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Smart city concept model — Guidance for establishing a model for data interoperability

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National foreword

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INTERNATIONAL STANDARD

ISO/IEC 30182

First edition
2017-05

Smart city concept model — Guidance for establishing a model for data interoperability

Modèle de concept de ville intelligente — Lignes directrices pour établir un modèle d'interopérabilité des données

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Foreword

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ISO/IEC 30182 was prepared by the British Standards Institution (BSI) (as BSI PAS 182:2014) and was adopted, under a special “fast-track procedure”, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, in parallel with its approval by the national bodies of ISO and IEC.

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0-Introduction

0.1 General

A defining feature of smart cities is the ability of the component systems to interoperate. This International Standard defines a concept model, and gives guidance to decision-makers on applying it to promote interoperability for data created, used, and maintained by a city across all sectors, on behalf of, and in collaboration with, its citizens.

Data is a resource that can transform the capability of a city, enabling the development of systems and services, and supporting informed decisions. However, decision-makers and citizens are unlikely to have the necessary expertise and are likely to rely on data specialists to deliver benefits from data to meet the objectives for their city.

Data is often labelled using language and terms from the sector that initially collected it for the provision of a service. For example, the health sector might refer to a patient and a care plan, social services might refer to a client, the education sector might refer to a pupil and a curriculum, and the transport sector might refer to a passenger and a travel plan.

Each sector has its own models and terminologies that enable data to be discovered and understood within that sector, but form a barrier to interoperability with other sectors.

The smart city concept model (SCCM) outlined in this International Standard addresses this lack of interoperability by defining an overarching framework of concepts and relationships that can be used to describe data from any sector. See Annex A for an example where terms from the health informatics concept model have been mapped to the SCCM. Mapping terms from many sectors to the SCCM provides a basis for discovering and sharing data about the same thing, from many sources.

Sharing data across a city requires more than the interoperability covered by the SCCM. For example, ensuring compliance, privacy, security, integrity, availability, and quality of data also needs to be considered by decision-makers. For example, data protection legislation and its provisions for usage of personal data is likely to impact some of the structural relationships between data from different systems that such sharing would introduce.

Although these concerns are beyond the scope of this International Standard, which focuses on the semantics of data, the bibliography provides a list of good practice materials that address these wider considerations. BSI PAS 181 provides guidance on the governance of a smart city programme and the management of data assets within it, and this International Standard is a tool to help with the implementation of this.

It is critical that decision-makers are involved in the development of a data ecosystem to support the development of the city. In the current landscape datasets are typically created by an organization for one particular purpose, and the potential for secondary use is not unlocked.

This International Standard is intended to facilitate discussions between decision-makers from each sector and the specialists who build and design the systems and services that enable the city to function. The components of the SCCM could form the basis of these discussions, by aligning ontologies to discover where data from different sectors is about the same thing or is related in a useful way. Use of the SCCM over time could increase the data literacy of non-specialists, allowing further value in city data to be unlocked, and reused, either in its original form, or as derived insight.

Each city is likely to take its own approach to organizing its data, reflecting the priorities and needs of the city, and the agencies and people participating. A citywide data ecosystem based on the SCCM, combining data from many sources, for the benefit of both the city and the citizen could

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support the reuse of data to improve services and gain insight into the quality of life of the city's citizens.

0.2 Relevance

This International Standard aims to look beyond the current use of data to facilitate city services, and encourage decision-makers to explore the reuse of data as a resource to innovate the future direction of systems and services. This approach could help organizations to develop a future landscape based on the interoperability of data, an approach that is relevant not just in cities, but also wherever many organizations provide many services to many communities within a place.

The SCCM assumes that structured, semi-structured and unstructured data is present in a city, and can be modelled using the concepts presented.

Four key types of insight have been assumed to be required when sharing data in a city:

- **Operational insight** – which examines characteristics of things such as buildings, communities and organizations, using data to evidence and improve their value for the city;
- **Critical insight** – the real-time monitoring of incidents and current cases, involving all relevant organizations from across sectors, who work together to achieve the desired outcome or response;
- **Analytical insight** – the exploration of the data ecosystem to determine patterns, correlations and predictions. This allows the development or innovation of systems or services, impact assessment of proposed changes to systems or services, or the evidencing of challenges and opportunities for the city; and
- **Strategic insight** – an overarching approach that examines outcomes related to strategic objectives, decisions and plans.

