Chapter 3
Projects for Smart Cities: Ecosystems, Connected Intelligence and Innovation for the Radical Transformation of Cities

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Abstract The aim of this paper is to shed light on projects transforming cities through smart systems, digital technologies, and e-services. The concepts of "smart city" or "intelligent city" appeared in the mid-1980s and since then an extensive array of articles and reports have been published. However, there is still fuzziness about what projects exactly make cities "smart". This is primarily due to complexity, as smart technologies, IoT infrastructure, crowdsourcing platforms, user engagement, co-design, and new decision-making processes overlap, creating hybrid systems and complex environments in which humans, communities, and machines interact. To understand the projects that make cities smart, we combine a literature review of the smart city supply chain, surveys on smart city projects, and case studies of projects to whose design or development we have contributed. Using data from 20 smart city reviews, we identify how different cities have organised their smart city transformation through projects, tease out the core features of smart city projects, relationships between projects and technologies, and the typology of projects and architectures of integration. In the conclusion, we define the drivers of smart city projects and city smartness along three axes (city ecosystem, connected intelligence, innovation) and nine properties of those axes. We argue that more so than technology, the smart city transformation is determined by systems integrating physical infrastructure, platforms for user engagement, digital technologies, and e-services. System integration rather than smart technologies is the major driver for a radical transformation of city routines.

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3.1 Introduction

Intelligent cities or smart cities[1] are shaped bottom-up, through e-services deployment, crowdsourcing and user engagement over digital platforms, and top-down through strategies and projects organised by national, regional, and local authorities. Yet despite the long-time which has elapsed since the concept of "smart city" and "intelligent city" appeared in the 1980s [1], there continues to be uncertainty about the drivers that make cities smart. There are misconceptions that smart cities will be produced through the automation of urban infrastructure, and the unsystematic deployment of digital applications, and e-services. There is no doubt, digital solutions contribute very much to smartness, but they need to connect to the non-digital fabric of cities, their physical and social space, and to their planning and governance procedures to generate a radical transformation.

The purpose of the paper is to shed light on projects that make cities smart and on the drivers of city intelligence or city smartness. We argue that the smart city transformation is multidimensional and the drivers of city smartness are mainly systemic. As W. Michell has put it "our cities are fast transforming into artificial ecosystems of interconnected, interdependent intelligent digital organisms" [2]. This does not mean that technology is not important, but the quest for the smart city is a quest for the integration of digital technologies with the non-digital assets of cities that are related to human intelligence, institutions, and communities.

To this end, we look into smart city projects, small and large initiatives that actively engage authorities, citizens, stakeholders, public and private organisations, introduce innovation into city routines, change key indicators, and contribute to the digital transformation of cities [3]. Besides the importance of smart city projects to the making of cities, there is limited literature on their variety, typology, structuring, and factors in their success and failure.

Our hypothesis is that city smartness is systemic, emerging into ecosystems from the convergence of numerous projects. Innovation as an outcome of city smartness comes from the integration of projects and is heavily dependent on institutional settings for collaboration in city ecosystems. Smart cities are networked cyber-physical-social spaces with strong connections between humans, digital systems, communities and institutions, which enhance learning, innovation, and optimisation. Smart city projects enable such systems to form and operate better. Their success or failure depends on factors that propel or constrain connected intelligence, in other words, the integration between human, collective, and machine intelligence to be found in city ecosystems.

In the smart city literature, there is some evidence corroborating this hypothesis. Kogan and Lee [2] for instance, argue that the most important factor that governs the success of a smart city project is not the smart infrastructure or the digital technology

[1] The terms "intelligent city" and "smart city" describe the same transformation of cities with digital technologies, though there are differences in the technologies used (platforms vs. IoT), impact (empowerment vs. automation), and innovation introduced. Hereafter, we use the terms alternately as denoting the same phenomena.

used but the level of citizen engagement. The contribution of stakeholders enables different perspectives to be balanced and a shared vision of the city to be formed. However, the dynamics of stakeholder engagement are also a source of complication and uncertainty in decision-making. Having studied smart city projects in the city of Amsterdam, Van Winden et al. [4] argue that success comes along with rollout, expansion, and replication. These are forms of upscaling pilot experiments and small demo projects. In rollout, the technology or solution that is successfully tested and developed in the pilot project is commercialised and brought to market (market rollout); expansion takes place by adding new partners, enlarging the geographical area covered by the pilot project, by adding new functionalities; in replication, the pilot solution is replicated elsewhere, in another community, city district or another city. Rollout, expansion, and replication engage the entire context and institutional setting of cities. In other studies, smart city projects have been considered within the interests of stakeholders and city organisations; though those interests turn out to be conflicting [5]. Success and failure come from a collective learning endeavour, in which digital technologies, e-services, data and analytics, interact with background processes, the local history, governance structures, and dynamics of cities [6].

To assess this hypothesis, we develop a methodology on three levels. First, we look at the relevant literature related to the supply chain of the smart city over which numerous projects are combined and through which the digital transformation of cities is channelled. Studying the supply chain allows one to develop a holistic view of smart city making, taking into consideration small and large projects, designed and developed by private companies, non-profit organisations, communities of users, as well as local and national authorities. Second, we analyse survey data from a large number of smart city projects planned by city authorities. Here, the questions are about the verticals or ecosystems in which projects are placed, the diversity and standardisation of projects, their digital and non-digital components, the engagement of citizens and stakeholders, as well as the impact on improving or innovating city routines. Third, we look at projects for the development of e-services, the most usual form of smart city projects created by companies and the private sector, and we go deeper with case studies to assess factors of success and failure.

The structure of the paper follows the deployment of this methodology. Following this introduction and problem statement, section two refers to the literature on the smart city supply chain. We discuss the theoretical framework of the intelligent/smart city as a new urban paradigm that enables and facilitates processes of digital transformation, optimisation, and innovation; the concept of the supply chain for the smart city; and the relationship between projects and strategic planning that makes cities smart. In section three, we look at empirical data from many cities all over the world. We analyse smart city projects from 20 cities, their typology, cyber-institutional-physical dimension, the ecosystems of cities in the process of digital transformation; and where available, the impact this transformation is having. Section four is about projects related to technology development and e-services, their factors of success and failure. It is based on smart city experiments carried out by URENIO Research and ITI-CERTH developed over recent years, focusing on rollout, expansion, and replication challenges. Section five is about the lessons learnt from smart city projects in light of the literature, survey data, and case studies discussed. Our conclusions discuss the core properties of smart city projects, and the integration of human, institutional, and machine capabilities, and the role of institutions in making complex ecosystems for smart cities.

3.2 Literature: Projects and the Supply Chain for the Smart City

Projects and planning are major drivers in the creation of smart cities. Understanding their contribution, success and failure factors, requires one to consider the fundamental entities, structure, and operation of the smart city, in particular the supply chain which gathers and interconnects all types of projects involved in the making of a smart city.

