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Technical Report

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ITU-T Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE)

FG-AI4EE D.WG1-11

Best Practices for Graphical Digital Twins of Smart Cities

Working Group 1 - Requirements of AI and other Emerging Technologies to Ensure Environmental Efficiency

Focus Group Technical Report

FOREWORD

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The procedures for establishment of focus groups are defined in Recommendation ITU-T A.7. ITU-T Study Group 5 set up the ITU-T Focus Group Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE) at its meeting in May 2019. ITU-T Study Group 5 is the parent group of FG-AI4EE. Deliverables of focus groups can take the form of technical reports, specifications, etc., and aim to provide material for consideration by the parent group in its standardization activities.

Deliverables of focus groups are not ITU-T Recommendations. For more information about FG-AI4EE and its deliverables, please contact Charlyne Restivo (ITU) at tsbfgai4ee@itu.int.

NOTE

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Summary

This example-based report focuses on how emerging technology solutions can best address environmental issues within cities. The data used is based on information gained from the United Nations "United for Smart Sustainable Cities" reports [b-U4SSC 2020]. Industrial Internet of Things (IoT) and smart cities gather a lot of data in data lakes and present the insights generated by machine learning or artificial intelligence in custom proprietary dashboards or in open APIs. It is a tedious task for stakeholders with low data literacy to apprehend so much information and in so many data formats in a way that helps them bend their decisions and adapt their behaviours towards a more sustainable future. In light of the United Nations' 2030 Agenda for Sustainable Development and the European Commission's Fit-for-55 programmes, there is a critical need for a visualisation tool which can help visualise and compare, in a consistent manner, the sustainability of smart cities in such a way that priorities can be identified and anchored at all decision-making levels and best practices can be scaled-up and replicated to other cities. The purpose of the document is thus to identify the emerging technologies which allow a prompt comparison between different cities and help detect low hanging fruits and areas of high priorities. In the sake of convenience and reproducibility, attention is drawn to potential universal data formats.

Keywords

U4SSC; emerging technologies; visualisation; KPIs; scalability; replication; sustainability; graphical digital twins

Change Log

This document contains Version 1 of the ITU-T Technical Report on "*Best Practices for Graphical Digital Twins of Smart Cities*" approved at the ITU-T Study Group 5 meeting held in X[Place]X on X[Date]X.

Editor:	Joel Alexander Mills Offshore Simulator Centre/AugmentCity Norway	Tel: +47 909 06 664 E-mail: jam@osc.com
Editor :	Pierre Major NTNU/OSC/AugmentCity Norway	Tel: +47 94035960 E-mail: pierre.major@augmentcity.no

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Best Practices for Graphical Digital Twins of Smart Cities

Summary

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1 Scope

This example-based report details how emerging technology solutions can be used to address environmental issues in an urban environment. The data used is based on information gained from the United Nations "United for Smart Sustainable Cities" [b-U4SSC 2021] reports. This Technical Report focuses on comparing results from different cities around the world and looking at the areas where cities gained low results. The report attempts to answer the following questions: What are the emerging technologies that could improve these results? How should the data be structured to improve results?

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.1 Internet of Things (IoT) [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

3.1.2 Smart Sustainable Cities [ITU-T Y.4900]: is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.

3.1.3 Big Data [ISO/IEC 20546:2019, 3.1.2] extensive datasets — primarily in the data characteristics of volume, variety, velocity, and/or variability — that require a scalable technology for efficient storage, manipulation, management, and analysis.

NOTE 1 – Big data is commonly used in many different ways, for example as the name of the scalable technology used to handle big data extensive datasets.

3.2.1 Digital twin [ISO/TR 24464]: Compound model composed of a physical asset, an avatar and an interface.

3.2 Terms defined here

3.2.2 Graphical Digital Twins (GDT): A graphical digital twin superimposes the spatiotemporal data, information and insights on a 3D model representative of the city (height map and satellite pictures) and its build environment (BIM and mobility infrastructure), as depicted in **Figure 3**. In this way, the data and their insights can be contextualised and more easily understood by all the stakeholders.