The SCCM is relevant to both open data, shared under an open licence, and closed data, where the security and privacy of the content is protected. When the same concept model is applied to all, it becomes possible to track where statistics, and analytics have been derived from operational data, and to observe the impact of strategic decisions.

Figure 1 illustrates the four levels of insight identified as present in a city. The diagram is not intended to represent insights as a hierarchy, rather it identifies that these insights will be present and might be stored and used in a variety of ways. The interlocking representation is designed to identify the fluid nature of the data within a city, constantly evolving and usable for all of the insights that might be gained from city data.

Also illustrated are a number of the SCCM concepts and how they are likely to be present to enable the insight to be gained, and subsequent action taken using the data.

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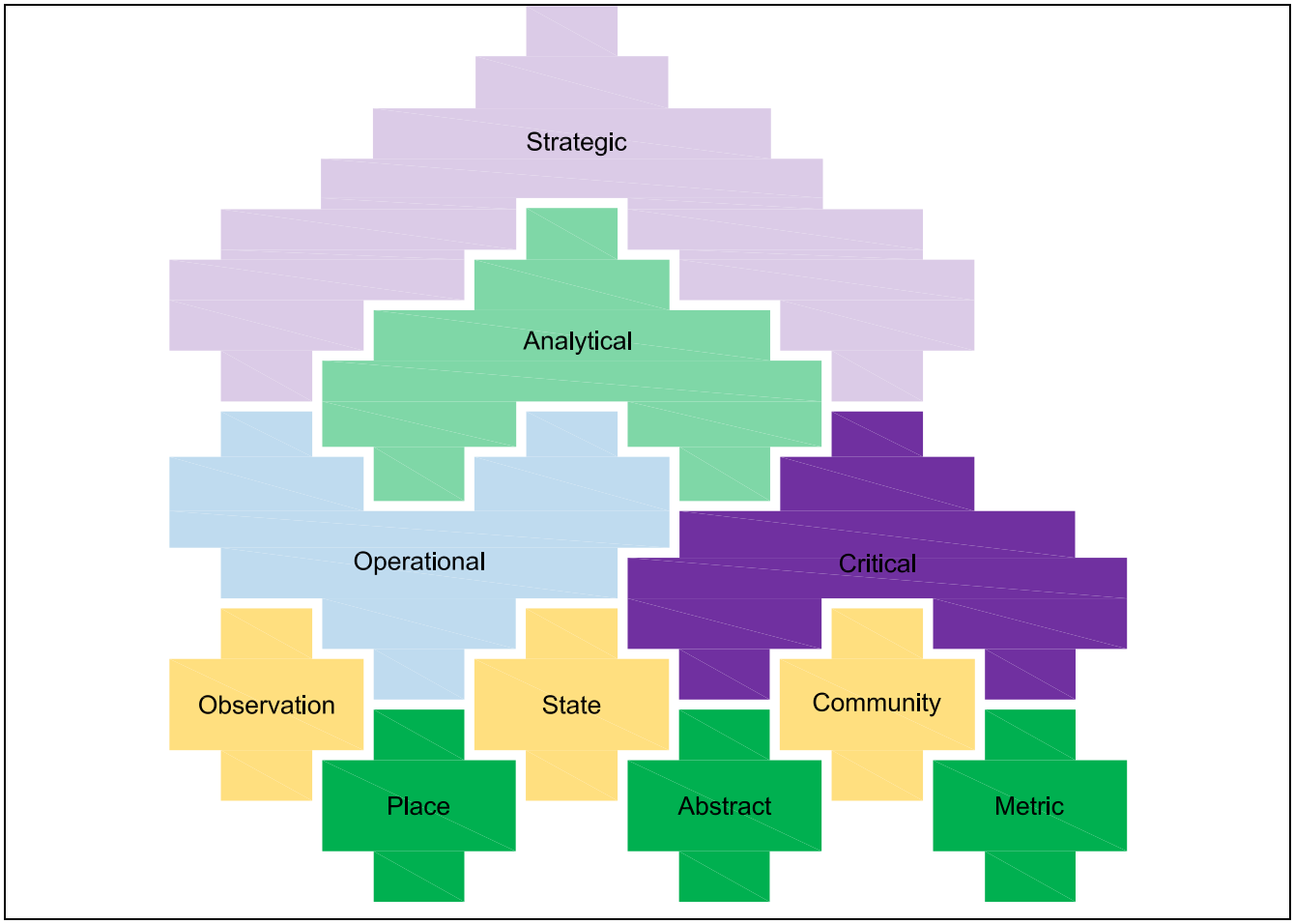
Figure 1 – Smart city levels of insight



