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# Integration of Smart City and Lifecycle Concepts for Enhanced Large-Scale Event Management

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**Abstract.** Hosting large-scale events is the dream of many cities around the world, however challenging. Hosting a large-scale event is a complex project that requires careful planning, precise implementation, interactive operation, and successful closure of all activities, with the involvement of all relevant organizations, authorities and stakeholders. Therefore, event organizers pay their utmost attention to the improvement of every aspect of Event Management. Application of smart city concepts can address the complexity of service provisioning during large-scale events, through better efficiency, higher quality, and real-time decision-making capabilities. Lifecycle management concepts can improve the whole event management cycle across different phases. This paper proposes combining Smart City and Lifecycle concepts to improve vertical service provisioning and horizontal integration between different sectors, across different phases while creating a suitable platform for information and knowledge sharing within the same event and with other similar events. This research aims to reach a more holistic smart event experience.

**Keywords:** Smart City, Lifecycle, Event Management, QLM, IoT.

## 1 Introduction

Events are different in scale, from small gathering up to mega-events like World's Fair (EXPO), international conferences, sports world cups, and Olympics. Mega-events are large-scale, with global audience, occurring regularly in different cities. Big cities compete to host large-scale events in order to achieve global exposure, prestige and persistent increase in recognition; in addition to many economic, social and cultural benefits. Barcelona, Sydney, Beijing and London have all seen these benefits from hosting the Olympics. The choice of the host city is normally through a bidding process. Nonetheless, winning the bid alone does not guarantee the success of the event. The success of the event for the host city means a memorable and smoothly functioning event [1]. The current and future view of hosting large-scale events is becoming more about end-to-end whole event experience that involves all utility sectors. To achieve such a view, vertical improvement and horizontal integration is

required in and between sectors like transportation, traffic, energy, water, waste, healthcare, security, etc.

Technology has mutual-benefit relationship with large-scale events. On one hand, mega-events can be large-scale showcase for technological innovation [1]. On the other hand, technology can address many of the complexity issues of large-scale events. In this context, Smart city services can address the complex congregations of people [11] and improve vertical service provisioning through smart transportation, smart energy, smart waste, smart ticketing, etc. Nevertheless, the full realization of a complete smart event cannot happen without horizontal flow of valuable information across different domains instead of being locked into vertical applications or what so called “silos”. K. Främling, et al. argue that this concept is closely linked to the concepts of Lifecycle Management, which is commonly understood as a strategic approach that incorporates the management of data, versions, variants and business processes associated with heterogeneous, uniquely identifiable and connected objects [4][5].

This paper proposes the integration of smart city and lifecycle management concepts to ensure systematic involvement and seamless data flow between enormous numbers of stakeholders from different sectors [1] in order to meet the requirements of the “event sustainability management” standard, which requires control of data/information, across all phases of event management cycle [6]. The remainder of this paper is structured as follows: Section 2 describes the related work of previous large-scale events and the applicable Smart City Framework (SCF). Section 3 explains the proposed approach of integrating smart city and lifecycle management concepts. Section 4 applies the proposed approach on the scenario of Qatar 2022 Fan Experience. Section 5 shades light on the conclusion of this paper and the proposed future work.

## 2 Related Work

### 2.1 Smart City Applications in Large-Scale Events

**London.** The 2012 Organizing Committee of the Olympic Games (LOCOG) has deployed Information and Knowledge Management (IKM) system with dedicated IKM team to ensure information traceability across all phases of event management cycle. The IKM team had three strategic aims: “*first, to improve business productivity through the deployment of a document management system and other collaboration tools; second, to embed knowledge from previous Host Cities across LOCOG through structured learning programs; and third, to ensure LOCOG’s knowledge, records and archives are captured and transferred as a legacy to future Host Cities*” [7].

The LOCOG has deployed number of digital online systems for accommodation, transportation, ticketing, procurement, and information and knowledge sharing. An innovative online booking system for accommodation was in place, allowing clients to make their own bookings and amendments and hotel operators to input their rooming lists. Through the system, LOCOG contracted a total of over one million room nights from major hotel chains and other providers.

