

Framework for Smart City Model Composition: Choice of Component Design Models and Risks

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ABSTRACT

This paper is a reflective overview of the knowledge on online conversion of services in the perspective of urban planning. It points that traditional planning aimed at building optimal spatial relationships between particular functions in urban environment. Appropriate decision-making rules had been introduced, contributing to a hierarchical land-use structure. This conventional approach has been recently challenged by the rapid ICT development which added a lively, virtual, non-spatial dimension of urban economy. The well-established foundations of urban planning started to shake, calling for a new paradigm. This paper looks for an alternative to traditional planning which would be able to develop policies for omnichannel services (i.e., enterprises that use both online and offline channels for communicating and distributing their products). The advantages of ‘e-planning’ in managing omnichannel services are outlined and a conclusion is drawn that only a multi-channel approach can bring appropriate answers to contemporary developments in services sector.

KEYWORDS

AI, Big Data, Component Design Choices, Composition of Design Models, Intelligent Society, Seoul Business Analysis Service, Smart City Design Models, Taipei Real-Time Construction Information Systems

1. INTRODUCTION

Recent Information and Communication Technology (ICT) advances have created a hyper-networked world, connecting people, machines, and devices. Every sector of our society has been affected. A majority of daily activities in business, government, healthcare, education, etc. occur online, generating huge amounts of data and creating what has come to be known as the Big Data age. Many cities around the world are taking initiatives to design and build smart cities projects in order to make technology innovations that address various challenges, such as infrastructure issues, traffic congestion, energy

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shortages, environmental pollution, and the lack of economic opportunities, as well as public safety, public health, social wellbeing, and high-quality education. The major application domains of these smart cities include urban planning, transportation, the environment, energy, social, economy, and public safety & security (Zheng et al., 2014).

There exist many definitions for a smart city, such as one claiming that a “smart city is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership” (Manville et al., 2014). By another definition, a smart city “integrates hardware, software and network technologies in order to connect seven critical city infrastructure components and services: city administration, education, healthcare, public safety, real estate, transportation and utilities” (Washburn & Sindhu, 2009). Other definitions can be found in Albino et al., 2015, and Paskaleva, 2011. Yet another approach stresses citizen-centric and citizen-driven innovations (Albino et al., 2015; Lee & Hancock, 2012; Lee & Lee, 2014), and others call for a triple helix model in which the dynamic interactions among academics, government, and businesses with different networked contributions can create ICT-based urban innovations (Leydesdorff & Deakin, 2011). IBM’s “smarter cities” concept also “emphasizes the need to better apply advanced information technology, analytics and systems thinking” (Dirks et al., 2010).

With many technology alternatives to consider, and many stakeholders to involve, many governments face various design options and models to consider and choose from. They face the problem of deciding which design alternatives may be the most appropriate in each particular smart city project. Smart city projects require multiple layers of design decisions among many possible alternatives, such as what services may be needed, who would provide the necessary data for creating the services, which stakeholders exist and whether or not they need to participate in the design process, creation/development tasks, or evaluation-only, etc. In addition to these design decisions, with the resurgence of Artificial Intelligence, smart cities are expected to become “intelligent cities,” fueling progress in every aspect of life. This intelligent agent-based and automation-driven society has forced citizens to redefine their routine operations, service consumption, and even their value systems. For instance, the online information-seeking behavior would change from primarily text-based interactions to multi-modal (voice and video, VR) interactions, from information-pulling to automated information recommendation and pushing, or from keyword-based query results to reasoning-based answers.

As society is soon going to be heavily dependent on these AI-driven advanced intelligent systems (including robots, “intelligent” devices, embedded systems, etc.), everywhere from routine operations to critical decision recommendations (Russell et al., 2015), it is important to design and develop a reliable, robust intelligent society, but also to recognize potential risks and harm in the design phase. The intelligent/smart city innovations affecting millions of citizens should not be an exception. There are great opportunities in terms of designing this new intelligent society (Hager et al., 2017), but policymakers need to consider the risks of such systems that may affect the daily lives of citizens all over the world.

The goal of this project is to propose a framework with which to identify alternative design and innovation models that smart city projects can adopt, as well as the risks to consider when choosing a design model. The framework we propose is based on the components and tasks that are required for developing a smart city. The components include the identification of stakeholders, the types of services, an intelligence or analytics component, integrated and linking data, and data collection from a variety of different sources. The proposed framework provides alternative design models and risks to consider and choose from. This framework implies that the smart city innovation involves many design models, rather than just one or two. We illustrate the utility of the framework by analyzing two smart city projects in Asia.

2. RELATED WORKS

There have been two main design strategies on city planning: top-down and bottom-up design models (Healey, 1996; Ioannis, 2014). The top-down design model emphasizes centralized and de-politicizing decision-making, as well as the power of technical experts. On the other hand, the bottom-up model has a greater emphasis on participation by citizens in terms of decision-making and the decreased importance of the role of technical expertise (Print & Milner, 2009). Many studies have used the two different design strategies as distinguishing criteria when analyzing smart city governance. In a case study in South Korea called a “U-city,” Shin (2009) remarked the U-city is a typical top-down city design model because it was entirely planned and implemented by the government and lacked public participation. Aina (2017) reviewed smart city developments in Saudi Arabia and analyzed the urban governance of each case, concluding that the mode of governance of best practices in Saudi Arabia’s smart cities is mainly the top-down approach, where public participation is very limited.

However, Feder-Levy et al. (2016) suggested a smart city model called “the well-informed city,” which pursues a decentralized and bottom-up model for a smart city service using information and self-organization. In this model, the information in the city is shared with the agents and the citizens themselves, and change can be created from the bottom up as agents self-organize around a new state using that newly acquired information. Leydesdorff and Deakin (2011) proposed the triple-helix model, which is useful for explaining networks of university-industry-government relations and dynamics through the perspective of innovation in smart cities. They stated that civil society’s support can be a key component of an innovation system in a smart city, and that it’s somewhat close to the bottom-up approach because it highlights interactions among actors in three institutional spheres.

