Future of Transport

System interoperability and standards

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Department for Transport

About

BSI

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Abbreviations

APDS	Alliance for Parking Data Standards organisation
API	Application Programme Interface
CAV	Connected Automated Vehicle
CCAV	Centre for Connected Autonomous Vehicles
CEN	European Committee for Standardization (Comité Européen de Normalisation)
CSV	Comma Separated Valuese
DfT	Department for Transport
FoT	Future of Transport
GBFS	General Bikeshare Feed Specification
GSM	Global System for Mobile Communications
GTFS	General Transit Feed Specification
IEC	International Electrotechnical Commission
ICS	International Catalogue of Standards
ISO	International Organization for Standardization
MaaS	Mobility as a Service
NaPTAN	National public transport access nodes
NeTEx	Network Timetable Exchange
OWL	Ontology Language of the Web
SLA	Service Level Agreement
TfL	Transport for London
UML	Unified Modelling Language

1. Future of Transport: System interoperability and standards

The Future of Transport (FoT) is an emerging and evolving concept which envisages citizens having their journey needs met by systems of interconnected transport modes and resources that are available 'as required' as a single item.

This system of transport suppliers and users requires that data exchanged between them can be unambiguously requested and understood. Standards provide agreed good practice on how things should be done and as such, standards underpin this interoperability.

BSI identified over 1,200 standards that are relevant to the development of the FoT with some bearing on system interoperability and data exchange. Whilst extensive, key standards were missing that would help drive the development of the FoT. In addition, there was fragmentation and a lack of full awareness of how existing standards could be used.

A programme of recommendations has been developed that can be implemented to address these issues.

1.1. Key findings

Analysis of the standards landscape for the FoT sector undertaken by BSI delivered four main conclusions:

A. System interoperability in the context of FoT is not limited primarily by the availability of technical data standards, e.g. standards for structure, format, exchange mechanisms, encoding or cataloguing.
There is an extensive range of generic specifications concerning all aspects of data interoperability. This includes technical standards for data itself, data publication and metadata, interfaces and exchange standards. In addition, guidance exists for how organisations should share data. At the same time there are also specific standards for the semantics of data exchange in the FoT context; these often build on the generic specifications. These standards are often segmented according to functional area, e.g. timetables, routes, fares. Furthermore, these standards may be development by distinct stakeholder communities e.g. different transport modes, without consideration for how they could be aligned going forward.

B. The awareness and understanding of the full range of technical standards and how to implement them needs to be advanced.
The standards relevant to the FoT sector are being actively managed at the national, European and international level. However, the diversity and on-going development of the subject area means that the standards landscape is complex and evolving. As a result, despite notable silos of detailed expertise in using available standards, there needs to be an improved understanding across the FoT sector of these standards and the tools that support their implementation. In summary, there needs to be better access points to current standards knowledge for those on the ground implementing data services.

C. **Data exchange in the context of FoT is primarily limited by the lack of standardised datasets and data services across the range of topics required.**
In many instances, data exchange does not happen, because the data is non-existent or not of appropriate quality. This raises two key issues. First, is that there is not an agreed definition of 'data quality', so data may be available but not suitable for all purposes in FoT. Second, although data exchange standards exist; data is not always published in accordance with these standards – or published at all. Various reasons were cited for this, including commercial sensitivity, lack or resource/expertise and lack of understanding of demand. In consultations undertaken as part of this project it was clear that certain data topics are missing and that actions should be undertaken to help fill these gaps. These topics are wide ranging and include information on pedestrian routes, street lighting, school holidays, parking, travel resource occupancy and pricing.

D. **The immaturity of the market has had a knock-on effect for system interoperability and is the principal blocker for widening data exchange in the FoT context.**
System interoperability is not being advanced because the market evolution is not clear. As this is an emerging market, the good practice rules of operation are still evolving. One of the central aspects to this relates to the roles and responsibilities of individual actors in terms of delivering an integrated transport. If market norms could be agreed, then questions such as 'who is liable if the service fails?' will become clearer and investment decisions potentially easier to make. In addition, FoT is advancing new collaborative approaches to working with data as both a commodity and as an infrastructure. Such practices are challenging traditional business models, and good practice for working in this way should be established based on experience in the FoT sector to date.

1.2. Recommendations

Based on the above conclusions, the following four recommendations are put forward to advancing FoT system interoperability and data exchange:

1. **FoT Framework:** ***Establish standards for how FoT should function and how actors should operate.*** Standards need to be developed to promote the scope and market norms that underpin the rationale and business cases for system interoperability. The focus initially needs to be on two areas: Actors' roles and responsibilities and management of data commons.
2. **FoT Data topic ontology:** ***Establish and maintain an agreed data and standards landscape to support FoT data exchange.*** The ontology would support navigation and use of the large number of standards available. At the same time, it would support consensus on the range of data topics relevant to FoT and the purpose of data collection activities.

3. **FoT 'Data Advisory Panel'**: ***Establish a proactive initiative to 'build and maintain' the FoT data infrastructure.*** This activity designs, supports and realises the tasks required to create and maintain the data that underpins FoT.
4. **FoT Community:** ***Establish a community with appropriate authority to provide leadership of good practice for data exchange***. This builds on existing communities with a focus on decision making and developing a roadmap for the data needed and the standards to be used to deliver FoT.

These recommendations are overlaid onto the FoT value chain in *Figure 1 – Recommendations in the context of the FoT value chain* below and summarised in the following sections.

Each of the recommendations can be implemented standalone, but there are relationships between them. Notably the implementation of Recommendation 4 (community) would be informed by the development of the framework standards in Recommendation 1. Similarly, the ontology (Recommendation 2) would provide a tool to inform the realization of the data Advisory Panel in Recommendation 3.

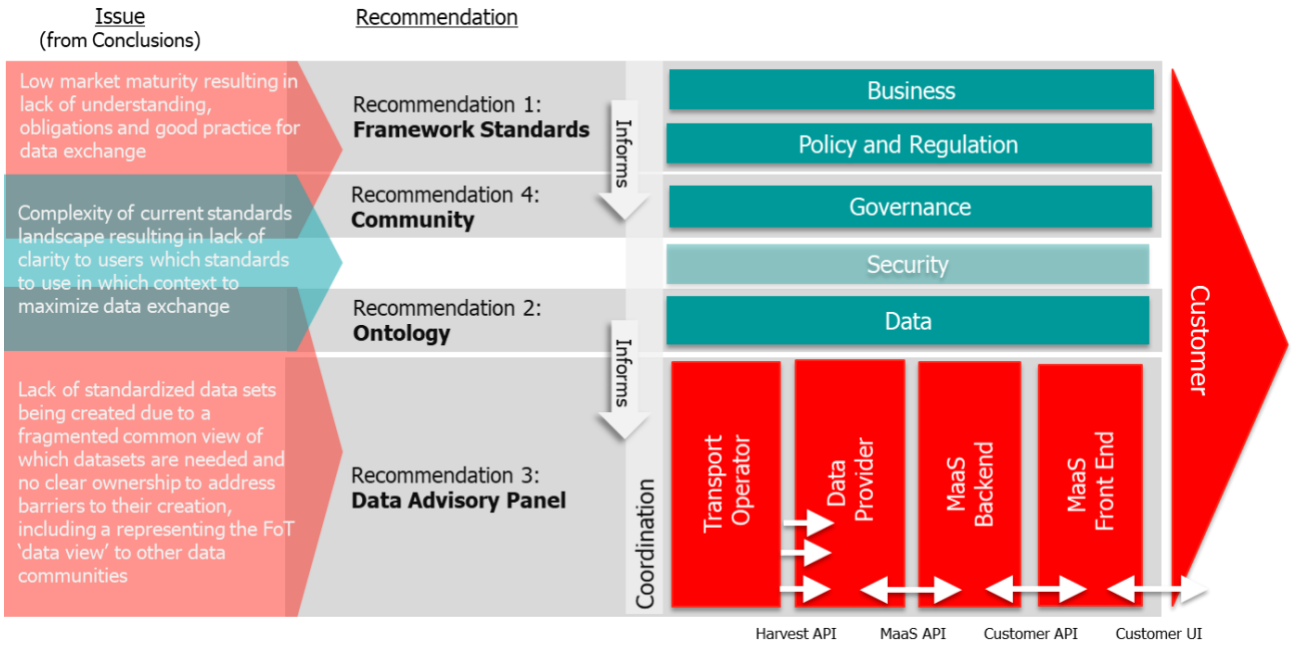

Figure 1 – Recommendations in the context of the FoT value chain

Recommendation 1: Framework standards

Establish standards for how FoT should function and how its actors should operate, including their data sharing responsibilities. Although not directly a data exchange issue, this underpins the rationale, market norms and business cases for system interoperability.

Rationale

This recommendation addresses the conclusion that the immaturity of the market is the principal blocker for widening data interoperability in the FoT context. Establishing standards, most likely in the form of a guidance framework, will provide an agreed reference to move the FoT conversation forward.

The standards should answer the question '*what is FoT*?'. Crucially they should cover the interaction points between the FoT service supply actors and the customer for the journey. The different actors include (amongst others): Local authorities, data providers/aggregators, transport operators, infrastructure providers and ticketing providers.

There is an immediate need for standards in two areas:

1. Principles for FoT operation:

- Definitions of actors and principles for cooperation, including entrance and exit of actors into the mobility delivery ecosystem.
- Responsibilities towards multi-modal journey fulfilment such that customers can rely on an end-to-end service and contingencies should it fail or change.
- Agreed definitions of common terms and journey metrics such as 'what is on time?'

2. Principles for data commons management:

- Responsibilities towards data sharing, use and reuse to ensure an adequate data infrastructure is maintained to support mobility activities, including good practice approaches to managing a data commons for transport services.

Implementation

These two standards can be implemented as a BSI Publicly Available Specification (PAS) and would be completed in approximately one year. BSI would establish and manage a dedicated and representative steering group to oversee the development of the guidance so that it would be developed by the FoT industry for the FoT industry. The experience of running the steering groups for these standards would provide a useful insight into the governance requirements for the FoT community.

Recommendation 2: Data ontology

Establish and maintain an agreed data and standards landscape to support FoT data exchange. The ontology would support navigation and use of the large number of standards available. At the same time, it would support consensus on the range of data topics relevant to FoT and the purpose of data collection activities. This should be updated regularly to signpost identified FoT data topics in the context of data purpose and data standards.

Rationale

This recommendation addresses the conclusion that there is not a full awareness and understanding of the full range of technical standards and how to implement them. Developing an ontology of FoM will support navigation of the FoT standards landscape and at the same time help the FoT community to define the breadth and depth of the data topics of relevance to FoT.

The ontology should include as a minimum the three data viewpoints of data topic, data purpose and associated data specifications. The ontology would support initiatives such as:

- implementation guidance for data exchange, (e.g. standards that can be used for a particular purpose)
- informing the roadmaps of standards development
- identification and creation of new data sets, through the analysis of data gaps
- harmonisation and efficiencies in existing data collection activities
- providing an interface to other government data initiatives (e.g. Geospatial Commission) to specify data needs from an FoT perspective.

There are some activities underway in the FoT sector that consider data exchange and standards, but these are fragmented. The ontology creation would act to coalesce these activities and provide signposting to the data and standards that are being used or could be used.

Implementation

This recommendation could be implemented in several ways and the most appropriate would need to be determined through a dedicated discovery activity. This should consider the immediate needs as FoT is evolving and the role an ontology could play in the future.

Although developing the ontology it should be a consensus-based activity, a formal standard would be too rigid a solution. An alternative would be a BSI agile standard or DfT private standard. The ontology need not be a document and could be implemented in the form of a spreadsheet, a diagram or a machine-readable computer ontology language such as OWL (https://www.w3.org/OWL/).

Recommendation 3: Data Advisory Panel

Establish a proactive initiative to 'build and maintain' the FoT data infrastructure. This activity designs, supports and realises the tasks required to create and maintain the data that underpins FoT.

Rationale

This recommendation addresses the conclusion that there is a lack of standardised data sets to support FoT and no sustained approach to build a data infrastructure in which FoT can operate.

The Data Advisory Panel should be an authoritative umbrella for the coordination of data-related activities that support FoT. The term 'Data Advisory Panel' is used here to represent a function that identifies and addresses data exchange opportunities and issues in a systematic and responsive way. This could include:

- Supporting the publication of data so they can be used in FoT context.
- Issuing guidance and recommendation for data exchange.
- Working with organisations on establishing data sharing agreements.
- Facilitating good-practice and conformance to standard data models and APIs. This includes making any recommendations for changes.

Implementation

This recommendation could be implemented in several ways and at different scales. The most appropriate would need to be determined through a dedicated discovery activity. Similar to Recommendation 2: Ontology, the Data Advisory Panel should be considered in the context of immediate needs and a roadmap for the future.

Implementation should consider the role and scope of the Data Advisory Panel to deliver the following outcomes:

- A signposting mechanism to existing data repositories and catalogues.
- Setting up an appropriate and authoritative infrastructure to provide appropriate governance of its activities.
- Liaison mechanisms with standards development organisations to support the formal standards development and revision process, including their international context
- Allocation of resource to projects 'as required'. This could include commissioning a project or simply providing input to an existing project.

Implementation should avoid setting up something new and provide a thematic (FoT) interface to what exists.

Recommendation 4: FoT Data community

Establish a community with appropriate authority to provide leadership of good practice for data exchange. This should build on existing communities with a focus on decision making and developing a roadmap for the data needed and the standards to be used to deliver FoT.