In any industry, the supply chain connects all components and inputs from the raw materials to the manufacturing of finished products, promotion and distribution to the final product reaches the user. The supply chain is both a product-based and an operations-based perspective.

In the case of smart cities, the supply chain includes all inputs, components, and projects that contribute to the production and delivery of smart city data, infrastructure, digital and non-digital services. The supply chain of a smart city, as depicted in the respective ontology, is extremely broad, extends over the entire city as a system of systems, includes bottom-up and top-down processes, projects and planning, as well as inputs from many fields of science and technology.

3.2.1 Intelligent/Smart City: A New Urban Paradigm

The intelligent/smart city is a new city planning and development paradigm. It has emerged as a disruptive approach at the convergence of (a) digital technologies and the capabilities they offer, (b) the knowledge and innovation-led development of cities, and (c) challenges faced by contemporary cities, such as urbanisation and growth, ageing of buildings and infrastructure, traffic congestion, use of fossil energy and environmental pollution, personal safety and security, citizens' quality of life and health [7–9]. In response to the challenge to provide urban environments free of crime, cities that are safe, inclusive and innovative, cities without traffic congestion and private cars, free of pollution and environmental degradation, the models of sustainable urban development, represented by the "green city", the "creative city", "smart urban growth" and others, evolved into a new paradigm, the intelligent or smart city [10].

Currently, the smart city is considered a hegemonic phenomenon in the contemporary metropolis transforming all subsystems of cities [11–13]. There is strong evidence supporting the argument that the smart city should be understood as an emerging holistic paradigm [14–16]. The smart city refers to a new reality, a new digital-physical-institutional architecture replacing the physical-social reality of cities [17]; a new set of technologies for making cities, with digital technologies added on to construction technologies and management science guiding city planning [18, 19]; a new way of operating for cities based on e-services that transfer activities from the physical space of cities into the digital space; new functionalities deriving from multidisciplinarity [20]; new externalities provided over platforms and the Internet changing the way innovation is produced and diffused [21–24]; and above all, new data becoming available along with e-services that transform cities into measured systems thereby enabling computation [25]. Even those critical appraisals which view the smart city as a technocratic construction made of disconnected pieces of the urban fabric and unsuccessful experiments generated by a forced union of incompatible elements do not deny the magnitude and disruptive character of this paradigm [26].

The significance of these transformations for cities is paramount: the theories of city organisation and growth that prevailed in the past, and the twentieth century in particular, are not adequate to describe, explain, and forecast how cities work and evolve today under the new functionalities offered by and impact of digital technologies. The intelligent/smart city paradigm fills this gap and offers a new understanding of the dynamics of cities in the twenty-first century.

A comprehensive understanding of the smart city paradigm and the respective supply chain can be obtained by looking into the ontology of the intelligent/smart city and the major classes and properties that compose this ontology. In a recent paper [27] we outlined three major groups of entities that compose the smart city ontology: (a) physical, social, and digital entities structured in communities and subsystems, (b) knowledge and innovation processes shaped by data and innovative e-services, and (c) processes of transformation for both urbanisation and city planning. These groups are depicted in Fig. 3.1. On the left side is the "community hub" containing spatial, social, and digital elements organised in city subsystems into a cyber-physical city. On the right side is the "urbanization and city planning hub", containing processes related to urbanisation, challenges, environmental processes, city planning, governance, and digital system design. At the centre is the "data and e-services hub" with its knowledge-supporting and innovation architectures, functions, and outputs. From these first level classes derive many other entities and relationships at successive levels of detail, giving a total of 1231 entities. The ontology makes clear that the core and driving forces of the new paradigm are "data", "e-services", and "innovation", which transform both the urbanisation and planning of cities.

The diagram showing the first level classes and the detailed smart city ontology also shows that projects from the private sector (in the form of e-services) and projects from public authorities (in the form of smart city planning) are placed in a nexus of relationships that connect challenges the cyber-physical city faces, urbanisation processes undergoing digital transformation, governance, and digital systems design. The digital and non-digital entities of the smart city ontology are interwoven in these types of projects, which in turn transform urbanisation and city planning.

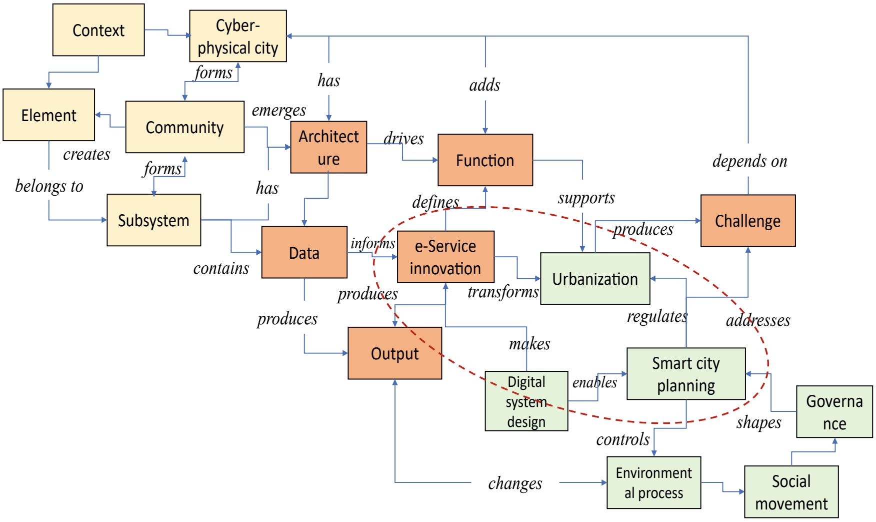

Fig. 3.1 Projects occupy a central place in the smart city ontology. *Source* Adapted from [27]

3.2.2 *Subsystems: The Smart City as a System of Systems*

Previous work and literature have documented that the smart city development, including the supply chain and projects, are fragmented into vertical subsystems. The system-of-systems view of the smart city is widely accepted, but there is no agreement about the granularity of its subsystems, their typology, the number of subsystems to be transformed in order for a city to be considered as smart.

Giffinger and Gudrun [28] have identified six major smart city subsystems: smart economy, smart environment, smart governance, smart living, smart mobility, and smart people. In a step further, Arroub et al. [29] consider these dimensions as interrelated smart city paradigms creating smart economies, smart environment, smart governance, smart mobility, smart healthcare, smart living. URENIO Research [30] classifies smart city solutions into 5 major domains (innovation economy, living in cities, city infrastructure and utilities, city governance, generic) and 17 subdomains. Frost & Sullivan [31] define a smart city as one that has an active plan and projects in at least five out of eight functional areas (subsystems), such as infrastructure, buildings, energy, healthcare, mobility, technology, governance, and citizens. Thus, depending on the level of granularity, a smart city may have a few or a dozen subsystems.

