# EMPOWERING SMART CITIES: LEVERAGING DATA INTEROPERABILITY FOR ENHANCED COLLABORATION

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***Pregledni članak***

## Abstract

*Smart cities and communities are rapidly gaining importance alongside the evolution of digital technologies. It is estimated, that more than 70% of Europe's population will reside in urban centers in the future, emphasizing the need for smart solutions for global challenges. Data interoperability, as outlined by ISO/IEC 30182:2017 standard, is pivotal for smart city development, enabling efficient collaboration across various community sectors. This standard guides establishing a model for data interoperability, facilitating coordination between decision-makers and experts across different domains. In essence, data serves as the cornerstone for informed decision-making and system development in smart communities, where accessing and comprehending diverse datasets can be daunting for decision-makers and residents lacking specialized knowledge. The ISO/IEC 30182:2017 standard simplifies this process, by fostering synergy among stakeholders involved in designing and operating community systems and services, serves as a blueprint for promoting data interoperability, and thereby enhancing collaboration and efficiency within smart city frameworks. Moreover, the standard's practical applicability in real-world settings underscores its significance for smart city initiatives. The paper will delve into the opportunities presented by this standard regarding data interoperability in smart cities while trying to illustrate its benefits through examples of a limited extent.*

***Keywords:*** *smart cities, data interoperability, ISO/IEC 30182:2017 standard, digitalization*

***JEL:*** *O2, O3, R0*

# INTRODUCTION

Most organisations involved in predicting urban development anticipate that by 2050, 80% of the world's population will live in cities, which must be "smart"[1]. This concept is based on the ability to connect and collaborate among the various components of a city, defining the interoperability of different city system components. Interoperability is the characteristic of a product or system that works with other products or systems [2]. Initially rooted in information technology and services systems engineering, interoperability refers to a product or system's ability to function alongside others [3]; a broader definition also encompasses social, political, and organisational factors that influence system-to-system performance [4]. In our case, interoperability refers to the cross-connection of data.

When discussing communities that are large enough for their operations to span across various sectors (like transportation and infrastructure, healthcare, information-communication infrastructure, utilities, etc.), we are primarily referring to cities. In this contribution, "city" is synonymous with communities with diverse operational areas.

Data underpin the transformation of cities' capacities and capabilities. They drive the development of systems and services, forming the bedrock of informed decision-making. However, data often come in domain-specific formats, using specialised language and terms unique to each field. For instance, healthcare data revolve around patients and treatments, education data concerns students and curricula, and transportation data may involve passengers and their journeys. Each sector operates with its own data models and terminology, creating barriers to interoperability across fields. This complexity means decision-makers and many city residents lack the expertise to utilise diverse data from various sectors directly. This task typically falls to domain experts manipulating and interpreting data within their specific fields. [5]

The Smart City Concept Model (SCCM), from the ISO/IEC 30182 standard, tackles interoperability by offering a universal framework of concepts and relationships to describe data across various fields. For instance, it includes mappings of concepts from healthcare informatics to the SCCM model. [5] Mappings from multiple fields to the SCCM model facilitate cross-sharing, linking, and data utilisation. However, city-wide use of interconnected data requires more than just SCCM interoperability. Decision-makers must ensure compliance with privacy, security, integrity, availability, and data quality standards. They must also assess and make decisions regarding data use, mainly concerning personal data, which must comply with legislation. This can impact the structural relationships between data from different systems. While these considerations are beyond the scope of the SCCM standard (which primarily focuses on data semantics), it does provide a list of best practices for data governance. Decision-makers must be involved in developing the data ecosystem that supports city development. Currently, data sets are typically created by individual organisations for specific, often domain-specific purposes, limiting their potential for secondary or broader use.

The ISO/IEC 30182 standard facilitates coordination among decision-makers and system experts across different fields within cities. Individual components of SCCM can form the basis for this coordination, helping to identify standard data ontologies and enabling useful links between diverse fields. As SCCM is utilised, it promotes greater data literacy among decision-makers and residents, even those not specialised in specific fields. This paves the way for more extensive cross-sharing, linking, and data utilisation, enhancing its overall value. Next, we'll delve into applying the ISO/IEC 30182 standard with an example, showcasing the SCCM model and its concepts and relationships. These concepts and their interconnections are pivotal for describing data from various fields for cross-linking and interoperability purposes.