3.2.3 Smart City Stakeholder: Smart City Stakeholders are any people involved in the development of smarter and more sustainable cities. They include, but are not restricted to citizens, interest group representatives, businesses, civil servants and urban planners, politicians and researchers. **Error! Reference source not found.** illustrates the smart city stakeholder in collaborating with the digital twin solution.

4 Abbreviations & acronyms

This Technical Report use the following abbreviations and acronyms:

AI	Artificial Intelligence
API	Application Programming Interface
ML	Machine Learning
IoT	Internet of Things
U4SCC	United for Smart Sustainable Cities
KPI	Key Performance Indicator
GDT	Graphical Digital Twins

5 Conventions

None.

6 Best Practices for Graphical Digital Twins of Smart Cities

6.1 Introduction

Smart cities are associated with Big Data, growing concerns about sustainability and climate change, and participative intelligent decision-making solutions. In this context, the challenges of citizen engagement in decision-making are data-privacy and the fact that the sheer amount and heterogeneity of insights from various domains make it extremely demanding for nonexperts to understand the situation and communicate priorities and solutions. As high-quality 3D graphical digital twins of cities are getting more widespread and affordable, we propose the introduction of 4D visualisations of geolocalised time-series in the twins. The method, applied in a city council, uses off-the-self hardware and game-engine, and creates immersive environments to convey multivariate spatiotemporal data in a data-agnostic manner.

Cities are complex systems of systems which are currently facing major challenges: accelerating population concentration, increasing congestion and air pollution, and climate change. Indeed, they host a growing number of the world's population; for example, 70% of the European population was urban in 2018 [b-Eurostat 2016] and 75% to 80% will be by 2050. According to the World Health Organization, 4 to 8 million people die prematurely because of air pollution every year. Two thirds of the world's biggest cities are coastal and will be impacted by sea level rise and more frequent and devastating extreme weather. Sea Level Rise threatens the lives of between 150 to 200 million people worldwide [b-Kulp & Strauss 2019]. The problem is thus systemic and cannot be solved by only optimising or upgrading the already existing cyber-physical infrastructure. A series of independent smart city initiatives have mapped the high-level UN Sustainable Development Goals to concrete key performance indicators (KPIs) to assist city councils in understanding the challenges, setting the policy priorities, and communicating them to stakeholders. One such initiative, United Nations for Smart Sustainable Cities [b-U4SSC 2020] has been adopted by a growing number of smart cities worldwide.

Sustainability is the balance between economic growth, social equality, and environment preservation; the U4SSC KPIs are a set of 91 indicators from these three areas and are a compass for smart and sustainable city-level decisions. It has proven demanding to communicate with stakeholders on the current situations, actions to take, and on progress made. Visualisations in 4D can help tackle such challenges.

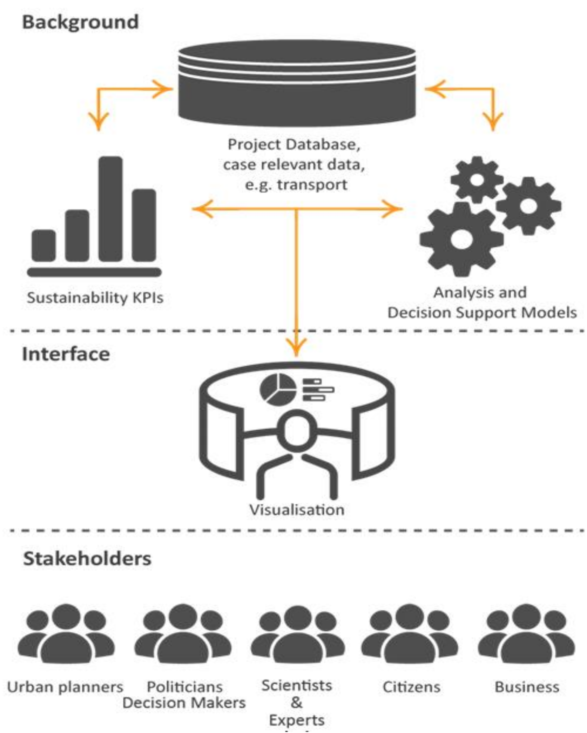

Figure 1 – **Smart City Stakeholder** [b-Major, Hildre & Zhang 2021]