The SCCM is assumed to be used for a variety of unstructured and semi-structured data streams as well as the structured data which currently powers many cities and organizations. This document contains a variety of useful data such as:

- METRIC: The public transport system has to cope with around half a million trips per day within the city.
- ASSUMPTION:
  - There could be up to an additional 150,000 people in the city by 2031.
  - It is estimated that the total demand for travel on the public transport system could rise to 4 million trips per day by 2031.
- OBJECTIVE:
  - Fewer cars on the road than today, despite significant population growth.
  - A public transport system that enables people to easily and quickly access all areas of the city.
  - Safer roads for pedestrians and cyclists.

Making data available, using the SCCM, enables organizations in a city to collaborate, for instance by sharing ASSUMPTIONs or OBJECTIVEs to gain strategic insight.

The strategic insight gained could also use operational insight from sensors in a city, such as data related to the average speed of traffic at a location over a period of time, this data would be represented in the SCCM as:

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An OBSERVATION of average speeds (STATEs) of the traffic (ABSTRACT) at a location (PLACE).

In order to gain critical insight a Twitter stream might also be used which after processing might contain entries such as:

"@cityX stuck in traffic for an hour in the city centre" created_at Fri Jul 20 *15:20:00 +0000 2014*

"@cityX where is the bus #stranded" created_at Fri Jul 20 *15:20:54 +0000 2014*

"@cityX nowhere to park again!" created_at Fri Jul 20 *15:21:03 +0000 2014*

Cities might choose to use certain Twitter handles or hashtags to allow citizens to contribute to the critical insight of their city.

After sentiment analysis of the Twitter stream the critical insight would be represented in the SCCM as:

Number of commuters (COMMUNITY) who are dissatisfied (METRIC).

0.3 Data sharing

The sharing of data for the benefit of all stakeholders is at the heart of smart city aspirations. Data can be used in real time, from sensors and tracking devices, through to the use of data to develop longer term plans to improve the well-being of citizens and businesses.

Involvement of the private sector will often be necessary for a smart city initiative. It is important that private sector partners realise that their participation may make their data subject to public sector controls.(e.g. data protection legislation).

The traditional approach to data sharing has required organizations to create individual agreements for each initiative where data is shared. Where a single organization has needed to share data from many sources, this would have required a multitude of agreements, relationships, data formats, and vocabularies.

A smart city consists of organizations across all sectors, facilitated by the sharing of data, based on a common framework of its meaning, and consistent use of identifiers and classifications. Cities organized in this way could experience the following benefits:

- reduced cost as the need to recollect and verify data is removed;
- integrated city systems and services driven by data;
- a common understanding of the needs of communities;
- shared objectives, collaboratively developed and evidenced using data;
- engaged and enabled citizens and communities;
- transparency in decision-making;
- development of partnership models;
- businesses and communities co-creating innovation; and
- consequently, improved quality of life for citizens.

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Smart city concept model — Guidance for establishing a model for data interoperability

1 Scope

This International Standard describes, and gives guidance on, a smart city concept model (SCCM) that can provide the basis of interoperability between component systems of a smart city, by aligning the ontologies in use across different sectors. It includes:

- concepts (e.g. ORGANIZATION, PLACE, COMMUNITY, ITEM, METRIC, SERVICE, RESOURCE); and
- relationships between concepts (e.g. ORGANIZATION has RESOURCEs, EVENT at a PLACE).

The SCCM does not replace existing models where they exist, but, by mapping from a local model to a parent model, questions can be asked about data in a new and joined-up way.

This International Standard is aimed at organizations that provide services to communities in cities, and manage the resulting data, as well as decision-makers and policy developers in cities.[1)]

The SCCM is relevant wherever many organizations provide services to many communities within a place.