Rationale

This recommendation addresses the conclusion that currently the FoT is fragmented in its approach to data exchange and there is no clear leadership in the data to be published and the standards to be followed. The development of the ontology (Recommendation 2) provides a 'map' for data-centric developments and the Data Advisory Panel (Recommendation 3) provide a mechanism for delivery. The FoT community would provide the strategic direction for both.

Traditionally strategic decision regarding the data to be exchanged and the standards to be followed have been fragmented across different transport modes. To bring about the changes in transport services, there is a need to engage in a coordinated manner the full breadth of FoT stakeholders to lead on the development and implementation of services. A practical example of this would be agreement, potentially mandated, on standards to be used for data exchange.

Implementation

As with Recommendation 3 (Data Advisory Panel), the FoT community could be implemented in several ways and at different scales. Not least, as it could have far reaching policy considerations for how transport services are operated in the UK. Accordingly, further consideration would be required to determine how the community should manifest itself in the medium to long term.

In the short term, the community should provide cohesion for the data exchange activities of existing working groups/initiatives, including, but not exclusive of: DfT's Transport Technology Forum, Connected Places Catapult and Zenzic (formerly Meridian and CCAV). The community would work with existing groups and activities to provide a joined-up FoT viewpoint. Practically this could realise a combination of events, workshops and meetings, supported by an online portal, enabling the secure sharing of information and collaboration on documents and files.

In the medium to long term the FoT community should look to leverage the activities of other communities and build on practices outlined in this report, used in the Fintech and mobile phone sectors, to accelerate innovation. This represents the transport community speaking a single voice to position FoT on par with other societal services such as commerce and telecommunication.

2. The Future of Transport relies on many types of standards to support data exchange

The future of transport relies on open and accurate data exchange between those requesting mobility services and those delivering it. Standards provide agreed norms and good practice for achieving this. BSI was commissioned to investigate the nature of the standards landscape surrounding the Future of Transport and how it supports data exchange.

2.1 Future of Transport context

The future of transport (FoT) has the potential to provide greater convenience to citizens, reduce carbon emissions, pollution and congestion. Dynamic, on-demand and automated approaches to transport provision can work alongside traditional transport modes to plug gaps in 'last and first mile' transport and logistics provision.

New approaches to mobility will enable individuals to plan and buy travel options from a range of multi-modal service providers, tailored to their needs. Services include: Public transport, car sharing, private hire, parking, taxis, bicycle hire, walking, emerging mobility modes including scooters, and connected autonomous vehicles, as well as private vehicles. FoT serves to address personal needs that can mix car ownership with access to more sustainable alternatives through efficient use of shared public, community and private services.

The Future of Transport is set to be ever more connected, with innovation across multiple modes of transport, between services providers and beyond mobility itself. This creates its own challenges, from new commercial models, changed payment relationships, to data privacy, security and interoperability.

2.2 System interoperability and data exchange

Successful take-up of new transport services depends very much on providing accurate and easy-to-use personalized services, that hide the complex relationships between the many service providers and ecosystem. These include transport providers, service aggregators, payment agencies, professional associations, regional transport agencies and local authorities, each with a different role in the market, operating within government regulation.

Ubiquitous, interconnected modes of transport rely on interoperability of systems across and between the transport modes and their operators and users. This interoperability depends as much on the policies and practices of the actors in FoT as the technology. There are, however, many actors involved with the deployment and operation of transport-related services; this creates fragmentation and barriers to data exchange, which may block FoT development.

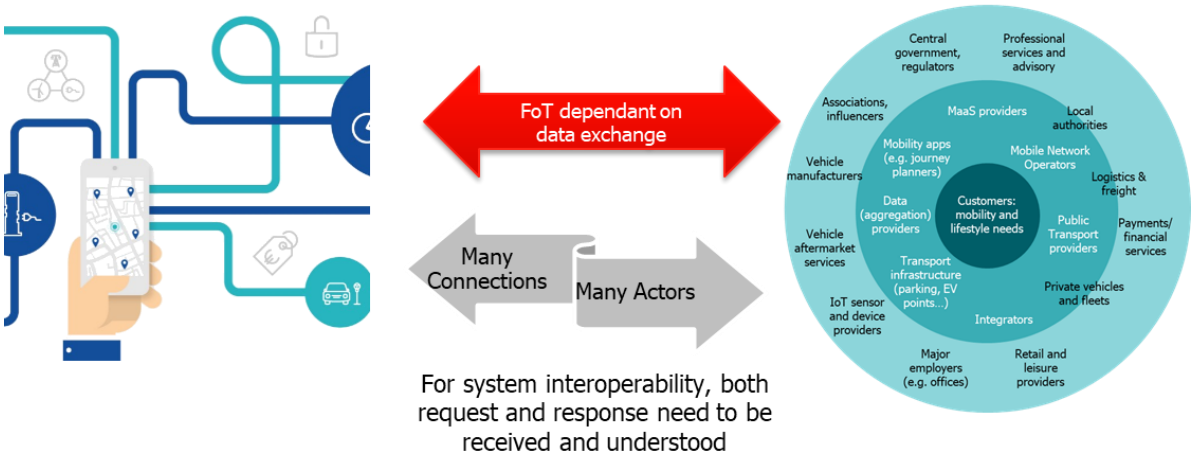

Figure 2 – The relationship between users and the FoT ecosystem

2.3 Standards

Standards provide a highly cost-effective way to overcome barriers and facilitate innovation. Standards represent an open and agreed way of 'how things should be done' with international reach and application.

Standards and innovation

Unlike regulation, standards are voluntary agreements arrived at by consensus. This means industry can develop standards to address their needs as they apply at a given point in time. In innovative and emerging areas, this means determining at what point some level of consensus is needed and where divergent investigation is still needed. In a similar context, industry can also choose when standards need to change; whether this is to update current good practice, widen the global uptake of the standard or decide that the practice no longer applies.

Standards take several forms related to data interoperability, including:

- Technical and process specifications
- Organisational codes of practice
- Guidance

The difference between these types of standard is largely in the precision of the agreement of good practice. If a product is to be certified as complying to a standard, then this standard will generally need to be in the form of a specification.

Figure 3 – Standards and innovation

Standards support system interoperability and data exchange in several ways, including:

- agreed specifications for the structure, content and exchange of information
- agreed definitions and classification of data types
- agreed organization practices for the creation, exchange and use of data.

This range of topics is important to consider, as system interoperability is often limited by a combination of these factors. Organizational procedures can be a far greater block on data exchange than technological factors such as data formats.

Within its portfolio of 37,000 standards, BSI manages and develops standards in the field of FoT (See *Figure 4 – BSI's core activity related to standardization in transport*) and provides UK representation to international standard development via ISO, CEN and IEC[1]. There is a range of current standards activities directly related to transport and mobility systems, but also data exchange more widely in other committees; for example geospatial information and positioning, rail, freight, communications and payment systems.

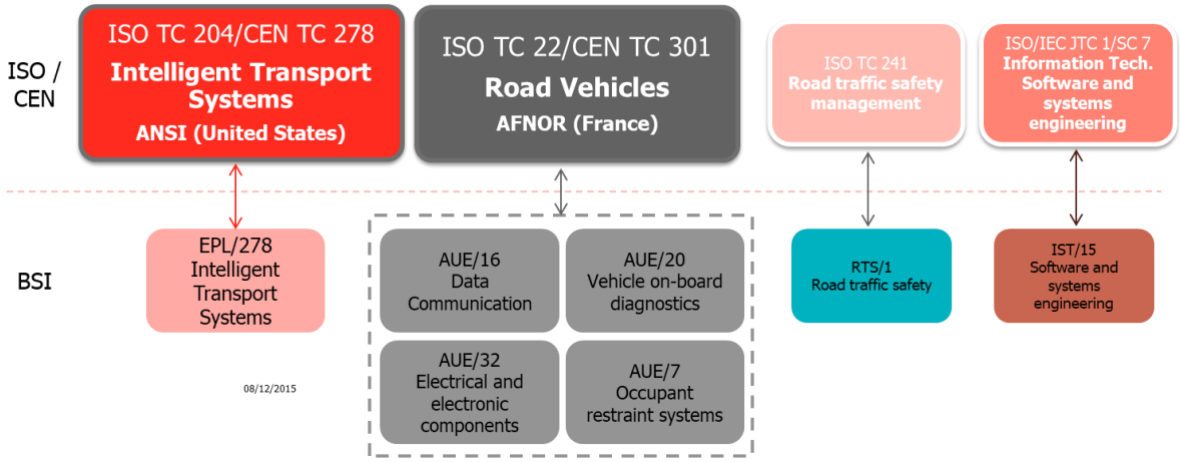

Figure 4 – BSI's core activity related to standardization in transport

3. Guidance is required on the availability and use of current standards

BSI identified some 1,200 standards that are relevant to the realization of the future of transport. This included standards developed specifically to support transport services as well as generic standards for data exchange. This is a large number of standards and not all relevant in all contexts.

Furthermore, there are overlaps in scope between standards developed by national standards bodies and those created by industry groups. Guidance is needed to support users to select and apply the appropriate standard in a given context.

3.1 Formal standards identified relevant to FoT

A search of national and international catalogues available to BSI identified 1,213 unique standards that could be used to support some aspect of data exchange in the context of FoT. This is a large number of standards, but reflects the breadth of topics that can be considered relevant. The topics considered for the search are shown in *Figure 5 – Conceptual view of the search terms used for the standards searches*. Note, as per the project brief, data security and cyber security were not included in the search.

[1] International Organization for Standardization, International Electrotechnical Commission, European Committee for Standardization (Comité Européen de Normalisation)

Figure 6 – Standards breakdown – BSI search terms shows the number of standards returned according to the search terms used. Standards could be identifed for each of the three topic levels used to define the search.

Analysis of these standards showed that over half were international standards with only 4% published solely by BSI. This is summarised in *Figure 7 – Standards search results by ICS Code*. Figure 7 shows the number of standards identified broken down by their top-level ICS (International Catalogue of Standards) topic. This highlights the wide distribution of topics FoT encompases.