6.2 Overview of Big Data and AI-ML generated insights for Smart Cities and Earth Observation: Formats, Structure, Storage, Challenges

This section will present a short overview of state of the art in the domain of big data for smart cities and earth observation and conclude with a list of unsolved challenges relative to the stakeholders' involvement in the behaviour change and decision-making processes. Table 4 in the appendix provides a non-exhaustive list of data and use cases relevant for smart cities.

Smart city data provide data and insights in the form of geo-referenced timeseries which are multivariate data. High-level decisions, priorities, and measurements must be interpreted in their spatiotemporal context. Instrumentation and measurement are hardly conceivable without a graphical representation of the values. The main challenges of big data are:

- Accessing the unfathomable amount of data, identifying which is business-critical, and presenting it in a human-friendly way through quick response-time, intuitive interaction, and understandable visualisation.
- Finding a balance between high-quality data and data privacy. General Data Protection Regulation (GDPR) is taken very seriously in Europe, especially when the trust of the citizens in the local authorities is at stake.
- Determining the reliability of data from sensors and insights given from predictions during the decision-making process.
- Domain knowledge is a requirement for understanding the underlying data, but not all the stakeholders have the necessary literacy to grasp the insights without additional help.

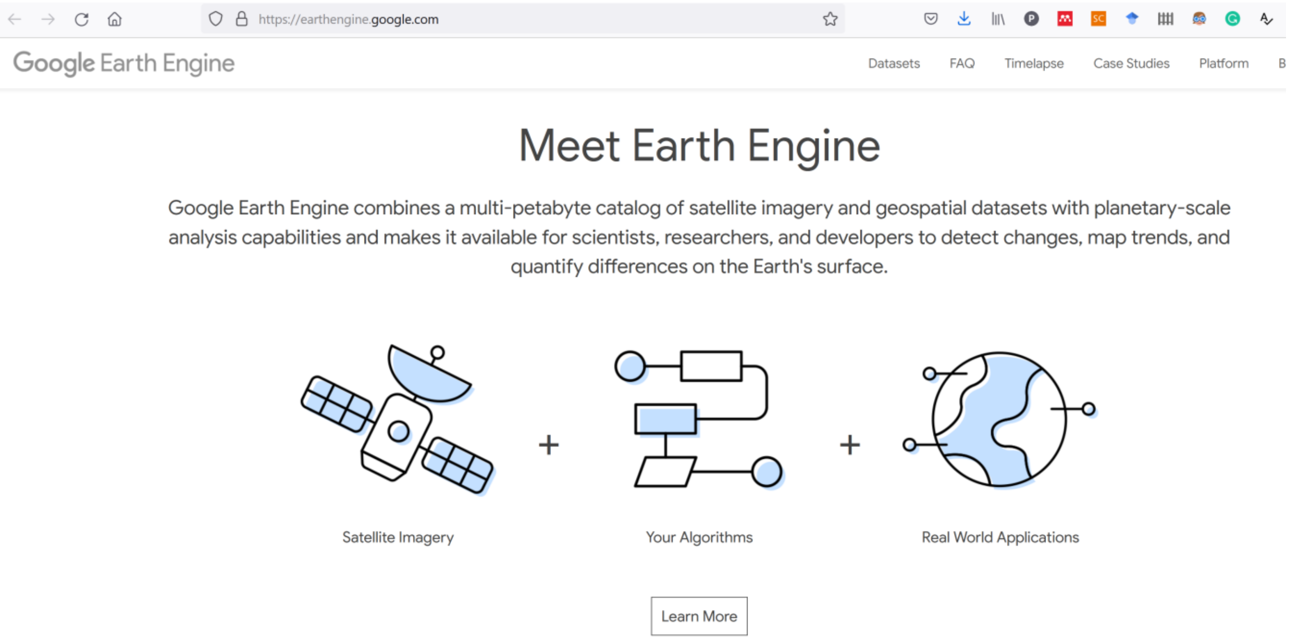

Figure 2 – Google Earth Engine