It does not cover the data standards that are relevant to each concept in the SCCM and does not attempt to list or recommend the sources of identifiers and categorizations that cities map to the SCCM.

The SCCM has been devised to communicate the meaning of data. It does not attempt to provide concepts to describe the metadata of a dataset, for example, validity and provenance of data.

It covers semantic interoperability, that is, defining the meaning of data, particularly from many sources. It does not cover other barriers to interoperability, some of which are described at **3.2**.

2 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 37100 and the following apply.

2.1 category
code for a definition of one or more common characteristics that can be used to classify things

2.2 class
specialization of a concept with common properties that can be the template for a specific data structure

2.3 concept
unit of knowledge created by a unique combination of characteristics

[SOURCE: ISO 11179-2:2005, **3.10**]

[1)] Decision-makers and policy developers are further described in BSI PAS 181.

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2.4 concept model
set of defined concepts and the relationships between them, chosen to be independent of design or implementation concerns, that can be used to describe a domain

2.55 data interoperability
interoperability concerning the creation, meaning, computation, use, transfer, and exchange of data

[SOURCE ISO/IEC 20944-1:2013, **3.21.12.4**]

2.6 dataset
identifiable collection of dataEXAMPLE Integer, Real, Boolean, String, Date, and GM_Point.

Note 1 to entry: A data type is identified by a term, e.g. Integer.

[SOURCE: ISO 19115-1:2014, **4.2**, modified]

2.7 directed graph
diagram in which concepts are represented as nodes, and relationships as edges between nodes, where the direction of the edges corresponds to the label for the relationship

2.8 entity
thing with distinct and independent existence for which a concept can be assigned

2.9 identifier
linguistically independent sequence of characters capable of uniquely and permanently identifying that with which it is associated

[SOURCE: ISO 19135-1:2015, **4.1.5**]

2.10 interoperability
ability of systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together

[SOURCE: ISO 37100:2016, **3.6.3**]

2.11 ontology
formal representation of phenomena of a universe of discourse (2.15) with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships

[SOURCE: ISO 19101-1:2014, **4.1.26**]

2.12 relationship
way in which two concepts can be connected

2.13 sector
classification for organizations that provide complementary functions

2.14 smart city
effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens

[SOURCE: BSI PAS 180:2014, **3.1.62**]

2.15 universe of discourse
view of the real or hypothetical world that includes everything of interest

[SOURCE: ISO 19101-1:2014, **4.1.38**]

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3 Using the SCCM

3.1 General

The SCCM can be used to:

- catalogue data holdings from different organizations, leading to improved discovery and reuse;
- promote definitive and authoritative identifiers and categorizations as reference information for each concept against which city data can be harmonized, and joined up;
- agree data standards for specialisms within a concept that are of particular interest to a city;
- understand datasets from other sectors;
- construct a local data ecosystem where data can be contributed and consumed by different organizations and people in a city.

BSI PAS 181 provides guidance on the development, agreement and delivery of smart city strategies. It presents this as a set of guidance notes, all of which need to be considered throughout the enactment of a smart city programme.

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Those that have particular applicability to data interoperability and sharing are listed in Table 1. All guidance notes should be reviewed within any smart city data-sharing project.

Table 1 – Relevance of BSI PAS 181 guidance notes to this International Standard

BSI PAS 181 guidance notes	Relevance to this International Standard[2)]
[B1] City vision	Data sharing activities need to be able to be related to the city vision.
[B2] Transforming the city's operational model	Deliverables need to contribute to the new integrated operating model and its information architecture.
[B3] Leadership and governance	Overarching leadership and governance need to be applied to data-sharing activities.
[B4] Stakeholder collaboration	Stakeholder engagement needs to include data owners and planned users.
[B5] Procurement and supplier management	Contractual arrangements need to address the maintenance and availability of data for as long as it is required.
[B6] Mapping the city's interoperability needs	Policy products that identify barriers to interoperability and address the mapping of city concepts.
[B7] Common terminology & reference model	Provides a common vocabulary for concepts across the city and their relationships.
[B9] Empowering stakeholder and service transformation	Where legally possible, shared data needs to be made open by incorporating it into an open data platform for downstream exploitation by citizens and businesses.
[B10] Delivering city-led service transformation	There needs to be an integrated business and information architecture within which data-sharing initiatives sit to guard against the building of new silos.
[B11] Identity and privacy management	Trust by citizens and businesses needs to not be threatened by data-sharing activities.
[B13] Resources mapping and management	Key assets need to be mapped and governance processes established to allow them to be managed separately from their original intended use. Effective data asset management is essential.
[B14] Open, service-oriented, city-wide IT architecture	Key principles underpinning the architecture need to address the means of holding data securely and, where appropriate, making it open for reuse.

