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DELIVERABLE

D2.4 – Definition of a ConceptuAl StandardS InterOPErability frAmework (CASSIOPEiA) for Smart City

Project Acronym: ESPRESSO

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1. Revision history and statement of originality

1.1. Revision history

Rev	Date	Author	Organization	Description
1.0	2016-06-27	Peter Parslow	OS	First release

1.2. Statement of originality

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1.3. Trademarks

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SuRe is a trademark of Global Infrastructure Basel.

TOGAF is a registered trademark of The Open Group.

2. List of references

Number	Full Reference
1	14-115 OGC Smart Cities Spatial Information Framework, 2015-01-21 http://www.opengis.net/doc/WP/smart-cities-sif
2	ISO/IEC JTC 1/SG 1 Smart Cities: SG 1 Second Phase Report; 2015-09-17
3	ISO 37120:2014 Sustainable development and resilience of communities — Indicators for city services and quality of life
4	PAS 181:2014 Smart city framework – Guide to establishing strategies for smart cities and communities
5	CityKeys D1.4: Smart city KPIs and related methodology, 2016-02-01, http://nws.eurocities.eu/MediaShell/media/D1.4-CITYkeys_D14_Smart_City_KPIs_Final_20160201.pdf
6	EUR 25942 EN: Science for Standards: a driver for innovation - JRC thematic report, *(date unknown)*, https://ec.europa.eu/jrc/sites/default/files/jrc_science_for_standards_reports_0.pdf
7	Energy ADE development Wiki as at 2016-03-21, http://en.wiki.energy.sig3d.org
8	D2.1: ESPRESSO: The Scope of Smart City Standardization, V4_1703 dated 2016-03-17
9	EUR 25589 EN: Science for Disaster Risk Reduction - JRC thematic report, 2014, https://ec.europa.eu/jrc/sites/default/files/jrc-science-for-disaster-risk-reduction-report.pdf
10	EUR 27187 EN: Science for Food - JRC thematic report, 2015, https://ec.europa.eu/jrc/sites/default/files/jrc-science-for-food-thematic-report_en.pdf
11	EUR 26659 EN: Science for Nuclear Safety and Security - JRC thematic report, 2014, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC90424/lbna26659enn.pdf
12	EUR 26066 EN: Science for Water - JRC thematic report, 2012, https://ec.europa.eu/jrc/sites/default/files/jrc_2012_science_for_water_en.pdf
13	EUR 25939 EN: Science for Energy - JRC thematic report, 2013, https://ec.europa.eu/jrc/sites/default/files/jrc_science_for_energy_report_1.pdf
14	EUR 27498 EN: Science for Environmental Sustainability - JRC thematic report, 2016, https://ec.europa.eu/jrc/sites/default/files/jrc-science-for-environmental-sustainability_en.pdf

15	Strategic Opportunity Analysis of the Global Smart City Market, 2013-08-30, http://www.frost.com/sublib/display-report.do?id=M920-01-00-00-00 *(summary only, as quoted in ESPRESSO D2.1)*
16	http://smartcitiescouncil.com *(but without buying their Smart Cities Readiness Guide!)*
17	ISO/PRF[1] 37101 Sustainable development in communities -- Management system for sustainable development -- Requirements with guidance for use, 2016-04-21
18	ISO/PRF[2] TR 37152:2014 Smart community infrastructures - Common framework for development and operation, 2014
19	City Protocol Society's CPA-I_001-v2 City Anatomy: A Framework to support City Governance, Evaluation and Transformation
20	British Standards Institution's PD 8100 Smart Cities overview – Guide
21	British Standards Institution's PD 8101 Smart cities – Guide to the role of the planning and development process
22	European Commission Smart Cities Stakeholder Platform Integrated action plan – report process & guidelines
23	ISO 16739 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries, 2013
24	SuRe® - The Standard for Sustainable and Resilient Infrastructure, v0.2 2015, http://www.gib-foundation.org/sure-standard/
25	D2.2: ESPRESSO: The Scope of Smart City use cases, 3.0 28 May 2016
26	OASCBGDOC-01-OCT-2015, BACKGROUND DOCUMENT for the Open & Agile Smart Cities collaboration initiative, 1 Oct 2015, http://oascities.org/wp-content/uploads/2016/02/Open-and-Agile-Smart-Cities-Background-Document-3rd-Wave.pdf
27	A Tale of Evaluation and Reporting in UK Smart Cities, Caird, S. with Hudson, L. and Kortuem, G. (2016), Open University SmartDframe project, http://oro.open.ac.uk/46008/7/__userdata_documents4_ctb44_Desktop_Tales_Smart_Cities_Final_2016.pdf
28	IDC Government Insights' Smart City Maturity Model
29	BS 8001 Framework for implementing circular economy principles in organizations – Guide, due spring 2017, http://www.bsigroup.com/en-GB/standards/benefits-of-using-standards/becoming-more-sustainable-with-standards/Waste-Prevention-and-Circular-Economy-Project/

[1] Currently "proof sent to secretariat", as at 2016-04-21
[2] An adhoc report

30	ISO/IEC 10746 Information technology – Open Distributed Processing, 1998, available at http://standards.iso.org/ittf/PubliclyAvailableStandards; diagram from associated WikiPedia article: https://en.wikipedia.org/wiki/RM-ODP
31	British Standards Institution's PAS 184 Smart Cities – Developing project proposals for delivering Smart City solutions, under development,