Figure 2 illustrates the Big Data process pipeline and value chain offered by Google Earth Engine: collecting **petabytes** of earth surface data in various catalogue, processing the data thank to ML and AI, then make useful human understandable stories that engage a wide audience and trigger decisions.

Such data-driven approaches are instrumental when trying to understand past geographical processes at the scale of the Anthropocene. But scenario-driven and insight-driven approaches are necessary to nudge stakeholders towards more sustainable high-level decisions.

Intuitive traffic-light-inspired colour-scheme visualisation, as depicted in Figure 3 easily communicate progress on key issues within the city or community. The offer a high-level easy to grasp insight which can be drilled down, if necessary, by showing the underlying data set in a spatio-temporal manner. As such, it combines both an intuitive visualisation and user interface allowing the user to interact with the data.

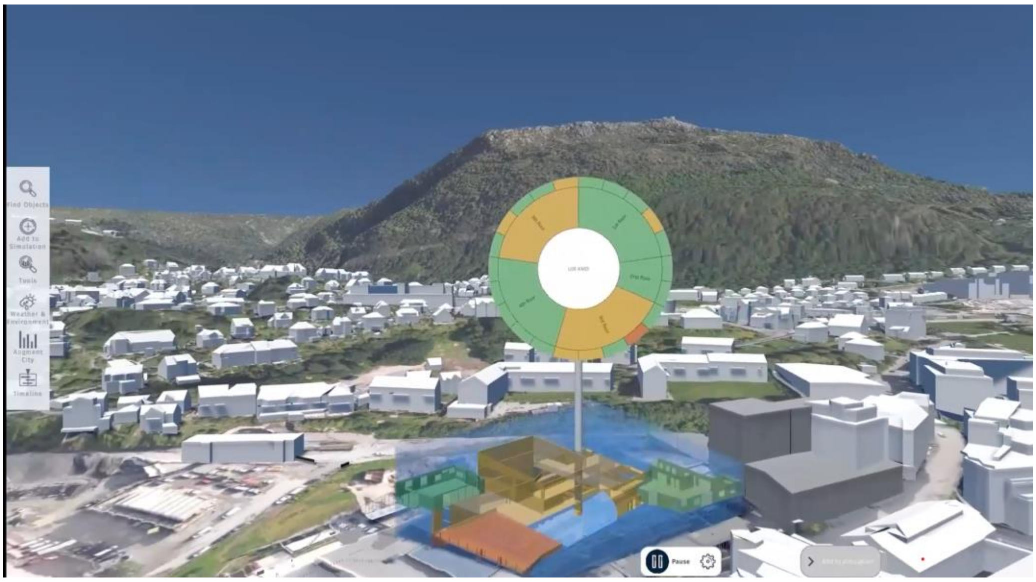

Figure 3 – AugmentCity's Lollipop data visualisation, Courtesy of AugmentCity

6.3 Limitation of current dashboards for Smart Cities and Earth Observation

This section will present a short overview of the state of the art in the domain of dashboard solutions of smart cities and earth observation and conclude with a list of unsolved challenges relative to stakeholders' involvement in the behaviour change and decision-making processes.

Figure 4 depicts one of the views of the Amsterdam Smart City Dashboard. One can see the geo-localised information with a lot of widget displaying real-time trends. Table 1 presents a short analysis of the pros and cons of current dashboards solution. To summarize, a dashboard is a tool to show the current situation, much like a car's dashboard. They can help decide on short term decisions but not on macro trends or multi-generational decisions.