3.2 Other barriers to interoperability

This International Standard focuses on semantic interoperability, that is, defining the meaning of data from many sectors. However, there are many other barriers to interoperability across a city. A city should also consider a framework for interoperability for each of the topics listed in Table 2.

[2)] This column only provides a high-level indication of the relevance of BSI PAS 181 guidance notes and is not intended to be exhaustive. That document and those generated by the smart city programme as a result of its use need to be referred to for the full details. (BSI PAS 181 provided the starting material for ISO 37106, currently under development.)

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Table 2 – Other barriers to interoperability

Barrier	Description
Privacy	Conforming to human rights and data protection requirements when handling data that refers to people.
Security	Protecting data from accidental or malicious destruction, or unauthorized access.
Integrity	Avoiding data corruption as data is handled, copied, processed, and transported.
Availability	The degree to which data needs to be consistently available to meet a purpose. Particularly relevant to real-time systems, which rely on the availability of data to perform. Availability can include normal operating services, and the time necessary to recover from a disaster.
Quality	Characteristics of data such as completeness, validity, consistency, timeliness, accuracy, precision, and tolerance. It is important to understand the quality of data when considering if it can be reused for a new purpose.
Provenance	The traceability of data, from collection, through each transformation, analyses and interpretation.

4 Concept, relationship and the SCCM

4.1 Concept

A concept defines a generalization of a type of thing. The definition of a concept in the SCCM is unlikely to be sufficient to describe a piece of data, but can be the foundation for data sharing between organizations that otherwise don't share a common business language.

Each concept has been selected for relevance in describing data that is valuable to share across a city, and for applicability across different sectors.

Each concept is defined by:

- a name;
- a definition that is sufficient to consider if an entity fits a concept;
- where relevant, notes that explain how the concept is used;
- examples of classes that would fit the concept.

When considering definitions for each concept in the SCCM, the *Oxford English Dictionary* [1] definition for each concept was taken into account.

4.2 Relationship

A relationship describes how two concepts are connected when describing data for a city.

Concepts and relationships in the SCCM are simple truisms that apply to all sectors and uses of data across a city.

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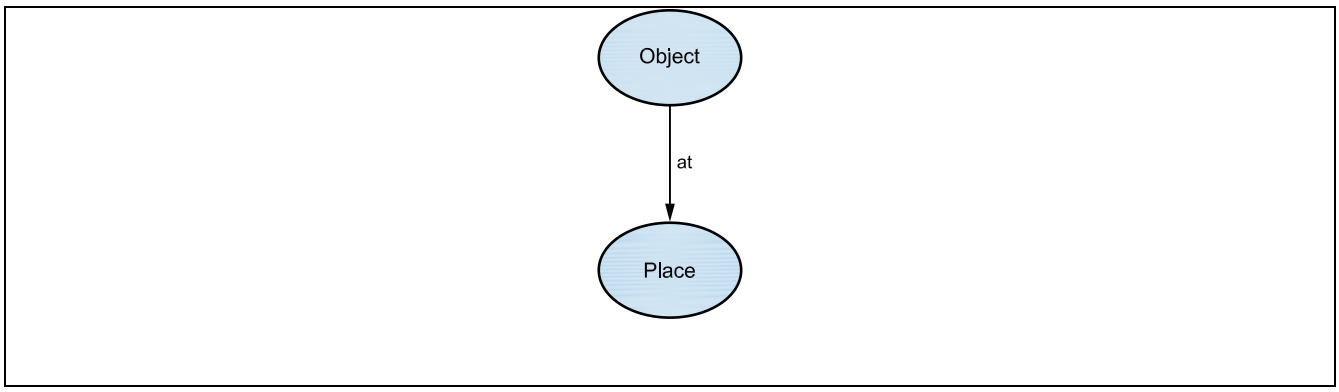
The relationships defined in the SCCM are not exhaustive; that is, any concept can be related to any other concept. The relationships defined in the SCCM have been selected to illustrate common patterns that occur across many sectors.