3. Table of Acronyms

Acronym	Description
3D	Three dimensional
ADE	Application Domain Extension, one of several extension mechanisms within CityGML
BSI	British Standards Institution, the national standards body of the UK
CASSIOPEiA	ConceptuAl StandardS InterOPErability – this document
CITIE	City Initiatives for Technology, Innovation and Entrepreneurship, a joint project of Nesta, Accenture and the Future Cities Catapult
DIS	(ISO) Draft International Standard
CityGML	OGC City Geography Markup Language
CPA	City Protocol Agreement, a consensus document of the City Protocol Society
ESPRESSO	systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities – project of which this document forms a deliverable
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE (German Commission for Electrical, Electronic & Information Technologies of DIN and VDE)
DIN	Deutsches Institut für Normung, the national standards body of Germany
EN	Either, European Standard Or, part of a document identifier, indicating the English language version of a document published by the European Commission
EIF	European Interoperability Framework
ETSI	European Telecommunications Standards Institute
eTOM	TM Forum's Business Process Framework, originally, "enhanced Telecom Operation Map"
EU	European Union
EUR	Part of a document identifier, indicating a document published by the European Commission
EUROCODES	the ten European standards specifying how structural design should be conducted within the European Union
GA	Grant Agreement, the foundational document of the project

IDC	International Data Corporation
IEC	International Electro-technical Commission
IFC	Industry Foundation Classes, defined in ISO 16739:2013, but developed and maintained by buildingSMART.
IHO	International Hydrographic Organisation
INSPIRE	Infrastructure for Spatial Information in Europe
ISO	Either, International Organisation for Standardisation or, part of a document identifier indicating an International Standard published by ISO
ITU	International Telecommunications Union
JRC	Joint Research Centres, of the European Commission
JTC 1	Joint Technical Committee 1, a joint committee between ISO and IEC
LandInfra	OGC Land and Infrastructure Conceptual Model Standard
LandXML	Land extensible markup language
MODAF	(UK) Ministry of Defence Architecture Framework
NWIP	(ISO) New Work Item Proposal
OASC	Open & Agile Smart Cities collaboration initiative
OASCBGDOC	Part of a document identifier, indicating a OASC Background Document
OASIS	Organization for the Advancement of Structured Information Standards; https://www.oasis-open.org
OGC®	Open Geospatial Consortium; http://www.opengeospatial.org
OpenGIS®	An old name for OGC
OS	Ordnance Survey, the national mapping authority of Great Britain; but sometimes an abbreviation for "open source", or "operating system"
OSI	Open Systems Interconnect (ISO/IEC 7498-1)
PAS	Publically Available Specification, a specific kind of document from BSI
PD	Public Document, a specific kind of document from BSI
PDF	Portable Document Format, formally defined in ISO 32000

PRF	In ISO/PRF, this stands for "proof", a mature but not yet published draft of a an ISO document.
RM-ODP	Reference Model for Open Distributed Processing
SDO	standards development organisation, such as ISO, IEC, ITU, OGC, …
SG	Study Group, a specific kind of sub-group of JTC1
SuRe®	The Standard for Sustainable and Resilient Infrastructure
TC	(ISO) Technical Committee
TOGAF®	The Open Group Architecture Framework
TM Forum	"the global member association for digital business"
TR	(ISO or IEC) Technical Report
UN	United Nations
UN SDGs	United Nations Sustainable Development Goals
UK	United Kingdom of Great Britain and Northern Ireland
VDE	(German) Association for Electrical, Electronic & Information Technologies

4. Executive Abstract

This document is the output of ESPRESSO Task 2.3. It is an initial description of CASSIOPEiA – a Conceptual Standards Interoperability Framework for Smart City. It presents the ESPRESSO project's initial findings on conceptual standards that are, or could be, used by cities that are making some progress towards being "smart cities".

There are many definitions of what constitutes a smart city or community, but they generally encompass at least these perspectives:

- Improved quality of life, sustainability, resilience, services,…
- Engagement with society: collaborative leadership, use of technology,…
- Decisions and processes driven by information
- Avoiding sector specific approaches; sometimes known as adopting a 'system approach'

Different jurisdictions, and different cities, take different approaches to organising the services which they provide. However, an important aspect of a city being considered 'smart' is that it does not manage sectors in isolation from each other; a smart city adopts a 'system of systems' view and actively avoids working in sectoral silos. This requires good information management, which is also an objective of developments under discussion in the construction and manufacturing industries.

For further information on what ESPRESSO means by "smart cities", see D2.1.

By "conceptual standards" we mean open standards or consensus approaches which fall within the enterprise viewpoint of the Reference Model for Open Distributed Processing. That means this document covers management approaches, maturity models, key performance indicators, and information models. It does not cover implementation specifications, either for information, services, information technology, or other infrastructure.