In addition, London 2012 designed and delivered a comprehensive Travel Demand Management (TDM) system, involving 1,300 buses and 4,500 cars serving nearly 300 venues (including hotels, training venues, etc.) [7][8]. Ticketing had another online system that availed 8.5 million tickets, 97% of which were sold. To avoid black market, the online ticketing system allowed ticket-holders to re-sell their tickets; 180,000 tickets were re-sold. Moreover, through the system, ticket-recycling program helped 15,944 tickets to be recycled, allowing more spectators to attend the remainder of the session when previous spectators leave early.

Another online platform was the “CompeteFor” which supported the procurement function when the volume of goods and services required reached its peak in the final year before the Games [8]. Finally yet importantly, Information and Knowledge Management (IKM) has been crucial component during and after the London 2012 Olympics. The LOCOG created a flexible extranet platform called ‘The Exchange’ that allowed sharing of information with a wide variety of external partners and stakeholders in a very simple and intuitive way – in all, 60 secure mini-websites were built which helped enable the ‘one-team’ planning approach with all relevant organizations [7].

**Rio de Janeiro.** Rio is the host city of two successive large-scale events, 2014 Football World Cup and 2016 Olympics. Hosting two mega-events represented an opportunity for Brazil (more particularly Rio de Janeiro) to build, expand and modernize its infrastructure and services in different sectors related to those mega-events [9]. Rio has created Centre of Operations to support the city in facilitating significant cross-disciplinary working as well as responding to natural disasters. Meantime, Rio has opened a significant amount of its data freely available to the public. The Centre of Operations houses representatives from over 30 different departments [9]. It includes a high-resolution weather forecasting and hydrological modeling system, which can predict heavy rains as much as 48 hours in advance. The Centre of Operations can monitor transportation issues through real-time data streaming from sensors and video cameras. Same time, residents have access to daily data feeds through mobile devices and social networks. According to Sergio Borger from IBM Research Brazil [16], *“Rio has become one of the world's smartest cities by infusing intelligence into its city systems and urban infrastructures, that uses analytics to draw insight from a vast urban network of sensors, digital devices and cameras to provide real-time and predictive data about weather, traffic, transportation, power failures and other challenges”*.

## 2.2 Smart City Framework

Smart city empowers event management with real-time decision-making enabled by real-time data streaming from every connected digital object, thanks to Internet of Things (IoT) [2]. The new sensing technologies, whether hand-held or remote devices, and the development in machine to machine (M2M) communications form dramatic changes in the IoT enabled smart services and applications offered to end users [12]. In addition to sensors and machines, users are becoming very important source of information. Thus, a coupled perspective including technologies and participatory governance for stakeholders and users [13] is essential for a smart city

model that continuously considers evolving needs [14]. The CityPulse project has proposed a Smart City Framework (SCF) to serve as a Reference Architecture Model (ARM) [2]. The purpose of the SCF is to set the main concepts, common language and the boundaries to be used by smart city stakeholders, partners and interested parties when engaged in technical discussions about smart city services.

The high-level view of SCF, illustrated in Fig. 1, has different interfaces (I/F) towards the applications and towards the information sources/ sinks. Information Sources include: Internet of Things (IoT) sensors deployed in a city environment; city information sources e.g. Open Data portals, city Geographical Information System (GIS) data etc.; and, user generated information through social media e.g. microblogs such as tweets that have been proven feasible for city related event extraction. Information Sinks include: IoT Actuators, City Datastores and social media channels through which cities could potentially push information to their citizens. The SCF consists of number of Functional Groups (FGs).