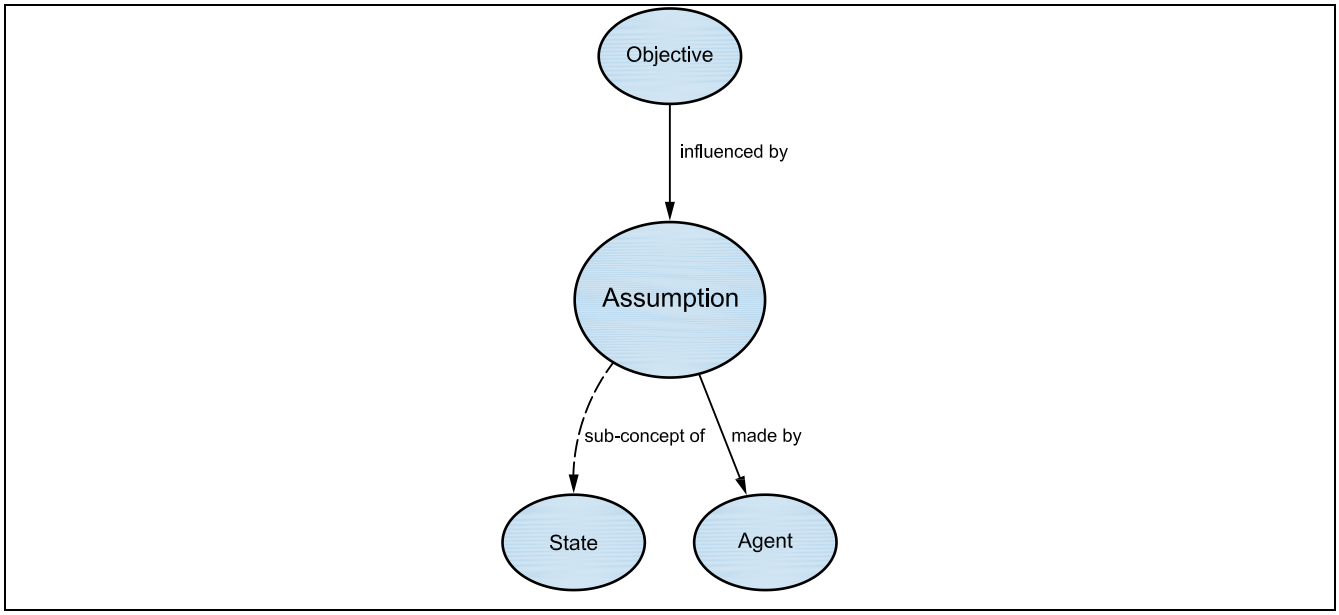
The SCCM shows concepts and relationships as directed graphs (Figure 2).

Figure 2 – Example of a directed graph



A directed graph is shown for each concept in the SCCM, defining each of the relationships for that concept (Figure 3).

Figure 3 – Example of a directed graph for a concept



Some concepts are defined as sub-concepts of other concepts. These are defined where specializing a concept is particularly relevant to a city, such as BUILDING. Relationships that are defined for a concept are also valid for its sub-concepts (Figure 4). Sub-concept relationships are shown using dashed lines.