# 1. STANDARD ISO/IEC 30182

The ISO/IEC 30182 standard aims to enhance the current use of data in city services, promoting the reuse of data by decision-makers for innovative, future-focused systems and services [5]. This approach could assist diverse organisations in developing a cross-linking data strategy, which is crucial for cities and various organisations serving communities in specific fields. SCCM assumes that in a city, structured, semi-structured, and unstructured data can be modelled using the concepts of this standard. We often refer to real-time data flows rather than just stored structured data. [6] Thus, SCCM is relevant for open data (accessible through open licenses) and closed data (where privacy and confidentiality are protected). In the rest of the paper, we do not specifically differentiate between open and closed data. However, we primarily encounter open data when discussing the challenges of linking data.

## 1.1. OPEN DATA

Open data is freely usable, often with just attribution or shared under the same conditions. It must be fully accessible in a suitable format, allowing for reuse and combination with other datasets without discrimination based on specific areas, individuals, or groups.[7] Like open data, government data are generated or collected by public bodies [8], meeting the same criteria. These data can be linked, meaning they are published and structured on the web for computers to recognise links, facilitating the search and connection of data from different sources. This improves data interpretation and analysis. [7] The benefits of open data are vast, from more efficient public administration to economic growth and enhanced social security. [8] They also include vital benefits [7,8]: Transparency, Unlocking social and economic value, Participation in governance, Reducing public expenditure, Increasing effectiveness and improving efficiency of public services, Improving social security.

In the European Union, an annual study assesses the maturity of open data across four dimensions: policy, impact, portal, and quality [9]. Countries are classified into four groups based on their performance in each dimension, ranging from most mature to mature least. These groups highlight significant gaps in overall assessments [10]:

- Trend-setter countries: Score range 94% – 98%.
- Fast-track countries: Score range 89% – 92%.
- Follower countries: Score range 74% – 86%.
- Beginner countries: Score range 17% – 66%.

Fast-track countries in open data show maturity across all four dimensions. They actively promote data publication strategically, improve data quality, and adhere to standards. Their national portals offer robust functionality for basic and advanced users. While monitoring data impact is limited, they focus more on encouraging data reuse. Though some issues persist, steps are being taken to resolve them. [10]

## 1.2. DATA EXCHANGE

Smart cities focus on data exchange to benefit all stakeholders, including real-time data from sensors and devices and long-term data for planning. Ultimately, this data aims to improve citizen and business well-being. Smart cities often need to include private sector data, where partners must understand their data becomes public sector property (e.g., in line with data protection laws). Traditionally, organisations needed individual agreements for each data exchange, especially when using data from multiple sources, leading to complex arrangements, format specifications, and domain-specific vocabularies. The smart city concept, per the standard, involves organisations from diverse sectors exchanging data using a defined framework. This framework ensures consistent data identifiers and classifications. Cities benefit in the following ways:

- Reduced costs, as data is unnecessary to be collected and verified repeatedly.
- City systems and services are integrated based on data.
- Common understanding of different needs of residents and communities.
- Shared goals developed through collaboration and data-driven decision-making.
- Engaged residents and communities who want to participate in development.
- Transparency in decision-making.
- Development of partnership models.
- Businesses and communities co-create innovations.
- Improving the quality of life for residents.

## 1.3. KEY TYPES OF DATA INSIGHTS

When it comes to data exchange in a city, the ISO/IEC 30182:2017 standard assumes four critical types of data insights:

- Operational Insight: Examines characteristics of entities like buildings, communities, and organisations, using data to prove and enhance their value for the city.
- Critical Insight: Monitors incidents and ongoing cases in real-time, involving cross-sector collaboration to achieve desired outcomes or responses.
- Analytical Insight: Explores the data ecosystem to identify patterns, correlations, and predictions, facilitating system or service development, impact assessment, proposed changes, or demonstrating challenges and opportunities for the city.
- Strategic Insight: Broad approach examining results related to strategic goals, decisions, and plans.