In the case study of Japanese’s smart city project (Kudo, 2016), the importance of citizen-participation in smart city is emphasized. Its governance model is based on New Public Management (NPM), which emphasizes public service organizations being more customer service oriented, as in the private sector (Ferlie et al., 1996). Thus, the NPM paradigm highlights the “centrality of citizens” as the recipient of services or customers to the public sector, and gives local agencies or public managers more freedom in terms of how they deliver services. Kudo (2016) explained that the stakeholders in public service delivery are considered as co-design, co-creation, and co-production. Regarding these three concepts, Sanders and Stappers (2008) used the term of co-design to refer to collective creativity as it is applied across the whole span of the design process. However, co-creation can be understood as creative cooperation and interaction between customers and service providers during the service delivery touch point (Steen et al., 2011).

As for co-production, the early definition of the term referred to the contribution by service users (or citizens) and providers in order to raise the quality or efficiency of the services (Ostrom & Ostrom, 1971; Brudeney & England, 1983). It originated from Ostrom and other economists who have studied collaborations between the public sector and citizens (Brandsen & Honingh, 2018). In addition, the relationship between citizens and professionals that make reciprocal use of their strengths could be categorized as a co-production (NESTA, 2011; Bovaird & Loeffler, 2015). By contrast, the term co-creation originates from commercial businesses that recently became popular in the public sector. Also, co-creation is a more encompassing concept implying all kinds of citizen inputs in services, while co-production is in the more specific implementation phase (Brandsen & Honingh, 2018, 2016).

There have been several attempts to mix these two approaches in smart city design. Breuer et al. (2014) argued that a strictly top-down approach might lead to authoritarian leadership, while a strict bottom-up approach might lead to confusion. Therefore, they suggested collaboration with stakeholders by adopting elements of the two approaches. Van Waart et al. (2016) analyzed the Dutch city of Rotterdam and emphasized the interaction between top-down and bottom-up approaches, concluding that the multi-level perspective is important in terms of understanding the dynamics of smart cities.

Capdevila and Zarlenga (2015) explained the Barcelona case with both approaches in parallel, because in that case, both top-down and bottom-up initiatives were treated as important to the overall

success. Zhilin et al. (2019) also argued that the city development model can be implemented with both approaches. Furthermore, it introduced a new framework which has *two-axis model*, where the self-governance axis ranges from the top-down governance to bottom-up self-governance, and the innovation axis which ranges from more human-driven to more technology-driven innovations. According to these two dimensions, the authors identified the four types of smart city development models: more government-driven initiatives, such as urban commons and citizen-sourcing, as opposed to more citizen-driven initiatives, such as DIY urbanism and peer production.

More socially-driven innovations, such as Urban Commons or DIY Urbanism, is in contrast to more technology-driven innovations, such as citizen sourcing or peer production. It reflected that a smart city development initiative involves a mixed view that is not a single top-down approach, nor a bottom-up (citizen governance levels), and how much technology is involved, as opposed to humans, in its solutions (technology use levels.) If we claim that smart cities' essential ingredient is innovation through technology, we can discard the human-centric innovations models (e.g. Urban Commons or DIY Urbanism), thus leaving the top-down vs. bottom-up initiative models. The four models are useful in concepts, but practically they focus on how much citizens are engaged in decision-making and how much their values are reflected in developing smart cities.

Gil-Garcia, Pardo, and Burke's definition (2010) states that developing integrated information systems is a complex and multidimensional phenomenon with four interrelated component parts: 1) trusted networks of social actors, 2) shared tacit and explicit knowledge, 3) integrated data, and 4) interoperable technical systems that can communicate with each other at the hardware/operating system level.

In smart city development, collaboration among heterogeneous actors is an important success factor in every aspect of design and development. The collaboration types among government agencies, partners, and citizens are described as networked governance model (Kapucu & Hu, 2020), collaborations that are only developed among public organizations (O'Toole & Meier, 2004), among public and private actors (Simmons, 2003), among non-profit and public agencies (Shaw, 2003), or among multiple non-for-profit organizations (Bryson, Crosby, & Stone, 2006). In the networked governance design model, the collaborating actors or stakeholders may participate in a wide variety of design decisions, including data collection, data integration, and data management and integration decision-making, as well as the ways in which these stakeholders work together, the structures of the partnerships that they form, the legal frameworks they comply with, and the incentives they have to cooperate with, etc.

We follow the claim that smart city projects are complex and multidimensional decision-making models composed by different types of decisions to make, and we propose a framework of smart city design models as a composite of decision models in its component dimensions.

3. SMART CITY DESIGN MODELS

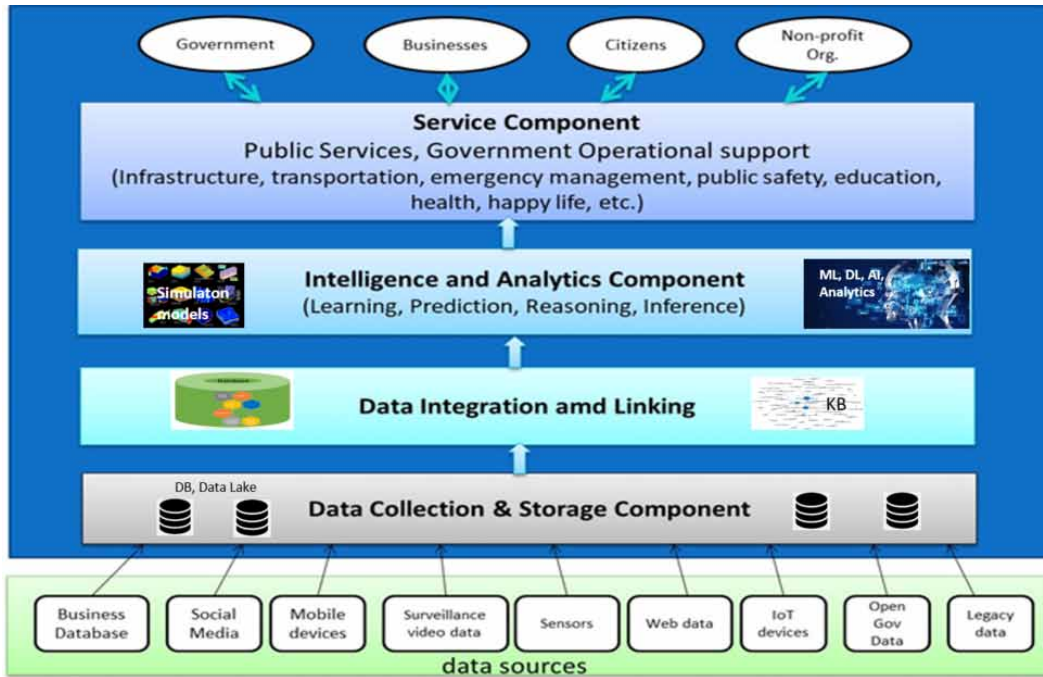
The smart city innovations are based on a Big Data and AI-based computational platform. We propose a framework with which to analyze the design alternative models and risk issues in the system design components, and we use the components of smart cities' generic computing architecture platform as dimensions with which to analyze design model decisions and issues.