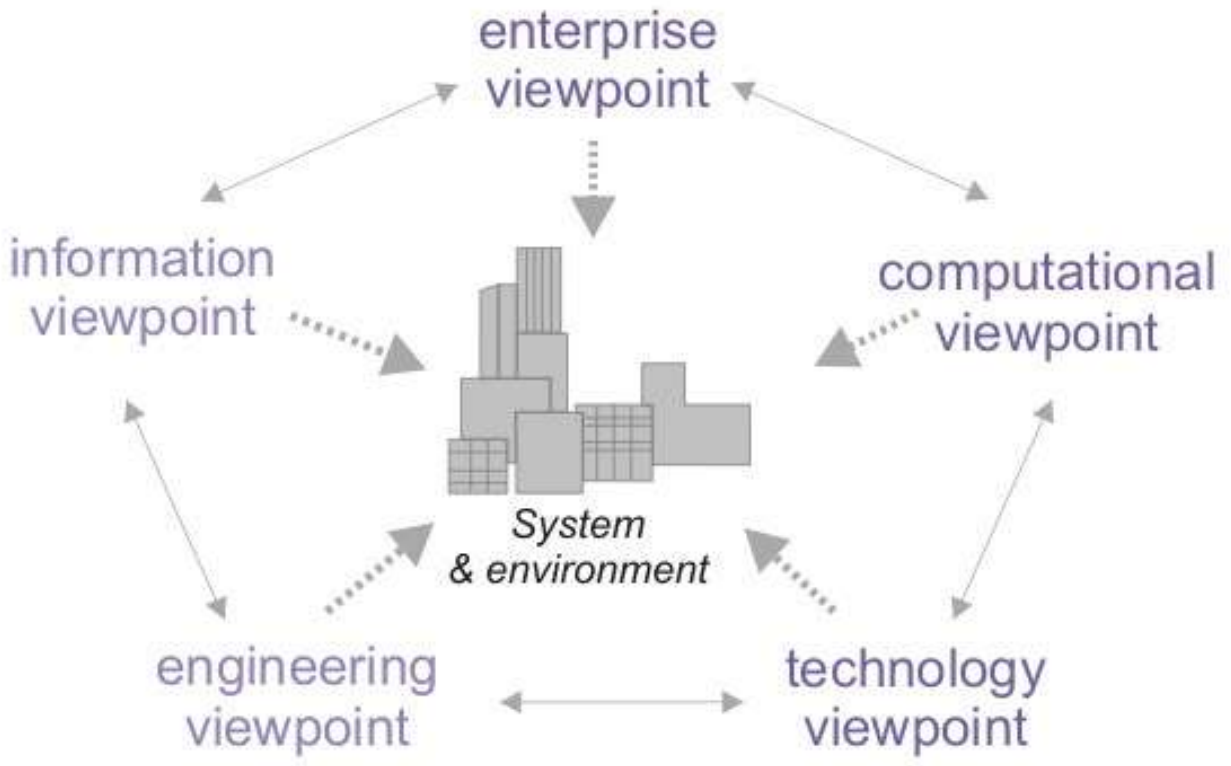

Figure 1 RM-ODP Viewpoints

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ESPRESSO Task 2.4 will extend this document to include technical standards, to identify gaps, and to identify strengths and weaknesses in the standards. This set of standards will then form the basis of an architecture, which ESPRESSO will then partially test, through use case driven pilots.

ESPRESSO Task 4.1 *Definition of shared vocabularies*, and 4.3 *Indicator platform* each develops an aspect of what is included in this deliverable.

A later version of this document will include feedback from these other tasks, from cities, from the European Innovation Partnership's Smart Cities Consortium, and the World Smart Cities Forum.

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7. Description of task

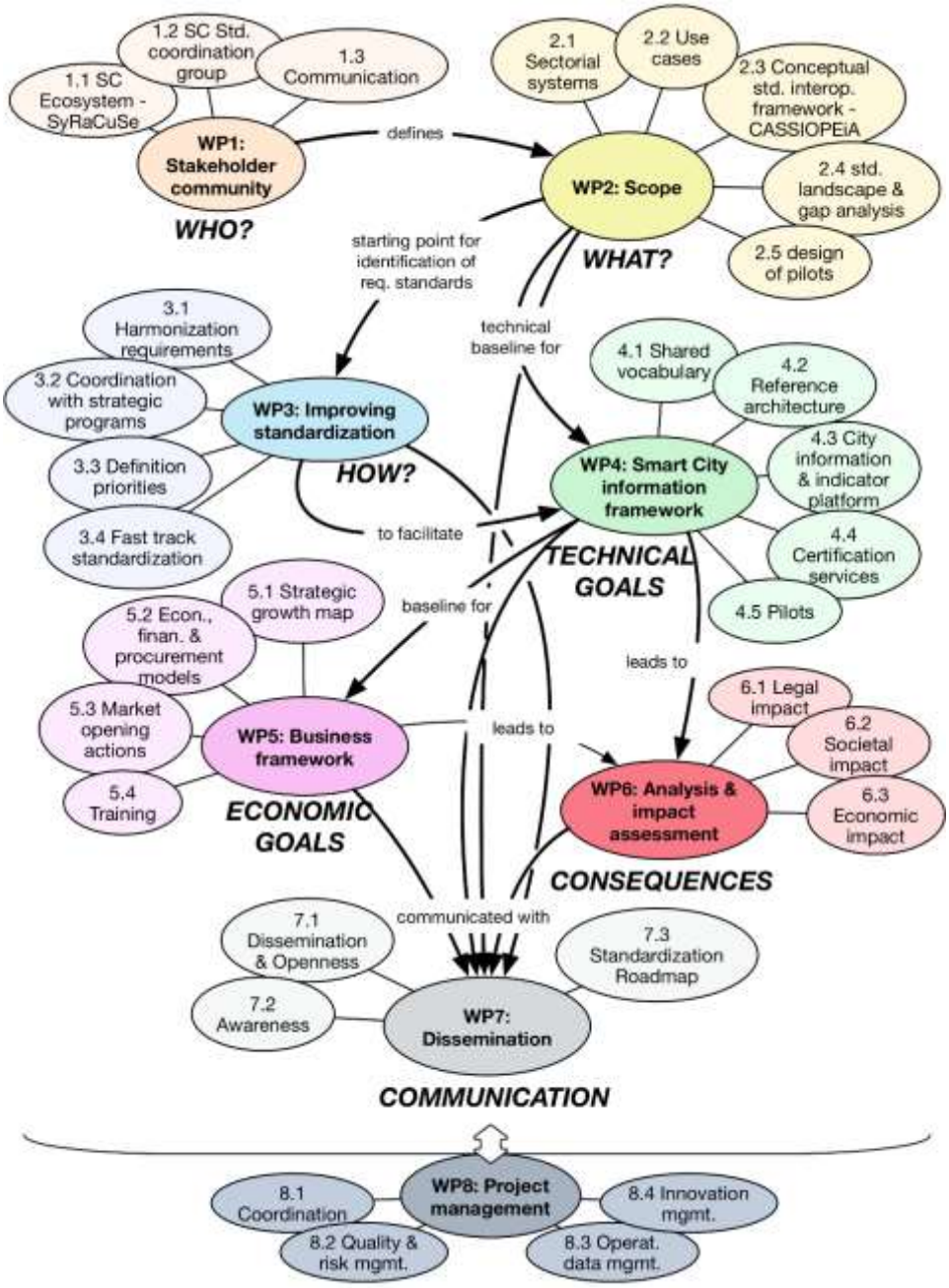

Figure 2 Overview of ESPRESSO Work Packages

This document is the output of ESPRESSO Task 2.3. It is an initial description of CASSIOPEiA – a Conceptual Standards Interoperability Framework for Smart City.