Bottom-up and top-down processes shaping the smart city are more clearly defined. Bottom-up here refers to all market-mediated processes for the supply of products and services composing a smart city. The provision of e-services by companies is the dominant form of bottom-up smart city development. Top-down here refers to central and local authority actions, including, policies, regulations and standards, plans, and projects for making a smart city.

Along the supply chain of the smart city, inputs come from various fields of science and technology, information and communication technologies, engineering, policy and management, geography and planning. The description of digital technologies for smart cities given by Frost & Sullivan covers a wide range of fields, such as smart grids, smart meters, broadband networks, sensor networks, digital management, e-services, as well as sector-specific technologies related to renewable energy, transport, health, government, and education [31].

The variety of subsystems, processes, and technologies that are used in the making of the smart city reveal a supply chain that is extremely complex. Apart from vendors of digital products and services, the supply chain also includes suppliers offering engineering services, building technologies, construction materials, developers of city infrastructures, and multiple providers of services related to city planning and design, consulting, innovation and knowledge management, civic services, finance, standards and regulations, and many others.

This landscape is far wider than just digital technologies and broadband services. The smart city is not a digital city only, but a fully-fledged physical, social, and digital system. The physical space, the standards and regulations, the social mix and activities are just as important as the digital technology. The same goes for context and skills. The city and the smart city are not objects, but complex cyber-physical-social systems emerging from individual actions and projects of the private and public sectors, and planning that coordinates and gives coherence to projects.

3.2.3 Smart City Projects

The smart city supply chain includes multiple digital and non-digital components in the form of projects. The report from the ITU-T Focus Group on Smart Sustainable Cities [32] provides good technical specifications of the digital entities and the ICT architecture of the smart city. From bottom to top this architecture is structured in four layers:

- the *sensing layer*, including sensors, actuators, cameras, RFID readers, GPS trackers, and the connecting sensor network
- the *network layer* with xDSL, FTTx, WiFi, metro network, 2G/3G/4G [5G] networks
- the *data and support layer*, including computing and cloud computing, various databases, application support servers, and data processing services
- the *application layer* with multiple applications for e-government, transport, healthcare, environment, safety, district and many other applications.

This architecture defines a digital system as a collection of components. Each component has a specific role within the system (i.e., authentication, data repositories, etc.), while all components interact to establish a coherent system. In turn, this digital architecture connects to non-digital entities of cities, such as activities, land uses, buildings, regulations, governance, and other elements of the physical, social and institutional context of cities.

All digital and non-digital components of a smart city can be considered as the outcome of a project. It may be a small project, such as installing a group of sensors to collect information or a web application to support an e-service; or, a larger project, such as developing a crowdsourcing platform with rules, complementors, and a community of users. Or, even larger, such as designing and developing a net-zero CO_2 smart district in which a group of smart systems, energy-saving solutions, building technologies, renewable energy production and nature-based solutions are orchestrated.

Thus, we concur with Bosch et al. [3, p. 7] that "a smart city project is a project that has a significant impact in supporting a city to become a smart city [...], actively engages citizens and other stakeholders, uses innovative approaches, is integrated, combining multiple sectors".

This process of integration between digital and non-digital elements in smart city projects is also reflected in the integrative framework for understanding smart city initiatives proposed by Chourabi et al. [33]. The eight components of the framework, derived from the exploration of an extensive array of literature, are depicted in two circles: the internal one includes technology, organisation, and policy. The external one includes people & communities, the economy, built infrastructure, national government, and governance. Each smart city initiative or project is defined by those eight axes that compose the integrative framework.

Another multi-dimensional taxonomy of smart city projects, which also shows the integration of digital, physical, social, and institutional components, has been proposed by Perboli et al. [34]. It is based on a trend analysis of Italian and European projects, includes three axes (description, business model, and purpose) and multiple categories per axis (Table 3.1).

These taxonomies show that smart city projects may be simple with a few components only or extremely complex. Projects can be undertaken by any actor, person, company, non-profit organisation, community, local central state authority. Their features can be digital, physical, social, and institutional, in multiple combinations. Their context, which is decisive in their success and failure, becomes part of their features, as technologies and tools are applied over the pre-existing physical background and activities.

Three major types of projects we can distinguish are those related to (a) information provision, creation of datasets and analytics, such as smart metering and data repositories, (b) the creation of applications and e-services, such as online transactions, e-government, health and education services, and (c) more complex projects combining physical, social, and digital elements of cities, such as smart districts, smart campuses, and smart city ecosystems.

This complexity of projects has one important implication. The impact of smart city projects seems to depend on their complexity. This has been studied in [35, 36] who define the operation of smart city projects along three circuits: c1—digital

Table 3.1 Taxonomy of smart city projects

Description	Business model	Purpose
Objectives:	**Managemen**t:	**Client**:
Governance, energy, security, etc.	Private, public, mixed	Private, public
Tools:	**Infrastructure financing**:	**Product**:
Cloud, database, legal tools, etc.	Private, public	Specific, no specific
Project initiator:	**Financial resources:**	**Geographical target**:
Public, private, mixed	Private, public	Urban, national, international
Stakeholders:		
City, citizen, SMEs, administrators,		

Source [34]

services and data deployment; c2—optimisation/innovation on the city's production side, related to choices of private and public investments; and c3—optimisation/innovation on the city's consumption side, related to the behaviour of citizens and organisations. The associated impact may be simple digitalisation, digitalisation leading to optimisation, or digitalisation leading to innovation.

Simple projects initiate digitalisation only. Some activity is transferred from the physical to the digital space without any changes in its features. The case is usual in e-transactions. While a transaction becomes digital, the underlying routine (actors, objectives, business model) remains the same. For instance, you can play chess over a physical table or an online digital table, but the rules, logic, and tactics remain the same in both cases. When digital deployment (c1) does not alter the related routines, the process is simple digitalisation. There is impact, but it is usually low.

More complex projects initiate optimisation together with digitalisation. An activity is transferred from the physical to the digital space, but together with digitalisation some features or performance are optimised. Within the limits of the underlying routine, performance may take the max. or min. value, depending on what is optimal. Automation, analytics, and guided behaviour can optimise activities along with their digitalisation. This is very usual in smart systems for mobility, energy, and utilities.

Then, highly complex projects may initiate, together with digitalisation, radical changes to underlying routines, introducing new operating models. This is the case for instance with *Vision Zero*, a combination of engineering, design, training, law enforcement and digital technologies to eliminate all traffic fatalities and severe injuries in cities, or with *Net-Zero Energy Districts*, which combine smart grid solutions, building refurbishment, spatial, financial, legal, social and economic interventions, and nature-based planning toward annual net-zero energy imports and net-zero CO_2 emissions.

