# An Urban Intelligence IT Architecture to Support the Development of Smart City Projects

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***Abstract*—This long abstract presents an IT architecture specifically devoted to supporting the development and deployment of the subsystems of an Urban Intelligence platform, allowing the implementation of smart city projects. Each layer of this architecture includes its own specific functionalities, as well as defines how data and information is exchanged within the layers and also with external systems. This architecture has already been successfully adopted in real-world smart city projects in Italy, demonstrating its value.**

***Index Terms*—Urban Intelligence, Smart Cities, Service Architecture**

## I. Introduction

City development and management must continuously adapt to changing environmental, economic, and social conditions. To address these complexities, multidisciplinary approaches are essential, as they enable analysis and understanding of the interactions among various physical components of urban environments and their relationship with residents. Digital Twins (DTs) have recently emerged as an instrument for effectively managing contemporary cities by enabling real-time monitoring and enhancing decision-making capabilities. A DT is a virtual model of a physical entity or system, accurately reflecting its characteristics, behaviours, and interactions in real time through the integration of sensor-generated data, computational modelling, and sophisticated analytics, providing an approach to modelling, simulating, and analysing complex systems synchronized with real-time processes across diverse application domains, including the various aspects of a city [1]. In detail, an Urban DT should provide a virtual replica of the assets, systems, and processes of a city, as well as reliable simulation and learning environments, realizing an Urban Intelligence (UI) paradigm [2]. This can be achieved only by integrating several different technologies, data, knowledge, and methodologies, such as Internet of Things (IoT) sensors, mathematical models, Artificial Intelligence (AI), Big Data Analytics (BDA), networking infrastructures, information systems, ontologies, advanced web services, and cloud or edge-computing environments, to the end of simulating, comprehending, and, where possible, predicting the dynamics, interactions, and evolution of urban layers [3].

These IT paradigms and technologies must be combined within an UI framework, which requires an underlying sophisticated IT platform capable of streamlining deployment, facilitating communication and integration among DTs and its other subsystems, managing and sharing data effectively, supporting advanced search, retrieval, and reasoning functionalities, and providing comprehensive visualization and interface capabilities. This long abstract introduces the latest evolution of the architecture of an IT platform designed to facilitate the design, integration, deployment, and management of DTs and any other subsystems within an UI framework, which has been successfully adopted in different real-world Smart City projects in Italy in Matera [1] and Catania.

## II. Architecture

Figure 1 illustrates the layers of the proposed IT platform architecture, which consists of six horizontal layers and a vertical layer:

- *Cloud Computing Layer*, which is responsible for providing all low-level services required for the implementation and deployment of UI modules and subsystems, following a cloud-based paradigm. This layer contains all the functionalities needed for installing and running the software that implements the modules and subsystems logically present in the higher levels of the architecture.
- *Data Layer* aims to acquire, store, integrate, manage, and make available all the data used by the UI framework and its modules, including any functionality related to the data, whether acquired from sensor networks, generated as results by various UI systems, or obtained from external IT systems.
- *Knowledge Layer*, which contains the city knowledge representation system, based on a city ontology, including the resources for modelling, managing, querying, and sharing the ontology.
- *Digital Twins Layer*, which includes the modules that implement the DTs devoted to model the various aspects

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of the city, simulating specific aspects of the city by interacting with systems in the other layers of the architecture.
- *Decision Support System (DSS) Layer*, which encompasses DSS functionalities based on data, ontologies, and the results of the DTs implemented at the lower levels of the architecture.
- *Data Visualization and User Interface Layer*, which includes systems for structured visualization of data and simulations/models results, as well as user interfaces for managing the functionalities provided to end users.

The vertical layer common to all horizontal layers is the *Communication Interfaces Layer*, which includes all communication interfaces needed for information exchange between layers, as well as for connection and interoperability with external IT systems, and, lastly, authentication and authorization functionalities.

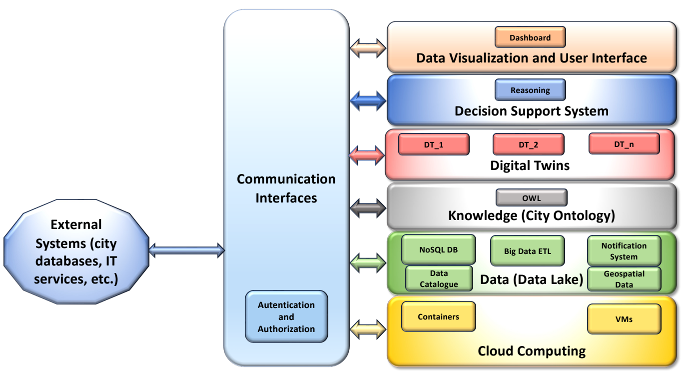


Fig. 1. Example of a figure caption.

More in detail, the *Cloud Computing Layer* includes the systems devoted to the deployment of software, allowing for their management and orchestration, promoting portability and ease of installation. The approaches considered include the use of containers (based on the Docker standard and managed through the Kubernetes container orchestrator), or the use of virtual machines, or dedicated servers on the cloud for the direct installation of the specific libraries and software.

*Data Layer* integrates several services, ranging from NoSQL and SQL Databases, GIS, Big Data ETL functionalities, and an asynchronous notification system (based on publish/subscribe mechanism, such as the MQTT protocol).

The *Knowledge Layer* has been included to encompass all functionalities dedicated to structured and formal modelling, representation, and organization of knowledge regarding the urban environment (covering any aspect that must be considered during the development of a dedicated city's urban ontology). Therefore, this layer contains the resources needed to create, manage and query the city's formal ontologies, which can be expressed using standard languages such as OWL, and SPARQL for semantic queries, providing a rigorous and structured definition of key concepts related to the urban environment (i.e., buildings, streets, infrastructures, public services, transportation, and energy, environmental and social resources, etc.).

The *Digital Twins Layer* is responsible for creating a dynamic, continuously updated digital replica of specific aspects of the city, accurately simulating and monitoring in real time all the corresponding urban components (such as transportation, air quality, physical infrastructures, etc.). This layer leverages data from various sources, including appropriately installed city sensor networks, GIS data, city ontologies, and data related to social aspects, and utilizes them for the implementation of simulation models required to realize DTs.

Within the *Decision Support System Layer* of the architecture, there are systems for building reasoning engines capable of deducing new knowledge from the structured data present in the Data and Knowledge layers, enabling, for example, logical inferences, as well as tools for creating predictive models, simulations, and optimizations. In this way, the UI framework can be provided for all subsystems dedicated to supporting decision-making and performing simulations or predictions in complex urban scenarios (e.g., urban mobility simulation, pollution, and others).

The *Data Visualization and User Interface Layer* includes graphical interfaces and real-time dashboards for the interactive visualization of data and information, tools for advanced spatial visualization using GIS maps, tools for visualizing three-dimensional representations of the city and its features, graphical interfaces for visualizing data acquired and stored in the Data layer, and, finally, user interfaces for interacting with the DTs and DSS systems, enabling the execution of user-requested simulations and predictions.

The *Interface and Communication Layer* includes specially developed APIs dedicated to acquiring data to and from the Data layer, which provide a common and standardized method for data exchange among the system modules present at the various layers of the architecture, as well as for external IT systems. This layer also includes advance authorization and authentication functionalities (i.e., based on the use of the OAUTH2.0 protocol), ensuring data security and privacy.

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