Together with the outputs of tasks 2.1, 2.2, 2.4, WP4, and WP5, this set of ESPRESSO deliverables should give a complete description of a reusable reference architecture for a smart city, covering People, Process, Transactions, Services, Technology, and Data.

This document follows the lead set by the ISO/IEC JTC1 Smart Cities report, and followed by the OGC Smart Cities Spatial Information Framework, in that it adopts an RM-ODP approach to defining the framework in which a Smart Cities technology is described.

So, to provide a complete picture, the Smart City system of systems would be described from three views: business process, knowledge management, and engineering. This task and document concentrates on the business process view, which the OGC white paper describes as the Enterprise View "including a definition of a Smart City, the Indicators for assessing the value of deploying the technology, and an overall set of components for the information system of a Smart City." As an organisation whose focus is on engineering, the OGC includes 'an overall set of components for the information system' in the enterprise view in their white paper.

The ITU Focus Group on Smart Sustainable Cities calls this the Application Layer.

The European Interoperability Framework (EIF) identifies five broad interoperability domains: technical, semantic, organizational, legal, and policy. PAS 181 uses this approach to classify the issues it has identified in each of three components, which are somewhat like RM-ODP viewpoints. This task relates to the 'Business management' component of PAS 181.

For this task, we have read a wide range of reports and studies, extracting the standards that are mentioned here. This forms an initial set which we are testing by means of a questionnaire to cities, which is running in parallel with partner review.

Task 2.4 will proceed to the more technical views.

8. Themes or sectors

Different reports group the services offered by cities in different ways:

ESPRESSO T2.1 was to establish the scope of ESPRESSO in terms of 'sectorial systems'. This standards framework should identify relevant standards in use in one or more sectors, including standards for delivering each service, measuring the performance (indicators) or maturity of the service, and other aspects of management. However, an important aspect of a city being considered 'smart' is that it does not manage sectors in isolation from each other; a smart city adopts a 'system of systems' view and actively avoids working in sectoral silos. ESPRESSO D2.1 identified a number of ways that different organisations have classified the services that smart cities provide:

Table 1 Summary list of key sectorial systems. Source: D2.1

ISO 37120	EU	ETSI	Networks European Technology Platform Expert Working Group on Smart Cities	PAS 181	DKE/DIN ROADMAP	International Electro technical Commission	Frost & Sullivan	Smart Cities Readiness Guide	ESPRESSO Grant Agreement
Economy	Smart Economy			Finance and economy					
Education	Smart People	Education/HR Development		Education and training		Education	(Smart Governance and) Smart Education		
Energy		Energy	Energy Efficiency	Energy	Energy	Energy	Smart Energy	Energy	(Energy efficient buildings), Energy management & Energy trading
			Smart Grids		Smart Grids	Smart Grids			Smart Grids
Environment	Smart Environment	Environment/Green Development	Environment	Environmental services					
Finance				(Finance and economy)					
Fire and emergency response				Policing and emergency response					
Governance	Smart Governance		Developing E-Government				(Smart Governance and) Smart Education		
Health	Smart Living	Health/Medicine	Health, Inclusion and Assisted Living	Health		Health	Smart Healthcare	Health (and Human Services)	
Recreation									
Safety					Safety and Security	Public Safety		Public Safety	SafeCity
Shelter				Housing	Buiding Construction and Urban processes	Building and Homes	Smart Building	Built Environment	Energy efficient buildings
Solid waste									
Telecommunication and innovation				Telecommunications			Smart Technology	Telecommunications	
Transportation	Smart Mobility	Transportation	Intelligent Transportation Systems		Mobility	Mobility	Smart Transport		
Urban Planning									
Wastewater				Waste				Waste (and Wastewater)	Waste management
Water and Sanitation						Water	Smart Infrastructure		

ESPRESSO D2.2 describes the highlighted "systems" as "of particular importance and relevance in the context of long-term, sustainable city development": Education; Energy Management; Environment; Transport / Mobility; Healthcare; Governance, Participation and Planning; Security / Safe City; Buildings; Infrastructure, wastewater, water and sanitation. Initial work with several cities suggested the following priority sectors: Governance and participation, Mobility and Transport, Energy, Water and Waste management.

The particular Use Cases listed in D2.2 are:

1. water and water management systems;
2. building management;
3. intelligent infrastructure management;

4. urban planning;[3]
5. Rotterdam Roadmap for Circular Economy
6. Use cases facilitated by the Rotterdam 3D Model – towards urban planning, infrastructures, and governance:
    - Visualisation of databases, e.g. air quality
    - Visibility and estimation of shadows
    - 3D cadastre
    - Visualisation for navigation
    - …
7. Tartu Paperless Government – governance and participation
8. Tartu Healthcare
9. Tartu SmartEnCity – energy systems, mobility (electric car network), building management

    Several other potential use cases are mentioned briefly:

10. Participatory Urban Planning
11. Participation through issue reporting
12. Participatory budgeting and expenditure maps
13. Real-time mobility planning

Additional reading for task 2.3 (this deliverable), has identified a number of other classifications, which are described in the sections below. However, a smart city should adopt a system approach to progressing towards its objectives, or solving its problems. Therefore, a strict classification of activity by sector or theme may be counterproductive.