Reducing the smart city supply chain and projects to vendors of digital technologies, e-services and e-infrastructure, is equal to reducing the impact of smart cities to digitalisation only. The supply chain of smart cities contains both digital and non-digital projects in tandem. The introduction of digital elements changes the specifications of non-digital ones. Web-based work from home, for instance, also changes the need for office space, housing, and transport. Defining the supply chain of the smart city by digital projects alone is extremely narrow, as it only records suppliers of the digital components of smart cities. On the contrary, the full supply chain of the smart city comprises projects for the physical, institutional, and digital space of cities, engages users and stakeholders in information sharing and participatory decision-making, transforms the operation model of city ecosystems, and can have a high impact through the replacement rather than optimisation of city routines.

3.2.4 Smart City Projects and Planning

"One swallow does not make a spring". It is not uncommon for a company to introduce a project, such as bike-sharing or scooter-sharing, or carpooling. Equally it is not unusual for a local authority to draw up an action plan and start implementing the projects contained in the plan. However, a single smart city project is not enough to change a city's subsystem, whether it is wide like the mobility ecosystem or narrow like the water infrastructure. Each smart city ecosystem needs a group of projects in order to be transformed. The smart city evolves from the execution of specific projects to the implementation of plans and strategies through which it becomes possible to tackle wider challenges; it becomes necessary to develop strategies that articulate projects to achieve a holistic and comprehensive city-wide change [37]. But looking into groups of projects having common objectives, we enter the domain of strategic planning or planning through projects [38].

Understanding the planning of intelligent/smart cities through the accumulation of e-services and projects, which are heterogeneous, and many times experimental and incomplete is far from the usual concept of coordinated and well-organised city planning. Thus, intelligent city planning is closer to making smart cities through evolution than through planning and implementation of detailed action plans. It is planning under conditions of complexity based on a rather chaotic interaction of simultaneous actions and decisions taken by many organisations each of which has its logic and own plan. The outcome is more guided by market forces through opportunities that arise over time, with the overall result being unpredictable and uncontrollable in advance.

Strategic planning through smart city projects reveals the complex character of the smart city as a synthesis of technologies, spatial and institutional elements, user engagement, and windows of opportunity which are fuzzy at the start of the planning process. The evolutionary features of cities, which until now were ascribed to the functioning of markets, are now shaping planning for smart cities [39]. The project dimension, with dynamics that combine strengths and resources from the private and public sectors, prevails over the strategy and planning dimensions of smart cities.

3.3 Smart City Projects from Around the World

There are a host of reviews on smart city plans and projects that can be used as material for meta-analysis. Such analysis can be performed on studies that address the same question, but the level of accuracy of each study may be questioned and the reports may have some degree of error. Meta-analysis is an established method that overcomes some of the problems accounted for in narrative reviews [40]. Detailed methodologies for synthesising research using meta-analysis have developed very rapidly in the medicine and health research sectors. Meta-analysis has also been used in ecology, education, marketing, and other fields of science. The dominant methodology for systematic reviews is based on randomised controlled trials. But some reviews have also combined data from observational studies and data from qualitative research [41–43].

To assess the drivers of smart city projects, we use the reviews in the book "Smart City Emergence", which allow one to understand some fundamental features of these projects. As stated in the introduction the aim of that book is "to collect and present information from several cities around the globe with regard to their SC development. More specifically, it presents how different cities have approached the SC; the vision that they defined for their SC and the problems they wanted to solve with the corresponding smart solutions; the projects that were launched and the timeline for their development; the corresponding budgets and the implementation methodologies, etc." [44, p. xxi].

After a chapter on project management, the book includes twenty city reviews highlighting how different cities have organised their smart city transformation. Forty-five authors contributed to the reviews and the cities are from all continents. While some projects are relatively simple and refer to the development of e-services, others include complex efforts of articulation between the public sector, private sector, and citizens. Regeneration of urban areas, intelligent lighting, automation of traffic lights, solutions for the development of a creative economy, co-working spaces and projects for start-ups are among them.

An overview of the cities, projects, and the domain or ecosystem of reference is given in Appendix 3.1. Appendix 3.1 does not account for projects related to broadband networks, wi-fi, and open wi-fi which are offered additionally. These networks are present in all cities and together with cloud computing form the basic infrastructure on which all smart city services operate.

3.3.1 Structuring by Ecosystems

A very clear message that comes across from the twenty cases relates to the setting of smart environments by ecosystems. In most of the twenty cities reviewed, the authors describe projects per ecosystem or sector (energy, environment, economy, etc.). We prefer to use the term "ecosystem", instead of sector or vertical market that are also in use, because of the emphasis given in ecosystems to networking and interaction among actors. The objectives of projects are either relevant to a specific ecosystem or common objectives that can be found across ecosystems. In the case study on Korea for instance, a common model for all smart cities is described, promoting an ICT-based growth of city ecosystems to sustain the innovation economy and support the fourth industrial revolution with sandboxes for experimentation [45].

Table 3.2 shows the city ecosystems in which projects are implemented. We have identified sixteen ecosystems, which are classified into three blocks, those related to (a) areas, (b) activities, and (c) networks. These three major types of ecosystems have quite different locational behaviour: area-based ecosystems cluster spatially to form city districts, activity-based ecosystems spread throughout the city, and network-based ecosystems locate along axes and transport networks. The number of ecosystems we identified is double the number of vertical markets mentioned in the Frost & Sullivan report [31] and more than double those mentioned in the grounding study by Giffinger et al. [28].

Most frequently cities focus on ecosystems related to networks and utilities (broadband, mobility, energy, etc.), followed by interest in ecosystems related to activities (economy, health, safety, etc.) and a few cities only work with area-based ecosystems, such as district renewal, or port and university campus renovation. Network optimisation seems to be the principal concern and objective in transport and utility ecosystems.

Some ecosystems garner a great deal of attention: governance (in 64.70% of cases), mobility (in 58.82% of cases), energy (47.02%) and health (35.29%). If we consider safety as an aspect of quality of life, then this group also garners a lot of attention (58.82%). Overall, most frequent is the digital transformation of governance, economy, and health in activity-based ecosystems; and broadband communication, mobility, and energy in network-based ecosystems. The missing cases are very significant with there being an absolute absence of digital transformation for areas such as the historic city centre, technology districts, housing districts, and activities such as manufacturing and culture. But this may be a random outcome of the sample used.