The Large-Scale Data Analysis FG addresses issues related to integration of a large scale of heterogeneous sources producing real-time streams and their semantic enrichment. The Reasoning and Decision Support FG tackles issues related to the ability of the SCF to adapt to alterations based on real-time information streams. It is mainly responsible for monitoring the semantically enriched streams and adapting the collection of stream information from one side and providing an API towards the Smart City Applications from another side. The Large Scale Analysis and Reasoning and Decision Support functionalities are supported by prior knowledge in the form of the Knowledge Base FG and Reliability and Quality of Information control mechanisms by the Reliable Information Processing FG. The Actuation FG covers any functionality that allows the SCF to push control commands or information to the IoT actuators, social media sinks and city information sinks. The Framework Management FG includes functionalities for the management of the SCF itself such as fault, configuration, security management etc. The Exposure FG covers the mediation of access with management and smart city applications.

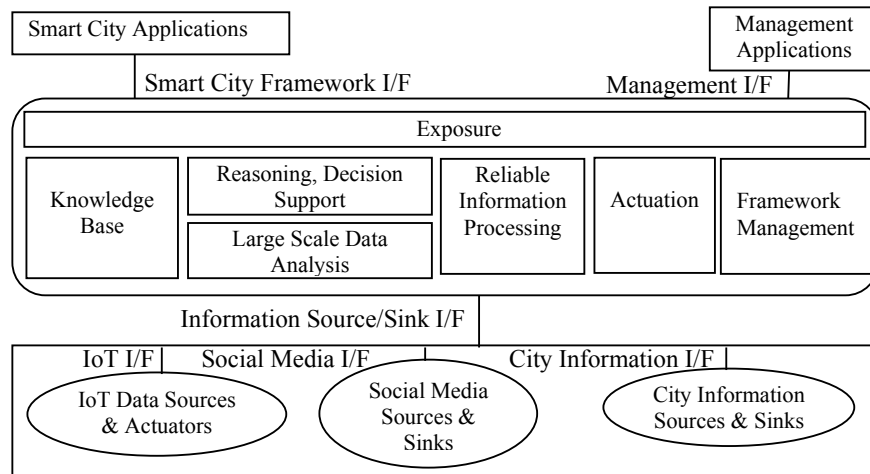


Fig. 1: High-level view of Smart City Framework [2].

### 3 Approach

As described in Section 2, the role of technology and particularly digital and smart solutions is becoming bigger in large-scale events. Yet, most of those solutions are vertically locked, where the data collection, processing, analysis and the resulting decisions and accumulated knowledge are normally locked within the boundaries of a particular domain: traffic, parking, energy, water, etc. Although, it is not expected that complete convergence will happen between those verticals; seamless flow of information can help horizontal integration to be realized. Such integration is important for efficiency purposes, taking into consideration that some parts of the value chain are not fiscally feasible or administratively possible to replicate.

#### 3.1 Smart City Model

On a very high-level, as illustrated in Fig. 2, the approach of this paper is to decommission the collected data, processed information and accumulated knowledge; and allow seamless flow between different domains, across all phases of event management cycle; and hence, break up the exclusive use of information by its specific domain. To do so, the Smart City Framework (SCF) – discussed in section 2 – will be decomposed in order to decouple the information sources and sinks from real-time intelligence functions. In the meantime, a new Lifecycle Management function shall be introduced to manage data, versions, variants and the business processes associated with heterogeneous, uniquely identified connected objects [4][5]. The Lifecycle Management, in the context of the large-scale event, shall support all phases of event management cycle; integrating people, processes, and technologies; and assure information consistency, traceability, and long-term archiving; while enabling intra/ inter-collaboration within the same event and with other relevant events [10].

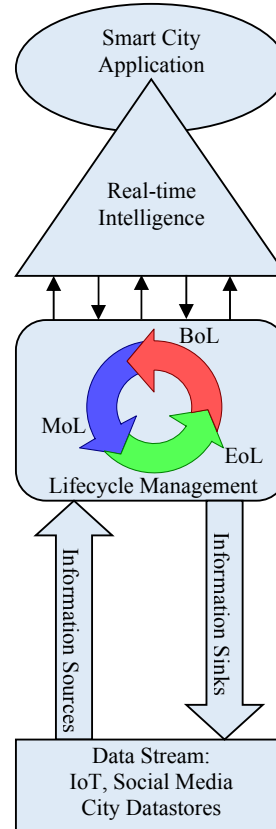


Fig. 2: Smart City High-Level Conceptual Model.

