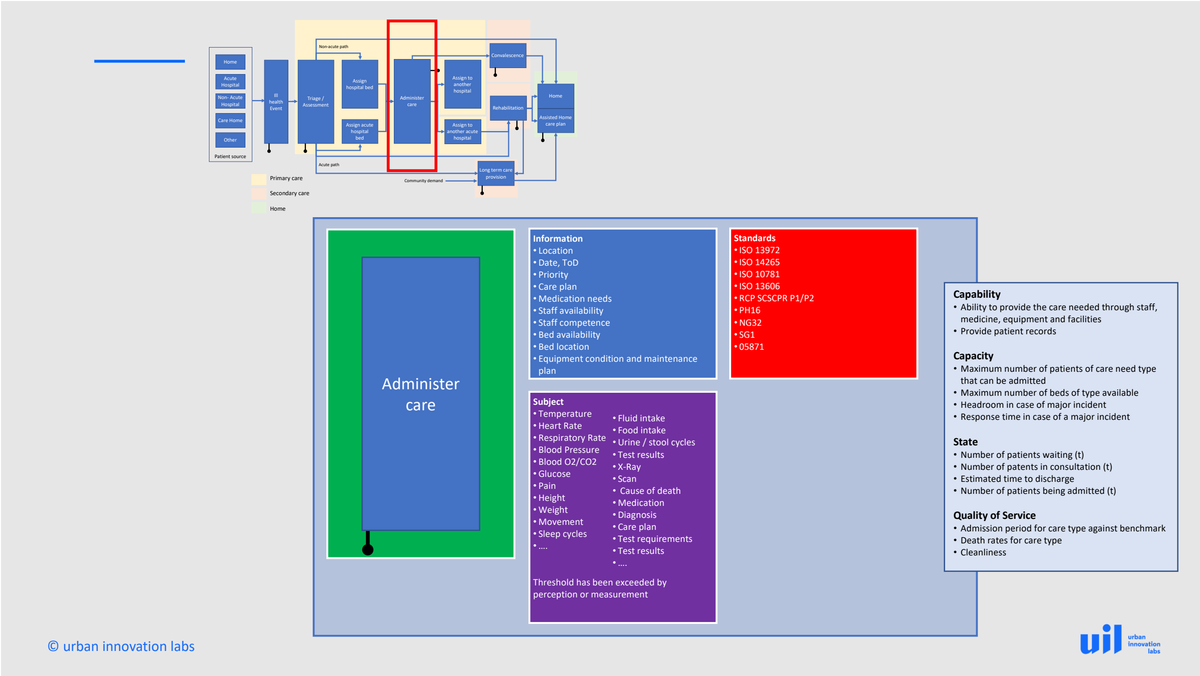

Figure 79 - Care administration pathway section

As care is provided and the patients' health monitored, a decision is taken about subsequent care actions. This may be a discharge to home, discharge to another form of care such as convalescence or rehabilitation, or transfer to another hospital. This section deals with the assignment of the patient to another hospital and is shown in Figure 80. This is analogous to the earlier stage assigning a bed, where the information needed is predominately about the facilities and staff available to provide the care indicated in the care plan. This is echoed in the applicable standards. The capability, capacity, state and quality of service for care provision can be measured and indicated in the light blue box.