3.3.2 Diversity and Standardisation of Projects Per Ecosystem

There is a high diversity of smart city projects and solutions across ecosystems. But inside each ecosystem, the diversity is low and similar projects are to be found in the same ecosystem across cities, regardless of the city geography, size, or level of

Table 3.2 Most common projects per sector or city ecosystem

Type of ecosystem	City ecosystems	Frequency in sample cities	
		No of cities	%
Area-based ecosystems (3.49% of all ecosystems)	1. District renewal-Multi-use districts	1	5.88
	2. Hub district (port / rail / airport)	1	5.88
	3. City centre / historic centre	–	–
	4. Technology district	–	–
	5. campus	1	5.88
	6. Housing	–	–
	7. Public space/natural ecosystem	–	–
Activity-based ecosystems (45.35% of all ecosystems)	8. Governance	11	64.70
	9. Health	6	35.29
	10. Startups, innovation, skills	5	29.41
	11. Safety	5	29.41
	12. Living, quality of life	5	29.41
	13. Education	4	23.53
	14. Tourism, hospitality, shopping	3	17.65
	15. Manufacturing	–	–
	16. Culture, recreation	–-	–
Network-based ecosystems (51.16% of all ecosystems)	17. Telecom, broadband	17	100.00
	18. Mobility	10	58.82
	19. Energy	8	47.05
	20. Environment	4	23.53
	21. Water	3	17.65
	22. Circular economy, recycling, waste	2	11.76

Source Data from Appendix 3.1

prosperity. Table 3.3 shows the most usual projects in two ecosystems (governance and energy) in which smart systems have been implemented in most cities examined. As we can observe, eight projects are the most usual one in both cases. Government and energy transformation takes place with a small number of projects mainly. On the other hand, comparing ecosystems, projects differ considerably, besides the fact that the same digital technologies of sensing, network, data processing, cloud computing, and application development are used.

The significance of this observation is paramount. The same digital technologies deployed in two different ecosystems lead to totally different projects and solutions for digitalisation, optimisation, or innovation. The diversity of context, actors, physical infrastructures, and social processes prevail over the homogeneity of digital technologies. The challenge for smart city projects inside each ecosystem is on the side of project design and innovation rather than on the use of technology.

Table 3.3 Standardisation of smart city projects per ecosystem

Smart city governance projects	Smart city energy projects
1. Online administrative services to citizens 2. Co-design of public services 3. Citizen reporting, complaints, requests to city administration 4. Citizen database and profile platform 5. Open data, data sharing with citizens and entrepreneurs 6. GIS data centre 7. Digital payments 8. Integrated city management system, command centre	1. Smart metering in buildings, energy control and saving 2. Energy integrated: retrofitting, PV panels, RES, and other solutions 3. Smart grid and use of renewable energy 4. District cooling and heating 5. Smart public lighting 6. Public electric vehicle charging 7. Energy-related platform and transactions 8. Data collection, mapping, and modelling of the energy system

Source Data from Appendix 3.1

3.3.3 Projects and Technology

However, the role of technology is not neutral. The technology used is specific to the ecosystem of reference and the type of project. This becomes evident by looking into another survey on IoT-based smart city use cases. IoT Analytics [46] carried out a survey of 50 city decision-makers from the world's leading smart city initiatives and classified the smart city vendors into six categories with respect to the products and technologies they offer: (1) sensor and end-devices, (2) network equipment and infrastructure, (3) connectivity and network-related services, (4) edge/core computing hardware and software, (5) software platforms and apps, and (6) professional services. Table 3.4 shows the top smart city use cases concerning IoT related projects. As one might expect, projects for mobility, environment, energy and building infrastructure are most usual, because the deployment of IoT and sensor

Table 3.4 Top 10 smart city IoT-based use cases

Rank	Use case	Share (%)	Ecosystem of reference
1	Connected public transport	74	Mobility and transportation
2	Traffic monitoring and management	72	Mobility and transportation
3	Water level/flood monitoring	72	Environment
6	Weather monitoring	68	Environment
7	Air quality/pollution monitoring	68	Environment
10	Water quality monitoring	64	Environment
5	Connected streetlights	68	Energy and utilities
8	Smart metering—Water	66	Energy and utilities
4	Video surveillance and analytics	72	Public safety
9	Fire/smoke detection	66	Building and infrastructure

Source IoT analytics, cited by [47]

networks mostly takes place in these domains. Uses cases in ecosystems related to governance, the economy or health, which are top in the "Smart City Emergence" survey, do not figure among the top places in the IoT Analytics survey. There is a correlation between the technologies used and the ecosystem for their deployment.

3.3.4 Typology of Projects and Architectures of Integration

We classified the projects in Appendix 3.1 into the three categories we mentioned in Sect. 3.2: (a) projects developing digital applications and e-services, (b) projects for data repositories, monitoring, metering, and analytics, and (c) cyber-physical projects with interventions on the digital, physical, and institutional space of cities. The allocation of projects in these three categories appears in Table 3.5 with the figures for the development of e-services and complex cyber-physical projects being close to each other. The cases for data creation, monitoring, and analytics are less frequent.

Project types tend to follow the ecosystem of reference: in ecosystems related to economy, government, education, and health it is the creation of e-services that prevail. Cyber-physical systems and IoT solutions prevail in ecosystems related to mobility, energy, and the environment. Projects for data creation, monitoring, and analytics are found in all ecosystems. However, there is no exclusion, and all three types of projects can be found in every city ecosystem.

Within each ecosystem, smart city projects can agglomerate but lack connectivity and integration. We have called this architecture "the agglomeration of digital applications and solutions" and it marks the lower level of spatial intelligence that can be found in smart cities [48]. It is usual in the starting phase of smart cities in the same way that the spatial agglomeration of activities is the starting phase at the beginning of urbanisation.

More integrated architectures are found in the domain of energy where a combination of smart grids, renewable energy production, building refurbishment, smart home solutions, and smart metering projects work together and form a very efficient system in energy usage and reduction of CO_2 emissions. Smart campuses and smart districts also follow similar architectures of integration. But their presence in cities is still rather limited.

Table 3.5 Allocation of smart city projects per type

Projects for smart city e-services	Projects for data creation monitoring, analytics	Complex cyber-physical projects	All projects
96	28	82	206
46.06%	13.59%	39.81%	100%

Source Data from Appendix 3.1

Overall standalone projects prevail over more complex and integrated ones. This is probably a trait indicating low maturity at the initial stage of smart city development.

3.4 Smart City Projects: Drivers and Barriers

We turn now to another type of evidence related to smart city projects that were designed and developed bottom-up. We refer to three projects started by two research organisations, URENIO Research, a lab at the Aristotle University of Thessaloniki, and the Informatics and Telematics Institute of the Centre for Research and Technology Hellas (ITI-CERTH). These started as experimental projects, in the framework of Horizon 2020 and other EU consortia, and were adopted and scaled up by cities. They are rather small projects focusing on the deployment of smart city services and technologies, but representative of the type of projects developed by companies and the private sector. Besides their size, they allow challenges in projects developed bottom-up and barriers due to the institutional inertia of the urban system to be identified.