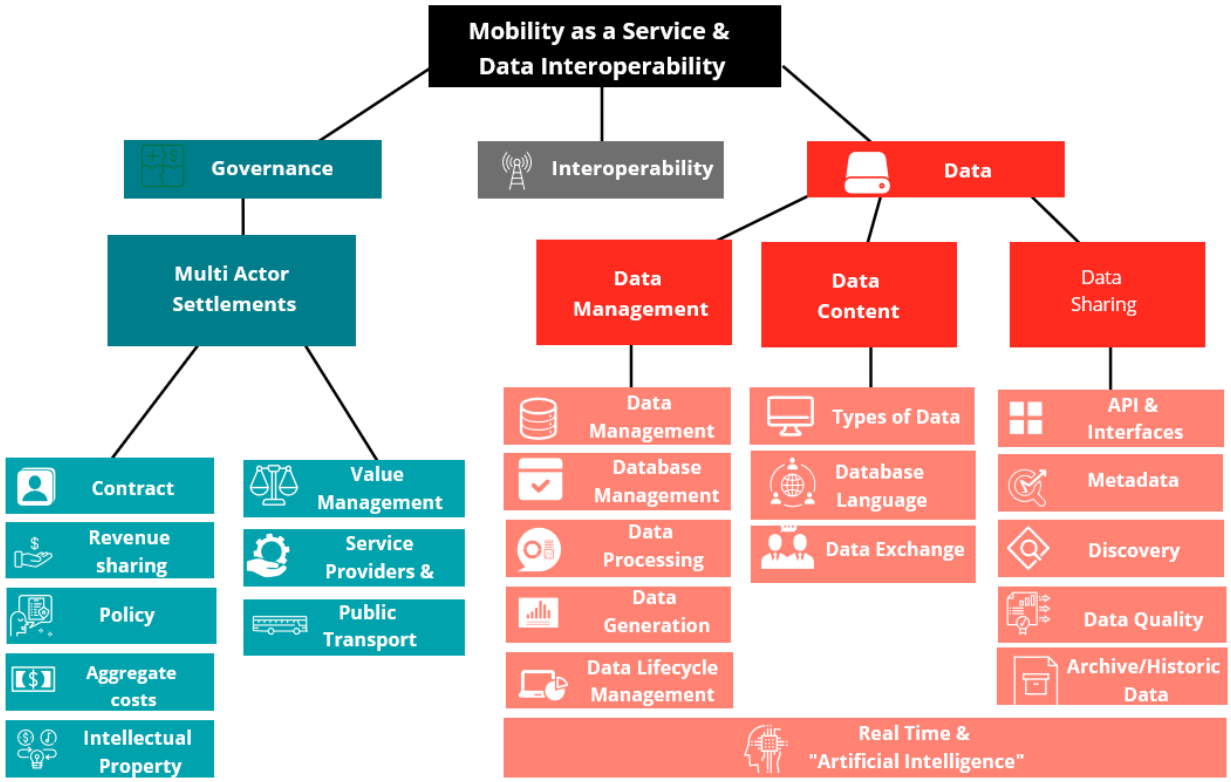

Figure 5 – Conceptual view of the search terms used for the standards searches

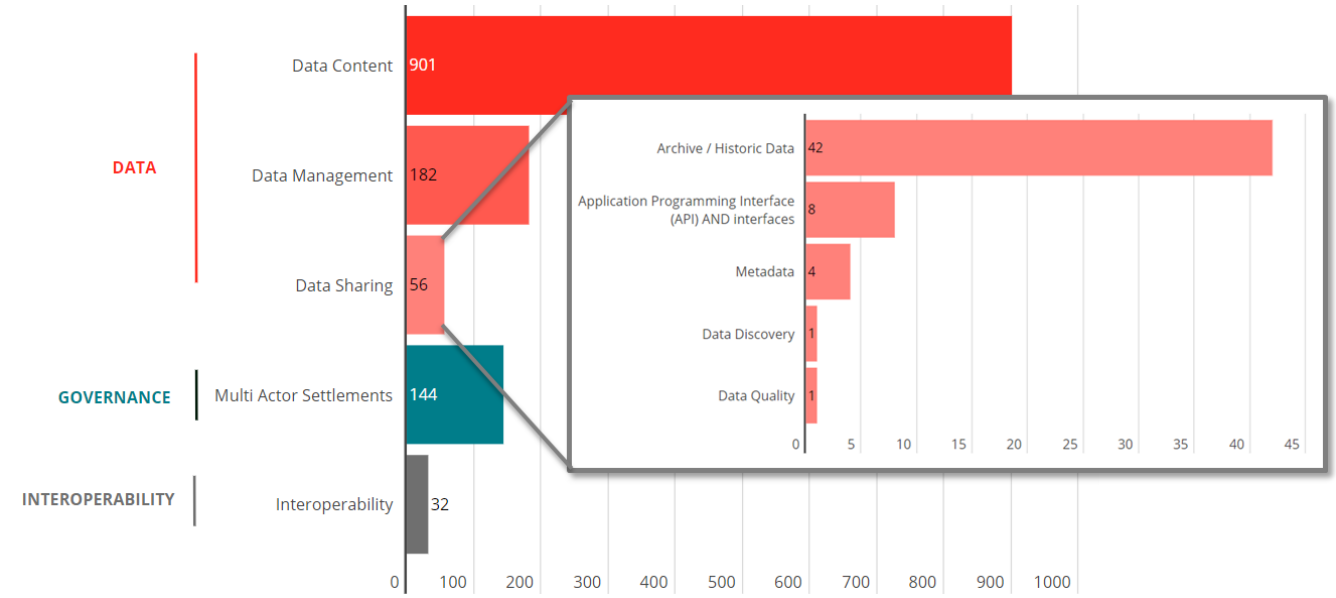

Figure 6 – Standards breakdown – BSI search terms

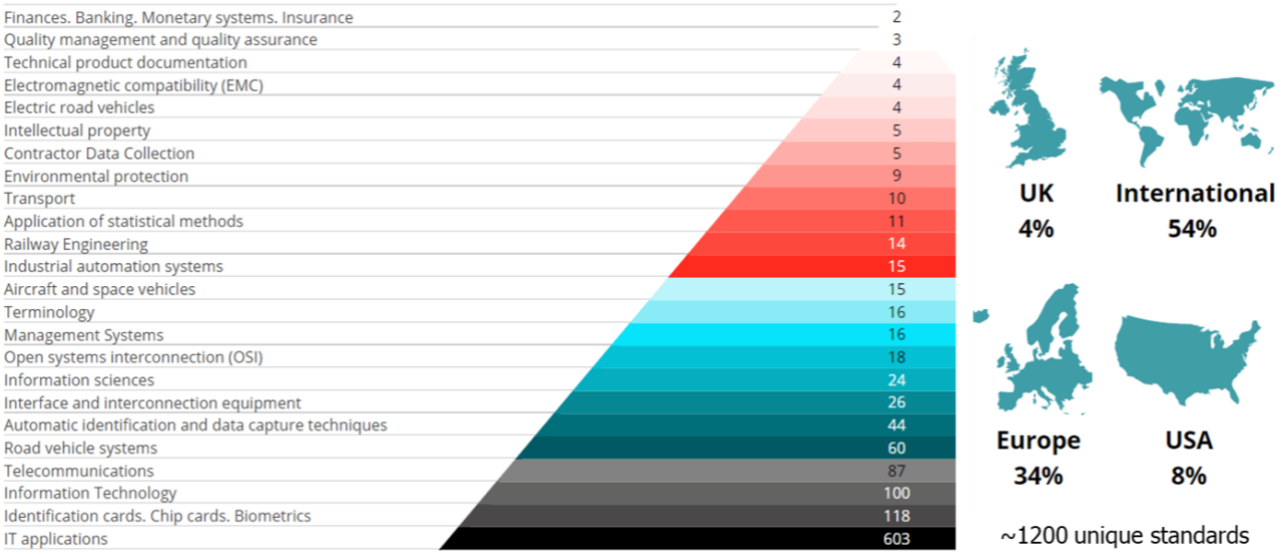

Figure 7 – Standards search results by ICS Code

3.2 Key observations from formal standards landscape

The standards landscape can be interpreted by the level of abstraction they define to support data exchange. The abstraction levels can be considered as:

1 Framework standards for the context and principles for data exchange. This defines how data exchange should occur, referencing other standards that should be used to realize the data exchange itself.

2	Component	standards for the building blocks or foundation structures of data exchange. This defines generic or multi-purpose artefacts for data exchange. These may be develped within the FoT community, however more generic components will be developed elsewhere. This includes general communication and data exchange standards.
3	Implementation	standard for operational data exchange; built on established components for a defined, precise purpose, e.g. realtime messaging. This is typically what is understood for data exchange standards as it is the tangible data that is exhanged.

Although this is not definitive, it provides a useful way to appraise the standards landscape. An example of this shown in *Figure 8 – Standards abstraction levels.*

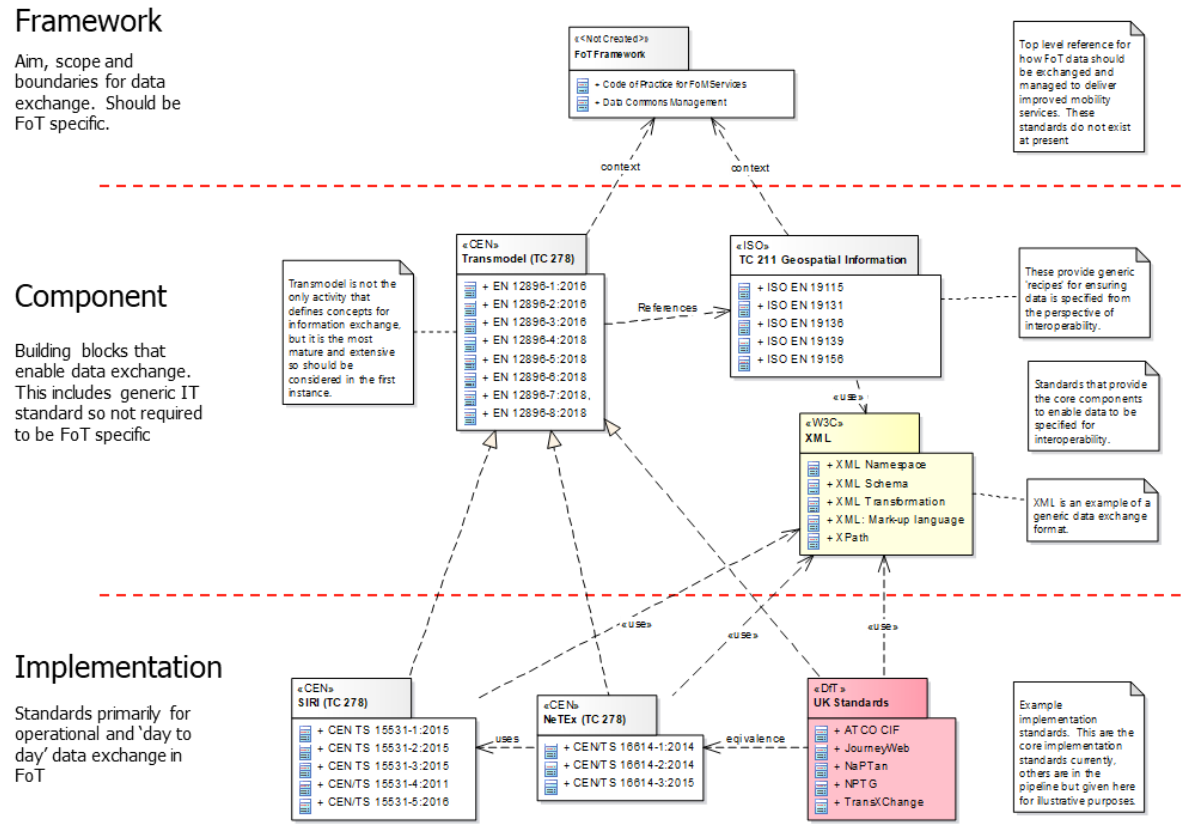

Figure 8 – Standards abstraction levels example

There are three key observations that came from considering the standards in this context:

1. **There is a well-established range of technical standards for data exchange that the FoT sector can use directly at the 'implementation' and 'component' level.**
   This includes generic data interoperability standards and those created specifically for the FoT context. The range of standards within the transport services community is extensive

and actively managed. However, this active management applies for subsets of component and implementation groups and is not holistic across the transport services community. This is considered in more detail in the section: 3.4 Core data exchange standards for transport systems.

In addition to these standards, there is an extensive number of standards at the component and implementation level from other communities that can be used 'as is' by the FoT community. A good example is standards for metadata. The international database and data management communities have developed ISO/IEC 11179 (and associated implementation specifications ISO/IEC 20943 and ISO/IEC 20944) to deliver generic, high-level metadata implementation for data management. In addition, the international communities associated with geospatial and environmental data have developed ISO 19115 (and associated implementation specification ISO 19139) to provide a very rich semantic description for dataset discovery and evaluation. These two standards are consistent with each other, but address different metadata uses. Both however represent a mature basis for FoT community metadata.

2. **There are standards at all levels that have been developed for other sectors and can be converted for use in the FoT sector.**
   There are standards that specifically address data interoperability issues for the non-FoT sector. These include sectors as diverse as banking and retail, but also related sectors such as smart cities. However, the data interoperability issues are similar and the FoT community can benefit for this at two levels: First is by a gap analysis to understand if these standards are relevant to FoT. Second is through 'translation' of these standards to the FoT context.

   As commentary on the above, consider the requirement '*on-boarding of new entrants in a multi-actor ecosystem*'. Whilst no standards exist for this in the FoT or transport context, this problem was identified in the finance sector in relation to the evolution of Fintech. There are parallels between Fintech and FoT in that they both represent disruption to an existing market organisation. As such, this standard could be used as a basis for approaches to on-boarding in the FoT sector, potentially informing whether specific guidance is required in the FoT context.

3. **There is limited guidance and frameworks on using technical standards to deliver FoT services.**
   Whilst there is an extensive and mature range of technical standards at the implementation and component level, there are no standards relating to the governance and application of the various instances or profiles needed. That is, which standard to use or how to use a standard in a given context.

   In domains such as smart cities there are standards that define smart cities at a high level of abstraction, including defining concepts and the expected roles and responsibilities of actors. Smart cities is a new concept and so the top down approach of standards

development is an obvious and established way forward. In FoT, an existing transport community exists and FoT is not about creating something completely new but integrating and utilizing existing practices from a new perspective. In effect, it has developed bottom-up with these top-level, framework standards to be developed.

3.3 Non-formal standards

Whilst several formal data interoperability standards exist, many implementations or application schemas that are deployed currently exist as non-formal standards not managed by national standards bodies. Such non-formal standards are managed by government, industry groups and individual companies and can be based on formal standards. This is not a problem and is often normal practice as part of the innovation lifecycle; as good practice becomes more established then the need to formalise this follows.

3.3.1 Core UK public transport data exchange

Currently, UK public transport data is exchanged using standards based on well-established grammars for data exchange such as XML. Under the auspices of Government, schema have been developed to specify the content of the XML files. As an example, TransXChange is part of a family of coherent transport related XML standards that followed GovTalk guidelines[2] and are aligned with the formal Transmodel standards framework[3]. TransXChange is the UK nationwide standard for exchanging bus schedules and related data. It is used for:

- the electronic registration of bus routes
- the Traffic Area Network
- the exchange of bus routes with other computer systems such as journey planners and vehicle real time tracking systems.

Datasets which underlie bus and coach transport data provision provided public bodies include:

- **UK National Public Transport Access Nodes (NaPTAN) database:** The nationwide system for uniquely identifying all the points of access to public transport in the UK. Each NaPTAN point can contain comprehensive data on street names, localities, stop type and geospatial coordinates. The dataset is made available in XML, GTFS or as a CSV.
- **National Public Transport Gazetteer (NPTG):** this dataset is closely associated with the NaPTAN dataset and contains details of every city, town, village and suburb in Great Britain. As a topographic database of towns and settlements, it provides a common frame of reference for the NaPTAN.
- **National Coach Services Database (NCSD):** This dataset contains scheduled timetable data for coach and strategic bus services across Great Britain.

2 GovTalk was a UK government initiative sponsored by the Cabinet Office promoting XML for data exchange. Archived pages can be found at https://webarchive.nationalarchives.gov.uk/20100512144349/http://www.cabinetoffice.gov.uk/govtalk/schemasstandards/e-gif/datastandards.aspx

3 In this context, these UK standards are largely equivalent to the formal NeTEx standard.

- **Transport accessibility data:** Department for Transport data to support accessible journey planning and covers accessible stations/stops and accessible services.
- **Registered bus services:** Operators of local bus services carried out in accordance with Section 6 of the Transport Act 1985 must register their services with a Traffic Commissioner in the traffic area in which the service operates. The Driver and Vehicle Standards Agency (DVSA) maintains an Operator Licensing Business System (OLBS) to record these registered services.