8.1. TM Forum Business Process Framework (eTOM)

The study group report to ISO / IEC JTC1 mentions the TM Forum's Business Process Framework 'eTOM', which is a "a hierarchical catalog of the key business processes required to run a service-focused business". The report recommends that JTC1 uses the eTOM approach to develop a Smart City Business Process View. eTOM contains the following major areas:

- *Strategy, Infrastructure and Product*
- *Operations*
- *Enterprise Management*

8.2. PAS 181

This specification, which has been proposed to ISO TC268 as a potential international standard, lists some cross cutting aspects of citizen-centric service management:

[3] 1-4 form the Rotterdam Adaptation Strategy, part of the Rotterdam Climate Initiative

empowering stakeholder-led service transformation, delivering city-led transformation, identity and privacy management, digital inclusion and channel management.

These are business services which cities will need in order to deliver the citizen-centric services in a smarter way.

In Note B2, PAS 181 lists a number of services which cities offer to citizens and businesses; it is unlikely that this is meant as an authoritative list: energy, waste, water, telecommunications, policing and emergency response, education and training, transport, health, social services, housing, environmental services, finance and economy.

PAS 181 joins these vertical services with integrated city-wide governance, consisting of service management, business management, technology and digital asset management. PAS 181 Figure 6 therefore identifies a number of barriers to interoperability within its business management component, which are areas that would benefit from standardisation:

8.3. CityKeys hierarchy

The European Union funded CityKeys project adopts a hierarchical approach to describing what a city does:

People

- Health
- Safety
- Access to other services
- Education
- Diversity and social cohesion
- Quality of housing and the built environment

Planet

- Energy and mitigation
- Material, water and land
- Climate resilience
- Pollution & waste
- Ecosystem

Prosperity

- Employment
- Equity
- Green economy
- Economic performance
- Innovation
- Attractiveness & competitiveness

Governance

Organisation

Community involvement

Multi-level governance

The final CityKeys theme, propagation, applies to smart city projects, not the cities themselves.

8.4. Open Geospatial Consortium

The OGC's white paper lists a number of "applications" that cities have in common: Education, Utilities, Environmental Protection, Emergency Services, Urban Planning, Health, Public Safety and security, Intelligent Buildings, Sanitation, Intelligent Transportation, and Open Data.

8.5. SuRe® – The Standard for Sustainable and Resilient Infrastructure

This is primarily a measurement framework for the management of infrastructure projects. The 76 criteria are divided into 14 themes, giving a hierarchy:

Environment

Land use & Landscape; Natural Resources; Environmental Protection; Biodiversity & Ecosystems; Climate

Governance

Management & Oversight; Sustainability & Resilience Management; Stakeholder Engagement; Transparency & Accountability

Society

Human Rights; Labour Rights & Working Conditions; Customer Focus & Inclusiveness; Community Impacts; Socioeconomic Development

8.6. BSI City Data Survey report

Ordnance Survey, on behalf of The British Standards Institute, undertook a survey of the data which various smart cities are using. The responses fell into a number of themes:

Infrastructure – KPI measures, Commercial, industrial activity measures.

Built environment – Assets, buildings, planning data, buried utilities

Energy – Electricity, gas, renewables.

Water – Supply, demand, natural flow and flooding.

Economic – Financial costs, financial benefits, financial asset flow, growth

Geo-spatial – Location, routing, terrain

Innovation – Ideas generation, creative thinking, new concepts

Logistics and services – City services such as waste management, street maintenance.

Transport / Mobility (public and private) – Road, rail, pedestrian, tram, bus, cycle.

Natural environment – Weather, climate, air quality, green spaces, trees.

Communications – networks (e.g. fibre, wifi, cellular), access points, Internet of things (IoT)

Social – Communities, deprivation, jobs, skills.

Health – Patient statistics, disease types, disabilities.

Technology – Sensors esp. real-time

9. Conceptual Standards Interoperability Framework

In this paper, we consider the standards which cities are using in four groups: management standards, maturity models, standard sets of indicators, and standard information models.

9.1. Management standards

Some cities and cultures do not appreciate being told how to manage themselves, whereas others are happy to adopt good, proven practice from others.

Cities consider seamless regulation in the construction sector highly important. Technical Standards play an important role in the process of receiving construction permits, procurement, implementation, and beyond. Standards also play an important role in urban homesteading, renovation, structural improvements, etc. However, cities are only interested in the technical details documented in standards. Managerial standards, management frameworks, or even detailed description of processes in the urban environment are – in a city's opinion – outside of an SDO's core competence and should by any means be regulated in a federal judicial framework. Once the framework is in place, technical details enabling coherence with named framework may be specified by technical standards. *As reported by the German Cities Association*

Conversely, five UK local authorities were on the steering group for the British Standards Institution's PAS 181 guidance and recommendations *Smart city framework – Guide to establishing strategies for smart cities and communities.*

Relevant standards:

- ISO/PRF[4] 37101 *Sustainable development in communities -- Management system for sustainable development -- Requirements with guidance for use*
- BS 8001 *Framework for implementing circular economy principles in organizations – Guide*; under development.

Other consensus publications:

- BSI PAS 181 *Smart city framework – Guide to establishing strategies for smart cities and communities.*

[4] Currently "proof sent to secretariat", as at 2016-04-21

- ISO/PRF[5] TR 37152:2014 *Smart community infrastructures - Common framework for development and operation*
- City Protocol Society's CPA-I_001-v2 *City Anatomy: A Framework to support City Governance, Evaluation and Transformation*
- PAS 184 *Smart Cities – Developing project proposals for delivering Smart City solutions*. Under development.

Other documents:

- BSI PD 8100 Smart Cities overview - Guide
- BSI PD 8101 Smart cities – Guide to the role of the planning and development process
- European Commission Smart Cities Stakeholder Platform *Integrated action plan – report process & guidelines*
- 100 Resilient Cities' *City Resilience Framework*
- *City Initiatives for Technology, Innovation and Entrepreneurship (*CITIE)

9.1.1. Discussion

Some definitions of a smart city imply that a city cannot be smart unless it takes certain approaches to its management. For example, ISO 37101 states *"Smartness means to contribute to sustainable development and resilience, through soundly based decision making and the adoption of a long and short term perspective"* – although I'm sure that each organisation would claim that its decision making approach is sound, and takes into account long and short term factors.