3.4.1 Improve-My-City: Collective Intelligence and Reward for User Engagement

The application and the respective e-service is a direct mechanism for citizen-government communication and collaboration. It is available through the web (https://www.improve-my-city.com/) and android and iPhone smartphones. The service enables citizens to report non-emergency problems and the city government to respond to their requests, and provide solutions and feedback to users. Citizen requests submitted are displayed on the city map and are accompanied by comments, pictures or video, and suggestions for solutions. Requests are classified into categories defined by the city administration and each request is transferred to the department responsible, which takes action to address it. Additionally, the backend of the application, deploys data on the cloud and provides analytics to aggregate and visualise data, identify areas where city problems are most frequently reported, and assess the performance of the city's administrative departments [16]. Improve-MyCity (IMC) promotes the participatory government of cities and acts as a medium for the engagement of citizens in the management and planning of cities.

IMC is an application and e-service in the field of social innovation. These innovations do not conform to the dominant concept of innovation as a new product and business development, but are innovations social both in their ends, serving social objectives, and in their means, based on collective action. IMC serves collective objectives, as citizens report issues to improve the city as a space of public goods and commons; introduces a bottom-up participatory government in which citizens direct and prioritise public action.

IMC is an open-source scalable software solution, initially launched in 2012 in the context of the EU's "PEOPLE" research project (EU-CIP). The PEOPLE project included a series of experiments in social innovation at the level of smart city districts in four pilot urban areas: the cultural district of Bilbao (Spain), the university campus and technology park of Bremen (Germany), the central commercial district of Thermi, a city within the metropolitan area of Thessaloniki (Greece), and the housing district of Vitry-sur-Seine, a suburb of Paris (France). The first version of IMC was developed by URENIO Research. ITI-CERTH then went on to develop the smartphone versions.

The e-service was initially provided by the town of Thermi to enable those who live, work or visit the city to report local problems such as discarded garbage, burned out light bulbs, broken pavement slabs, illegal billboard posters, illegally parked vehicles, and so on. Citizens made suggestions for improving the city's infrastructure, but also commented on and voted in favour of existing requests.

On a larger scale, the service was introduced by the city of Thessaloniki to manage the daily problems of citizens, providing a platform for submitting, managing, and analysing such requests. Requests are submitted under clear terms related to the operation of the service, the submission of requests in predefined categories, the posting of non-emergency requests, the posting of content that is not untrue, defamatory, inaccurate, aggressive, offensive, threatening, or detrimental to the privacy of a person. Entries are personal views and experiences of their authors. The administrators of the service do not guarantee the accuracy of the information published and also retain the right to delete inappropriate content. Requests are free, but the user remains solely responsible and accountable for the content of the entries.

To date, more than 60,000 requests have been submitted in Thessaloniki and 3000 in Thermi, which is a much smaller community. The application is multilingual and is already used in 30 other cities across Europe, the US, Mexico, Brazil, Angola, Indonesia, India, and Russia. The two municipalities, Thessaloniki and Thermi received awards for the implementation of Improve-my-City from the Council of Europe at the inaugural event of the "European Badge of Excellence in Good Governance" Programme. The success of this type of e-service can be attributed to several factors [49]:

- IMC includes a *recommendation/reward system* in which citizens raise demands and suggestions and the public authority respond to these demands.
- IMC is *interactive* and provides a solution that incorporates best practices towards user experience such as keyboard-friendly interfaces and offline use of mobile devices.
- IMC offers *analytics* documenting fields of concern for citizens, weaknesses in the urban system, as well as the public authority's performance in responding to these demands.
- IMC relies heavily on the principles of *openness and transparency*, which we found to be fundamental for the smooth operation and adoption of smart city

services. Municipalities that try to limit transparency by displaying to users only their submitted issues and not showing issues reported by other citizens tend to receive a negative assessment [50].

All-in-all, Improve-my-City is a smart city service that introduces innovation into the mainstream city top-down administration, offers a digital platform that can be adapted to the challenges faced by each community, works as a crowdsourcing aggregator of citizen requests and ideas, rewards citizens for engagement, and promotes collective intelligence in setting priorities for city planning and management.

3.4.2 CUTLER's Smart Parking: New E-Services Over Data

The city of Thessaloniki is densely populated, and many city districts host mixed land uses of residential and professional spaces, hotels, shops, entertainment areas, hospitals, and others. There is high level of commuting and strong demand for public parking spaces. Since both residents and visitors must be served, the available parking space needs to be controlled and allocated accordingly. Since November 2017, a new controlled smart parking system has been introduced in three municipal districts in which the available parking space is divided into blue and white areas, intended for the parking of residents and visitors. Visitors pay a fee to park their vehicles in white sectors. Residents can freely use any blue sector in their district. The system is supervised by the Municipal Police which carries out daily patrols of the city streets, scanning car plates, and issuing tickets in case of illegal parking by either visitors or residents. The need to optimize Thessaloniki's Controlled Parking System (CPS) has motivated the development of solutions to improve the following aspects.

First, optimal allocation of parking sectors: When the CPS started operating in November 2017, an initial allocation of residents' and visitors' sectors was decided upon. The main criterion for the allocation was land use, thus more white (visitors') sectors were assigned to streets close to shops while more blue (residents') sectors were assigned to streets around residential blocks. Moving from decision-making through intuition to decision-making based on data, the Municipality of Thessaloniki has decided to rely on the CUTLER platform for the optimal allocation of white and blue sectors based on the following data: GIS data on land use, census data on population and number of cars per block, environmental data on air pollutants and traffic emissions, social data on citizens' complaints about the existing allocation of on-street parking space and, finally, data on revenues of the system and the legal or illegal behaviour of CPS users from the date the CPS began operating until the date of a new intervention to the system. By resolving the parking problem and the traffic generated by the parking problem, the expectation has been a decrease in air pollution in the city centre, improved quality of life for both residents and visitors, and increased municipality revenues from visitor tickets. In this context, the goal was to examine the problem of optimally allocating public parking space to city centre residents and visitors (white & blue sectors), considering economic, social, and environmental aspects.

Second, optimised patrol routes: Every day, based on the available numbers of municipal police officers, patrols in pairs are organised to monitor the CPS. The CUTLER platform was customised so it would recommend patrol routes that cover as many CPS sectors as possible with the aim of reducing illegal parking. The decision-maker can set a maximum number of kilometres that a pair of police officers can walk during their shift, while the recommended patrol routes are of similar distances so that all available personnel are treated equally. The aim is to handle the available workforce as efficiently as possible to save working hours that can be assigned to other tasks. After deciding on the patrol routes, the decision-maker can monitor the effect of that decision on the CPS (revenues, legal and illegal scans, etc.) and finally evaluate that decision based on parking-related and social KPIs. In this process, the goal is to specifically examine the design of optimal patrol routes to supervise the CPS and reduce illegal parking, taking into account economic, social, and environmental aspects.