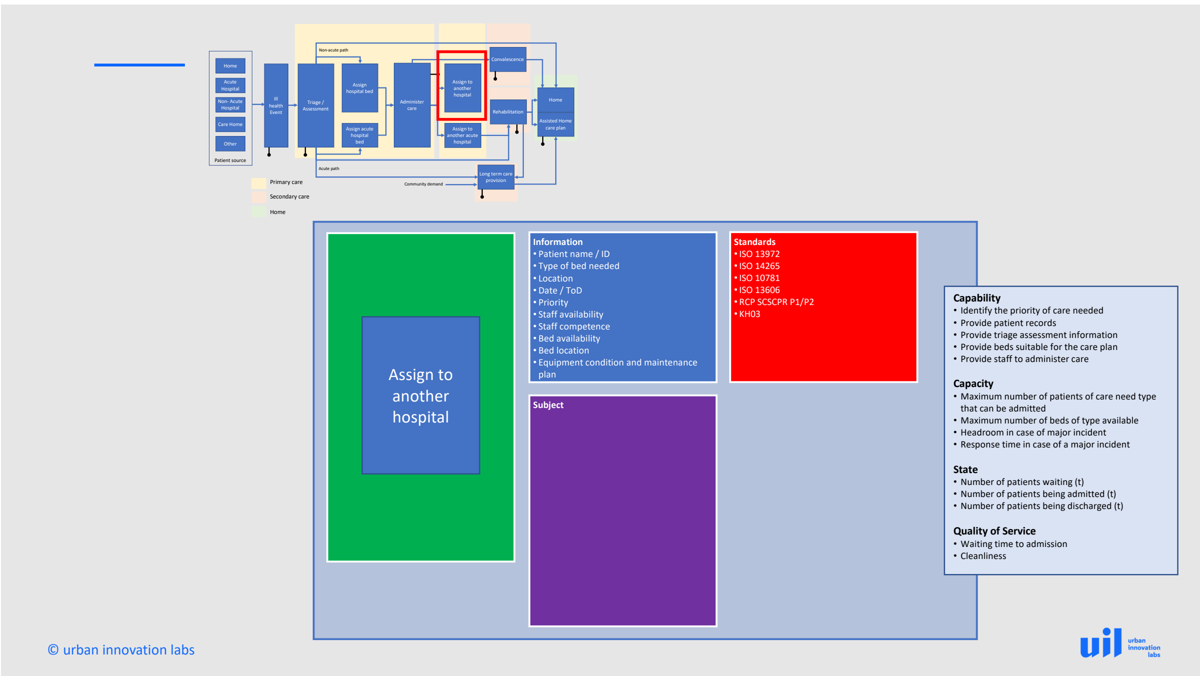

Figure 80 – Assign to another hospital pathway section

A pathway for after care administration is convalescence, rehabilitation or long-term care. The information pathway for all are similar. The convalescence pathway in Figure 81 has been used as illustration of this pathway. The type of information needed to make a decision and the standards that underpin the decision-making is similar to administer care. The reality of this stage is that the care provider has access to the type of information described, whereas the expected capability, capacity, state and quality of service is similar.