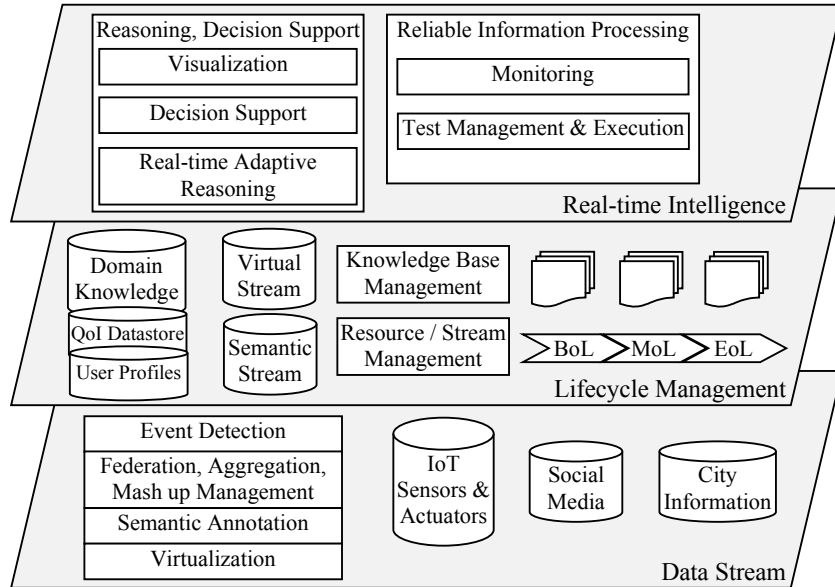


Fig. 3: 3-layers model for the functional view of the SCF.

In more details, this paper proposes a 3-layers model for the functional view of the Smart City Framework (SCF). The three layers are namely: Data Stream, Lifecycle Management and Real-time Intelligence, as depicted in Fig. 3. The Data Stream layer is proposed to undertake four main functions from the Large Scale Data Analysis FG: Virtualization; Semantic Annotation; Federation, Aggregation and Mash up Management; and Event Detection. The Virtualization function provides open APIs and common services to publish real-time data streams from different information sources and create virtual representation of them. The Semantic Annotation function annotates the virtualized data streams using prior knowledge about the information source (e.g. location). The Federation, Aggregation and Mash up Management function integrates and abstracts the federated data streams, and also integrates heterogeneous data streams and (semi) static data sources to generate mashed up streams according to the application requirement. The Event Detection function deals with changes and variations over time and transforms observations and measurement data (originated from sensory devices) and relations into higher-level abstractions to formalize concepts and knowledge from the underlying raw data.

The Lifecycle Management layer is proposed to manage and perform access to different types of data/ information streams in the Datastores of the Knowledge Base FG. This layer gives access to raw virtualized and semantically annotated streams. The Resource/Stream Management function maintains stream storage configurations (which stream to be stored). In addition, User Profiles are stored for the user-centric decision support that takes into account the types of users and provides access control and rights management. The Lifecycle Management layer has also access to static/factual Domain Knowledge as well as inferred knowledge objects and rules. It

also maintains the Quality of Information (QoI) knowledge that can be used to assess the Reliability of Information.

The Real-time Intelligence Layer is proposed to undertake three main functions from the Reasoning, Decision Support FG. The Real-time Adaptive Reasoning function is to identify and react to changes. However, the Decision Support function is in charge of reasoning about events that are relevant for a particular task (e.g. computing the optimal path from one location to another, according to some constraints and preferences specified by the user explicitly or implicitly derived by users' profiles). The Visualization function provides user interface for easy configuration purposes. The Real-time Intelligence Layer is also responsible for the Reputation and QoI Evaluation, as well as testing the reliability, robustness and performance of the Smart City applications.