The aforementioned technical solutions have been decided on and designed in collaboration with the policymakers of the Municipal Police and enjoyed their full support during implementation. Nevertheless, they have confronted several barriers that hinder their fully successful implementation. These include:

Data exists but is not always readily available: The volume and diversity of the data generated daily in cities by citizens, businesses, and the public administration are constantly increasing. City administrations struggle to fully exploit this data and improve governmental processes. While data is out there, public administrations cannot always access it. This is due to data openness, with data belonging to or managed by private organisations, civil society organisations, or other government departments within the same organisation. It becomes necessary for the cities to open up communication channels allowing them to negotiate with new partners to gain access to information that can greatly enrich urban planning and dialogue. This has been the case for a significant amount of CPS-related data that were hosted by a private company. Despite the existence of a contract stating that the data generated through the CPS system is the property of the municipality, it has proved extremely difficult to obtain the necessary amount of data at the necessary level of granularity.

Legal issues hinder data collection & processing: Legal issues impede the acquisition and processing of available data, especially third-party data and sensitive/personal data. Different datasets adhere to different sets of rules of usage, thus making it extremely difficult for the data managers in the public administration to know how to handle them. This has been particularly relevant in the case of the CPS, since data like car plates, GPS locations of cars and penalty notices should be treated as sensitive data, with strong anonymisation measures being required.

Change management for key stakeholders to move away from intuition-based decision making: Despite the success of the aforementioned technical solutions to collect the necessary data, insightfully present them and extract the necessary pieces of evidence, we were frequently confronted with a situation where it was impossible to convince some key stakeholders about trusting the system and accepting suggestions that were not aligned with their intuition. Building an accurate system is as important as convincing its end users to put their trust in it, and their early involvement in the design phase is an effective way to achieve the necessary change management.

Non-technological factors can always be a reason for cancelling out a certain solution: Even in cases where everything works as expected a smart city solution may still be confronted with socio-cultural or political conditions that render its value minimal. This has been the case for the application of the CPS in municipal districts outside the city centre, where the opposition from permanent residents to the controlled parking system has forced the authorities to suspend its application.

3.4.3 STORM Cloudfunding: Organisational and Institutional Barriers

Cloudfunding is a web application that supports civic crowdfunding, enabling cities to collect funds for social and charitable purposes. The application can support funding of various city projects, such as those related to the improvement of the urban environment, social entrepreneurship, youth startups, and others. The service entails donation-based crowdfunding and offers multiple benefits to city authorities, as it raises public participation and brings flexibility into the funding of small-scale projects for urban regeneration [51, 52].

The service was designed in the context of EU's STORM project which aimed to address public authorities' need to shift to a cloud-based paradigm in e-services provision. The project provided a set of guidelines to public authorities and policy-makers based on direct experimentation in many European cities. The project also delivered a consolidated cloud-based services portfolio validated in four pilot cities (Valladolid, Thessaloniki, Agueda, Miskolc). Following an open call for cities, the experimentation of cloudification was carried out in three more cities: Athens, Veria, and Guimaraes.

The Cloudfunding application has been tested in the city of Thessaloniki to support co-funding of three types of projects: (a) projects for the improvement of the city environment (i.e. the creation of parks and playgrounds, restoration of monuments, expansion of bike lanes, etc.), (b) projects for social entrepreneurship (i.e. the creation of non-profit enterprises to promote objectives that improve city life or strengthen its social capital) and (c) projects for knowledge-intensive and technology-based youth entrepreneurship. In all categories, the city administration would act as a mediator of the whole funding and implementation process.

The main technologies used for the cloudification of the service were (a) Open-Stack, the most popular and most adopted opensource, for the implementation of the IaaS layer, (b) Cloud Foundry for the implementation of the PaaS layer, (c) LAMP (Linux, Apache, MySQL and PHP) for applications, and (d) MySQL/MariaDB and PostgreSQL database engines for the implementation of the Database Services

Module. Although Cloudfunding seems a straightforward smart city application, its implementation revealed significant legal and institutional barriers.

An initial set of challenges were confronted during service development. The initial aim was to develop the service over the opensource application CrowdTilt. However, installing the application on the Linux platform was not sufficiently well documented and was very difficult to achieve, but most significantly, it could not accept contributions/payments in Euro but only in US dollars through a payment processor company called “Balanced Payments”. Altering the CrowdTilt source code so that another payment processor could manage payments in Euro was a possible yet difficult and lengthy process. As an alternative, other similar opensource solutions were reviewed (among which, Catarse, an opensource crowdfunding platform for creative projects, and IgnitionDeck, a plugin for the WordPress platform) but finally, Goteo was chosen, and a branch of it was developed for the city of Thessaloniki. Goteo (https://en.goteo.org/) is a web application and service that allows collective campaigns for crowdfunding to be published, offering dynamic visualisation and classification of initiatives and campaign tracking.

The most difficult set of challenges, however, were not technological but related to the legal and institutional framework of operation by the city administration. First, was *the ability to process payments* without the use of an automated payment system that would temporarily withhold the money until the project on the crowdfunding platform achieved its funding goal (or not). The municipality could retain donations for a limited time period and, even more so, return them in case the crowdfunding project did not achieve its goal. This problem could be solved using a payment processing company like Paypal, although the Municipality faced significant organisational limitations in creating and validating a Paypal account.

The second was the *ability to process a high volume of small-scale transactions*. The Municipality is legally allowed to receive money from donations, yet it has to provide receipts for each of these donations, no matter how small they are. If the funding target is not met, all contributions must be reimbursed. This created a significant administrative burden on the administration which was already characterised by a low level of flexibility and a rigid organisational structure.

Third, was *the freedom to allocate municipal resources to a specific action* that would be decided on through the crowdfunding platform. Based on existing legislation, the financial resources of the Municipality are gathered, and an annual budget is approved, to be distributed to mostly predetermined services and activities. These rules are the opposite of the Cloudfunding service’s logic for short-term decision-making about project acceptance and the allocation of resources based on successful projects whose details are not known beforehand.

These challenges, and many similar smaller ones, were magnified in the case of Thessaloniki which was criticised for economic mismanagement and had to undergo a very strict monitoring process for all its financial operations. As a response, it was proposed that the management of Cloudfunding would be undertaken by the Metropolitan Development Agency of Thessaloniki, a non-profit development agency set up by the Municipality, which has greater flexibility and less strict rules for financial management and operations. Despite the efforts made, the service was never initiated.

3.5 Discussion

Smart city projects can address all challenges faced by cities, day-to-day usual problems or wicked problems and the grand challenges of growth, poverty, sustainability, and safety. Projects may be deployed top-down in the framework of smart city strategies by public authorities, or bottom-up for the creation and offering of e-services by private organisations and companies. A review of the literature and the cases we analysed in the previous sections allow three major drivers that shape smart city projects to be identified.

