Does End of Life Matter in Smart Cities?

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Abstract. In the smart city ecosystem, smart systems go through different phases of development from conception and design, through deployment and operation till end of service and retirement. Normally, city operators pay less attention to End of Life activities, compared to other phases of lifecycle. however, in the End of Life, the decommission of certain smart system shall be subject to applicable laws and regulations, like data privacy and cyber security. In addition, the outage of such smart system should be strategically aligned with the vision of the smart city. In this paper, we present the scenario of FIFA World Cup™ 2022, where Qatar has committed to donate part of its sports infrastructure to other countries. We particularly focus on the lifecycle of an IoT-enabled smart parking use-case in Lusail City.

Keywords: Smart City, IoT, Lifecycle Management, End of Life, Ecosystem.

1 Introduction

Smart city ecosystems, like other kinds of systems, consist of elements, functions and interconnections, but elements are intelligent and adaptive [1]. In addition, smart city ecosystems include humans, whether users, policy makers, regulators, vendors; and have business models and processes. It is also subject to applicable legal and regulatory frameworks. As many stakeholders adopt smart solutions in the city environment, the level of complexity increases from smart devices, to smart systems, to a compound system of interrelated/ interdependent systems. The lifecycle aspect of smart city systems is very important, like other engineered systems, and even more important in the case of complex SoS [9] [10].

Smart city system development, operation and maintenance are very complex tasks and involve numerous stakeholders from different disciplines and domains. In most cases, these systems are at different phases of design, deployment and operation, i.e. at different phases of lifecycle. Moreover, in such an innovative and responsive ecosystem, due to very rapid technological changes and altered consumer requirements, smart city systems can have multiple versions, variants and upgrades. Hence, lifecycle management concepts are very important to better manage smart city development as a complete ecosystem across different phases of lifecycle [5][6].

adfa, p. 1, 2011.

Qatar is the host of FIFA World Cup™ 2022. The Supreme Committee of Delivery and Legacy (SCDL) is responsible for the delivery of the required infrastructure to provide world-class services and create lasting legacy for Qatar. Qatar has committed, as per the bid file to FIFA, to donate parts of infrastructure and systems to future mega-event hosts. In this paper we propose the application of lifecycle management to manage different phases of a smart parking system, with a special focus at the End of Life (EoL). The remainder of this paper consists of four sections. Section 2 presents the background of smart city lifecycle management and importance of its applications. Section 3 includes the lifecycle-based modeling of smart city ecosystem. Section 4 demonstrates the lifecycle approach in a smart parking use-case. Section 5 includes conclusion of this paper.

2 Background

Lifecycle management is more than a technology solution; it is a strategic approach that enables more efficiency, higher quality, cost effectiveness, rapid innovation and better collaboration between stakeholders. As lifecycle management has enabled large enterprises to better manage their portfolio of products and services; similarly, lifecycle management can enable city administrators to better manage public services and supporting infrastructure. Hence, lifecycle management is important to manage business processes and data associated with heterogeneous connected objects in the smart city context [3].

For a smart city, lifecycle management is particularly important due to the following reasons [7][8]:

- Diversity of application domains, heterogeneity of data sources, big number of stakeholders and interdependency between different smart systems.
- In a complex smart city ecosystem, boundaries between sectors are blurring; different stakeholders are required to work together to design, deploy and maintain smart services.
- Being customer-focused, smart city service systems should be responsive to user requirements and customizable to public as well as personal requirements.
- Being technology-intensive makes “time to market” very critical factor for the smart city ecosystem that should be also agile and adaptable to technology and business disruptions.
- As a complex ecosystem, smart city is subject to multiple jurisdictions across different domains, and has to validate and prove compliance to all relevant regulatory obligations at all stages.

In the same time, absence of a clear lifecycle management vision can result in the following:

- Vertical “siloed” model of smart city with inefficient system design and disjointed operation process.

- Actors and partners – at different lifecycle phases – use different platforms and different ways of handling data, which consequently result in difficult collaboration, inefficient and delayed exchange of data/ information.
- In a "siloed" ecosystem, data is scattered, difficult to trace and less reliable. Moreover, there is lack of efficient change notification process between interdependent/ interrelated smart systems; and, engineering change processes are difficult to implement and track.
- Regulatory failure at different phases of lifecycle that may incur expensive fines, rework and write-offs.
- Delay in "time to market" which has severe business impact, in such an innovative and dynamic ecosystem, if a competitive smart solution gets to market first.