Use of data exchange standards by Traveline

The most comprehensive dataset of scheduled UK public transport is compiled and kept by Traveline – the Traveline National Dataset (TNDS) – which it makes available to third parties under the Open Government Licence. TNDS contains public transport timetables for bus, light rail, tram and ferry services in Great Britain. It is compiled from local data in the TransXChange format.

Realtime bus APIs are provided by Traveline. This is an API of bus departures by bus stop – Nextbus API. It provides real time departures where they are available and scheduled where they are not. Nextbus API is based on the formal SIRI standard, using the SIRI-SM function through a request/response communication mechanism. SIRI is an XML protocol that allows the exchange of real time information about public transport services and vehicles.

Currently in the UK, Traveline transforms its datasets into GTFS (See *Figure 11 – GTFS and NeTEx*) to enable UK transport options to feature on Google Maps. It's also offered alongside information in TransXchange format by other providers of transport information (e.g. Nottingham City Council).

Figure 9 – Use of data exchange standards by Traveline

Rail data in Great Britain

Data for railways is managed separately to other public transport datasets. The Great Britain rail dataset is held by Network Rail, and includes a wide range of open data that includes timetables and live information:

- SCHEDULE – daily extracts and updates of train schedules from the Integrated Train Planning System, in CIF and JSON formats
- MOVEMENT – train positioning and movement event data
- TD – train positioning data at signalling berth level
- TSR (Temporary Speed Restrictions) – details of temporary reductions in permissible speed across the rail network
- VSTP (Very Short Term Plan) – train schedules created via the VSTP process which are not available via the SCHEDULE feed
- RTPPM (Real Time Public Performance Measure) – performance of trains against the timetable, measured as the percentage of trains arriving at their destination on-time
- SMART – train describer berth offset data used for train reporting
- Corpus – location reference data
- *BPLAN* – train planning data, including locations and sectional running times.

Figure 10 – Rail data in Great Britain

3.3.2 General Transit Feed Specification (GTFS) – the Google feed

GTFS, also known as 'GTFS static' to differentiate it from the GTFS real time extension, defines a common format for public transport schedules and associated geographic information. GTFS 'feeds' let public transport operators publish their data and developers write applications that consume that data in an interoperable way. It is a feed specification that enables transport data to appear on Google Maps.

GTFS and NeTEx

Google General Transport Feed Specification (GTFS) is a widely used format for distributing timetables to third parties. The NeTEx and GTFS formats should be considered as complementary, covering different stages in the data management process: NeTEx is 'upstream', GTFS is 'downstream'.

NeTEx differs from GTFS in that it has a much wider scope, and that it is intended for use in back office use cases under which data is generated, refined and integrated (requiring the exchange of additional elements used to construct the timetable), rather than just for provisioning journey planning systems (the prime purpose of GTFS).

Because it uses XML, NeTEx can package a complete data set as a single coherent document that can be managed and validated. By comparison, GTFS uses a traditional flat file format; this is compact and efficient but requires multiple files to describe the different types of element and thus additional rules for naming and packaging the files as a zip. It is possible to generate a full GTFS data set from NeTEx but not vice versa. The NeTEx UML includes a GTFS mapping package which shows how each GTFS element may be populated from the corresponding NeTEx element. An example of this is given in Annex 4.

Source: http://netex-cen.eu/?faq=how-does-netex-compare-with-gtfs

Figure 11 – GTFS and NeTEx

3.3.3 Open source bike share feed: GBFS

The General Bikeshare Feed Specification (GBFS) is an industry open data standard for bikeshare. GBFS makes real time data feeds in a uniform format publicly available online, with an emphasis on findability. Under the North American Bikeshare Association's leadership, GBFS has been developed by public, private sector and non-profit bike share system owners and operators, application developers, and technology vendors.

- GBFS is a specification for real time or semi-real time, read-only data. The spec is not intended for historical or archival data such as trip records. The specification is about public information intended for bikeshare users.
- GBFS is targeted at providing transit information to the bikeshare end user. Its primary purpose is to power tools for riders that will make bike sharing more accessible to users.

GBFS is intended as a specification for real time, read-only data – any data being written back into individual bikeshare systems are excluded from this specification.

GBFS microbility example

Los Angeles has required that all scooter companies provide their data in real time using their Mobility Data Specification. This is an open source specification inspired by GTFS and GBFS. Specifically, the goals of the Mobility Data Specification (MDS) are to provide API and data standards for municipalities to help ingest, compare and analyse mobility service provider data. MDS is currently comprised of two distinct components:

- The provider API is to be implemented by mobility service providers, for data exchange and operational information that a municipality will query. Service provider presents the historical view of operations.
- The agency API is to be implemented by municipalities and other regulatory agencies, for providers to query and integrate with during operations. Agency provides tools to inform and permit future operations.

Cities and regulators can choose to implement Agency and Provider either separately, concurrently, or by endpoint. The specification is a way to implement real time data sharing, measurement and regulation for municipalities and mobility service providers. It is meant to ensure that governments can enforce, evaluate and manage providers.

Full documentation available on Github: https://github.com/CityOfLosAngeles/mobility-data-specification

Figure 12 – GBFS Micro mobility example

3.4 Core data exchange standards for transport systems

Whilst it is agreed FoT is a broad topic, debate on the standards landscape sought to ascertain what can be considered the core data exchange standards for transport systems. An analysis of this is presented in Annex 5. This is a complex picture and a simplified view of this is presented below in *Figure 13 – Simple view of core data exchange standards for transport systems.*

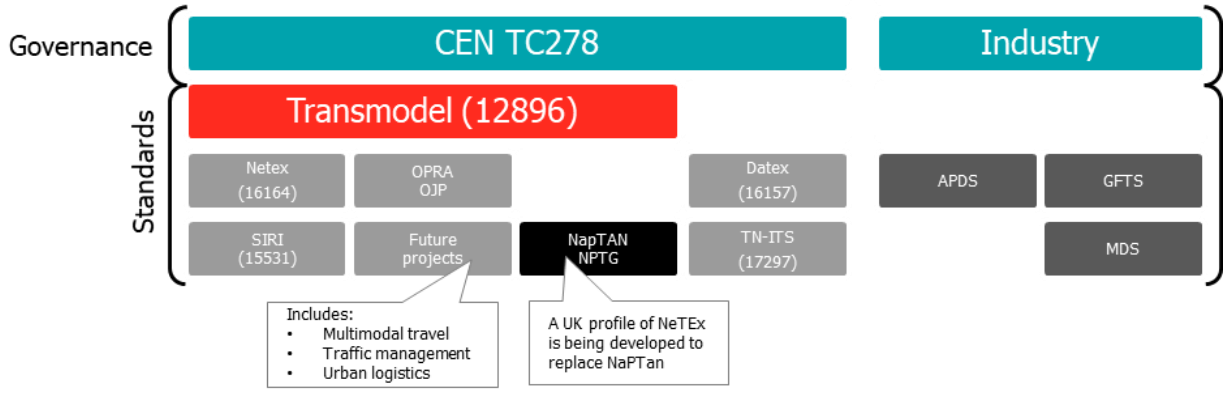

Figure 13 – Simple view of core data exchange standards for transport systems

Most of the core standards are developed through the international committee ISO TC 204 (Intelligent Transport Systems) and the European standardisation committee CEN TC 278 (Intelligent Transport Systems). There is common working between these two committees but CEN TC 278 is not a mirror committee of ISO TC204. Key points to note on developments are:

- Many, but importantly not all, of the implementation-level standards developed by CEN TC 278 are based on the Transmodel reference ontology. This defines a common set of concepts and relationships (See *Figure 14 – CEN Transmodel project for public transport data exchange*).
- The current UK core standards for bus transport are based on the Transmodel reference. These currently being migrated to a UK profile of NeTEx.
- Although the DATEX II and TN-ITS standards are not formally based on Transmodel there are attempts to ensure they align.
- APDS is an industry standard for parking data definitions but uses concepts from DATEX II and TN-ITS and is proposed to ISO TC204 as a new standard.
- Future projects under the Transmodel framework include urban logistics, traffic management and multimodal journeys.
- A formal mapping between GFTS and NeTEx has been completed (see *Figure 31 – Example NeTEx and GFTS mapping*).

These standards are largely segmented and designed by the function (for example 'real time messaging') they specify and so it is not evident which standards should be used for a given activity; for example, 'micro-mobility'. Any activity will encompass typically the same functions, but from a different viewpoint and so it is important that any standard that considers data exchange from an activity ensures functional aspects are consistent with existing standards to ensure interoperability.

CEN Transmodel family of standards

Transmodel has been developed under the aegis of CEN (Comité Européen de Normalisation) by Technical Committee 278 (TC278), Working Group 3 (WG3). The CEN Transmodel standard is a conceptual model which names and represents public transport information concepts for a wide set of functional areas, and which can be used to compare and understand different models.

Transmodel covers network topology representation, scheduling, operation monitoring, fare management, passenger information and driver management information domains. Transmodel should be viewed in the context of the European ITS Directive 2010/40/E since it facilitates the definition of the necessary requirements to make EU-wide multimodal travel information services accurate and available across borders to ITS users.

The Transmodel project outputs have previously been used both to underpin a number of CEN application data standards, such as CEN SIRI and CEN NeTEx, and also to rationalise national standards such as the UK NaPTAN standard. OpRa is a new CEN project also utilising the Transmodel framework.

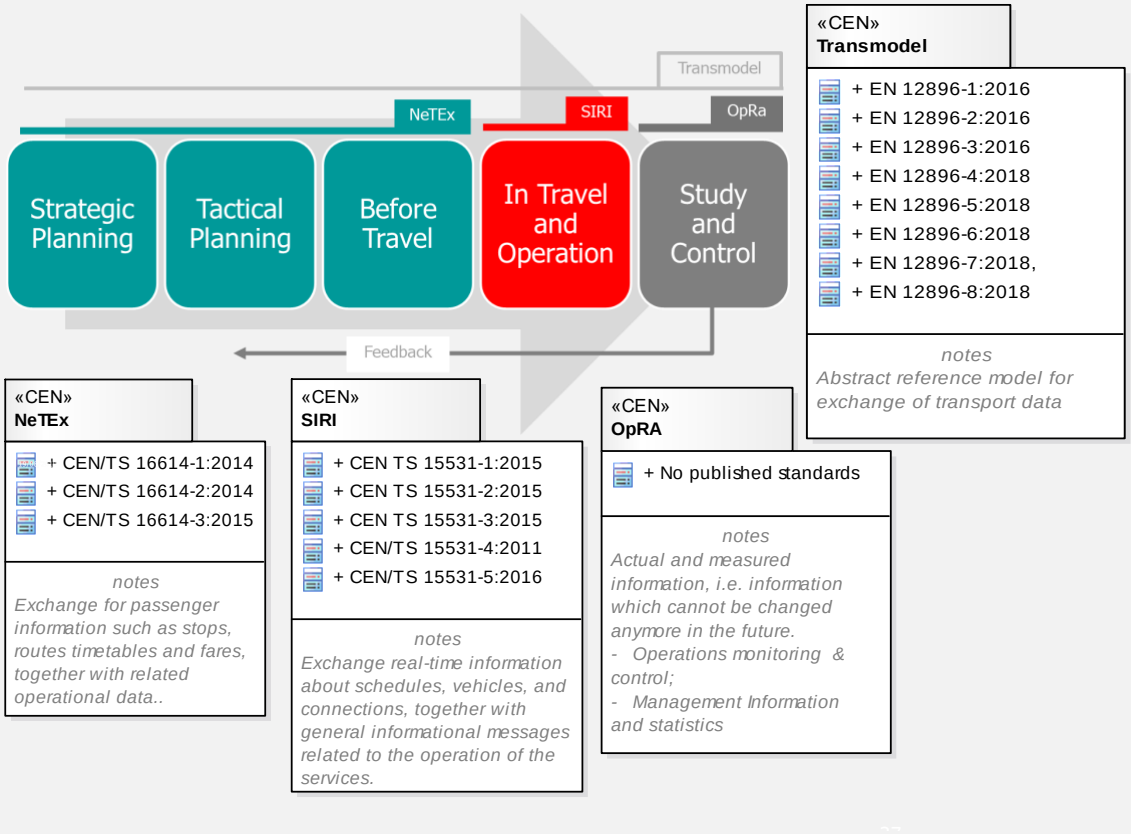

Figure 14 – CEN Transmodel project for public transport data exchange

4. New standards are required to define FoT operations at a holistic level

The standards landscape identified many standards related to aspects of the future of transport (FoT). Standards that dealt with FoT at a holistic level were absent. Although not directly a data exchange issue, such standards underpin the rationale, market norms and business cases for data exchange. As a priority, new standards are required for how FoT actors should collaborate to deliver transport services and how data is shared and managed as a common FoT infrastructure.

4.1 Six scenarios that constrain the delivery of future transport services

A BSI-convened Expert Group [Annex 1] agreed a user story that captured the key sentiments of FoT from a user's perspective and subsequently identified requirements that would need to be realized to enable the user story to be fulfilled. The user story is summarised below in

Figure 15 – User story for the Future of Transport.

Figure 15 – User story for the Future of Transport

The Expert Group identified six scenarios that prevent this user story being realised. The scenarios were used as the basis for the standards search so that we could test what agreed, supporting good practice exists. The six scenarios are:

1. Multi actor settlement: There is not currently an agreed understanding of how distributed transport actors should work and operate together, in particular in the context of liabilities for ensuring journey fulfilment should one part of an integrated journey fail.
2. Total journey cost-benefit: In the FoT context, it would be expected that the scope of costs and benefits will widen to be beyond just a single transport component, to include the wider journey purpose and associated benefits and impacts.
3. Data sharing: In simple terms, there is not widespread consistent good practice across FoT on how data should be shared, but also so that the costs and benefits of data sharing are equitable.