A generic architecture of urban computing (Zheng et al., 2014) suggests layers of service provision, urban data analytics, urban data management, storage, and data sensing and acquisitions. The common features from this and other smart city notions include: interconnected technology, being data-driven, having innovative policy decision support, and utilizing intelligent public service provisions.

The smart cities project involves design and implementation decisions on the following subtasks:

1. Identify and motivate collaboration actors and stakeholders.
2. Identify and design end user application and services according to requirements.

Figure 1. Component Architecture of Smart City Platform (Source: Authors' own elaboration)



3. Develop the analytics and intelligence engine to provide insights and knowledge products.
4. Develop the smart city's domain-specific integrated knowledge base and process taxonomy.
5. Identify data providers and owners, and develop their metadata in order to describe their dataset.

We propose a framework of smart city design decision models for each subtask, consisting of the following components: (1) stakeholders and actors component to decide who may be involved in the design and development, such as citizens, or businesses that participate in the smart cities; (2) a service layer where the design decisions involve whether services are designed for internal process optimization for a government unit, across-government agencies, or targeted for citizens, businesses, etc.; (3) an intelligence component that decides on the types of analytics, intelligence, and reasoning capabilities in order to transform diverse data sets into patterns, knowledge, insights, and predictions; (4) a data integration, sharing, and linking component that requires decisions on the levels of the integration of the data from disparate systems and format required; and finally (5) a data collection and storage and management component that needs a governance model to decide on the needed data sets and the collection, storage, and management of the datasets from multiple sources, including city systems, sensors, IoT devices, and human sensors (smart devices or social media). This architecture of different component layers is shown in Figure 1.

In each layer of the generic smart city architecture shown in Figure 1, a spectrum of alternative smart city design models can be chosen, and the risks in each layer can be analyzed.

1. *Stakeholder Component dimension* addresses policy questions regarding whether or not a stakeholder (end user) is deeply involved in making decisions on the smart city initiatives. Different types of smart city *governance models* can be possible, ranging from a government-centric to a participatory model to a collaborative and co-production governance model. The

risk factors to consider in the policymaking include whether or not any one group is missing or under-represented, thus creating a power imbalance and digital divide.

2. *Service Provision dimension* defines policy decisions regarding whether a service focuses on the government's internal optimization, the citizen-facing public service delivery within or across agencies, or the provision of inter-city services that connect to or share services with different cities. Some risk issues that policy decision-makers need to consider include whether there are some services that are not getting enough of attention, what the decision factors are in terms of selecting target services, and whether the resources are fairly allocated. In addition, the intelligent service integration machines may cause uncontrolled behaviors, i.e. unwanted services that may cost citizens unintentional costs, inconvenience, or threats.
3. *Intelligence Analytics and Reasoning dimension* addresses the policy decisions on the level of computational automation and machine reasoning and intelligence. The potential smart city models include a basic descriptive model, an advanced decision support model, and an intelligent predictive and autonomous model that can learn, predict, and react to the context with an understanding of citizens' needs. Policymakers need to address risk-related questions, such as whether or not powerful machine learning and deep learning techniques can be used for the profiling of individuals or groups of people. What are the consequences if the machine predictions or reasoning that directly control crucial infrastructure, as in cyber physical systems, or critical services, as in healthcare, are wrong?
4. *Data Integration, Sharing and Linking dimension* addresses data sharing across different data sources. This dimension sheds light on the various possible collaboration models. The policy choices can generate a variety of the smart city models, ranging from a siloed city model to a federated collaboration model among agencies to a fully connected smart city model, which allows for the seamless data flow between different systems. The policy issues include how the data sharing is promoted by different data owners, and the risk-related policy issues may be how to securely share the data and how to address the privacy concerns of individuals.
5. *Data Collection and Storage dimension* addresses policy issues regarding whether the data collection, monitoring, and storing policies are transparent, consent-based versus proprietary, i.e. closed data collection/monitoring, partially open data collection, or open data sets. The relevant policy and risk discussions include a standardized process of the data collection, monitoring, storing, and publication, as well as a consent process for data collection or a discussion regarding whether the collected data may be biased.

The proposed work provides a framework of identifying a spectrum of alternative smart city models and of policy analysis considering risk issues in each component dimension.

The intense interest in utilizing Big Data and AI in the realm of smart megacities will require understanding the various policy and risk issues that may arise, such as privacy, consent, ethical considerations of data collection, monitoring, storage, sharing and using, and the widening inequality created by the smart urban applications that will be used daily by all citizens in the megacities. Cataloging these policy choice options and risk issues, and storing the design policy repository in the Smart City Platform to share, will allow intelligent city designers to compose and generate alternative service design models by considering the model possibilities and risks in each domain.

Composability of models in the Smart City Platform: Designing a smart city service is a composition of different component design models in each design dimension. For the same service design, different policy choices in each dimension will select a different design model and will generate different smart city design models. For instance, Table 2 shows that two alternative composite of models can be used for a smart startup service:

In each design dimension, the choice of design model is subject to the resources and other constraints, as well as the associated risks. Making available a repository of explicit design policy models can not only ease the design of complex smart city services, but the composability of design

Table 1. Alternative Smart City Design Models and Risks by Architectural Component Dimension

Design Dimension	Alternative Smart City Design Models	Risk Factors
Stakeholders/ Governance	· Government-centric smart city model · Participatory model · Collaborative/co-production governance model	· Missing or under-represented stakeholder groups · Power imbalance · Digital divides
Target Services	· Internal service model · Intra-agency public service model · Inter-agency public service model · Inter-city service model	· Unclear or bias in service selection · Service needs not to be recognized · Service integration failure · Unfair resource allocations · Autonomous service integration and execution
Intelligence/ Analytics	• Descriptive city model • Insight-based city model • Predictive city model • Autonomous, cognitive model	• Lack of transparency • Poor accountability • Unfairness • Profiling individuals or groups • Wrong or biased ML or deep learning models • Harmful intention or behavior models • Wrong reasoning or prediction models
Data Integration and connection	• Siloed model • Federated collaboration model • Fully connected model	• Secure data sharing • Privacy preserving data sharing/integration • Data usage enforcements • Data ownership issues
Data Collection/ storage and management	• Closed data city model • Partially open data city model • Open data model	• Surveillance by data • Lack of data governance policy of the data collection, monitoring, storing, and publications • Lack of consent in data collection • Biased data, missing data, low-quality data, fake data • Data integrity, identifiability

Source: Authors' own elaboration.