The vision of applying lifecycle management in the smart city context is to address the aforementioned issues to better integrate all smart city systems. To achieve such a holistic vision of complete smart city ecosystem, interrelated/ interdependent systems can exchange system data that include Bill of Material (BOM), versions, variants, stats and other lifecycle related data. Through lifecycle management systems, stakeholders can connect to a single platform to collaborate across lifecycle phases. They can access and share information, monitor and manage activities throughout lifecycle, and produce accurate reports.

3 Smart City Lifecycle-based modeling

Lifecycle-based modeling is essential to support the evolutionary path of smart city development, where smart city service systems can be consistently designed, built and operated in phases and in a modular way. Lifecycle-based modeling encourages innovators and entrepreneurs to develop endless number of new smart services and applications over the top of existing smart infrastructure and wealth of information. In addition, lifecycle management joins up many previously separate and independent processes, disciplines, functions and applications. It also maximizes reuse of smart city knowledge between different domains at different phases. In short, lifecycle management offers managers visibility about what is really happening with smart city systems and with their development, modification and retirement projects.

Hefnawy, Bouras and Cherifi [4][5][6] proposed a lifecycle-based model, as illustrated in Fig. 1, that combines the following three viewpoints: First, a layered architectural framework to deliver a common basis for the description of smart city systems. Second, domain representation to reflect different application domains, such as energy supply, traffic and public health. Third, lifecycle (time) viewpoint to represent the development of smart city systems and mentions roles of all involved stakeholders across time.

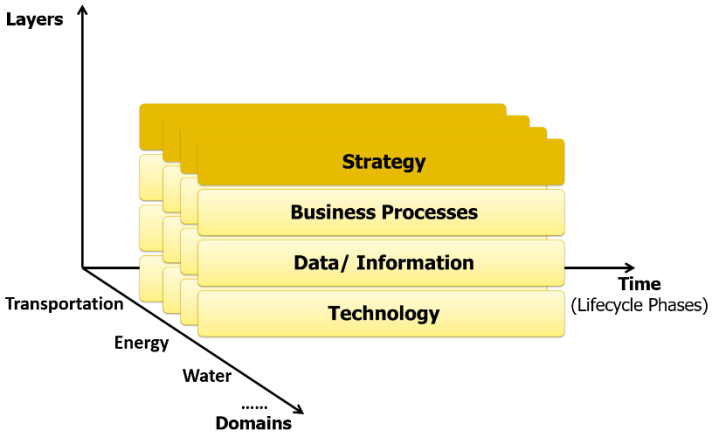

Fig. 1. Three-Dimensional Smart City Modeling Approach

Combining the three mentioned viewpoints provides a holistic view of smart city as a comprehensive ecosystem to better integrate people, processes, data and systems; and assure strategic alignment, and information consistency, traceability, and long-term archiving. Considering the big number of stakeholders involved in public service delivery, lifecycle management enables interoperability between different stakeholders at different levels of the multi-layered architecture. In line with the European Interoperability Framework (EIF), presented in Fig. 2, lifecycle management addresses interoperability requirements:

"…enabling disparate and diverse organizations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organizations, through the business processes they support, by means of the exchange of data between their respective ICT systems" [14].

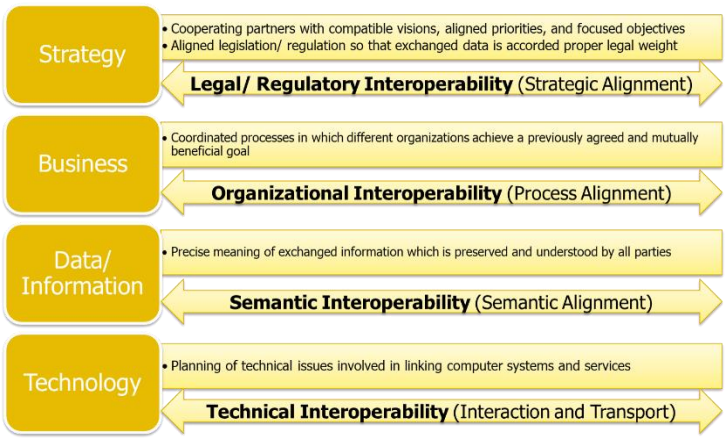

Fig. 2. Interoperability against Layers and Time

4 Smart Parking Use-Case

To better understand the proposed approach, the following use-case is a high-level example that is based on real information from Lusail City that will host the opening and final matches of FIFA World Cup™ 2022 in Qatar. Ras Abu Aboud stadium, shown in Fig. 3. [12], is one example of an innovative design concept using modular building blocks. The modular building blocks are modified shipping containers, each containing fundamental stadium elements and systems that can be quickly assembled and disassembled at various locations as required. The stadium is intended to be reassembled in a new location in its entirety or built into numerous small sports and cultural venues. This commitment entails physical infrastructure and smart system handover, as well as knowledge transfer.