The ISO's working definition is "A smart city should be described as one that

... dramatically increases the pace at which it improves its social economic and environmental (sustainability) outcomes

... by fundamentally improving how it engages society, how it applies collaborative leadership methods, how it works across disciplines and city systems, and how it uses data and integrated technologies

... in order to transform services and quality of life to those in an involved with the city (residents, businesses, vistors)" [2].

ISO 37101, the OASIS Transformational Government Framework, and the other less formal consensus documents from BSI and network groups all recommend collaborative and citizen centred service design and management, rather than "traditional" command and control management systems. Many of these include a management process such as the Integrated Action Plan. These approaches, although standardised, do not imply that all cities are the same; they allow each city to decide its priorities, and how to tackle them.

In all cases, a city may well focus its management on what it is trying to achieve, rather than on any input from the 'smart' angle. For example, if a city's main aim at present is to improve its economic sustainability, or its resilience in the face of natural risks,

[5] An adhoc report

that may well steer the choice of management approach. It may be possible to adopt standards developed for sustainable management of organisations, for example BS 8001, which may then be supported by related standards for particular sectors.

The *City Resilience Framework*'s approach to leadership and strategy seems relatively top down, with an emphasis on strong leadership and a city vision, but it does advise inclusive decision making. It seems likely that a combination of top down and bottom up approaches will be most effective.

In addition to these broad approaches to managing a Smart City, it is clear that a smart city is itself an organisation which will be using information technology. There are a lot of standards for how any organisation should govern and manage IT, and the JTC1 Study Group report recommends that these are applicable to a Smart City. Examples include:

ISO/IEC 38500:2015 *Governance of IT for the organization*

ISO/IEC 20000 series *Service Management*

ISO/IEC 27002 *Code of practice for information security management*

ISO/IEC 29100:2011 *Information technology – Security techniques – Privacy framework*, and related standards

9.2. Maturity models

Relevant standards:

- ISO/PRF[6] 37101 *Sustainable development in communities -- Management system for sustainable development -- Requirements with guidance for use*. Note: the maturity matrix is in an informative annex.
- ISO/NWIP 37153 is to contain a maturity model

Other consensus publications:

- BSI PD 8100:2015 Smart Cities overview – Guide; Annex A is a Capability Assessment tool

Other documents:

- *The Smart City Maturity Model* developed by the International Data Corporation (IDC, 2013)
- Deloite *Smart Cities*
- The Urban Tide *Overview of the Smart Cities Maturity Model*
- Scottish Cities Alliance *Smart Cities Maturity model and Self-Assessment Tool*

9.2.1. Discussion

One common mechanism for focussing improvement is to assess the maturity of an organisation or process against some widely accepted bench mark. Several such maturity models have been developed. Although most maturity models have five levels, not all of them follow the common underpinning definitions that may be familiar to

[6] Currently "proof sent to secretariat", as at 2016-04-21

software engineers or business process people, from 1980s work at Carnegie Mellon University[7].

Pretty much all maturity models have five levels or stages, with names such as: ad hoc, opportunistic, repeatable, managed, and optimized. These tend to have broadly similar definitions, with the higher levels explicitly requiring continuous improvement. Some, such as the BSI capability assessment tool, have five levels, but they are more subjective: lagging, developing, competent, progressive, and excelling. These can still be useful for a self-assessment of strengths and weaknesses; areas for development in the near future.

The different 'smart city maturity models' suggest applying these to various aspects of either projects, organisations, or 'cities'. For example, IDC advise addressing several "key dimensions": strategy, culture, process, technology, and data. The specifics of assessing the level of each dimension make up the maturity model. As yet, no one maturity model has been published as a standard, or widely accepted.

ESPRESSO Work Package 5 will include guidance on using maturity models as part of a smart city's strategic growth.

9.3. Indicators

Relevant standards:

- ISO 37120 *Sustainable development of communities - Indicators for city services and quality of life*

Other consensus publications:

- ISO/TS 37151 *Smart community infrastructures – principles and requirements for performance metrics*
- United Nations Sustainable Development Goals
- *Key Performance Indicators*, ITU-T Focus Group on Smart Sustainable Cities.

Other documents:

- EN 1990-1999?
- *The European Smart Cities Ranking Model* developed by Vienna University of Technology/University of Ljubljana/Delft University of Technology (Giffinger et al., 2007)
- *The Smart City Reference Model* developed by Zygiaris (2013)
- *The Smart City Index Master Indicators* developed through the Smart Cities Council by Cohen (Smart Cities Council, 2014)
- *Huawei UK Smart Cities Index*

Current projects:

- CityKeys project's *Performance Measurement Framework* [http://www.citykeys-project.eu]

[7] *Managing the Software Process*, 1989, Watts Humphrey

- Triangulum Project Framework, a Smart Cities and Communities Lighthouse Project [http://triangulum-project.eu]
- European Innovation Partnership on Smart Cities and Communities [https://eu-smartcities.eu/]

9.3.1. Discussion

There is an often quoted maxim that "If you can't measure it, you can't manage it", and 'indicators' are generally seen as a useful part of any improvement effort, including a city making itself more sustainable or smarter. However, there are those who disagree with the benefit or cost effectiveness of quantitative measurements[8]. There are also questions about the comparability of indicators between cities or even between different periods of time, as methodologies, algorithms and source data that lead to the calculation of the indicator values are often not explicitly published. So a good set of indicators includes a methodology, and encourages open publication.