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Table 1 – Analysis of Current dashboard

Pros	Cons
• Gather all dynamic real-time (IoT) information in one place: • Engage users through 3D visuals • Provide historical and real-time data or can provide short term trends such as overnight or 15-minute traffic surges or energy demand • Some provide possibility to interact remotely with actuators such as	• Expert-centric: require a high level of literacy to grasp the many visualisations and make correct decisions • Expert-centric: information is in the hands of a few people in operational centers • Seldom provide long term scenarios that are necessary for planning sustainable cities

emergency valves for floodings, lighting	• Seldom provide long term Anthropocenic analysis of cities • Very often proprietary protocols • Provide information but no insight • Narrative is challenging to engage citizen • Limited collaboration possibilities

6.4 Overview of Graphical Digital Twins for Smart Cities and Earth Observation

This section will address how graphical digital twin solutions of smart cities and earth observation can solve the aforementioned challenges and also investigate the scalability and replicability of such methods.

As seen in Figure 4, Graphical Digital Twins (GDT) of cities help contextualise information geo-referenced information. Virtually any kind of data can be related to a location by joining and merging datasets. Furthermore, the datasets are very often dynamic and historical. There exist many solution providers which have developed a smart city platform for their main and only client on a project basis. The GDT are thus not replicable and scalable to other countries and cities. International smart city standards, such as U4SSC, should be supported as minimal requirement of GDT. This will ensure the scalability, portability, and comparison of the standard solution.

Furthermore, many GDTs solutions, such as Figure 4, focus on IoT and thus lack the flexibility to show different datasets that are more soft such as quality of living or citizen wellbeing and or outcomes of hydrographic simulations (storm surge impact, strom floodings etc.).

Figure 4 – GeoDan/Huawei Amsterdam Smart City Platform

6.5 Data Formats for Graphical Digital Twins for Smart Cities and Earth Observation

This section will address how data need to be structured in order to be intuitively presented in graphical digital twins. **Error! Reference source not found.** shows an overview of the data formats.

Error! Reference source not found. shows an example of hybrid approach using a dynamic REST API to create a CSV based heatmap. CSV files are the best candidates for a wide variety of users. They allow showing data in various case studies (see Table 4) in digital twins and prototype solutions. Integrating static and dynamic REST APIs can be seen as the next step to automate manual work and guaranteeing interoperable solutions.

Table 2 – Data Formats

Standard Name	**Description**	**Use**
CSV	Excel (See **Error! Reference source not found.** for an example)	Broad Audience
NETCDF	Multivariate Scientific raw low level data	Scientific
HDF5	Multivariate Scientific raw low level data	Scientific
OpenStreetMap	Road Description Network	Mobility visualisation and simulation
GeoTiff via WMS	Raster Pictures	Textures picture of terrain
Lollipop	Hierarchical structured high level data	Showing high level KPIs
Static data REST API (arcgis, azure, google, AWS)	Access to datalake	Commercial, productive use, too complex for wide audience, but best way to automate servcices and visualisation
Dynamic Data REST API (JSON)	On Demand calculations	Mobility simulation and information see **Error! Reference source not found.**

time	value	lat	lon
07/06/2021 13:02	600	59.901845	10.645841
07/06/2021 13:02	600	59.902192	10.645841
07/06/2021 13:02	600	59.902540	10.645841
07/06/2021 13:02	600	59.902887	10.645841
07/06/2021 13:02	600	59.903235	10.645841
07/06/2021 13:02	600	59.903582	10.645841
07/06/2021 13:02	600	59.903930	10.645841
07/06/2021 13:02	600	59.904277	10.645841

Figure 5 – Spatiotemporal Time Series

Table 3 – Heatmap of distance to bus stops (high frequency lines left, low frequency lines right) Courtesy of AugmentCity and Entur