Fig. 3. Ras Abu Aboud Stadium

In this use-case, we aim to build a scenario of a smart parking service system that is integral part of a complete smart city ecosystem to serve FIFA World Cup™ 2022. The smart parking system is promised to be decommissioned and donated to other countries after the event. The reassembly of stadiums and supporting infrastructure and systems can be in entirety or in parts. For this purpose, it is required to design, build, operate and dissemble these components in modules. While, to achieve the bigger vision of a smart city, these modules should be able to integrate within the complete ecosystem in a seamless way and across all phases of lifecycle. We propose a Smart Parking System (SPS) adjacent to FIFA World Cup™ 2022 stadium. The proposed SPS will be reassembled after the event in another location. The SPS is designed as per the requirements of Smart Qatar Program and SCDL. Table 1 illustrates SPS design considerations across SPS lifecycle.

Lusail City consolidates public and private parking inventories in Lusail Command and Control Centre (LCCC). The SPS shall be able to exchange correct system data and relevant information regarding parking status. The SPS shall allocate the optimal parking space based on set criteria and handle vehicles inside the parking through tracking and guidance mechanisms in a multi-tasking manner.

Table 1. Smart Parking System Considerations

- **Strategic Alignment:** Design in modular way (BoL); Reassembly after event in a new location (EoL);
- **Compliance:** All personal data should be retired (EoL) in compliance to Personal Data Protection Law;
- **KPIs:** Parking Cruising Time and Vehicle Mile Travel (MoL);
- **Processes:** Approval, Modification, Notification, between SCDL Construction (BoL, EoL), Smart Parking Sites' Operators (MoL, EoL), Technology Vendor (MoL, EoL);
- **Data Exchange:** Static and Dynamic Data in DATEX II format, between Smart Parking Sites' Operators;
- **Knowledge Preservation:** from BoL, MoL, and EoL to be transferred to the new location operator;
- **Technology:** The Open Group Standards as an Open IoT Standards and Platforms: Aras Innovator as lifecycle management system.

- **Operating Environment**

The SPS is proposed to operate as part of an integrated parking system, within Lusail smart city environment. Marina district (in Lusail City) has total of 2,200 public parking spaces in 4 identical underground parking sites, 3 basement level each. Currently, only one site is operational by Qatari Diar VINCI Park (QDVP[1]). QDVP contract includes management, operation, maintenance and repairs. Operators of the remaining 3 sites have not been yet selected. The presentation of QDVP operation in Lusail in Fig. 4 below [11].

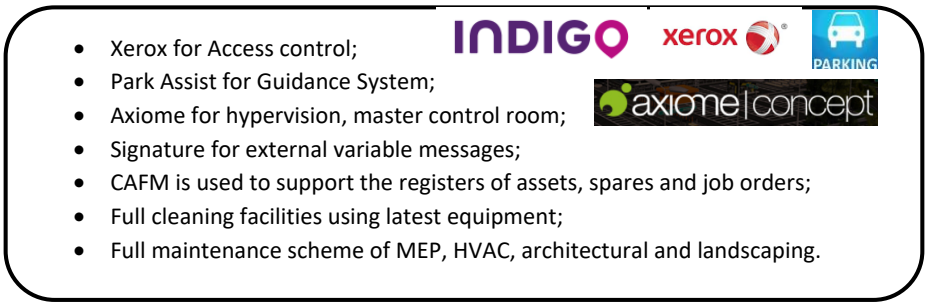

Fig. 4. Presentation of QDVP Operation

[1] QDVP is a joint venture owned 51% by Qatari Diar Real Estate Investment Company (a subsidiary of the Qatar sovereign fund, Qatar Investment Authority) and 49% by Indigo.

- **System Description**

As described in Fig. 5, the SPS is operating within a smart city environment. All smart city systems are interacting with Lusail Command and Control Centre (LCCC). The SPS will interact through external interfaces with Database System, Web Portal System, and LCCC.