The choice of indicators may follow on from the choice of management approach, or be driven from the city's main goal. For example, a focus on sustainability may be best supported by using the indicators associated with the UN Sustainable Development Goals (UN SDGs). A joint project between UNECE and ITU elaborated some of the UN SDG indicators which were felt relevant to Smart Sustainable Cities. There are several ongoing pieces of work on how to measure against the UN SDGs.

The approaches to measurement and indicators can be considered to fall into several categories:

- Quantitative: generally collections of specific measurable things, which are known or assumed to be *indicators* of the desired outcome.
- Subjective: measures of citizen satisfaction and well being
- Check list: sets of yes/no questions, which taken together can be an indicator

Different sets of indicators also set out to measure different things. Some measure the outcome, or progress towards it: measurements of sustainability, resilience, or well-being. Others measure the inputs: activities which it is assumed or believed will achieve the desired outputs. In some cases, this distinction is not as clear as may be assumed. For example, ISO 37120 includes unemployment rate, and square meters of public outdoor recreation space per capita. Both of these could be considered outcome indicators, or they could be seen as inputs towards a higher level output of social sustainability, or well-being.

The ITU-T Focus Group's key performance indicators focus on ICT-related matters, but the six dimensions measured do include the impact of the ICT on environmental sustainability, productivity, quality of life, equity and social inclusion, and physical infrastructure.

Some indicators within many sets are intended to allow the city to categorise itself, in order to compare against other similar cities, for example by population, economic factors, or climate.

[8] "It is wrong to suppose that if you can't measure it, you can't manage it – a costly myth." W. Edwards Deming, The New Economics

At present, many cities are simply evaluating the projects which they are carrying out, rather than the city as a whole: "All the cities interviewed said their approach to smart city evaluation was currently focussed at a project level, primarily driven by their external funders' requirements." [27]

There are two problems with measuring outcomes. Firstly, it is difficult to attribute causality, because cities are complex systems with complex interactions.

Measuring against a standard set of indicators, as is done by the World Council on City Data using ISO 37120, has two potential benefits. Firstly, it allows cities to choose to learn together with other cities in a similar position. Secondly, it can give a more objective idea of areas for development. However, there is some concern that a "league table" approach, which easily results from adopting a standard set of measures, can distract from the city's own aims.

Repeatedly measuring against the same indicators allows a city to monitor its progress, and focus its future investment. Reporting publically helps a city be more transparent. These benefits are true whether the indicators chosen are specific to that city, or more widely used.

Publishing the measures, including the underlying data and the methodology used, aids transparency, and this in turn can improve participation.

Example: London Sustainable Development Commission has reported against almost the same indicators in 2004, 2005, 2008-09, and is public about there being five areas in which the measures are in decline, as well as twelve which are improving. This comparison remains possible even though the report is now structured into "4Rs – Responsibility, Respect, Resources and Results", whereas the earlier reports were structured in line with the Brundtland Report [The World Commission on Environment and Development's *Our Common Future*, 1987], into social, environmental, and economic spheres. In 2015, London assessed itself against all the indicators in ISO 37120.

The CityKeys project intends to test its performance measurement framework, including 73 city indicators, between July and September 2016.

The Triangulum project intends to produce a set of smart city indicators drawing on the work of the European Innovation Partnership on Smart Cities and Communities.

ESPRESSO Task 4.3 will define a smart city indicator platform; a set of online services to help cities assess their own performance, and compare themselves against others. The approach has been to select a set of indicators from the existing standards. The output of that task (ESPRESSO D4.3) contains a more extensive discussion of the various sets of indicators which are in use.

A second edition of this document will learn from these other activities.

Quantitative indicators

ISO 37120 is widely quoted as the international standard for indicators. It covers a number of themes, including energy, transportation, governance, health, recreation, safety, solid waste, waste water. The World Council for City Data uses ISO 37120.

ISO/TS 37151 considers that a community has infrastructure in order to support facilities which enable services. It describes metrics for the community infrastructure,

but mainly for the ICT infrastructure as opposed to the ICT embedded in facilities or equipment as a mean of control. *Or natural green infrastructure, which is acknowledged.*

There are other sector specific measurement and evaluation standards, particularly in the energy sector:

- "ITU-T L.1440 methodology to evaluate the environmental footprint of various smart city solutions" *unclear which sector(s) this relates to; it certainly includes energy*
- "Recommendation ITU T. L.1430. Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects."

Also in construction safety (EUROCODES), and waste (IEC/TR 62635)

There are European Commission directives setting indicators in some sectors, such as the EU Water Framework Directive. Other EC initiatives are developing Key Performance Indicators for sectors such as intelligent transport systems.

The EU CityKeys project apparently studied 43 indicator frameworks before selecting 73 city indicators. Many of these are quantitative, but some are subjective.

There are seventeen UN Sustainable Development Goals, each of which is split into several sub-goals. Each sub-goal has one or more quantitative indicators, although not all are equally well defined. *An adhoc group of ISO TC211, OGC, and IHO, is investigating the geo-information requirements and standards which will support calculating the values of these indicators.*

Subjective indicators

As well as some CityKeys city indicators, there are other sets of subjective indicators that could contribute to measuring sustainability.

Direct measures of well-being are necessarily subjective, while quantitative measures of health and fitness, for example, are only measuring potential contributing factors. Example include the UK Office of National Statistics (*Measuring Personal Well-being in the UK*[9]), and the informal What Works organisation[10].

The CITIE framework allows cities to compare themselves with other cities. The indicators appear to be assessed subjectively.

Huawei commissioned a UK Smart Cities Index from Navigant Research, a market research company. They assessed cities on five aspects of strategy: Smart City Vision, Digital Innovation, Service Innovation, Sustainability Goals, Stakeholder Engagement; and five similar aspects of execution: Implementation, Digital Delivery , Service Delivery, Environmental Impact, Community Reach.

Check lists

Someone said that some indicator sets are just lists of yes/no – can't find the reference!