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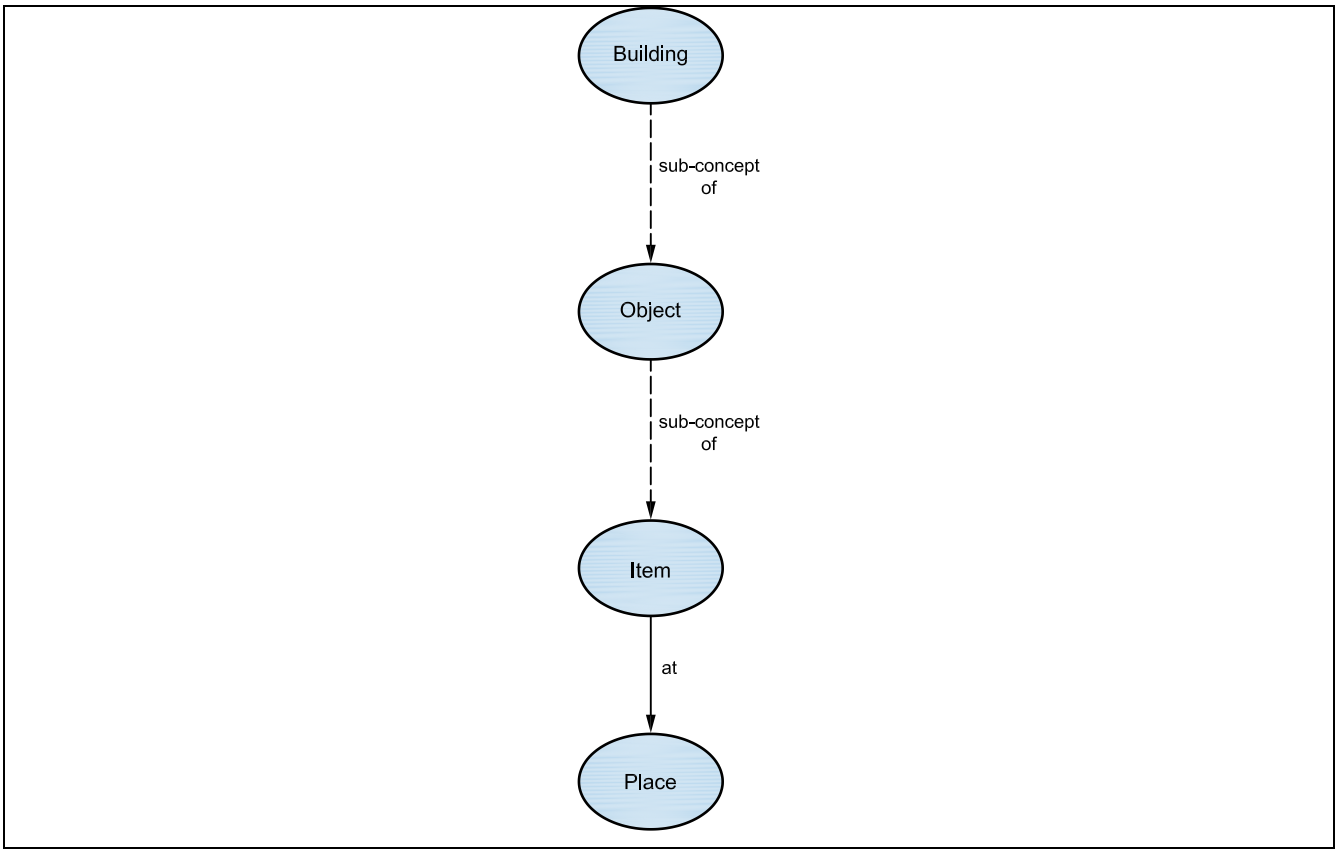
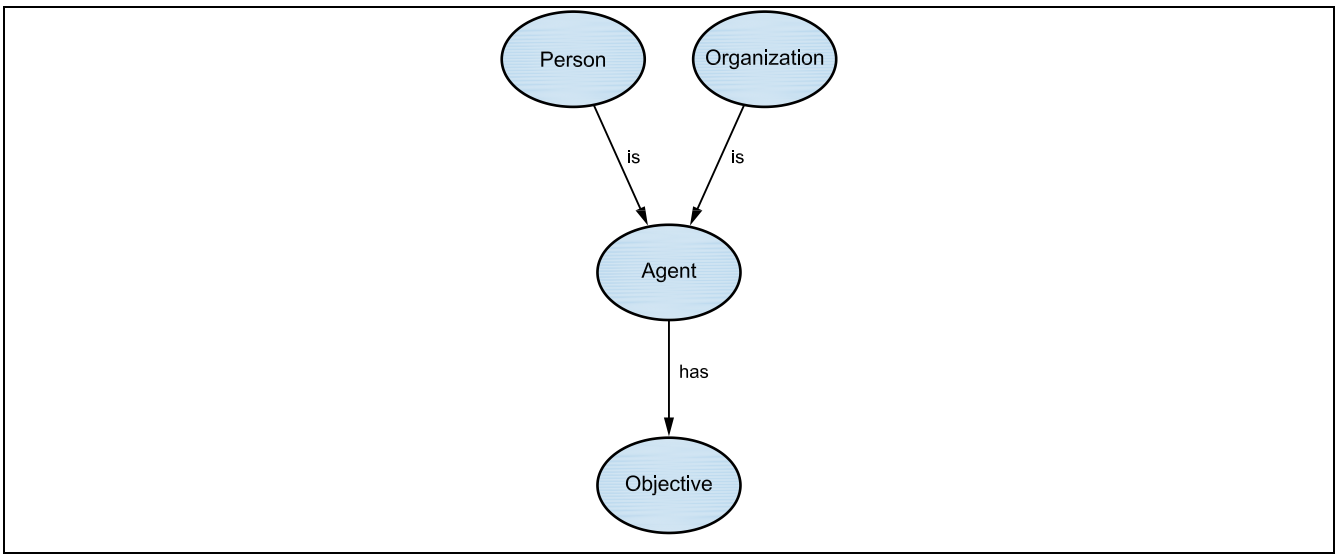
Figure 4 – Example of sub-concepts