4. Multi actor service ecosystem: FoT requires multiple actors to cooperate and collaborate to deliver the overall journey to the consumer. This is not current practice where there is often competition between different transport modes.
5. Terminology and content models: There is not wide agreement on the data needed to support FoT. This includes the precise topic of the data and how this should be structured and assured so it can be used easily and with confidence.
6. Data publishing for transport resources and assets: Data is not published in consistent ways, introducing extra effort to cleanse and assure the data.

These six scenarios are summarised in *Figure 16 – FoT Scenarios used to define the standards landscape.*

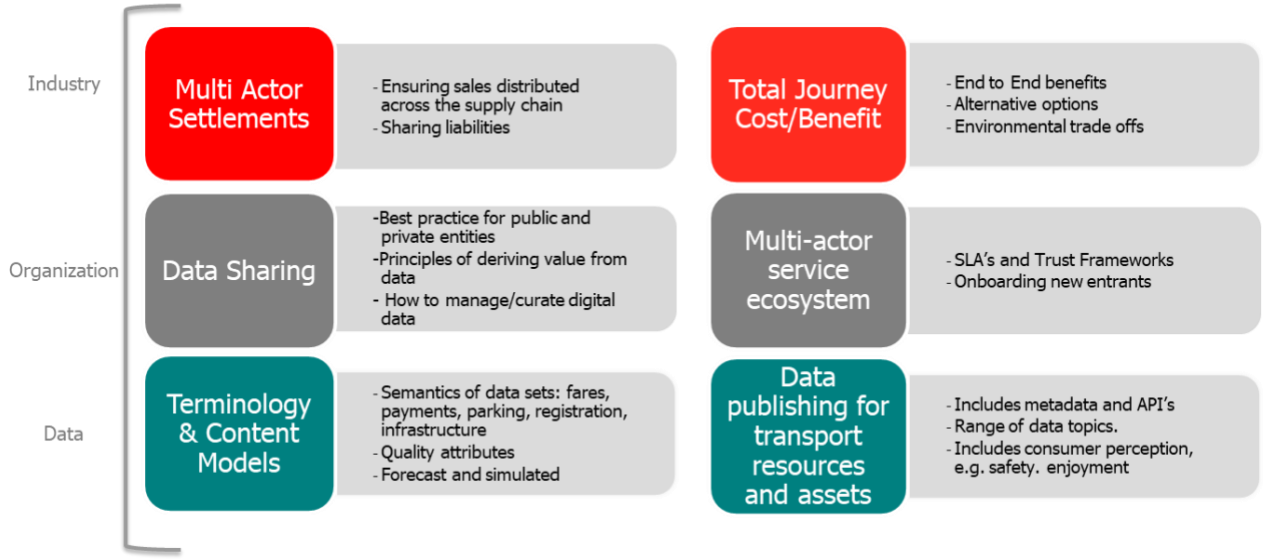

Figure 16 – FoT Scenarios used to define the standards landscape

4.2 How the FoT value chain is constrained by standards gaps

An analysis was undertaken of FoT constraints in the context of the wider FoT value chain. Previous analysis[4] had proposed a reference architecture for mobility as a service and this architecture was used to define an FoT value chain as shown in *Figure 18 – FoT Value chain and identified constraints.*

The value adding services in the value chain take data and process it to deliver services to the customer. A transport operator provides an API to enable a data provider/aggregator to collect and process data and deliver it in a standard way to the back end of a transport service. The front end of the transport service provides a customer-facing API that allows customer user interfaces to be realized and hence offer services to customers.

Enabling these value-add services to function are a range of support services. These include the business, policy, regulation and governance aspects of FoT. Security and data are shown

[4] "MaaS: Exploring the opportunity for MaaS in the UK", Transport Systems Catapult, July 2016

as general supporting concepts as they are included in the reference architecture from which this value chain is derived, however security was explicitly excluded from this study.

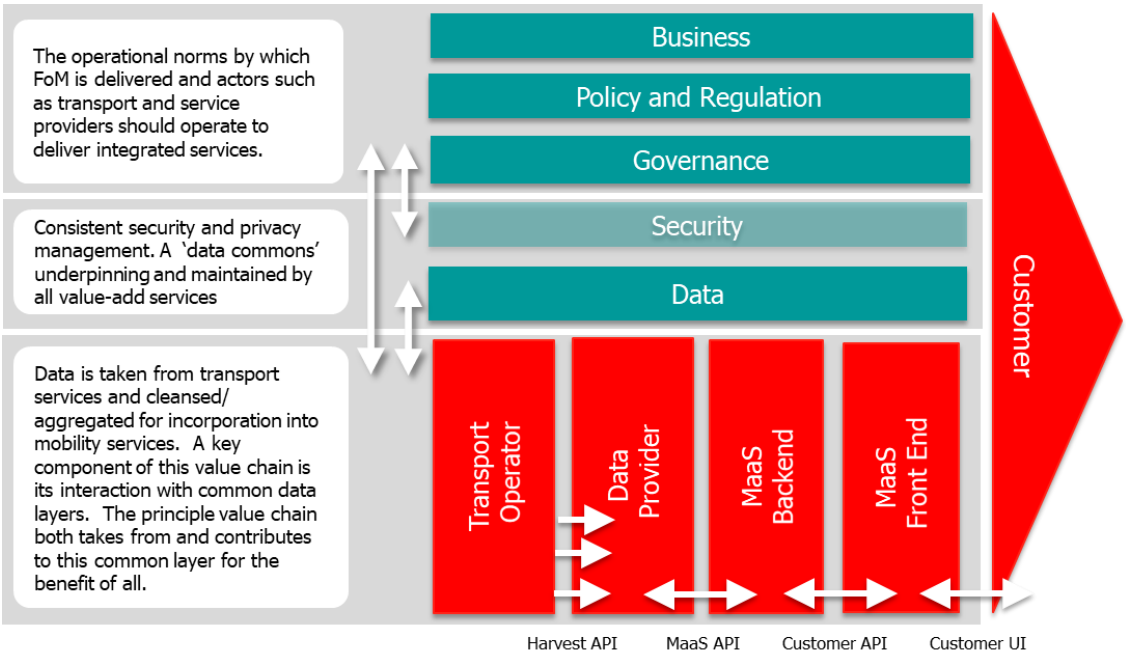

Figure 17 – Value chain for FoT data services

The constraints identified were mapped to this value chain and this is shown in *Figure 18 – FoT Value chain and identified constraints.*

Most of the constraints have one or more dependencies to the enabling activities in the value chain. Even for constraints associated with 'data'; although there are dependencies with the value adding activities, the issue is a much as about 'how' data is used (governance), particularly in the context of a 'data commons' that is used and updated by actors in the value chain.

This overall pattern is one that BSI has observed on similar emerging topic areas, whereby top-level guidance (either voluntary or regulated) is required to help define market operations and thus support the evolution of value-adding activities.

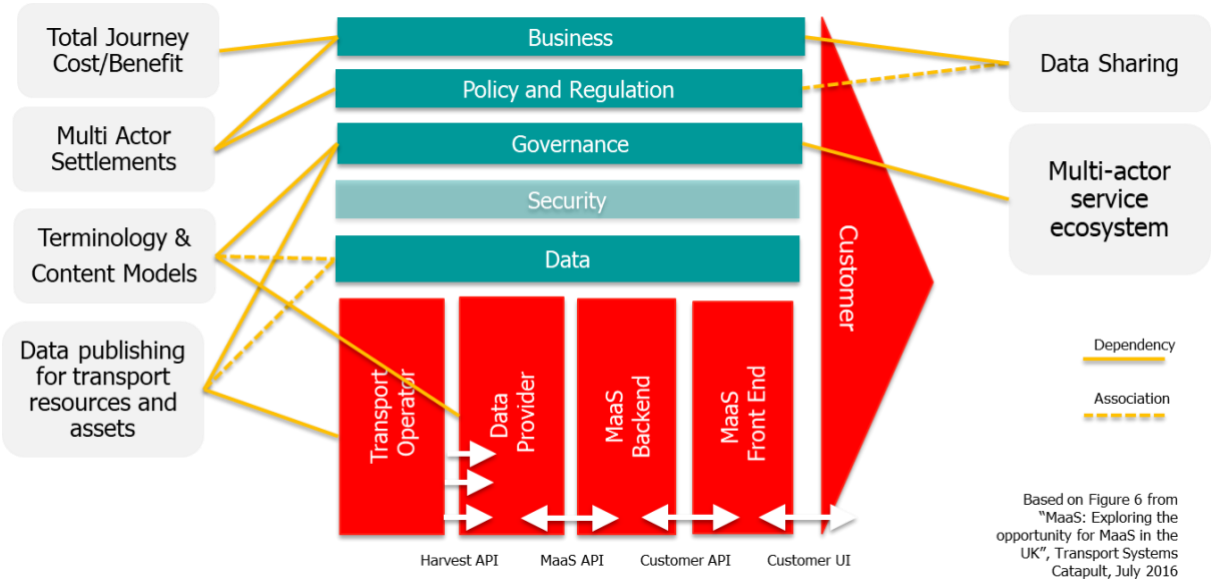

Figure 18 – FoT Value chain and identified constraints

4.3 Data commons management is a key part of the FoT value chain

A final and important industrial consideration is the concept of a data commons to underpin FoT data exchange activities. Mobility zones are increasingly adopting this concept, see *Figure 19 – Data commons and mobility services.* These adoptions have some similar approaches as well as differences and there is now the opportunity to look to establish good practice for this, covering topics such as:

- Selection of organisations to have access to a data commons
- Selection of approaches to host and manage a data commons
- Ingestion of data into a data commons and data archiving and management
- Obligations on transport operators and service providers to use the data commons
- Obligation of organisations delivering the data commons.

Data commons and transport data

Transport authorities have recognised the role they can play in delivering a quality controlled common data layer for transport actors to use to support innovation in service delivery.

Transport for the North have a track record in facilitating the creation of common data layers to support transport services. Analogous to weather forecasts, they would like to establish a common forecast for transport needs that service providers can respond to, recognising that everyone benefits from having this data available.

Transport for London adopt an open data approach by All public TfL data (or 'open data') is freely released here for developers to use in their own software and services. TfL encourage software developers to use these feeds to present customer travel information in innovative ways - providing they adhere to the transport data terms and conditions.

Figure 19 – Data commons and mobility services

5. A shared FoT ontology is required to support and advance data exchange

For FoT to develop, a shared and precise understanding of 'data' is essential, such that it can be consumed in a trusted manner. At the same time, guidance is required on the availability and use of current standards to enable this.

Some activities are underway in the FoT sector to advance data exchange and standards, but these are fragmented. The ontology would act to help coalescence these activities and provide visibility to the data and standards being used or could be used.

5.1 A shared understanding of FoT data is required

A lack of consistent terminology was cited as a key barrier to data exchange (Section 4.1). The challenge is that a completely consistent terminology across FoT is not possible (or beneficial) due to the spectrum of different actors FoT encompasses requiring their own vocabulary. To address this, a shared understanding of these vocabularies is required.

A FoT ontology would be tool to build a shared understanding of data by making explicit viewpoints that define data such as the 'topic', 'purpose' and 'specification' as shown in *Figure 22 – Concept of a FoT data ontology.* Other viewpoints could be added to the ontology to help understand the governance of the data such as 'data owner' and 'data publisher'.

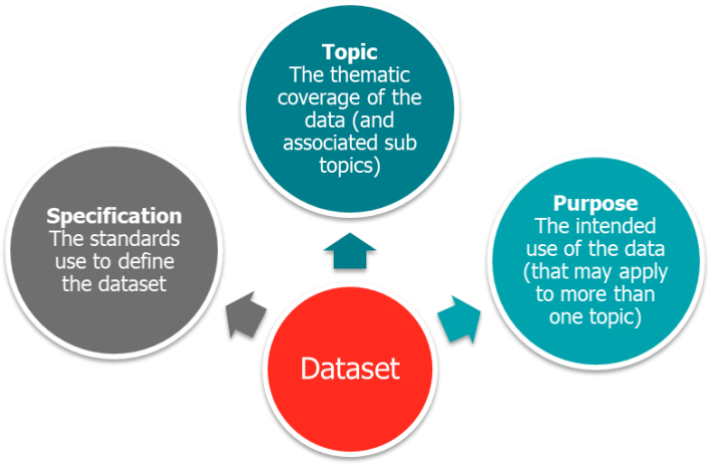

Figure 20 – Key data viewpoints in a FoT ontology

An example of this is illustrated by the different understanding and requirements of 'parking data' by FoT actors. This could mean data sets that contain:

- maximum available parking spaces
- spaces available at this current time
- spaces forecast to be available at time X
- average occupancy of parking spaces
- peak occupancy of parking spaces
- validity of a vehicle to be parked at location Z.

Each of these datasets address different purposes related to parking. In this example; strategic capacity planning, operational capacity planning, and parking enforcement.

The data purpose often defines the specification of the dataset more than the data topic. A dataset for operational capacity planning will need to suitable for real time transmission and be updated frequently. A dataset for enforcement will need to have precise vehicle identification.