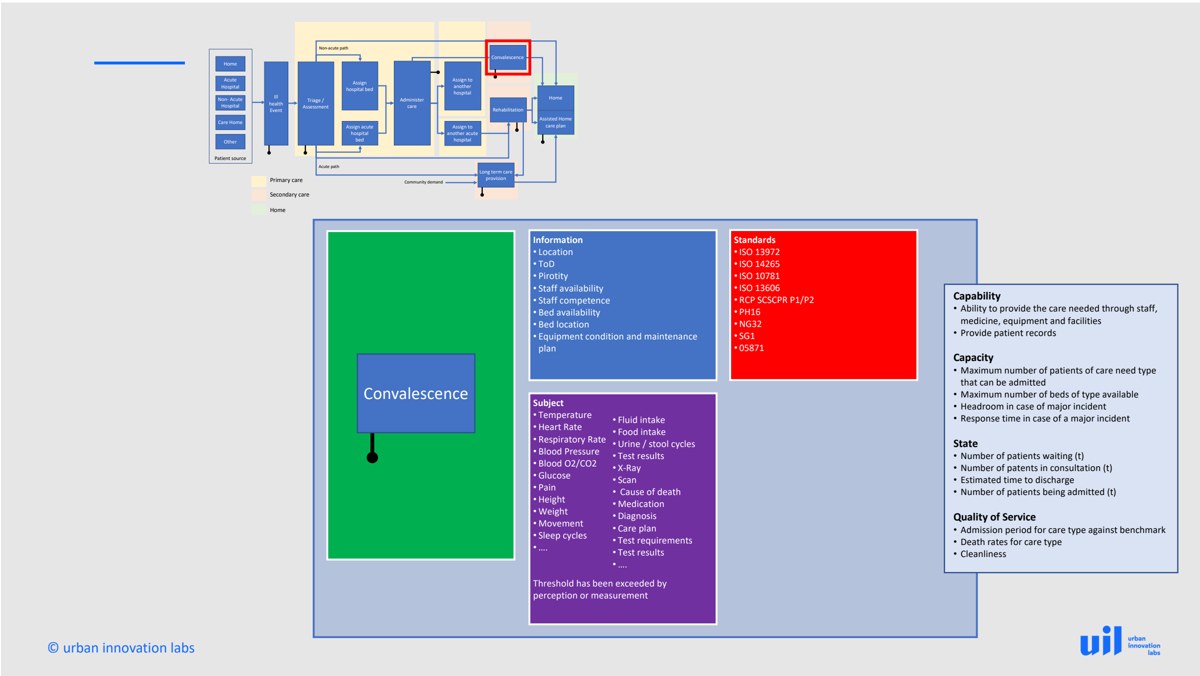

Figure 81 - Convalescence pathway section

The final stage of the pathway is care at home, either with or without an assisted home care plan. This care plan is informed by the patients' health condition, the available assets at home and triggers events for additional assets or modifications to be made to ensure that care can be provided. This is shown in Figure 82. The standards or guidelines are different focussing on the preparation of the domestic environment for home care. All of these standards are VDE standards from Germany without a direct UK equivalent. The capability, capacity, state and quality of service for care provision can be measured and indicated in the salmon box.