Table 2. Alternative Smart City Designs composed of different design models

Dimension	Design Alternative 1	Design Alternative 2
<i>Stakeholders/ Governance</i>	Government-centric model	Participatory model
<i>Target Services</i>	Intra-agency public service model	Inter-agency service model
<i>Intelligence/Analytics</i>	Insight-based city model	Predictive city model
<i>Data Integration</i>	Siloed City model	Federated collaboration model
<i>Data Collection/storage</i>	Partially open data city model	Partially open data city model

Source: Authors' own elaboration.

model choices could also be used to explain why a design model is chosen in each design dimension, as well as what risk-related policy considerations are taken in a particular design decision.

4. ANALYSES OF SMART CITY CASE STUDIES

We use the multi-layer framework of design models in order to analyze the smart city design strategies and development used in two smart city projects: Smart Public Infrastructure in Taipei City in Taiwan, and the Neighborhood Business Analysis in Seoul City in South Korea.

4.1 Smart Public Infrastructure in Taipei, Taiwan

In this case, we introduce and analyze the design models of a public infrastructure-related smart city project in Taipei City, Taiwan. The governance of public works in cities is responsible for the construction, maintenance, and management of urban public infrastructure. While public works manage the design and construction of new roads and pipelines, existing roads and pipelines need to be constantly maintained or renewed in order to provide optimal service for citizens.

Specifically, serviceable road conditions are often disrupted by the need of road construction or the need for aboveground or underground pipeline maintenance, which are either initiated by public infrastructure management or by private-sector developments. For example, the maintenance of underground electricity lines will necessitate the excavation of roads. New business or property developments from private sectors, on the other hand, will need to open up pavements in order to complete necessary connections to current electricity, gas, and public transportation systems. With the growing quantity and complexity of both ongoing and new projects, the public works present an opportunity where this research can offer improvement.

The analysis will look into each design dimension that we presented in Section 3, and then present the design models chosen for infrastructure maintenance.

Stakeholder Component Dimension

While construction projects are indispensable for urban development, they unfortunately cause inconvenience to citizens due to the interruptions of the normal functioning of urban infrastructure and services. For example, the construction on roads will lead to the reduction of road lanes available for public use, thereby causing traffic congestion due to the reduced service level because of the traffic. As complexities grow with multiple parties involved with public works, the duration of construction is often unexpectedly extended, and thus further creates unnecessary social and political issues.

Hence, for public sectors, along with the needs of private sectors and citizens, the government has recognized the need to introduce smart technologies into the management of roads and pipelines, in the hopes of better responding to those aforementioned challenges. In Taiwan, based on the needs of multiple parties, Taipei City is establishing a new organization named the Road & Pipeline information Center (RPIC) which embarks innovation by introducing the concepts of smart cities and government into practice.

RPIC demands all stakeholders, such as departments or sections within governments, private enterprises such as water, natural gas, and electricity, along with any related commercial pipeline operators, to staff the RPIC headquarters. RPIC operates on a 24-hour basis, and it notifies representatives from various stakeholders to collaborate with each other to respond to any incoming needs. For example, RPIC mandates that all road excavation requests need to be submitted through a system called Taipei City Road Construction Real-Time Information System, and the system will then schedule the most suitable timeframes based on holistic needs. This helps to reduce unnecessary excavation, and thereby increases citizen's satisfaction towards the improved quality of public works.

Regarding its endeavors for building a smart city, Taipei City's case exemplifies a government-centric model, because Taipei City takes the initiative to plan and create the organization, as well as to develop infrastructure and technologies in order to consolidate all necessary resources. Participating parties comply with the city government's initiatives to staff the center, and deploy infrastructure and use technology to join in necessary collaborative operations for the better management of roads and pipelines. In addition, in order to fully streamline RPIC operations, 43 entities and enterprises whose businesses are associated with road or pipeline constructions are required to join in RPIC operations, such as natural gas, electricity, water, telecommunications, sewer, transportation, energy, etc. Because of the comprehensive inclusion of various stakeholders, the risk is reduced to the extent that some organizations may not be able to participate during the starting phase of the initiative, such as those related to national security or defense. This risk could be mitigated through advanced collaboration with other governments for complete inclusion.

Service Provision Dimension

RPIC has developed a new system called the Taipei City Road Construction Real-Time Information System, which offers a comprehensive and overall information service regarding the construction projects related to roads and pipelines in the city. For example, the site provides information for road closures, road construction, scheduled construction, etc. Figure 2 shows the construction information displayed in the Taipei City Road Construction Real-Time Information System.

RPIC remotely monitors construction projects using real-time technologies and delivers real-time citywide information to citizens. It asks stakeholders such as contractors to equip mobile devices and cameras on construction sites in order to satisfy the need of reporting and communicating construction information. The information is displayed on the Web, available for users, so that the necessary operations can be identified, planned, and scheduled.

Accordingly, this service model pertains to the internal optimization model, which can help the government to better plan and schedule projects or to reduce possible conflicts or problems beforehand. With these capabilities, citizens will be provided with city infrastructure information and can plan ahead for any repair and maintenance that may cause inconvenience, such as road closures, service shutdowns, or general construction disturbances. Possible risks include failing to promote the service well enough to attract citizens' attention and awareness, which is essential for the systems' usefulness and for RPIC's efforts to be fully recognized and appreciated by the public.

Intelligence Analytics and Reasoning Dimension

Powered by smart technology, the system further integrates construction data with a planning and scheduling platform in order to better manage the excavation and refill requests. Through the systems' assistance, RPIC is able to consolidate related work requests or job needs into more integrated and compact work plans. For example, the system can suggest preferred alternatives in order to plan and schedule a new construction request, since the system is able to take into consideration whether or not there are construction projects happening nearby or road closures in adjacent neighborhoods, for stakeholders' management and planning needs.