Some concepts in the SCCM have been created to represent a group or choice of concepts. These are designed to reduce the number of relationships that would otherwise have been created. For example, the AGENT concept combines the concepts of PERSON and ORGANIZATION, which then enables a single relationship to be valid for both (Figure 5).

Figure 5 – Example of a group concept



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When the SCCM is viewed in its entirety, the number of concepts and relationships can be overwhelming and it becomes hard to see how data would be mapped to it. The SCCM contains a series of views in which a small number of concepts and relationships have been selected to illustrate a data-sharing scenario across a city.

Further views can be created by selecting concepts and relationships from the SCCM.

5 Mapping a dataset to the SCCM

5.1 Dataset

A dataset is a container of information, where that information has some repeating structure.

Where a dataset can be mapped to the SCCM, it can be linked to other related data and shared with organizations and people from beyond the originating sector.

The first step to mapping a dataset to the SCCM is to identify the separate entities that the data describes. An entity is a thing with distinct and independent existence, particularly when other data, from other sources, might also refer to the same thing. Figure 6 gives an example of a dataset in a city.

Figure 6 – Example of a dataset listing reported faults to lamp posts

Case Number	Lamppost Reference	Location	Reported Date	Reported By	Fault
1234	ab123	Outside number 10 Hugh Street.	04/03/2014	Bert Smith	Light flickering

In this example, there are entities for:

- the case;
- the lamp post;
- the location of the lamp post;
- the reporting of the fault;
- the person reporting the fault; and
- the condition of the lamp post.

Mapping these entities to the SCCM would give:

Entity	Concept
Case	CASE
Lamp post	OBJECT
Location	PLACE
Report	EVENT
Reporter	PERSON
Condition	STATE

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5.2 Class

Concepts from the SCCM are unlikely to be sufficient to adequately define the meaning of data. The meaning and structure of entities in datasets are likely to be fully defined in a data model, as a class. Where these classes can be mapped to the SCCM, it becomes possible to read the same, or related, data across datasets.

5.3 Identifier and category

For entities of the same class, an organization can use a set of codes to uniquely identify an individual instance (e.g. the lamp post reference in **5.1**). By using a consistent code in many datasets, an organization can join up its data where it refers to the same entity.

An organization can create its own codes, or it can reuse codes from another organization, particularly where that organization is a definitive source of information for that class of entity. For example, Companies House provides a registration number for each company in England and could be considered the definitive source for that information.

These codes are identifiers when they can be used to name an individual instance of an entity.

Where a city can agree a common identifier set for a type of entity, different organizations can share information about it. For example, using common identifiers for lamp posts could join up data about:

- energy use;
- accidents; and
- faults.

Categories provide a set of terms that can be used to group things for a type of entity (e.g. a type of health condition). By using consistent categories for a type of entity, organizations can discover groups of data, statistics and insight.

The SCCM proposes a set of concepts that can be used to organize and promote consistent use of identifiers and categories across a city. Organizations might then also publish the types of entity that their data describes as a class.

5.4 Prime concept

A prime concept is one that can be used to map city data.

A list of prime concepts is provided at Table 3. Each concept is described in detail in Clause **7**.

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