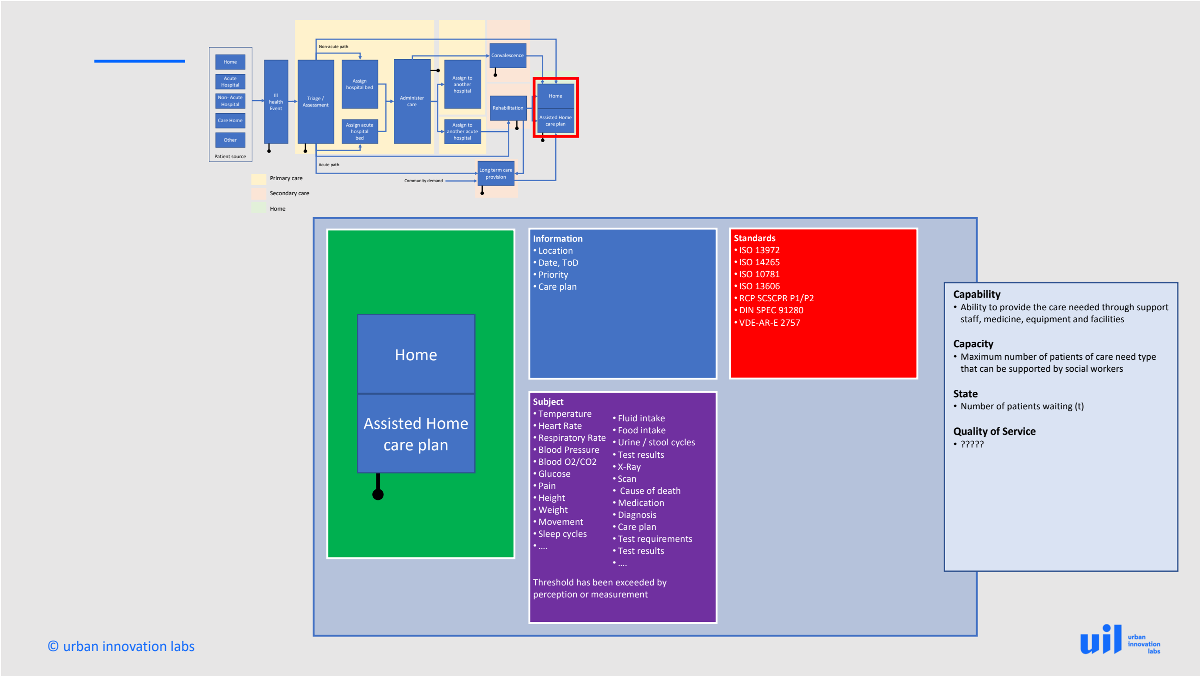

Figure 82 - Home care pathway section

All of these pathways have focussed on the service rather the assets. These building assets are very much in support of the care provision, rather than central to the provision of care. Whereas the equipment assets are intrinsically linked to the provision of care and measurement of health, Figure 83 illustrates the administration of the care service, the asset involved in supporting the care, the information needed and the underpinning standards throughout the lifecycle.

Figure 83 - Hospital asset for administration of care

7.6 Commentary

Standards

As with the previous use cases, the standards analysis has shown that the selection of keywords used for the service did not bring all of the relevant standards to the surface. It required expert knowledge of the domain and prior-knowledge of the applicable standards that are often worded or categorised using descriptors that are not immediately apparent. Healthcare has many standards associated with the equipment used to provide health care, and an emerging cluster that describe the data structure, with de facto standards defining content. The main standard defining health care provision is ISO13972: this provides the detailed clinical model that should be used to basis for the implementation of the clinical quality management processes for the underpinning services. However, the service provision is not described within this or other de jure standards, but within a range of de facto standards. Within the scope of the use case, the de facto standards from NICE, CQC, NHS digtal, RCP and so on appear to provide the backbone to data definition, service definition and quality of service. However, the study has not surfaced any descriptions for capability of service provision and capacity appears to be a retrospective report rather than an operational tool. This is with the exception of bed planning tools, that are largely proprietary and not integrated with the service provision.

Pathways

The healthcare sector is very diverse, with a vast range of services provided by a multitude of commissioning bodies. This means there are many potential pathways that could be drawn within the healthcare sector. The one chosen, bed blocking, is believed to demonstrate the general scale of the opportunity and also the challenges that exist. It demonstrates a challenge that unless solved soon, will have a significant societal impact. It also demonstrates that the use of information, with clear segregation of personal information, can be used to manage a very complex and dynamic system.

When the pathways are linked to the assets, the difference of the asset type becomes apparent. Equipment assets are fundamental in the provision of the service, built assets are fundamental to the overall provision of the service by way of location and supporting infrastructure for access and egress, but thereafter it is a shell that provides the space from which the service can be provided. The service layer factors are more dominant than the assets. The facilities management function, like any facility, can be explored in regard to other systems, like energy, or availability of capacity. However, it is difficult to establish gains in efficiency of the service provision of healthcare.

Key equipment assets, for example, MRI scanners, are monitored very closely as they are normally part of PFI deals and therefore have a direct link between their availability and payment. Other equipment is not so bankable but associated with the service provision. However, there is no transactable or bankable link here between the asset or equipment performance and actually making people better.

It is recognised that there are operational efficiencies with a new facility and this has an impact on health care provision, but this starts to push at the boundaries of the scope: to focus on information standard definition. If it yields savings that can be redirected to tackle the challenges such as bed-blocking that would be transformative, but sadly with the current financial challenges these benefits are needed to balance the books, rather than leverage improvements in service to the most vulnerable members of society.

8 Commentary

The analysis of the different use cases, the creation of the individual information pathways with the detailed standards analysis has highlighted the need to have an abstraction framework that allows the context of the ecosystem in consideration to be linked through to the asset and services. An example of such a framework has been developed is shown in Figure 84.

This example ecosystem is from the perspective of a city administrator who will commissioning, or stakeholder involved in the provision of health care, transport and electricity supply. The purpose, service provided, and evaluation process are described by the management system developed in accordance with ISO90001. As it is a city administration the guiding principles, governance and delivery processes are described in the Smart City Framework in PAS181.