Figure 2. Pipeline information demonstrated on Taipei City Construction Real-Time Information System, Road and Pipeline Information Center (RPIC), Taipei City, Taiwan (Source: Taipei City Government, at <https://dig.nco.taipei.gov.tw/dig/>)



In addition, since there often may be multiple excavation requests from different enterprises on the same road segment, this system is able to integrate multiple requests into more consolidated work plans, and identifies a suitable party to refill the excavation after all of the projects are completed. This helps to avoid repeated excavation on roads for reducing inconvenience. The construction information is not only offered online, but is also provided on bulletin boards on-site.

With these various planning and scheduling features, this system helps to reduce potential conflicts among related stakeholders and unnecessary disruptions to citizens, and thereby to improve the quality of urban infrastructure management. Regarding these current features, the system provides an advanced decision support model that better satisfies the needs of contractors, governments, and citizens. The possible risk pertains to more delicate scheduling and planning functions by incorporating multiple parties' needs aimed at a more complete coverage, such as from the various civilian groups, citizens, or other governments.

Data Integration, Sharing, And Linking Dimension

Through RPIC, the information is shared on a real-time basis among the various stakeholders, as their representatives stationed at RPIC are able to respond to the information on a real-time basis in order to improve service quality. For example, regarding the integration of construction site images, all construction sites are monitored using real-time cameras along with GPS-equipped cameras mounted on vehicles. The information is transmitted to RPIC center machines and consolidated into the system through a cloud service. Mobile devices such as tablets or mobile phones can join in the network to share real-time construction images or video feeds. This increases the transparency of the decision-making process, and particularly helps to build necessary coordination among various parties in the event of emergencies or unanticipated events in which multiple construction sites are involved.

In addition, benefits are shown in terms of helping Taipei City build long-awaited 3-D mapping systems of pipelines. Historically, the pipeline systems in Taipei City are not well-managed: various stakeholders have installed pipelines on their own, and there is a lack of centralized management integrating all stakeholders. Over the years, undocumented pipelines have been rampant both aboveground and underground in Taipei City, causing challenges when it comes to repair, maintenance, and long-term urban development.

In order to develop a solution for pipeline management by utilizing the chances of opening up roads for construction, RPIC measures the coordinates of preexisting pipelines and consolidates new pipeline information as a foundation to build new 3-D pipeline mapping system. The system as shown in Figure 3 is helpful for the future planning of new excavation projects in order to avoid damaging preexisting pipelines during the construction. Also, with the development of such a system, the city government will be able to better manage urban infrastructure during unexpected events such as disasters or other emergencies.

The data integration presents an integrated and connected smart city model based on seamless data flows among systems using cloud services, and on developing 3-D modeling systems that further enable services for future design and planning needs for building and construction. Possible risks are related to data and information sharing with security or defense considerations.

Data Collection and Storage Dimension

Regarding the data collection policy, Taipei City follows an open data and partially open model. For example, for the information provided from the real-time system, information such as the name of the contractor, the name of the project, the scope of the project, project duration, and on-site contact person information are open to citizens. The system also provides to the public maps of various pipelines, such as natural gas, electricity, water, telecommunications, sewer, energy, etc. Meanwhile, RPIC asks stakeholders to use mobile devices and to install surveillance cameras on construction sites to report engineering images and video footage in real-time. This information is collected by the contractor and is shared with authorized individuals or parties, which in turn helps to enhance the

Figure 3. Various pipeline information displayed on Taipei City Road Construction Real-Time Information System by Road & Pipeline information Center (RPIC), Taipei City, Taiwan (Source: Taipei City Government, at <https://dig.nco.taipei/tpdig/>)



quality management of projects. Potential risks pertain to inaccurate or biased data in the system, as well as sub-standard data management, such as failing to update data in a timely manner.

As a result of Taipei City's smart city deployment, the total amount of excavation cases reduces by 31% after implementation. In addition, the number of excavations on the same section of roads reduces by 67%, which marks the success of Taipei's efforts to reduce unnecessary excavations to create a more suitable living environment for citizens.

4.2 Local Business Analysis Service in Seoul Metro City, South Korea

As a leading country of e-government services, Korea's e-government is transforming into citizen-friendly services. In particular, the Seoul Metropolitan Government (SMG) tries to provide customized services for individual citizens and to support job creation by opening and sharing public information and offering advanced services in order to help their local businesses. Using Big Data, cities try to enhance their ability to serve their citizens and to address major national challenges involving the economy, healthcare, job creation, natural disasters, and terrorism. Among them, promoting start-up businesses and job creation are one of the major issues facing the SMG. The SMG introduced a local (neighborhood) business analysis service, which is dubbed as 'GolmokSangkwon' (literally translated as Alley Business District) Analysis Service (golmok.seoul.go.kr). This smart city project is intended to support and expand small local alley businesses and small start-up companies as a strategic e-government service project, and to serve as a success case of Big Data Analytics as part of the fourth industrial revolution.

Stakeholder Component Dimension

One of the primary issues facing the SMG is 'job creation' within local businesses. However, the new startup entrepreneurs, or self-employed small business owners, lack the necessary information to make important decisions regarding where to open, what businesses may be most suitable, and what risks may be waiting for them. The lack of information related to the trade are considered to be a big barrier for start-up and existing businesses to thrive. In order to help business owners and start-up entrepreneurs, the SMG selected small businesses in local areas around the city, which is called 'Golmoksangkwon.' This is a range of commercial forces formed along narrow roads near residential areas, rather than in the business district. The local business areas have to be defined in

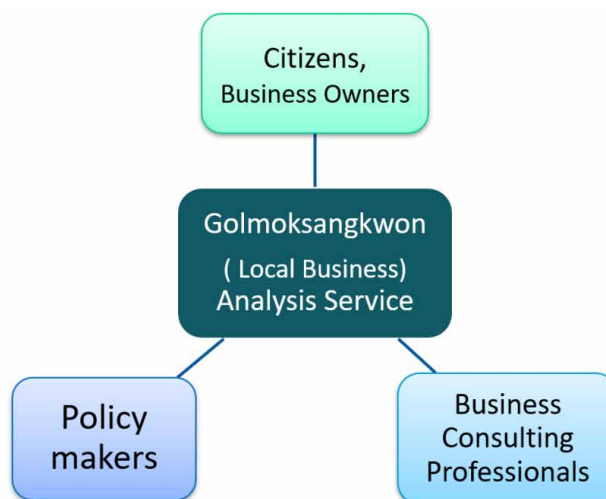
order to identify stores and businesses in the area. Some of the criteria designated by the SMG that must be met in order to qualify for the local alley business district include the following characteristics:

- The area should not include large distribution facilities.
- Must be in a place where housing is concentrated.
- Businesses should be on back streets away from four-lane highway streets.
- Businesses within development districts or traditional market business districts, near big department or corporate buildings, are excluded.
- Schools, parks, or mountainous areas are excluded.
- 100 or so designated businesses will be chosen that are closely related to residential needs.
- Etc.