If the same conceptual model is used for both data types, it is possible to track where statistical data has been derived from operational data. The analytics can be identical, and impacts on and from strategic decisions can be monitored. To gain insights at the strategic level, SCCM directs us to have organisations in the city collaborate by exchanging `ASSUMPTIONS` or `OBJECTIVES`. For the use of operational insights into data, we can utilise data obtained from sensors installed in the city. An example of such data is the average traffic speed at a specific location during a particular time. Per SCCM, this data would be represented as: An `OBSERVATION` of average speeds (`STATE`) of the traffic (`ABSTRACT`) at a location (`PLACE`).

## 2. SCCM MODEL

The standard describes SCCM and provides guidelines for linking data across smart city systems. It coordinates ontologies across different sectors. SCCM was designed to facilitate communication of the significance of mutual data. It does not attempt to provide a concept for describing metadata, validity, or data origin. It is based on and defines [6]:

- Concepts (`ORGANIZATION`, `PLACE`, `COMMUNITY`, `ITEM`, `METRIC`, `SERVICE`, `RESOURCE`);
- Relationships between concepts (`ORGANIZATION` has `RESOURCE`, `EVENT` at a `PLACE`).

SCCM doesn't replace existing models but enables mapping from local or domain-specific models to a higher-level model for querying and managing data. It also doesn't standardise data formats or structures within concepts nor specify sources for identifying or categorising data mapped to SCCM. It focuses on semantic interoperability - defining data meaning, especially from multiple sources. [6] SCCM can be used for [6]:

- Creating a data catalogue from organisations, enabling improved overview and data reuse.
- Defining identifiers for categorising concepts, allowing data harmonisation and merging.
- Establishing data standards specific to various areas within a concept, crucial for the city.
- Understanding data collection from diverse sectors.
- Establishing a local data ecosystem where multiple organisations and residents can contribute to and utilise the data.

However, SCCM does not address all requirements for cross-linking data, which should be considered at a different level of data linking. This international standard focuses on semantic interoperability – defining the meaning of data from various sectors. These data are generated, used, and maintained in all aspects of smart community operations on behalf of and in collaboration with residents. [6] Various barriers need to be considered for cross-linking data, as outlined in Table 1. The information security model includes terms and concepts for addressing risks in information systems. A typical model provides confidentiality, integrity, and availability [11], ensuring these aspects for all information and data. Table 1 illustrates these aspects: confidentiality through privacy and security, integrity, availability, quality (important in data processing), and authenticity (defining data source or origin).

Table 4: Data cross-linking requirements that SCCM does not include

| **Obstacles** | **Description** |
|---|---|
| Privacy | Respect for human rights and requirements for the protection of personal data. |
| Security | Data protection against accidental or malicious destruction or unauthorised access. |
| Integrity | Ensuring the immutability of data during its processing, copying or transmission. |
| Availability | The degree to which data must be continuously available to fulfil the purpose. This is especially important for real-time systems that rely on data availability for execution. Availability may include the regular operation of the Service and the time required to recover from a disaster. |
| Quality | Data characteristics include completeness, validity and consistency, timeliness, accuracy, precision and tolerance. It is essential to understand data quality when assessing whether it can be reused for a new purpose. |
| Originality | Data traceability is from collection to transformation, analysis, and interpretation. |

## 2.1. CONCEPTS DEFINED BY SCCM

Concepts in SCCM generalise specific types of entities. While not detailing specific data attributes (e.g., data type like integer, text, actual number, etc.), SCCM's concepts facilitate data exchange among organisations lacking a common business language. Each concept is chosen for its relevance in describing shareable data across diverse sectors. They include a name, definition (sufficient for assessing correspondence), (if necessary) notes (clarifying usage), and examples (of classes describing data structures) [6]. Table 2 outlines concept groups, and Table 3 lists fundamental SCCM concepts, forming the basis for other concepts or groups.