However, there is not a defined method or approach to describing what the service needs to do or how much of that is available, the capability and capacity. Nor, is the condition described or performance provide against a benchmark, state and quality of service, in a consistent and agreed form. Definition of this capability, capacity, state and Quality of Service (CCSQoS) is a central element in making the overall ecosystem function.

Assuming the CCSQoS is defined by the city administrator this can be used a basis to engage with the providers of health care, transport and energy. Each sector has its own way of describing the service provision to varying degrees of detail and for health care this uses the same management framework as ISO9001. Save the Rail Infrastructure (RINF)[82] specification developed for European rail system integration, the other sectors considered do not have a method of describing the Capability of the service to be provided. Capacity is often described but in terms not aligned to the Capability which can be misleading. State is described in most cases, but the data structure and timing of the notifications is not always in a timeframe that allows for meaningful close loop intervention. Quality of Service is frequently used but again not linked to the Capability. Sections 5, 6 and 7 have described the CCSQoS for each of the sectoral use cases and activities involved in the delivery of the use case.

The CCSQoS can be broadly described using information defined in a range if specific standards, guidelines and codes of practice. However, the vast number of standards involved lends itself to the adoption of a meta-standard that enables the key elements of individual standards to be combined in an overarching definition that can be augmented with to address any gaps in the available landscape.

The assets required to fulfil these services can be defined using the activity:asset model described in Figure 9. Which is defined to fulfil the organisations purpose defined in ISO9001 and realised through the Strategic Asset Management Plan from ISO55001 that results in an Organisational Information Requirement (OIR) providing the ‘ask’ of an asset that is described by the Asset Information Requirement (AIR) detailed in BS1192:3 and fulfilled in the Employers Information Requirement (EIR) detailed in BS1192:2.

When this is considered as a service ecosystem, it is possible to link the service outcomes with the asset performance and then to the design and build.

[82] http://www.era.europa.eu/Document-Register/Documents/RINF%20Application%20Guide%20%20V%201.1.pdf