By utilizing these stringent criteria, the SMG identified 1,010 alley business districts. The service of analyzing neighborhood business districts is designed to support three types of stakeholders, as shown in Figure 4: self-employed business owners and potential start-up entrepreneurs so that they may analyze the businesses and competitors, and monitor the environment and profitability of their businesses; professional consultants and experts who conduct comprehensive consulting services, such as business transformation, sales growth, market growth, and start-up survivability, considering changes in the business environment; and SMG policymakers for monitoring and analyzing all aspects of the businesses throughout different local districts, including types, profits, concentrations, and the number of self-employed and startup businesses and closures, in order to make efforts to reflect them in the policy and to provide practical support.

In other words, the decision to initiate the project exemplifies a government-centric model in which the Seoul City government defines what could be qualified as alley business districts and the start of the project. It is strategically chosen as a service platform that uses Big Data and Analytics in order to encourage new and existing small businesses and startup companies to prosper in residential areas to create more jobs and to avoid closings. However, they seek out cooperation from various stakeholders in order to identify their needs and requirements, such as business owners, start-up entrepreneurs or investors, and professionals at small business centers.

Figure 4. Stakeholders for the Neighborhood Business Analysis Service (Source: Authors' own elaboration)



Service Provision Dimension

The services for the neighbourhood business district include locating the neighborhood business districts in Seoul, new business risk assessment services, business status by neighborhood district, and trend analyses, as well as individual business information services on the online platform dashboard, as shown in Figure 5. These information services were designed by the Seoul Metropolitan Government based on research regarding the information that new business starters and existing business owners needed.

These designed services can search a neighborhood business district, show the current business status and difficulties experienced in the market, and support future entrepreneurs or the self-employed who are suffering from intensified market competition and competition with large retailers, in order to make decisions on how to locate the stable neighborhoods for establishing their business operations.

Intelligence Analytics and Reasoning Dimension

The detailed information services include the capabilities of searching neighborhood business districts and analyzing businesses and their customers by gender, day, or age group, as well as their sales trends. Figure 6 shows neighborhood businesses in the Kwanak district (located in the southwest of Seoul) with all of the information analysis controls. The particular selected business information including name, address, and history (when they were established and when they closed) is shown on the information panel on the right, and more analysis information by business type (e.g. franchised, regular stores, and total number of stores) by different temporal intervals (daily, weekly, or quarterly), and demographics and sales volume by gender, age groups, etc. through controls is shown in the bottom panel.

Due to the high concentration of similar businesses in the market, short-term closure and conversion rates are very high. Therefore, it is necessary to respond appropriately to market changes and to reduce uncertainty in order to improve profitability. By analyzing the big data, existing and

Figure 5. Online Platform for Neighborhood Business District Analyses (Source: Seoul Metropolitan Government - <https://golgok.seoul.go.kr/main.do#>)

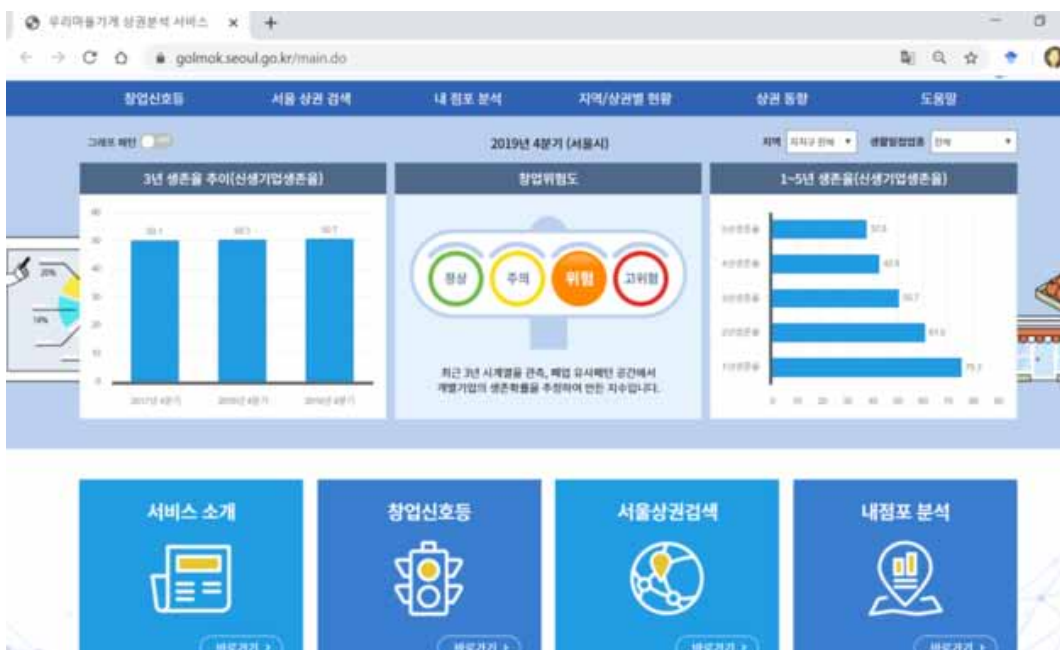
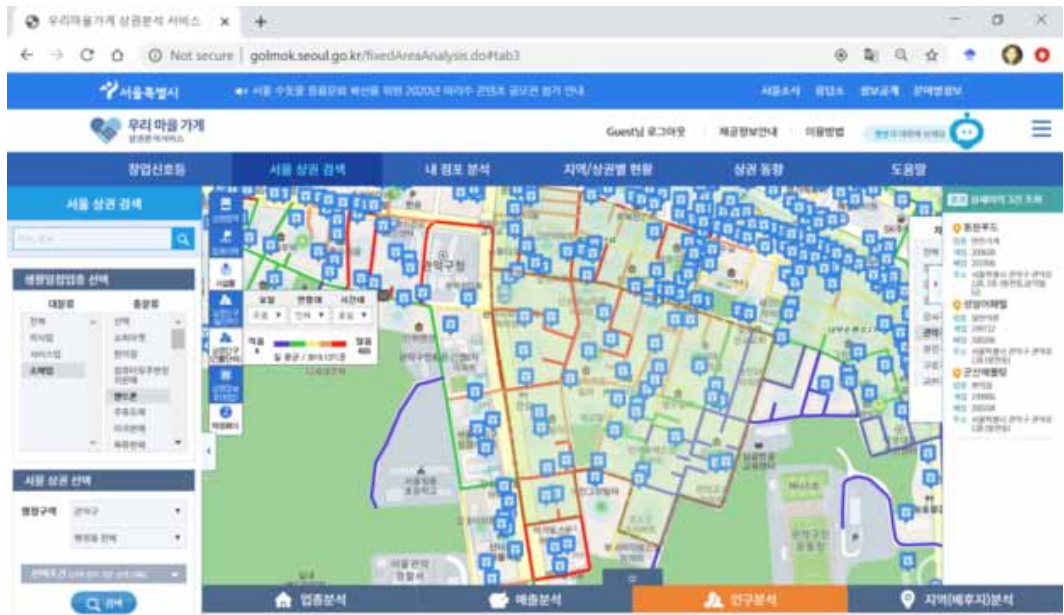