At the same time 'parking' relates to adjacent topics such as kerbside management and electric vehicle charging which define the nature of the parking resource and how it should be managed. Depending on the topic and purpose, different standards will be used in the specification of the dataset. An example of this is shown in *Figure 21 – Example of parking management data exchange.*

Parking management

Parking management increasingly encompasses a range of different topics, especially as parking becomes more automated with dynamic parking bays, the increasing demands of the kerbside (parking, waiting, loading, setting down) and different modes of transport requiring to be parked. These different viewpoints on parking data are naturally associated with different standards. To provide a harmonised view on parking management, the Alliance of Parking Data Standards have developed a specification with the intent that it is formalized through ISO TC 204. The APDS specification reuses concepts developed in related standards (notably DATEX II and TN-ITS) and seeks to provide interoperability with systems that may use these standards.

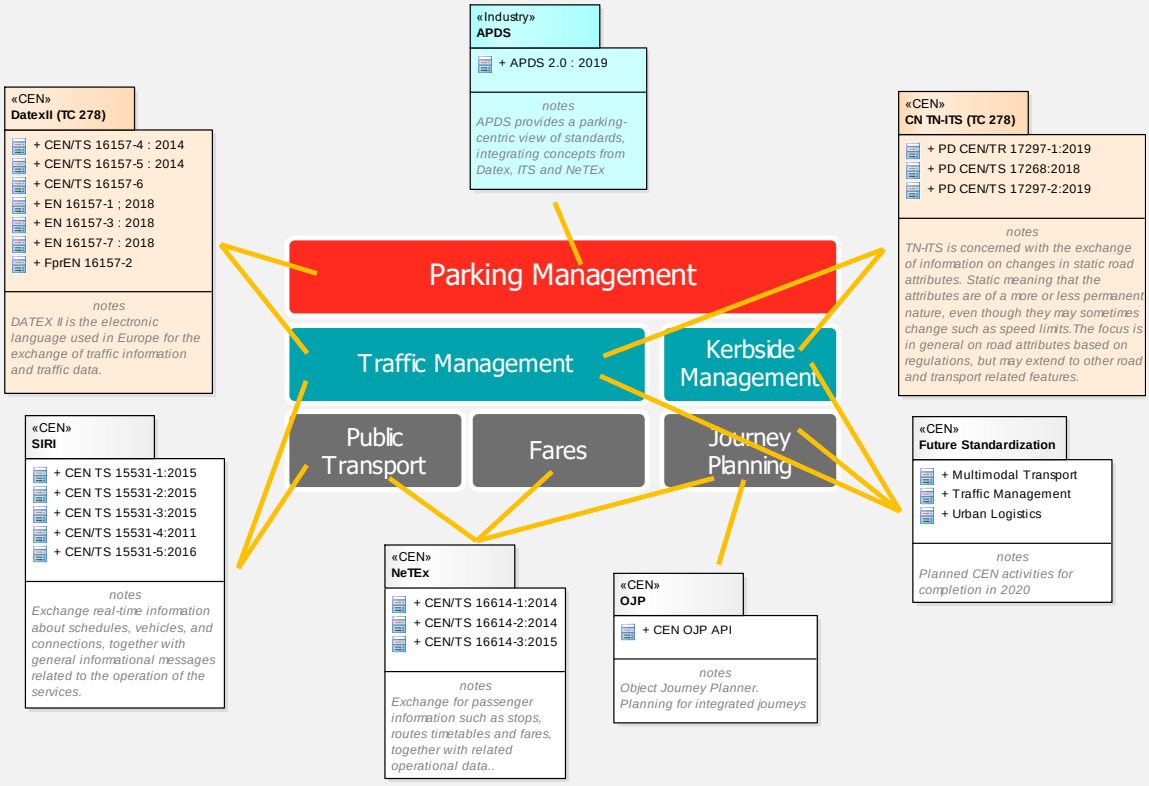

Figure 21 – Example of parking management data exchange

5.2 An approach to define an ontology of FoT data topics was identified

Approaches to fully develop and manage an ontology would need to be considered further, but through workshops and desk research, this study identified three top-level data topics that were helpful in defining the scope of FoT from a data topic perspective:

- Journey: Where do you want to go, what effects will it have and what events could modify this journey?
- Transportation: How can I make the journey and its underlying infrastructure?
- Contract: The ticketing information that allows the journey to be executed.

A preliminary consideration of the data topics in a hierarchical structure is shown in *Figure 22 – Concept of a FoT data ontology*. A more detailed representation of this ontology is given in *Figure 30 – FoT Data ontology* in Annex 3.

FoT Data topic ontology

The diagram is a preliminary concept for a data and standards ontology, indicating a hierarchical relationship of the data topics that would need to be considered. Other cross-hierarchical relationships, along with other data topics could be envisaged and these would need to be explored to identify the data that need to be part of the FoT infrastructure. The 'travel resource' topic under 'transportation' is the data type that is core to FoT and the data topic most people think off when they consider FoM. This covers the mode of transport and its attributes such availability, location and schedule/progress.

This ontology only looks at the data topic. Adjacent ontologies for 'purpose' and 'specification' would also be required along with their relationships to give a useful landscape to inform improvements in data exchange.

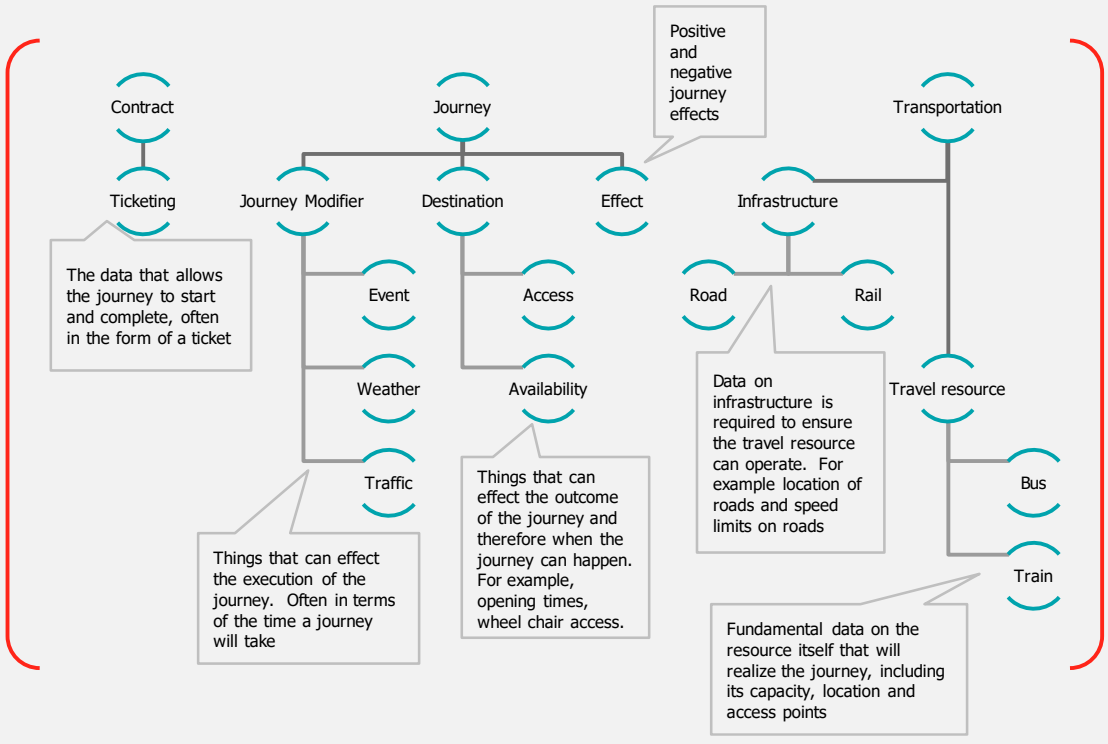

Figure 22 – Concept of a FoT data ontology.

6. A Data Advisory Panel is needed to populate the FoT data infrastructure

System interoperability in the context of FoT is primarily limited by the lack of standardised datasets and data services across the range of topics required. Various reasons were cited for this including commercial sensitivity, no obligation to publish data, lack or resource/expertise and lack of understanding of demand.

A Data Advisory Panel would be an authoritative umbrella for the coordination of data-related activities that support FoT. The term 'Data Advisory Panel' is used here to represent a function that identifies and addresses data exchange opportunities and issues in a systematic and responsive way.

6.1 Scope of the Data Advisory Panel

The exact role and scope of the Data Advisory Panel would need to be established. However, from the consultations undertaken as part of this project, the following activities should be incorporated:

- Coordinate and build consensus between local, regional and national data providers, policy and regulation to ensure consistent data sets are created
- Act as a voice for the FoT community to other data providers on which the FoT community relies
- Advise and promote good practice on data collection methods and compliance to standards, liaising with the standards development organizations and regulators
- Where necessary, commission and manage targeted interventions to ensure data sets required for FoT are realized to an appropriate quality.

6.2 Include a structured appraisal of data relevancy

To aid in this appraisal of actions the Data Advisory Panel should take a structured approach to classify the data exchange barriers and therefore what action should be taken to address them. For example, there is no point developing new standards for data exchange if the data topic offers limited benefit to improving interoperability or is of a quality that would make its use unattractive.

Previous work[5] by the London School of Economics has recommended screening data attributes to appraise where it sits in a hierarchical framework of six criteria. This is shown in *Figure 23 – Data screening matrix*. The value of the data increases with satisfying attributes towards the top of the framework and decrease towards the bottom. In reciprocation however, it is generally easier to satisfy criteria near the bottom of the list.

[5] Dyer, B & Millard K, 2002, A generic framework for value management of environmental data in the context of integrated coastal zone management, Ocean & Coastal Management 45 (2002) pp59-75

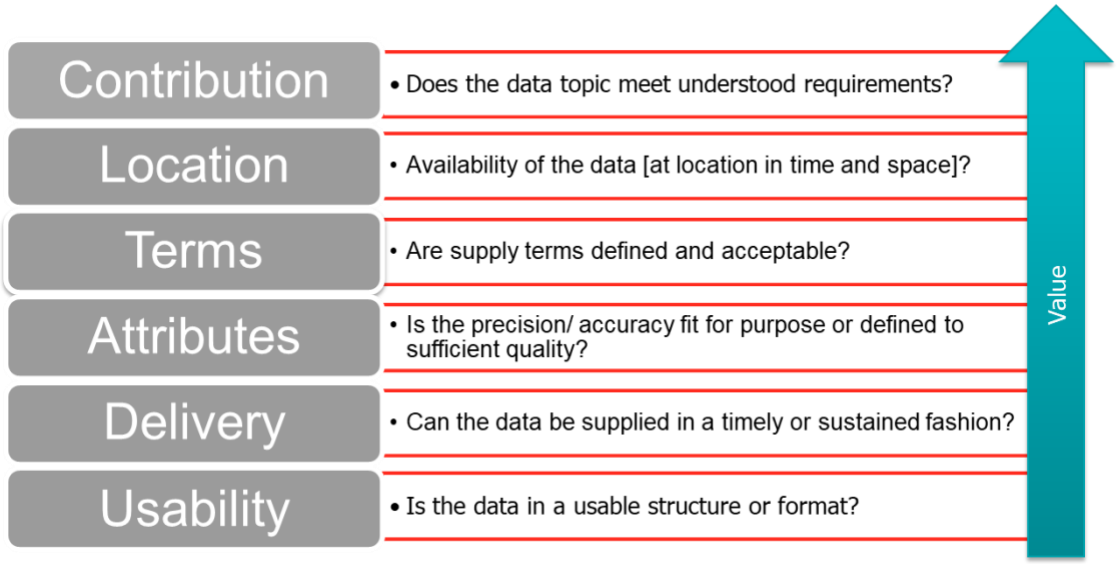

Figure 23 – Data screening matrix.

Two examples of the application of this approach are shown in *Figure 24 – Example of using value screening for data supplies* on the following page. In this approach, a simple 'traffic light' categorisation is used to appraise the data.

Any matrix that shows 'green' at the top and 'red' at the bottom like the school holiday data would indicate useful data that is not being adequately shared and investment to unlock it would be beneficial. Conversely, any matrix that shows 'red' at the top would indicate limited use of the data and therefore limited return from investment to undertake activities such as data cleansing or format transformation.

The pattern shown for the proprietary data supply in the second example is typical of many digital data feeds. There is a range of established practices to transform such data so that its representation in the matrix moves from 'amber' to 'green', however achieving this is both technically challenging and labour intensive. Undertaking such transformations requires both domain-specific technical capabilities and often a change in contractual and business relationships with data providers.

The process of transforming data from proprietary to standardised schemas not only supports data sharing and data reuse; the process provides for additional benefits such as:

- Data insights – enables data to be passed through an algorithm to derive information such as average or peak values
- Data quality monitoring – enables content of data to be measured and alerted if there are changes or missing data fields
- Sharing sensitive data – enables making sensitive data shareable by transforming into alternative less sensitive but useful data[6]

[6] Section 6.3 introduces the concept of data product specifications as a tool to define precisely data sets with particular for a characteristics for a particular purpose.

School holiday data

School holidays have a significant impact on accurate journey planning. During school holidays there is reduced traffic on the roads during the commute window both for schools and workplaces. At the same time there can be increased demand on journeys related to holidays and recreation. School holiday data (when schools are on holiday) are maintained by local authorities, but all do it differently and designed to be read by humans, not transport systems. This is despite there being dexchange schema available within NeTEx and DATEXII frameworks for this purpose.

Contribution	• Clear requirement for data that could have a big impact on journey planning
Location	• Data exists across the country
Terms	• Supply terms is 'to be established', but expected not to be a blocker
Attributes	• The precision/ accuracy/quality believed fit for purpose but not tested operationally
Delivery	• Cannot currently be supplied in a timely or sustained fashion
Usability	• Currently largely PDF, but an XML schema available.