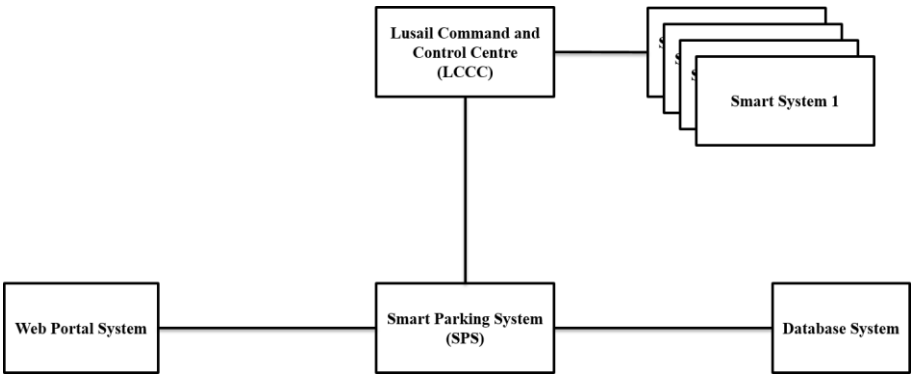

Fig. 5. SPS Overall Description

- **Integration of SPS within the Smart City Ecosystem**

To ensure integration of the SPS within the smart parking system of Lusail City, which is part of the complete smart city ecosystem, we ensure interoperability at different architectural levels and between different platforms, as illustrated in Fig. 6 and explained in the following sub-sections.

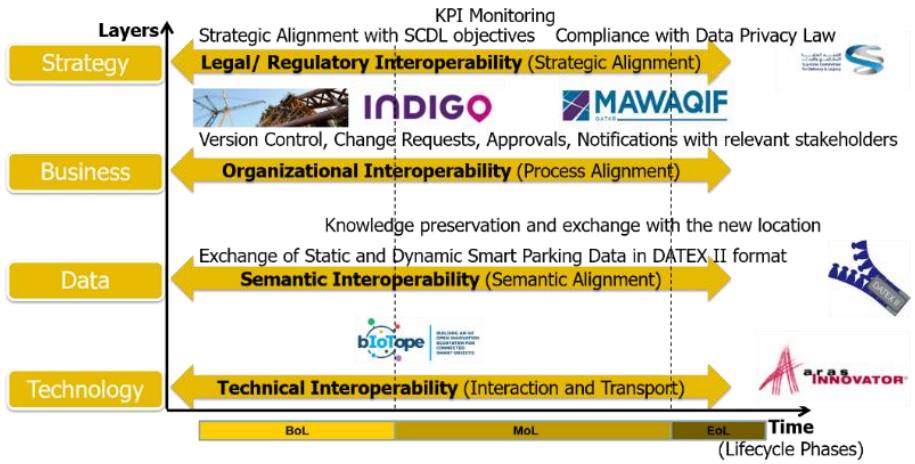

Fig. 6. Multi-Level Interoperability of SPS

— **Strategic Alignment**

The SPS is aligned to Smart Qatar [13] strategic objectives and SCDL requirements for FIFA World Cup™ 2022. The following are the strategic objectives that the SPS contributes to:

- Giving back 96 hours per year per person of time lost in traffic;
- Reducing CO_2 emissions equivalent to 29,000 homes annually;
- Attracting 600,000 visitors to sports events.

The proposed SPS, as part of the bigger city parking system, contributes towards the achievement of the above strategic objectives. This contribution shall be continuously measured across lifecycle, through KPI monitoring. In addition, legal and regulatory compliance shall be verified and recorded at all phases. Legal and regulatory compliance includes adherence to Qatar's Transportation Master Plan, Open Data Policy and Personal Data Protection Law. SPS shall open up its parking related data during MoL. All personal data that will be used by SPS shall be ensured retired before the decommission of the system at the EoL.

— **Business Processes**

The use of lifecycle management system integrates all relevant stakeholders, according to their roles/ access rights, in approval, modification, and notification processes. Fig. 7 compiles relevant stakeholders who are involved in business processes. Lifecycle management ensures continuity of processes amongst stakeholders at different phases of lifecycle.

Fig. 7. SPS Relevant Stakeholders

— **Information/ Data: Semantic Interoperability**

To realize the full promise of a complete smart city ecosystem, SPS integrates in a bigger smart mobility system that is together with other smart systems form Lusail smart city. For this purpose, we use DATEX II standards to exchange information between different parking site operators, LCCC, and traffic management centers. We use

static parking publications for parking infrastructure, facilities and geo-referencing, which is low frequency in nature. While, we use dynamic parking publications for high frequency data about occupancy, status of facilities and temporary changes of static data. DATEX II provides a very extensive parking model (data catalogue). For the purpose of this use-case, we have selected limited number of classes and attributes. We have used DATEX II conversion tool, presented in Fig. 8. [2], to select relevant parts of the UML model and to create a Sub-Schema.