Table 5: Concept groups defined by SCCM.

| **Concept** | **Description** | **is a building block of a concept** |
|---|---|---|
| ABSTRACT | It exists in mind or as an idea but not in the physical world. | ITEM |
| AGENT | An AGENT is some kind of element, object or unit (ITEM), but most often, it is a PERSON or an ORGANIZATION that provides a SERVICE or plays a role in an EVENT. | ITEM |
| COLLECTION | It is a group of ITEMs, defined by an AGENT, to be managed or executed together. | ABSTRACT |
| ITEM | An individual element, object, or unit - especially as part of a list, collection, or set. | |
| RESOURCE | An item, item, or unit (ITEM) that an AGENT can use to generate a benefit. | |

Table 6: Basic concepts defined by SCCM.

| **Concept** | **Description** | **is a building block of a concept** |
|---|---|---|
| ACCOUNT | A container or collection of information stored by AGENT, in which data from EVENT relating to the role of an element, object or unit (ITEM) is recorded. | ABSTRACT |
| AGREEMENT | An agreement between AGENTs on a mode of operation is reached through negotiations. | ABSTRACT |
| ASSUMPTION | An assumed or assumed STATE. | STATE |
| BUILDING | A structure created by man, on a permanent or temporary PLACE, intended for the residence of PERSON or some other OBJECT. | OBJEKT |
| CASE | A container or collection of information that records the history of EVENTs triggered by a SERVICE request. | ABSTRACT |
| COMMUNITY | A group of PERSON and/or ORGANIZATION that share characteristics, such as PLACE, circumstances, etc. | ITEM |
| DECISION | A conclusion or solution is reached after deliberation. | ABSTRACT |
| EVENT | An EVENT that has occurred or may occur. | |
| FUNCTION | COLLECTION of SERVICEs. | COLLECTION |

| Concept | Description | is a building block of a concept |
|---|---|---|
| METHOD | A predetermined process or set of steps to achieve an OBJECTIVE. | ABSTRACT |
| METRIC | A measure of demographics, characteristics, activities or performance. | STATE |
| OBJECT | Individual element, object or unit (ITEM) in the physical world. | ITEM |
| OBJECTIVE | The goal that the AGENT wants to achieve. | ABSTRACT |
| OBSERVATION | The execution of an EVENT in which the STATE is recorded. | EVENT |
| ORGANISATION | A group of PERSONs united by a common goal. | AGENT |
| PERSON | An individual human being. | AGENT |
| PLACE | A geographical or virtual part of space. | |
| PLAN | A list of steps with defined time and RESOURCE used to achieve an OBJECTIVE. | ABSTRACT |
| RULE | An explicit or understood provision or principle that regulates conduct or procedure in a particular field of activity. | ABSTRACT |
| SERVICE | Ability to execute one or more METHOD. | ABSTRACT |
| STATE | At a particular moment, the circumstance or condition of an individual element, object or unit (ITEM). | |
| TARGET | Desired STATE. | STATE |

Here are some examples of valuable data according to the corresponding concepts:

- METRIC: " City's public transport system should manage around 500,000 trips daily."
- ASSUMPTION: " By 2031, an additional 150,000 residents could inhabit the city." and "It's projected that by 2031, the overall demand for public transport trips might rise to 4 million per day."
- OBJECTIVE: "A public transport system ensuring convenient and swift access to all city areas." and "Enhanced safety for pedestrians and cyclists on roads."

## 2.2. RELATIONSHIPS AND DEPENDENCIES BETWEEN CONCEPTS IN SCCM

Concepts in SCCM are interconnected based on mutual dependencies, which are universal facts across all fields. Each concept can be linked to any other, forming a web of relationships. The standard compiles commonly used relationships, with some concepts defining others. These concepts serve as building blocks, termed "sub-concepts of concepts" in the standard, indicating a concept can consist of multiple components. [6] Figure 1 illustrates an example of four concepts and their mutual relationships. The dashed lines represent connections between a concept and its building block, demonstrating the shared relationships. Figure 1 illustrates an OBJECTIVE based on an ASSUMPTION, which has a building block of STATE. The assumption, in turn, is based on an AGENT.

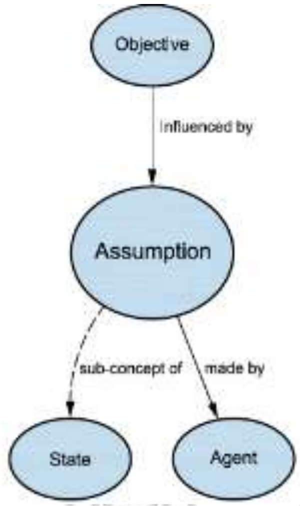


Figure 4: An example of four concepts and their interrelationships and dependencies.