Proprietary Loop-based Traffic Classification Data via DATEX II

Transport for West Midlands (TfWM) contracted Chordant, to share various proprietary transport source data feeds transformed into DATEXII schema. Chordant found that fitting proprietary traffic data into the DATEX II schema can be achieved but is not straightforward. As example a road loop traffic classification data feed contained an integer field called 'vehicle separation' or 'headway'. It wasn't sufficiently explicit if this was a measurement of time (s) or distance (m) thus meaning it could not be included in the DATEXII publication. The data feed supplier provided the clarification and the headway field could then be included in the DATEX II specification.

Contribution	• Clear requirement for data for operational and strategic transport planning
Location	• Coverage is suitable, however hard to determine as datasets does not indicate the specific location(s) in a standardized format; often refer to logical locations (see Attributes))
Terms	• Ownership and licencing terms vary a lot and are often not explicitly clear when a vendor system provides such data.
Attributes	• Attributes required are present, but not always fully defined with measurement units absent.
Delivery	• Can be supplied in XML or JSON through reliable and secure API from to data consumers
Usability	• The data is usable, but only to data transformation professionals; not an end-user or system requiring unambiguous content

Figure 24 – Example of using value screening for data supplies

6.3 Make use of product specifications to accurately define datasets

A FoT dataset may be created and shared using a range of standards and for a multitude of purposes. There is currently, however, limited evidence of using data product specifications to define datasets in an unambiguous manner to support their publication and use. Very often the discussion on data standards focussed on 'data content and structure' – which is just one consideration for a full data product specification.

Data product specification

A data product specification is a detailed description of a dataset or dataset series together with additional information that will enable it to be created, supplied to and used by another party. A data product specification may be created and used on different occasions, by different parties and for different reasons. It may be created by producers to specify their product or by users to state their requirements.

There are standards for data product specifications, for example, ISO 19131. ISO 19131 is adopted by the EC Inspire Directive to define data specifications for harmonised data exchange across Europe (see https://inspire.ec.europa.eu/Themes/Data-Specifications/2892). Although the standard is developed under the auspices of ISO TC211 (Geospatial Information) it is not specific to geospatial information. Factors included in a data product specification are outlined below:

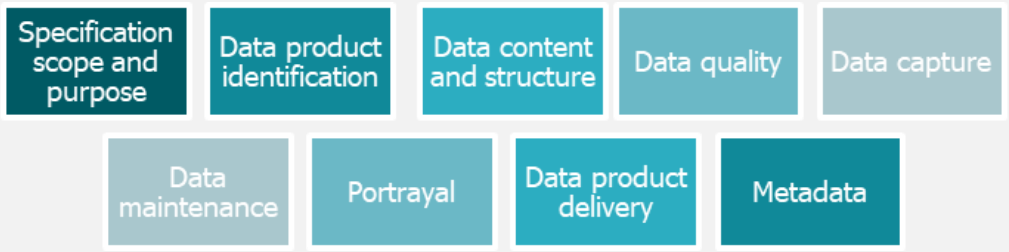

Figure 25 – Data product specification

For system interoperability, any dataset needs to be appropriately specified for its intended purpose. If the data product is very stringent (strongly-typed), then very reliable and precise data transfers can be realised – this is important for automated systems. However, the cost of this is increased data creation and management costs. If the data product is too loose (weakly-typed) then systems can be very agile and a range of technologies applied. The principle downside to this approach is that is imprecise and can only convey basic information with any accuracy. This is summarised in *Figure 26 – Parking example of strong and weak typing of data*

Figure 26 – Parking example of strong and weak typing of data

7. A community with appropriate authority is required to lead improvements in FoT data exchange

The recommendations outlined in this report require to be taken forward under the auspices of an appropriate governance board informed by relevant community members. There are several active communities within the FoT, some with a data focus however these are not tasked with driving the FoT forward as a data centric operation across all transport modes.

We recommend building on these structures to establish a permanent governance structure to operate FoT in a similar manner to other data-based industries.

7.1 FoT governance and mission

The governance and community model for FoT will reflect the type of enterprise it desires to be. Organizations such as Ordnance Survey, Met Office and British Geological Survey that have data product generation at their core are organized on the creation and distribution of definitive data products. Some of these data products support FoT operations. At the same time there are also other industries such as Finance and Telecommunications, who although do not create data products as an output, rely on data interoperability at the sector level to support core to their business.

As FoT develops and looks to implement the recommendations of this report, their impact will depend on the type of 'organization' it is. For example, the responsibilities it has towards

both the creation of data products and facilitating the flow of data amongst and between its actors. The governance structures (and overarching mission and vision) it has in place will be integral to realizing this.

7.2 FoT can learn from the experience of other industries

FoT is a new and emerging industry and many system interoperability issues identified came about through a lack of clarity as to how the market should operate and perform. A key part of this was the central concept of offering a mobility package and the roles and responsibilities for the delivery of the package, especially the associate liabilities should the package fail to be delivered. This included not only failure of, for example, a transportation component, but also failure of the data on which the FoT system relied. This topic emerged constantly throughout the validation workshop.

The financial services industry faced similar issues to the FoT sector as they extended the traditional financial services market to a wider ecosystem of actor in the context of Fintech. An industry wide governance board was established at the request of HM Treasury to systematically address these issues, as outlined in *Figure 27 – FinTech – Extending the financial services market.*

The FoT sector can also consider the experience from the telecommunications market (see *Figure 28 – Learning from telecommunications innovation*). The development of mobile phone technology opened the communication market for new industry players and the government acted to ensure regulation support optimal market conditions. In this situation, the government introduced incentives to the market in return for a kind of commercial franchise initiative. A similar approach in the FoT sector could yield similar benefits.

Fintech – governance and market evolution

To identify the key initiatives that need to be implemented to continue to support the growth of UK FinTech a panel was established with responsibilities to:

- Compile and keep up to date a list of all current initiatives designed to boost the growth of the FinTech sector.
- Prioritise the list to identify where there is greatest need for industry intervention to accelerate progress. A focus will be to where there are key blockages in delivery of these existing initiatives and where further collaborative engagement across FinTech and FS more broadly will accelerate progress.
- Develop action plans for these prioritised areas, identifying where the panel and the support function can add value and accelerate change.
- Consider what new initiatives are required to meet the Panel's 2020 FinTech vision.
- Maintain an open dialogue with Government on the progress of these measures. To provide a coordinated approach for the FinTech sector, supporting the government in disseminating key messages and announcements to all in the sector.

Full document: https://www.techcityuk.com/wp-content/uploads/2017/03/UKFinTechdeliveryPanel-DraftTermsofReferenceFinal-1-1.pdf

Activities of the panel and members: https://technation.io/about-us/fintech-delivery-panel/

Figure 27 – FinTech – Extending the financial services market

Telecommunications – learning from history

In January 1989, the UK Government published the document 'Phones on the Move'. Based on the responses received, the Government swiftly issued an invitation for companies/consortia to bid to operate new Personal Communication Networks (PCNs). From initial public consultation to award of PCN licenses was 12 months and nationwide networks launched around four years later. With PCN, the UK Government encouraged the new licensees to adopt a common GSM-based standard approach, rather than proprietary solutions.

This changed the direction of mobile communications in Europe **–** using GSM in additional spectrum yielded reduced costs, bigger scale and triggered massive inward investment into the UK. Use of the new spectrum opened-up the USA market to GSM; the key to GSM becoming a global standard, not just a European one. Costs to consumers plummeted and usage grew hugely.

Department of Trade and Industry, January 1989, Phones on the Move, Personal Communications in the 1990s **–** a discussion document.

Figure 28 – Learning from telecommunications innovation

Annex 1 Project

A1.1 Brief

Following the Department for Transport's (DfT's) consultation on the Future of Transport in the autumn of 2018, BSI, as the National Standards Body, was commissioned to analyse the current standards landscape for system interoperability and data exchange in the mobility and transport context. The aim of this project was to look at core transportation standards and widen this out to consider the broader context of FoT and data interoperability.

As FoT is an evolving market, an understanding was required of standards gaps, adoption and governance, including UK influence of these standards to provides a strategic reference for activities going forward. Specifically, this was to include:

- data exchange standards specific to the transport and mobility sector
- generic data exchange standards that could be applied to the transport and mobility sector
- data exchange standards in other sectors that could be applied to support the FoT.

The work excluded aspects of interconnect service delivery that are generic to all digital services. It is recognised that such topics are important, but to include them in scope would detract from considering the core FoT data iexchange issues under investigation. Excluded topics include:

- Cyber security
- Data privacy
- Digital identity management
- Payment services.

The work also excludes work directly related to connected and automated vehicles (CAVs). CAVs are often considered synonymous with FoT, however FoT has a far wider context. Currently, there is a programme of work looking at data and standards explicitly in the context of CAVs as outlined in *Figure 29 – Connected and Automated Vehicles Programme*, below:

Connected and Automated Vehicles (CAV) Programme

BSI is working currently with CCAV (Centre for Connected and Autonomous Vehicles) as part of a programme to accelerate the development of UK CAV industry capabilities in areas such as design, testing and manufacture of CAVs.

The programme workstream on CAV data is exploring standards to:

- promote the management of safety-critical and personal data
- support incident investigation
- improve reliability of sensor data for onboard perception systems
- improve mapping and classification of navigation object
- develop real-world testing of CAVs in simulated environments.

The CAV programme is not examining data needs and issues related to planning, designing and delivering Mobility as a Service models or non-CAV modes of transport.

Figure 29 – Connected and Automated Vehicles Programme

A1.2 Approach

BSI adopted a standard project management approach, with a dedicated project manager and an expert group to work with DfT to oversee the project to a successful conclusion. The project was divided into three work packages including:

1. **Scoping and scenarios**
   Establishing a small expert group to scope scenarios and use cases that illustrate data interoperability, based on real-world examples and requirements e.g. multimodal transport to test data interoperability dependencies. The members of the Expert Group are given in A1.3.
2. **Standards landscape**
   Using output from the scenarios, searching for formal and industry standards. This included technical standards for data exchange as well as standards for data policy and governance that define how data exchange should take place.
3. **Standards insight and validation**
   A draft report of the findings was presented and analysed at a workshop with industry stakeholders. The topics discussed at the validation workshop, along with the attending organisations is given in Annex 2. The findings, including recommendations were summarised and presented to DfT's data board.

The following sections of this report outline the approaches and findings of each of these three activities.

A1.3 Expert Group

The organizations represented on the BSI Expert Group were:

- BSI
- Chordant
- Conduent
- Conigital
- DfT
- IM23
- ITSO
- Oxfordshire County Council
- Transport Systems Catapult

A1.4 Organisations at validation workshop

The following organizations were represented at the validation workshop:

- Arup Group Ltd
- Beate Kubitz
- BSI
- Cambridgeshire County Council
- Centaur Consulting Ltd
- Climate Associates Ltd
- Cobalt Telephone Technologies Ltd (RingGo)
- Department for Transport
- First Group
- Highways England
- HORIBA MIRA Ltd
- Hyperlocal Cities Ltd
- ITS United Kingdom
- ITSO Ltd
- MobiHub Ltd
- MTR Corporation Ltd
- Nottingham Trent University
- Optibus Ltd
- Oxfordshire County Council
- Reynolds Consultancy Ltd
- RTIG-Inform
- S.H.E. Ltd
- Steam Intellect
- Suffolk County Council
- South Yorkshire Passenger Transport Executive
- Thomson Reuters Corporation
- Transport Systems Catapult
- Traveline UK
- West Yorkshire Combined Authority

A1.5 Scope of validation workshop

The Validation workshop was help in March 2019 and considered questions in the following three sessions:

Session 1 – Standards at the FoT sector level

- Roles: Is there sufficient clarity overall of the roles and responsibilities for all actors to facilitate data interoperability in an FoT context? Is any specific guidance needed to ensure everyone can work together to support data interoperability?
- Governance: The standards landscape results would suggest an absence of industry-wide specific guidance on best practice for data interoperability. These are plenty of standards that cover all aspects of data interoperability, but not how they should fit together and applied in the FoT context. Do you agree with this?
- Infrastructure: Is (a lack of) supporting infrastructure an issue? So although the relevant standards exist, they are not realized in practice, e.g. registries of existing data specifications and APIs.

Session 2 – Standards at the organisational level:

- Are there good examples of organisational procedures/practices that facilitate data interoperability in the FoT sector by particular organisations?
- The landscape results would suggest that what is lacking is guidance or specifications on how to perform particular tasks, e.g. data publishing for re-use. Is this the case? What guidance do you feel is needed for organizations from your perspective?
- There seems to be blockers around liability management and multi-actor fulfilment. This is not strictly a data interoperability issue, but is it something that affects your organisation? What guidance is needed in address this?

Session 3 – Standards at the data level

- The scenarios and use cases highlighted little issue with the technology end of the data interoperability stack. At the same time there is an extensive suite of standards covering the technologies of data interoperability, also suggesting 'no issues'. Is this correct or are there specific technology issues that limit data interoperability in the FoT context?
- Interoperability issues with data level standards seem to be concerned with data semantics and data packaging such that 'consistent' data can be queried and accessed, especially by data aggregators. Is this correct?
- Are there particular data types (e.g. particular topic, or historic data, or real time data) that causes interoperability barriers? How do these barriers manifest themselves and how could they be overcome?