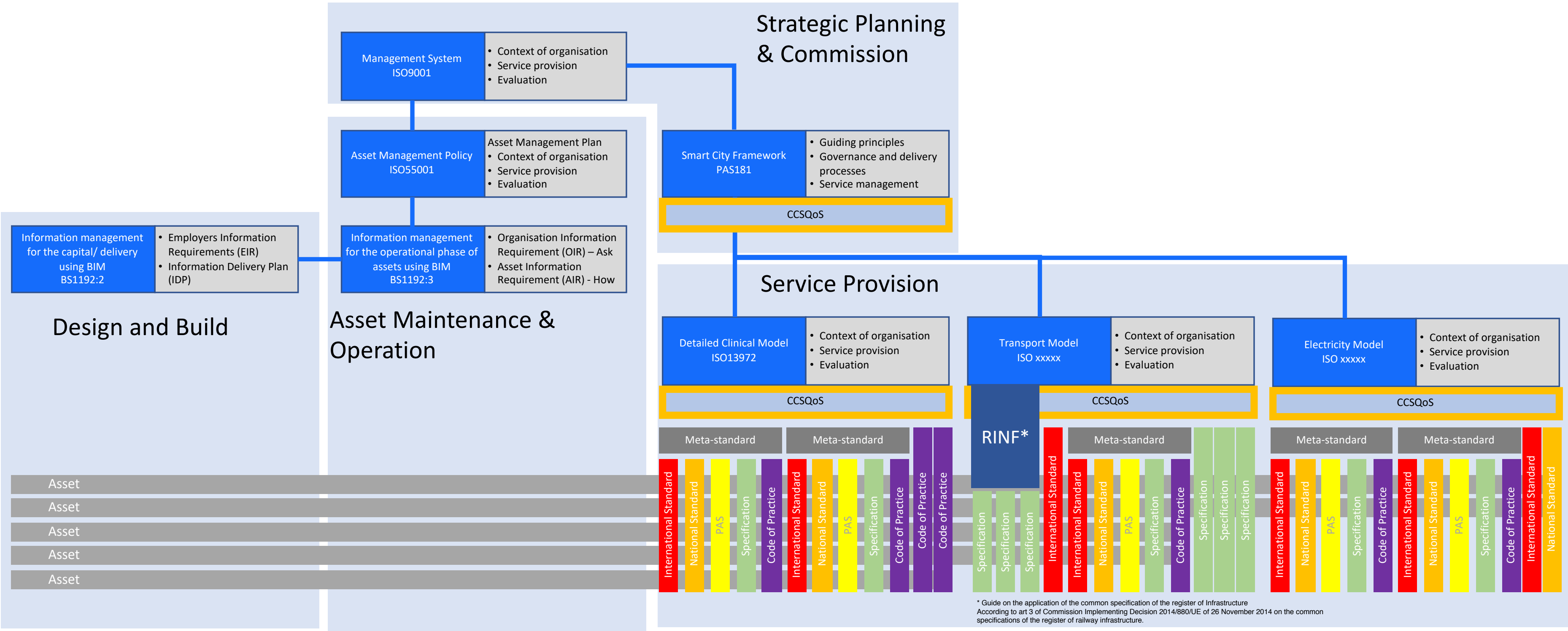

Figure 84 – Overall asset and service outcome lifecycle framework

9 Conclusions and Recommendations

This work package demonstrated that the information pathway approach works. A trace of information about the service provision and asset requirements for the purpose of planning, designing, building, maintaining and/or operating the asset to fulfil the outcomes and performance objectives has been established for each use case.

Three use cases were selected, demand side regulation of electricity, integrated traffic management at a network (urban/extra-urban) level, and care of the elderly and the impact of hospital bed blocking. For each use case, the is very large number of possibly applicable standards and this is amplified further when de facto standards are considered. This requires expert sectoral knowledge and knowledge of the de jure and de facto standards which in itself is a specialism. When the expert knowledge is applied it is possible to identify which are key in the definition of the service and the information associated with the provision of the service. The assets can be described using the existing IFC or COBie data structures and this will allow for easy migration to a future state.

For demand side regulation of electricity, the pathway was established with relative ease as the network is contained with a series of assets that are well defined. When the information required to describe the service was analysed, it was found at a transmission level information existed and is described by international standards. As you move from transmission to distribution to use, the information is contained within National Grid codes, the Distribution Network Operators or the smart meter data collection service, DCC. At a device level there is no definition for the purpose of demand regulation.

The transport pathway proved to be a challenge construct at an abstracted level due to the complexity in the network description, the actors, the probes and the interaction with other modes. That said, it was constructed, and the information needed for the service identified. This information was described in a range of standards that are focussed on a mixture of device and service.

The healthcare pathway was by far the most challenging as the association of the service and the asset was the most decoupled. The healthcare facility is governed by a range of well-defined rules and then execution of the service occurs within the confines of the facility with very little interaction with the direct outcome. The equipment within the facility is more closely coupled as it directly involved the service provision.

The hypothesis has been successfully tested to show Smart City standards and BIM standards can be linked, aligned and augmented with sectoral de jure and de facto standards, guidelines and codes of practice to enable these pathways to be established.

One of the key principles of the information pathways was the service providing the socioeconomic benefit could be described in terms of its capability and capacity, which is informed by its state and provide a measure of quality of service. This is key, as it allows for a consolidated catalogue of information to be surfaced at a service layer making it possible for different services to interact with the just the key information to describe what it does and much of it is available.

None of the use cases had de jure or de facto standards identified that described the capability of the assets associated with the service. Capacity was described, in engineering terms rather than the amount of a capability available. The state is discoverable from analytics of available information and the quality of service is defined but would benefit from being associated with the capability and capacity.

This approach where the service is abstracted to defining the capability, capacity, state and quality of service and identifying the associated information has been shown to provide a framework in which different standards can be assessed and gaps in functionality defined. It is suggested the approach is tested on further pathways to increase confidence in the approach. Then a guideline produced to that can be used in the market to begin the process of advocacy and if applicable crystallised in the appropriate form of standard

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