All relationships (mutual dependencies) between concepts are detailed and described in Table 4. These relationships between concepts are as crucial as the concepts themselves, as they define their mutual connections and contextualise them within specific scenarios.

Table 7: Relationships between individual concepts as defined by SCCM

| **Characteristic** | **Designation** | **Origin** | **Sink** |
|---|---|---|---|
| appliesTo | applies to | DECISION | ITEM |
| | | AGREEMENT | SERVICE |
| assumptionMadeBy | made by | ASSUMPTION | AGENT |
| atPlace | at | ITEM | PLACE |
| | | EVENT | PLACE |
| caseHasPlan | Has | CASE | PLAN |
| collectionContains | Contains | COLLECTION | ITEM |
| collectionDefinedBy | defined by | COLLECTION | AGENT |
| Contains | Contains | ORGANISATION | ORGANISATION |
| | | SERVICE | SERVICE |
| | | ACCOUNT | EVENT |
| | | PLAN | PLAN |
| | | FUNCTION | SERVICE |
| | | PLACE | PLACE |
| | | COMMUNITY | COMMUNITY |
| | | CASE | EVENT |
| has | Has | AGENT | OBJECT |
| | | AGENT | ABSTRACT |

| Characteristic | Designation | Origin | Sink |
|---|---|---|---|
| hasAgreement | has | AGENT | AGREEMENT |
| hasObjective | has | AGENT | OBJECTIVE |
| hasOutcome | has outcome | EVENT | STATE |
| hasPlan | has | AGENT | PLAN |
| hasResource | has | AGENT | RESOURCE |
| hasRoleIn | has role in | ITEM | ACCOUNT |
| | | ITEM | CASE |
| | | ITEM | EVENT |
| hasState | has state | ITEM | STATE |
| | | PLACE | STATE |
| hasTarget | has target | PLAN | TARGET |
| influencedBy | influenced by | SERVICE | OBJECTIVE |
| | | DECISION | OBJECTIVE |
| | | PLAN | OBJECTIVE |
| | | OBJECTIVE | ASSUMPTION |
| memberOf | member of | PERSON | ORGANISATION |
| outcomeOf | outcome of | DECISION | EVENT |
| ownedBy | owned by | ACCOUNT | AGENT |
| planDerivedFromMethod | derived from | PLAN | METHOD |
| planForEvent | plans event | PLAN | EVENT |
| providedBy | provided by | SERVICE | AGENT |
| raisedFrom | raised from | CASE | SERVICE |
| Records | records | OBSERVATION | STATE |
| relatedTo | related to | ITEM | ITEM |
| resourceFor | for | RESOURCE | PLAN |
| | | RESOURCE | SERVICE |
| responsibilityOf | responsibility of | SERVICE | AGENT |
| ruleFor | for | RULE | SERVICE |
| serviceImplementsMethod | implements | SERVICE | METHOD |
| takesDecision | takes | AGENT | DECISION |
| targetOfObjective | of | TARGET | OBJECTIVE |
| usedBy | used by | SERVICE | COMMUNITY |
| | | ITEM | AGENT |

The standard presents nine common examples of connections between concepts within SCCM, illustrating data-sharing scenarios. These examples, called "views" in the standard, depict a relatively concise set of concepts and their relationships. Although there are originally nine examples, we will look at the "ITEM view" as an example, which is one of the more complex views. Figure 2 illustrates the selected example based on the definitions from Tables 2, 3, and 4.