Figure 6. Business District Search and Business Status Analyses by type, sales, customers (Source: Seoul Metropolitan Government - <https://golmok.seoul.go.kr/main.do#>)



future business owners can monitor the change of the alley business trends and consumer changes continuously.

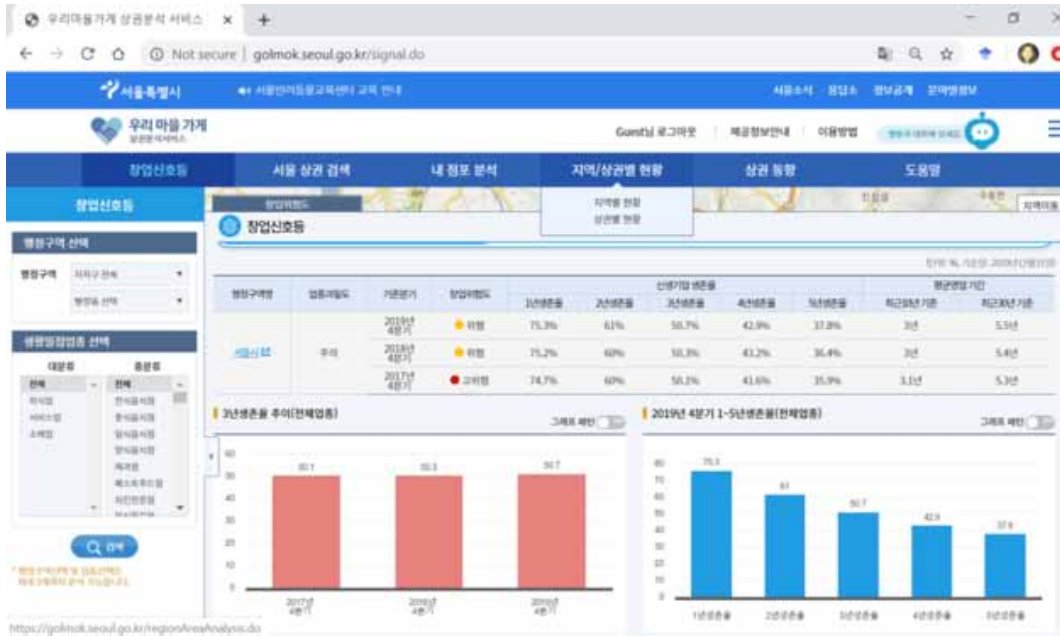
The SMG has analyzed the credit card usage from sales and rental quotes in order to help small business owners who want to start businesses and to assess the survivability of future businesses and business risks as time progresses. Figure 7 shows the three-year survivability trends by the 4th quarter from 2017 to 2019 (the lower left red bar graph) in percentage, as well as the projected survivability in upcoming years. The predicted survivability rates decrease as the years pass, and the average business years (from opening to closing) based on the last 10 years and the last 30 years are shown on the table on the upper right. The risk index/level prediction uses a geographically weighted regression model that identifies the relationship between the closing rate and the closing explanatory variable of the commercial company, which varies depending on the commercial sector. The identified coefficients are weights of explanatory predicting variables. The risk levels for new startups can be shown on a district map in four levels: cautious areas with relatively low risk; suspicious areas where the risk of new start-ups is relatively high; risky districts where the risk of new entrants and entrepreneurship is relatively high or significant; and high-risk areas for the start-ups. The analyses are based on all business types in the neighborhood business districts in Seoul, but they can also be dissected by district or by business type.

In addition, the report can be generated in order to show the trends and summary of businesses by the day, by quarter, or by year. According to the SMG's analysis of licensing data for lifestyle-related industries in 2016, the survival rate of shops that were opened 10 years ago was 2.8% lower than that of 21% for locals. However, the average sales period was 8.9 years for local commercials, which was slightly longer than 8.3 years for development commercials.