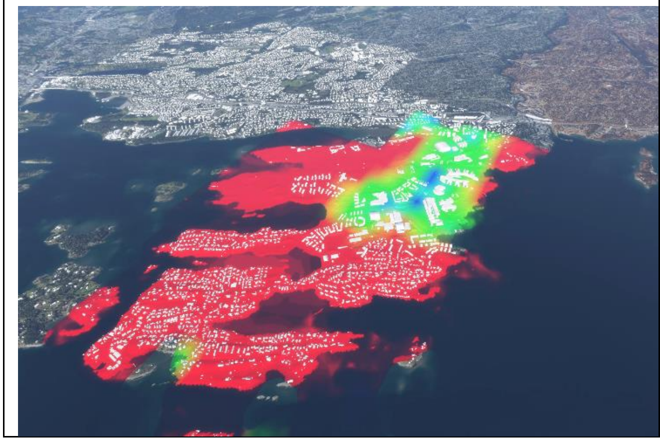	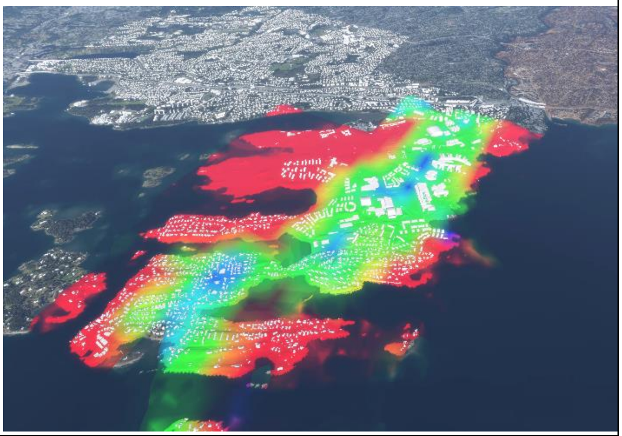

Table 4 – Smart City Data Analysis [b-Major, Hildre & Zhang 2021]

Type	Description	Relevance	Scalability	Privacy
BIM	Building and Road Information CAD, Timed BIM	Current and future city Contextualise energy consumption, infrastructure needs	Local and private data, international standard format	Occasionally critical
Energy & Water	**Energy and Water Usage in districts** **KWh/day/hour, m^3/day** **Geolocalised time-series**	**Civil defence** **Current and future infrastructure needs**	**National database**	**Critical**
Weather	Historic and Forecast Geolocalised time-series	Contextualize outdoor activities Civil Defence	Worldwide Service	Irrelevant
Air Quality	Historic and Forecast Geolocalised time-series PM10, PM2.5, PM1, NOx, SO_4	Health and environmental consequences	National Service	Irrelevant
Mobility	**Inductive Loop Data** **Geolocalised time-series** **Vehicles/hour/day etc**	**Network utilisation of vehicle and bike infrastructure, Emissions, congestion**	**National Service**	**Occasionally critical**
Public Transport	**Automatic Passenger Counting** **Per bus, ferry line and stop** **PAX, revenue**	**Monitoring and planning of infrastructure**	**Regional Service**	**Critical**
Demographics	Historic and Forecast Geolocalised time-series (age, gender, wealth, school pupils)	Contextualize and plan infrastructure needs: schools, roads, bus lines	National Service	Irrelevant
U4SSC KPIs	**91 sustainability KPIs**	**Identify priorities for sustainable planning**	**Worldwide Service**	**Irrelevant**
Emergency Response	Fire and -ambulance Response Time Minutes to destination Geolocalised time-series	Identify areas with poor coverage Plan infrastructure	National Service	Critical
AIS	Automatic Identification System Geolocalised Time-Series	Air quality correlations Traffic planning	Worldwide and National Service	Occasionally critical
Outdoor Activity	Geolocalised Time-Series Outdoor activities with Strava Outdoor Path	Contextualize outdoor activities Identify preferred routes	Worldwide Service	

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