### **3.2 Quantum Lifecycle Management**

Focusing on Lifecycle Management, Product Lifecycle Management (PLM) has been proven to trace and manage all the activities and flows of data and information during the product development process and also during the actions of maintenance and support [10]. The Open Group has standardized Quantum Lifecycle Management (QLM) as an extension to and derivative of PLM [15], with two differentiating features. First, PLM is mainly focused on information about product types and their versions, however QLM may be applied to any "object" lifecycle including human, services, applications, etc. [15]. Second, current PLM tools (CAD, PDM, ERP, etc.) focus more on Beginning of Life (BOL) information [5], however QLM extends to include detailed information about usage in Middle of Life (MOL) and End of Life (EOL), as well [15]. Accordingly, this paper adopts QLM as a Lifecycle Management system that is more suitable for smart city services and applications.

QLM messaging specifications consist of two standards: the QLM Messaging Interface (QLM-MI) that defines what types of interactions between objects are possible and the QLM Data Format (QLM-DF) that defines the structure of the information included in QLM messages [4]. QLM standards can serve the requirements of the smart city high-level conceptual model shown in Fig. 2 from different perspectives. The QLM standards, as proposed by The Open Group, provide generic and standardized application-level interfaces [4] in order to create ad hoc and loosely coupled information flows between any kinds of products, devices, computers, users and information systems when and as needed [4] [3]. In addition, QLM applies Closed-Loop Lifecycle Management (CL2M) that enables the information flow to include stakeholders and customers; and enables seamless transformation of information to knowledge [5]. QLM, through CL2M, enhances information security, interoperability, manageability; but most importantly for this research, information visibility and information sustainability to ensure data availability for any system, anywhere, and at any time, while being "consistent" (i.e., not outdated or wrong) [5].

For the purposes of large-scale events, smart city infrastructure, services and applications, can be either newly established or customized to serve the needs of the event. In both cases, like all other aspects of the event, smart city shall be subject to



the same phases of event management cycle. Large-scale event has three distinct phases: Beginning-of-Life (BoL) that includes conception and planning; Middle-of-Life (MoL) that includes operation and maintenance; End-of-Life (EoL) that includes post-event activities [6][17]. Fig. 4 represents two-dimensional mapping of event management versus time and service. The time dimension represents the three phases of event management cycle: BoL, MoL and EoL. The service dimension represents all relevant services during large-scale events, e.g. transportation, energy, accommodation, food, health, etc. The proposed approach aims to improve event management across the two dimensions, time and service, by introducing Lifecycle Management and Smart City respectively. The combination of Lifecycle Management and Smart City can ensure maximum level of horizontal integration and vertical improvement.

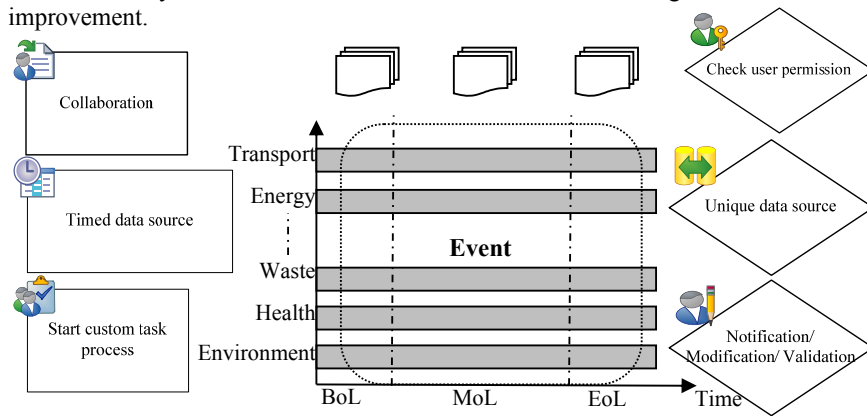


Fig. 4: Two-dimensional representation of event management.