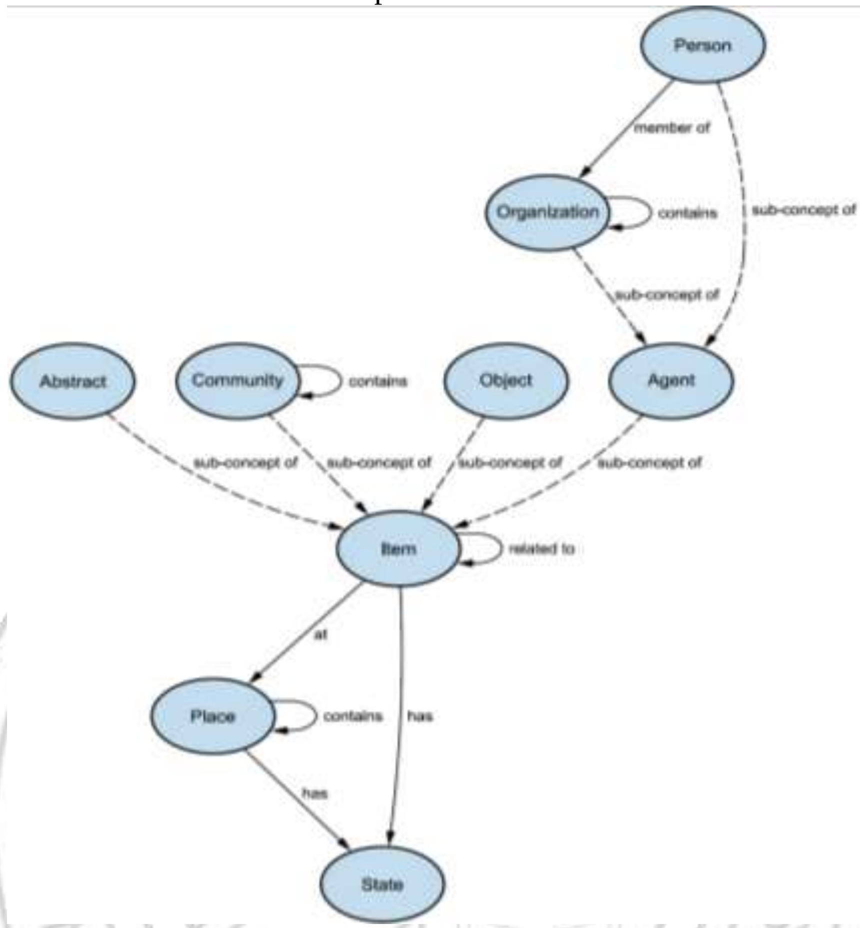


Figure 5: An example of using a "view" on the concept of ITEM.

A community or city contains elements, items, or units (ITEM) referenced by data from many organisations. When and if different organisations can agree on a common ITEM identifier, they will ensure information about it. It is most likely that the ITEM can be an OBJECT, for example, a lamp post, a BUILDING, which is a building block of the concept OBJECT, or a road. An ITEM can also be an ORGANIZATION (local council or energy supplier), a PERSON (resident or service user), or a COMMUNITY (commuters or low-income families). In a community (city), we refer to non-physical entities such as services, contracts, decisions, or cases. These non-physical entities are also ITEMs, which SCCM envisages as a component of ABSTRACT, which consists of several other components. ITEM can be used in conjunction with a PLACE, describing where the ITEM is located. Although ABSTRACT has no physical existence, it can still be linked to a PLACE. PLACE is used to describe a geographical location or area. Some PLACEs are precisely described with coordinates and boundaries, while others are less precise, perhaps only with names. The ITEM and PLACE change over time and can take on multiple STATEs. STATE typically describes the condition of the ITEM or PLACE. It can be characterised subjectively based on the observer's perspective (the state of a building is poor). However, STATE can also be characterised quantitatively (room temperature) or as a statistical value (the state of satisfaction of a community). A smart city should base its decisions on a shared understanding of the `STATE` in which a specific `ITEM` is located. These values can be used in real-time or as a basis for implementing `PLANs` to change the community (`STATE`).

SCCM assumes that all the concepts mentioned above can be components of the `ITEM` concept. As noted, all relationships (interconnections between concepts) that apply to a concept also apply to its components.

## CONCLUSION

The data ecosystem of a community based on SCCM combines data from numerous sources, benefiting both the community and its residents. In this approach, the community utilises its method of organising data to ensure the execution of community priorities and needs, as well as those of collaborating agencies and individuals. Connected and open public sector data enable flexibility in integration and higher data quality, new services, and cost reduction [7], as data is shared and reused multiple times. Additionally, they enable transparency in operations and participation in governance [8], increase the success and efficiency of public services, and improve social security [10]. The advantages of using open data are significant and still underutilised. Therefore, a smart city should make decisions based on a shared understanding of the `STATE` in which a specific element, subject, or unit (`ITEM`) is located. These values can be used in real-time and serve as the basis for implementing `PLANs` to make changes in the `COMMUNITY`.

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