[9] http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/publications/measuring-subjective-well-being-in-the-uk.pdf
[10] https://whatworkswellbeing.org/what-works/evaluation-wellbeing-impact/

9.4. Information models

Relevant standards:

ISO TC268 has two standards under development covering these areas:

- ISO/DIS[11] 37102 *Sustainable development and resilience of communities – Vocabulary*
- ISO/IEC DIS[12] 30182 *Smart city concept model -- Guidance for establishing a model for data interoperability*, which adopts the PAS 182 text.

ISO TC211 and OGC have a number of relevant standards for describing the physical and social geography:

- ISO 19152 *Geographic information – Land administration domain model*
- OGC 12-019 *City Geography Markup Language (CityGML) Encoding Standard*
- OGC 14-005 *OGC Indoor GML*
- OGC 15-111 *Land and Infrastructure Conceptual Model Standard (LandInfra)*, under development

Note, these ISO and OGC information models build on a common collection of underlying ISO standards about how geographic information should be structured. So many of these ISO 191xx standards are indirectly relevant.

There are many information standards in the area of Internet of Things and other sensors; these will be covered more in the Engineering Viewpoint. Examples are OneM2M from ETSI and partners and SensorML from OGC.

Other consensus publications:

Two British Standards Institution Publicly Available Specifications document ways to join up data from different service sectors:

- PAS 180 *Smart Cities – Vocabulary*
- PAS 182 *Smart city concept model - guide to establishing a model for data interoperability.*
- PAS 282 *Hypercat*; under development, adopting the Hypercat consortium standard for managing collections of connected devices.
- City Protocol Society ontology

The European Commission INSPIRE initiative has developed a set of compatible information models for exchanging environmental data. These cover a number of themes including Transport Networks, Buildings, and facilities that may be involved in energy production or waste management.

EUROCODES provides information for a common approach for the design of buildings, civil engineering works, and construction projects.

[11] 12 week ballot initiated 2016-04-02
[12] 12 week ballot initiated 2016-04-07

CitySDK [http://www.citysdk.eu] contains an implied information model, which has grown as it has been developed to support a few specific themes.

Other documents:

LandXML, being superceded by OGC LandInfra

9.4.1. Discussion

There appear to be two aspects of open standard information modelling that are helping cities become smarter: semantic interoperability between sectoral data, and models of the physical city ("city model"). Semantic bridges can either consist of an agreed vocabulary, use of which will improve communication, or a more formal ontology, which allows datasets to be integrated automatically, once the formal mapping is accepted and the existing datasets are mapped to the common model.

CityGML is the main information model used to underpin city models. Although the OGC CityGML specification is officially an XML encoding, the specification contains an information model, which several organisations and many cities have implemented within relational databases.

Use cases claimed for CityGML based city models include efficient energy use, optimization of transport, noise analysis, tourism, simulation as well as resilience/public safety.

LandXML is also a transfer format with an implicit information model, which is used in the construction of transport infrastructure. OGC is preparing a specifically conceptual information model, LandInfra, and then plans to work on a GML/XML encoding of it. This is sometimes described as working alongside CityGML, but concentrating on the infrastructure rather than the city, but LandInfra's declared scope is "land and civil engineering infrastructure facilities … improvements constructed and operating on land". It aims more for compatibility with ISO 16739 *Industry Foundation Classes*, which concentrate on the planning, design, and construction of facilities. Building Smart International, the owners of IFC, are looking to extend its usefulness to facilities management i.e. the operational use of the digital model to support efficiencies for the built asset. This will bring it more in to the domain of smart cities.

Some sectors have specific common information models, at least in Europe, where the city may need to report against a European Community Directive. Examples include environmental and quality of life factors governed by the EC Water Framework Directive, Noise Directive, Air Quality Directive, and food testing infrastructure. The EC INSPIRE Directive aims to provide a set of compatible information models which can be used for each of these reports, and other environmental information exchange. The models are mainly developed to the extent required for reporting, and are less detailed than may be required for a technical "smart city".

10. Annex 1: Architectural frameworks

Different publications and organisations use distinct approaches to describing the structure of what they are talking about – these are architectural frameworks, and are themselves the subject of a range of standards. This annex contains a pragmatic cross walk which we have established between the different frameworks that we have found

to be used when preparing this document. It is offered only to support the decisions we have made about classifying certain things as, for example, "technical" or "non-technical".

Framework	Used by	Notes
Reference Model for Open Distributed Processing (RM-ODP) ISO/IEC 10746	This report	
OpenGIS® Reference Model (ORM) OGC 08-062r7	OGC	Based on RM-ODP
The Open Group Architecture Framework (TOGAF) https://www.opengroup.org/togaf/		Various national government flavours, such as MODAF (UK Ministry of Defence)
Open Systems Interconnect (OSI) ISO/IEC 7498-1	Apparently favoured by ISO/IEC JTC1	
TM Forum Frameworx	ISO/IEC JTC1 Study Group 1	

10.1. Crosswalk

Different sources use various architectural frameworks to classify their approach. In order to relate the reports together, we have used the following "cross walk". That is, we have considered terms that are placed in the same row in the table below as equivalent. For example, if a report states that something is in the TOGAF application layer, we consider it to be in either the RM-ODP Computation or Engineering layers, depending on whether it is a software or hardware standard.

ESPRESSO grant agreement terminology	RM-ODP	OGC	TOGAF	OSI	Frameworx	Notes
conceptual; non-technical	Enterprise	Enterprise	Business process	n/a	Business Process	
"information models"	Information	Information	Business Information	n/a	Information	conceptual & logical data models

“technologies”	Computation	Service	application	Level 7?	Application	application software interfaces
“technologies”	Engineering	engineering	application	Levels 6, 5, and arguably 2-4	Application?	software implementation
	technology	technology	infrastructure	Level 1, and arguably 2-4	Integration?	This row often includes operating system, database systems and middle ware