#### 4 Scenario of Qatar 2022 FIFA World Cup Fan Experience

The demonstration scenario will focus on the fan journey for the Qatar 2022 FIFA World Cup, across different phases of event management cycle: BoL, MoL and EoL. The BoL phase includes all fan activities prior to arrival to Qatar, e.g. ticket booking, accommodation booking, visa issuance, trip planning, etc. The MoL phase starts with the fan arrival to the airport, all the way till departure. The MoL phase includes all fan activities during event timeframe in Qatar, e.g. arrival/ departure procedures, transportation, accommodation, attending matches, food, health, security, etc. The EoL phase includes all related post-event activities, after fan departure, e.g. photos/ trophies exchange, surveys, etc. First, each fan should have one unique profile that includes all personal details, contact numbers, social media accounts, payment tools, booked tickets, accommodation, arrival/ departure details, planned touristic trips and any other relevant information. The fan should have an interactive user interface that is secure and strictly accessible by unique username and password. Through the user interface, fan should have exposure to all available services, across the lifecycle, in order to request information, plan and use those services.

The application of QLM on the fan lifecycle will enable data/ information seamless exchange with different phases of other intersecting lifecycles, like transportation, health, energy, food, crowd management and other event lifecycles. Access rights to fan data/ information shall be defined as per each “user profile”, e.g. stadium operator can have access to fan ticket and personal ID; hotel can have access to booking details, arrival and departure time. Fan data sources can be smart wearable devices, social media, and associated smart cards and RFIDs. Fan can define his own privacy settings to decide on which information to be exposed, with whom, and level of exposure. On the other hand, fan can receive information through push notifications using interactive user interface, social media, SMS, or through information and multimedia self-service kiosks that can recognize the fan and provide the needed information or guidance.

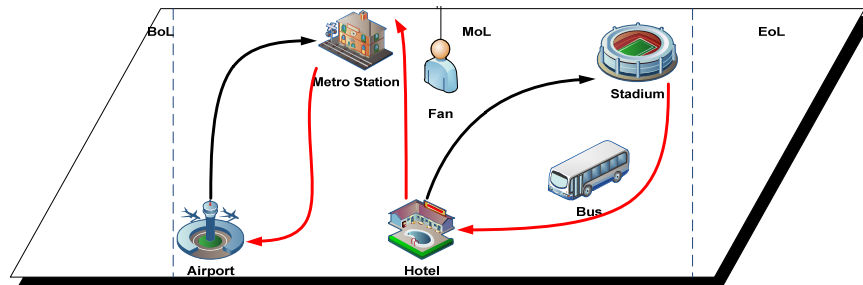


Fig. 5: Demonstration Scenario: Fan Lifecycle.

Ideally, the fan will put his plan during BoL and hence the fan profile will be updated. Through QLM systems, all relevant information will be exchanged with different phases of concerned lifecycles. Smart transportation, booking, ticketing and other relevant smart city systems will aggregate all service requests from all fans and plan their resources, during BoL; and operate accordingly during MoL, as presented in Fig. 5. Nevertheless, this scenario is too ideal to become reality. The common practice is that last minute changes happen and plans alter. Here comes the great value of smart city applications and their ability to adapt using real-time decision-making capabilities. For example, in case of last minute or during the event change of any planned activity, the event detection in all relevant lifecycles shall detect this change; the reliability of the information should be tested and accordingly real-time adaptive reasoning and decision support shall trigger corresponding action(s).

## 5 Conclusion and Future Work

In this paper, we propose the integration of smart city and lifecycle management concepts to enhance large-scale event management. The application of smart city services and applications has been proved to address the complexity of service provisioning in the intensive crowd of mega-events. While lifecycle management, in the context of large-scale events, will support all phases of event management cycle; integrating people, processes, and technologies; and assure information consistency, traceability, and long-term archiving. The integration of smart city and lifecycle

management concepts will result in vertical improvement in service provision and horizontal integration between different domains.

Although, PLM has been proven very successful to trace and manage all the activities and flows of data and information during the product development process and also during the actions of maintenance and support; QLM adds new capabilities that make it more suitable for smart city modeling. This paper adopts QLM as a more suitable lifecycle management system to be used for smart city modeling.

However, the presented concepts have shown good level of applicability, it should be subject to more in depth practical test of implementation. The way forward can be using the QLM standards: Data Formats and Messaging Interface, to model data exchange between multiple smart city domains in the context of large-event management.

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