Data Integration, Sharing, and Linking Dimension

The data used in the business analytics and information services were collected from 100 of the most residential neighborhood related businesses, including 10 of the most popular business types of newly

Figure 7. New Start-up Business Risk Information Service (Source: Seoul Metropolitan Government - <https://golmok.seoul.go.kr/main.do#>)



established businesses, such as restaurants and bars. The 33 kinds of datasets were integrated in order to provide an analytics service and business information, such as:

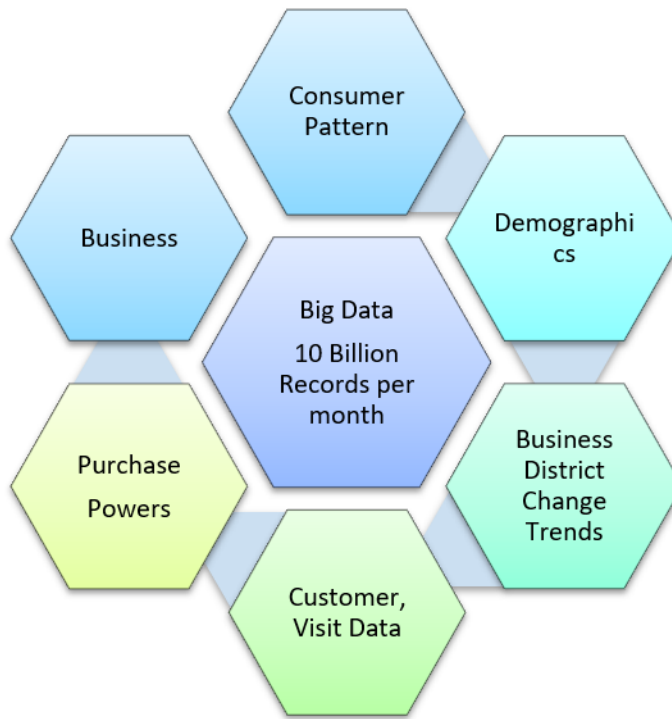
1. Demographic data (neighborhood population, employment, income levels, population flows)
2. Infrastructure (buildings, apartments, and number of households, transportation stations, etc.)
3. Business data (the credit card usage data for sales volumes, number of employees, established and closure dates, survivability, and franchise status)
4. Property/Rental data (rental amounts, store purchase/sale history)
5. Business district type (neighborhood local district, development district); and so on.

The database was developed to store 10 million records per month, which allowed for different types of statistical and predictive analyses, such as risk index for start-up businesses, sales trends, competition and survivability prediction, and customer and demographic analyses, as shown in Figure 8.

The third party company was hired through alliances with public and private institutions in order to develop Big Data infrastructure that integrates disparate datasets from government agencies (maps, streets, store registry) and private company data (credit card usage) and mobile phone location data (telecommunication data) with business data (sales data, store/businesses types) and a moving population. The integrated data was the basis for the analysis and information services such as start-up risk indicators, industry-related indicators, and sales trends.

In the data integration and linking dimension, a fully integrated model through the collaboration between government and a third-party company has been used.

Figure 8. Big Data and Analyses types (Source: Authors' own elaboration)



Data Collection and Storage Dimension

The thirty-three data sets are collected from diverse sources, and they show that the collection was performed through a collaboration between governments, private companies such as credit card or bank card companies, or telecommunication companies (e.g. KT) (SMG Database). The public-private alliance shows that the design part uses an open data model. The individual business data records with estimated sales are prepared by the SMG Small Business Policy Research Center and made downloadable as open datasets and accessible with API (SMG Open Data). The dataset is updated every 3 months.

5. DISCUSSION

Table 3 shows the summary of the design models used by the Taipei Smart Infrastructure project and the Neighborhood Business Service of the Seoul Metropolitan City Government. Although both provide public-facing services, their primary services are the information shared among public works working on roads and construction projects within Taipei, while the primary services are geared toward the public, especially business owners, potential investors, and entrepreneurs, as well as the professional business consultants in the Seoul City Business Service project. While Taipei focuses on information updates and sharing in public works locations, giving citizens and contracting public workers insight into traffic issues and roadblocks, Seoul City's Business Service tries to predict the risks facing business districts in different years after starting businesses, as well as sales predictions, so that potential and current business owners could make a decision and begin planning.

Seoul City's project used the federated collaboration data model, which shares data from the city and private companies (e.g., bank, transportation, and telecommunication), as well as local small businesses and large public facilities. Taipei chose the fully connected data model using the internal

Table 3. Comparison of Design Models for Seoul and Taipei Smart City Projects

Dimension	Taipei Smart Infrastructure	Seoul City's Local Business Service
<i>Stakeholders/ Governance</i>	Government-centric model	Participatory model
<i>Target Services</i>	Internal service optimization model	Intra-agency public service model
<i>Intelligence/Analytics</i>	Insight-based city model	Predictive city model
<i>Data Integration</i>	Fully connected data model	Fully connected data model
<i>Data Collection/storage</i>	Open data model	Open data model

Source: Authors' own elaboration.

dataset within RPIC and contractors' data shared from their work locations. Taipei's data is open to the public through the service, and Seoul City also chose to have the data openly available for analysis, searchable as well as downloadable and processable via API. Thus, it also chose the open data model. The privacy of data issues in Seoul City's project is mitigated by using the aggregate data use (e.g. transportation use data in a location is not on an individual, but rather the aggregated number of people by different time interval) and the use of projected sales data, instead of the actual sales data.

6. CONCLUSION

We presented a set of smart design analysis dimensions and possible alternative design choices (models) that one can consider, as well as the risk issues associated with the design model choice. The proposed framework of multi-dimensional smart city design models is based on the generic smart city system architecture, which consists of the various sub-components of governance, service, analytics, data integration, and data acquisition design layers. In each layer, there is a design choice that ranges from closed to open models and from centralized to participatory or grassroots models. In each layer, the design model choice may involve some risks. For instance, with the fully connected data model in the data integration layer, the designers should be aware of heightened privacy risks in terms of sharing the connected data.

The framework aims to promote AI-driven smart city development in which the design models and risk potential should be considered as part of the core design process, rather than add-on features. We analyzed two cases of smart city projects using the smart model design and analysis framework: the Smart Public Infrastructure in Taipei, Taiwan, and the Local Neighborhood Business Analysis Service in Seoul Metro City, South Korea. Though both cases are government-initiated, their design choices in the different design layers have demonstrated differences. The data sources are also different: Taipei City's project heavily sources data from internal sources and their contractor's field data, while Seoul City relies on diverse partner data, in addition to several agency data sources.

A repository of design models, as well as guidelines and pitfalls in different dimensions, can provide the smart city innovators and developers with more possibilities in the creation and implementation of a new smart city, rather than limited design choices, such as government-centric or participatory design and technology- or social-oriented designs. Following the design of smart city architectural component layers, the design choices can be made in a more fine-grained manner in each layer, and their design choices' risks in each layer can be considered.

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