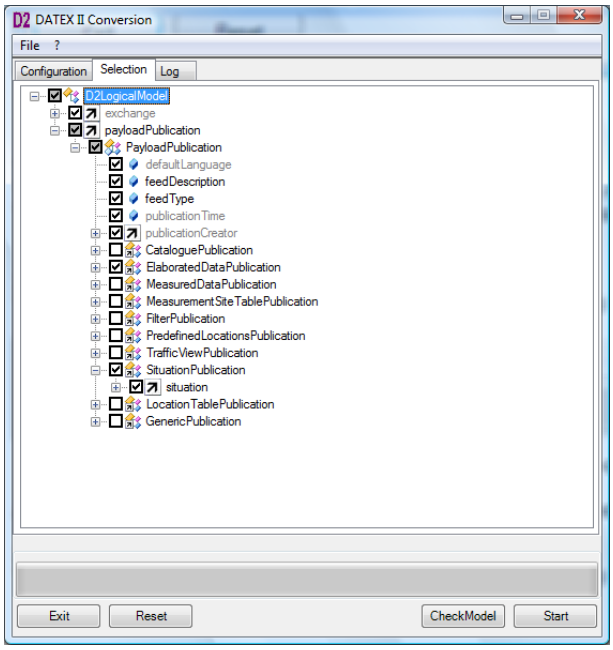

Fig. 8. DATEX Conversion Tool

– Technology

In this use-case, we use The Open Group Standards for IoT. To enable peer-to-peer publication and discovery of parking-related information, several O-MI edge nodes have been implemented in an aggregated form. The implementation of the O-MI nodes is in accordance to the XSD schema released by DATEX II conversion tool for the selected classes. Fig. 9 illustrates the Object Tree structure in O-MI node, as pushed by Java agent.

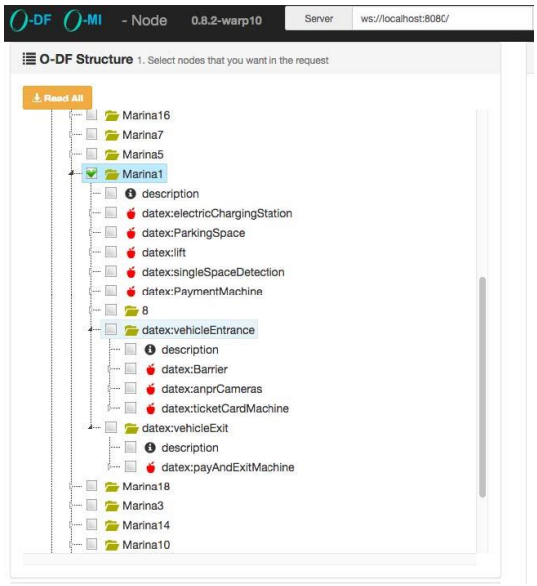

Fig. 9. SPS O-MI Node Implementation

5 Conclusions

This paper examines the proposed lifecycle-based approach in a smart parking system. The lifecycle-based approach is proved very relevant to this use-case for many reasons: need to manage End of Life Activities, and in general the whole lifecycle; need to integrate with other smart parking operators and with other smart city services; time-to-Market is very critical in a time constrained event like FIFA World Cup™ 2022.

We start by designing the SPS itself and ensure it fulfils all business and customer requirements. The SPS is designed to report a correct information regarding the current parking status online, and allocate the optimal parking space based on set criteria and handle vehicles inside the parking through tracking and guidance mechanisms in a multi-tasking manner. The SPS detects the vehicles as they enter the facility, providing a real time visual aid to direct the vehicles to a specific space.

The SPS is designed in a modular way to ensure integration within Lusail City parking system and within the bigger smart city ecosystem. For this purpose, we align the SPS with the operating environment on 4 levels: strategy; business processes, information/ data, and technology. KPIs of the SPS performance shall be continuously monitored across lifecycle. In addition, regulatory compliance shall be verified and recorded at all phases. Legal and regulatory compliance includes Qatar's Transportation Master Plan, Open Data Policy and Personal Data Protection Law. The use of lifecycle management system integrates all relevant stakeholders, according to their roles/ access

rights, in approval, modification, and notification processes. For semantic interoperability purposes, we use DATEX II standards to exchange information between different parking site operators, LCCC, and traffic management centers. While, we use The Open Group Standards for IoT technology.

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