Annex 2 FoT data topic ontology

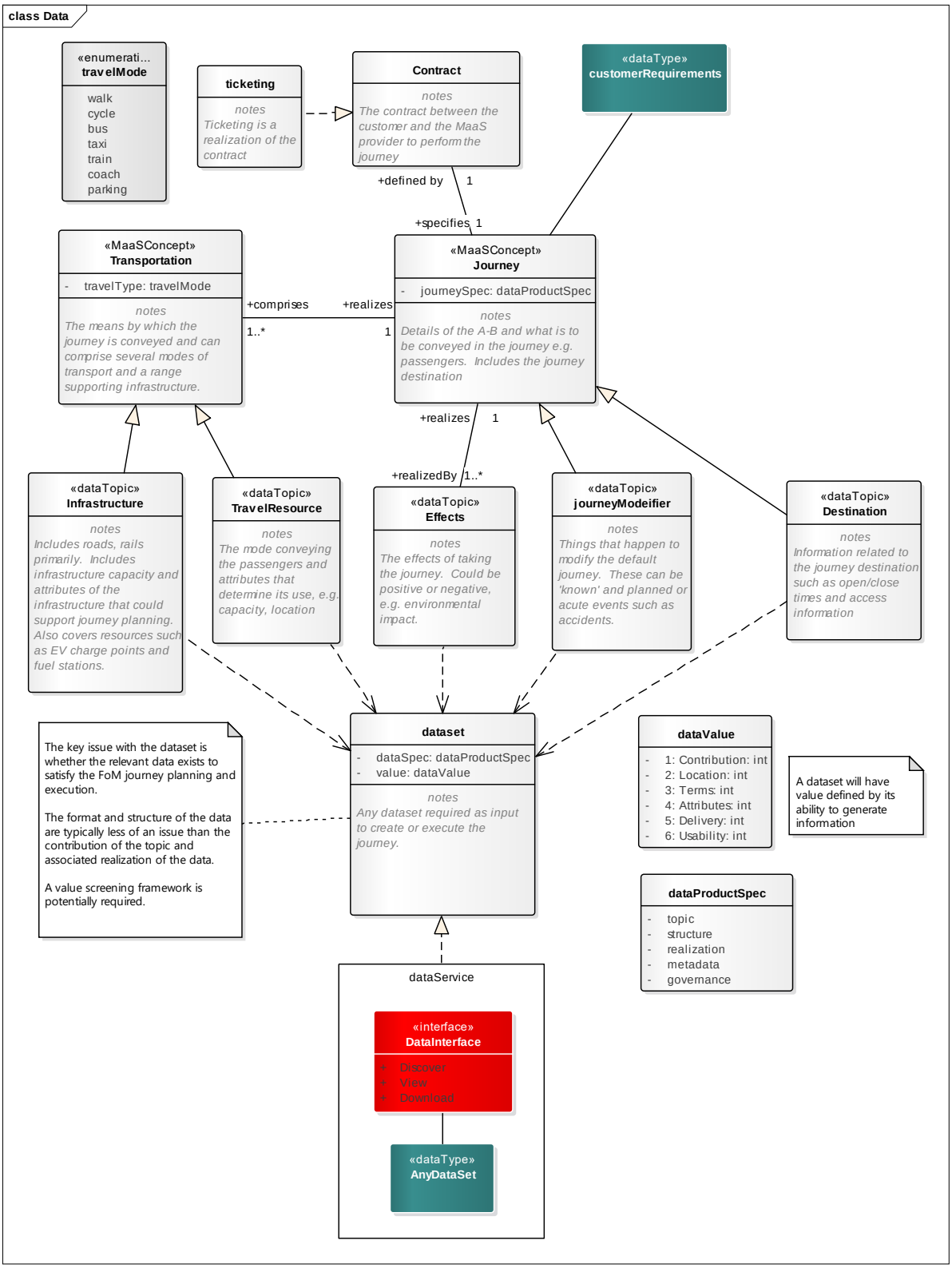

Figure 30 – FoT Data ontology derived from this research

Annex 3 NeTEx and GTFS

NeTEx and GTFS have semantic similarity. As a result of the widespread use of GTFS in Google services CEN TC 287 has undertaken agreed mappings between NeTEx and GFTS. *Figure 31 – Example NeTEx and GFTS mapping is an example mapping* published at http://netex-cen.eu/

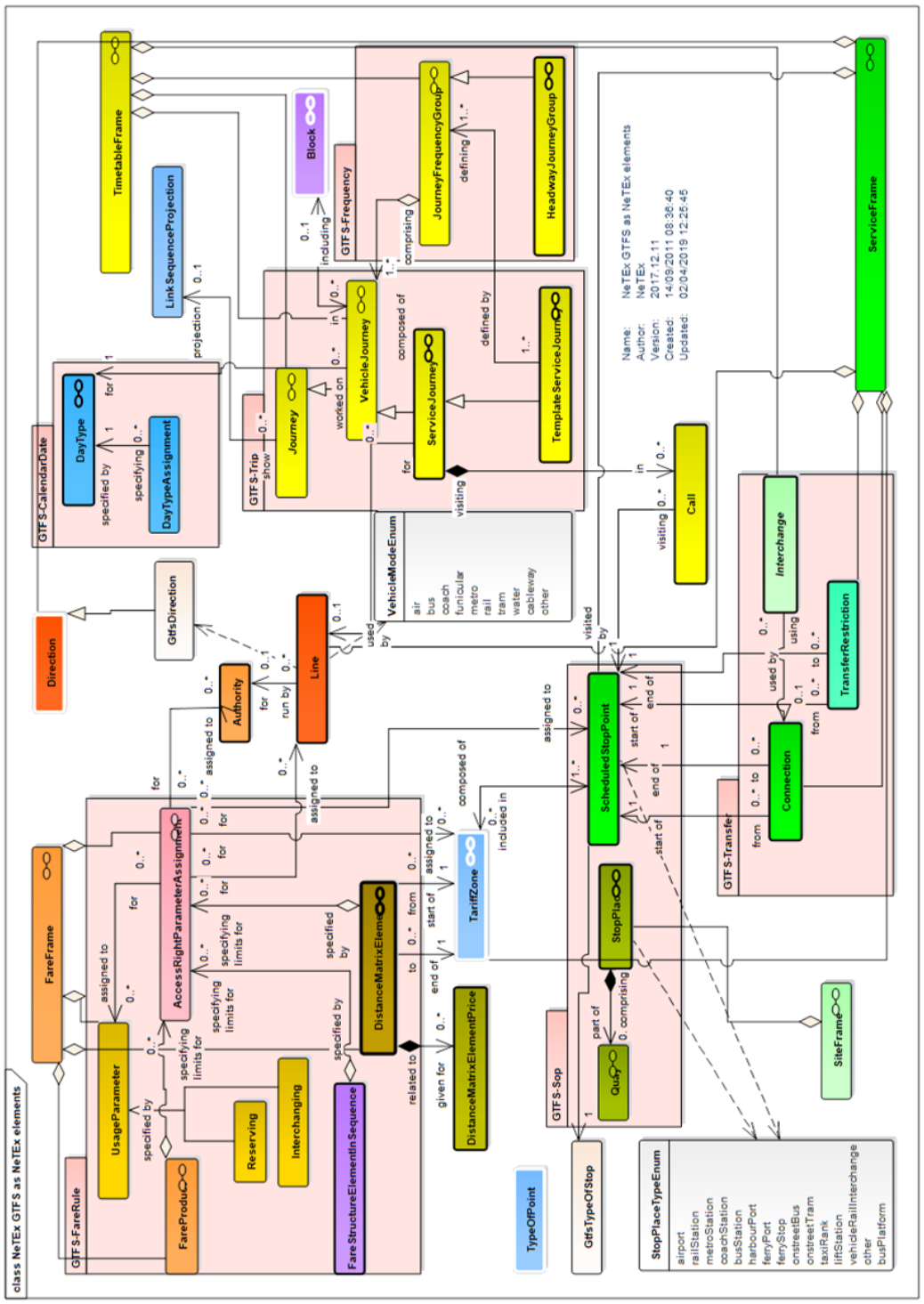

Figure 31 – Example NeTEx and GFTS mapping

Annex 4 Core standards for transport data exchange

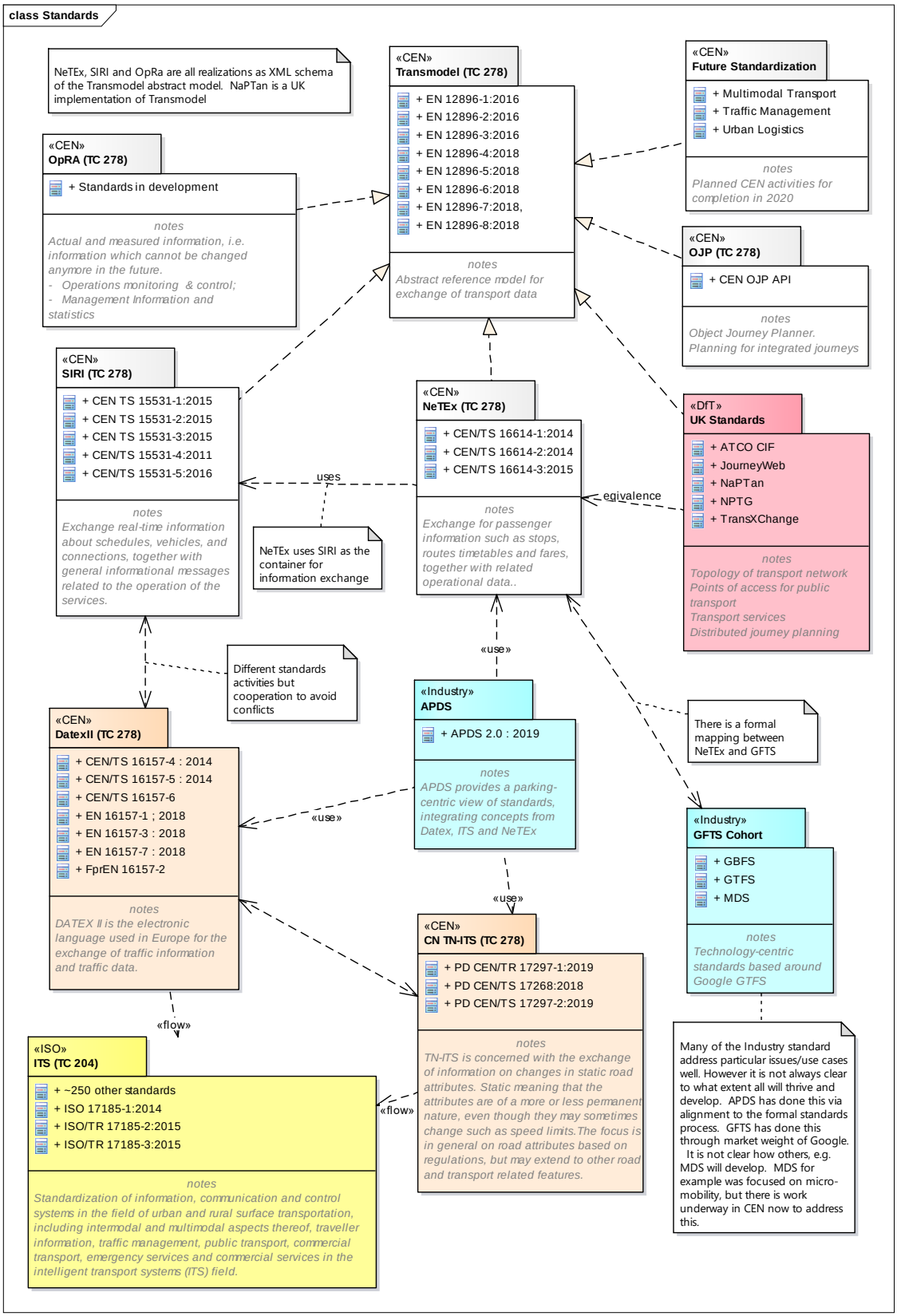

Figure 32 – Core standards for transport data exchange

Annex 5 Standards development organisations

For the purpose of this research, formal standards searches have been carried out for the following list of countries and standards development organisations worldwide:

- Leading European standardization organizations:
  - Germany (DIN)
  - Austria (ON)
  - Belgium (NBN)
  - Denmark (DS),
  - Spain (AENOR)
  - France (AFNOR)
  - Italy (UNI)
  - Norway (STANDARD ONLINE AS)
  - Netherlands (NEN)
  - Poland (PKN)
  - Czech Republic (CSN)
  - UK (BSI)
  - Russia (GOST)
  - Slovakia (UNMS)
  - Sweden (SIS)
  - Switzerland (SNV)
  - Turkey (TS),
  - Lithuania (LSB)

- European and international standardization organizations:
  - CEN European Committee for Standardization
  - CENELEC European Committee for Electrotechnical Standardization
  - ETSI European Telecommunications Standards Institute
  - IEC International Electrotechnical Commission
  - ISO International Organization for Standardization

- US-based standardization organizations:
  - ANSI American National Standards Institute
  - API American Petroleum Institute
  - ASME American Society of Mechanical Engineers
  - ASTM American Society for Testing and Materials
  - EIA Electronic Industries Alliance
  - IEEE Institute of Electrical and Electronics Engineers
  - NEMA National Electrical Manufacturers Association
  - NFPA National Fire Protection Association
  - SAE Society of Automotive Engineers
  - UL Underwriters Laboratories and over.
- Others:
  - ITU International Telecommunication Union
  - JSA Japan Standards Association
  - CSA Canadian Standards Association
  - SABS South African Bureau of Standards.

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