First, *the ecosystem* in which projects are located: The city is a system of (eco)systems, and challenges, problems, stakeholders, and activities differ from one ecosystem to another. Ecosystems define the context and the dynamics of change. Smart city projects are organised by ecosystems, and usually many projects, whether independent or integrated, are necessary to change an ecosystem. Still, the smart city domain is very fragmented in vertical markets (energy, mobility, governance, real-estate) with little interoperability and exchange. Smart city projects follow this fragmentation, and the ecosystem of reference defines the know-how available and the potential for change.

Second, *the connected intelligence* mobilised by projects into the respective ecosystem: Smart city projects and experiments reveal various architectures of connectivity between digital and non-digital components and competences of the smart city, ranging from simple agglomeration of solutions over a common platform to orchestration of input–output and the flows between projects. Yet, digital technologies deployed by smart city projects may impact all types of intelligence to be found in cities. Human intelligence through learning and use of software that simplify complex methods and tasks, collective intelligence through online collaboration and crowdsourcing, and machine intelligence through data, analytics, AI, and prediction. These types of intelligence in combination, which we call connected intelligence, enable optimisation and innovation, and the aims and impact of projects to be realised.

Third, *the innovation* introduced by smart city projects: Projects may produce (a) simple digitalisation, (b) digitalisation and optimisation, (c) digitalisation and innovation. In all cases, digitalisation is the baseline, and then optimisation or innovation or both can occur. Many projects just transfer activities from the physical to the digital space. This is the lowest level of innovation that can be achieved. In other cases, digitalisation, automation, and sharing lead to optimisation in the use of resources. Sensors and smart metering allow for energy savings and mobility. Sharing can optimise the deployment of effort, capital, and infrastructure. More complex, cyber-social-physical projects, integrating digital and non-digital technologies, can radically change the operation model of an ecosystem. Such radical changes affect sectors of the city economy with the development of platform-based ecosystems (hospitality, real estate, financial services), the city governance with forms of direct democracy,

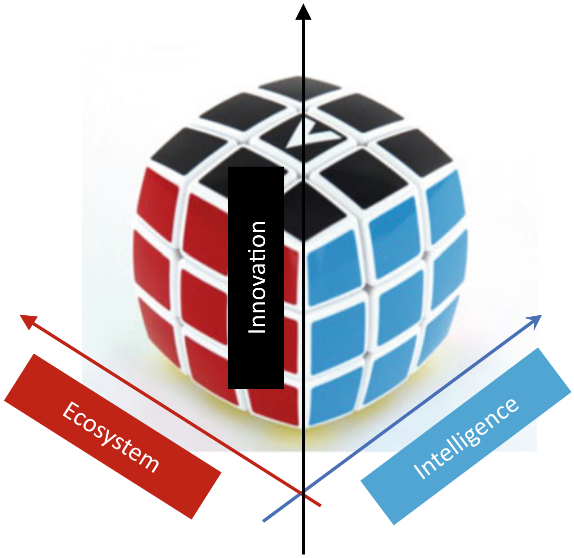

Fig. 3.2 Intelligent City Cube—drivers of smart city projects

the mobility ecosystem with Mobility-as-a-Service (car sharing, carpooling, self-driving cars), the energy ecosystem with the deployment of distributed renewable energy.

Identifying these conditions suggests that the major drivers of smart city projects and city smartness are those of the ecosystem of reference, the project's connectivity and architecture, and the impact on optimisation/innovation of city routines. This allows one to define a typology of smart city drivers by those three dimensions. The outcome is an "Intelligent City Cube", presented in Fig. 3.2, that allows projects to be classified by three broad properties (1) ecosystem of reference, (2) connected intelligence, and (3) innovation, and in three alternative forms per property, as below:

Ecosystem of reference	(1.1) Area-based	(1.2) Activity-based	(1.3) Network-based
Connected intelligence	(2.1) Data-based	(2.2) E-service-based	(2.3) Cyber-physical-social
Innovation	(3.1) Digitalisation	(3.2) Optimisation	(3.3) Innovation

In the Intelligent City Cube, 27 combinations of drivers can be defined, though some types are non-consistent, such as cyber-physical-social projects having a digitalisation-only impact. Among these combinations some are indeed the most common, such as "area-based ecosystem" + "cyber-physical-social entities" + "innovation" in projects for smart districts; "activity-based ecosystem" + "e-service" + "innovation" in platform-based ecosystems; "network-based ecosystem" + "e-service" + "optimisation" in smart transport and smart utilities; "activity-based ecosystem" + "e-service" + "digitalisation" in smart marketplaces.

3.6 Conclusion

Through a literature review, data from surveys on smart cities from around the world, and case studies on the development of smart city services, it becomes possible to identify the main features, drivers, and barriers in projects being implemented to make cities smart.

A fundamental conclusion is that city authorities organise the smart city transformation by vertical markets or vertical ecosystems. We have identified 16 different city ecosystems in which smart city projects are deployed. However, each city develops smart city projects into a limited number of ecosystems, ranging from 1 to 7, on an average into 4 ecosystems.

Smart city projects differ substantially per ecosystem of reference. On the contrary, within ecosystems the similarity of projects, as we move from one city to another, is high. Moreover, within an ecosystem, a limited number of projects is used to turn it smart.

Given the organisation of smart city projects per ecosystem, the project dimension seems to prevail over planning. The latter is closer to strategic planning (or project-based planning) than to full control of cities through master planning.

Smart city projects fall into three major categories related to the design and development of e-services, the creation of datasets, monitoring and analytics, and complex projects combining physical, institutional and digital elements. Most usual is the deployment of e-services, however the impact of complex cyber-physical-social projects is higher.

Digital technologies on which smart city projects rely are standardised in a few segments such as the cloud, IoT, network, applications development, and data analytics. However, the same digital technologies used in different city ecosystems produce very different projects. The ecosystem context and sectoral technologies make the difference. The project design brings together digital technologies, sector-specific technologies, physical and institutional contexts.

Integration is just as important as technologies. Usually, smart city projects are disconnected and lack integration. Connectivity within projects, linking digital and non-digital features, and connectivity across projects is low, especially in e-services. However, the connectivity of resources and capabilities among human actors, communities, and digital technologies is a prime factor for innovation and impact.

Together with the above drivers, our analysis also revealed some major barriers to the success of smart city projects. The main barriers are financial, legal, and institutional. This is due to the social and institutional inertia of cities and defensive behaviours of city actors against novelties, especially when a radical change of the existing city routines is introduced. Looking at the transformation of cities with smart systems and technologies from the perspective of routines allows one to understand the rise of city smartness from an innovation theory perspective, depending on innovation systems that are also becoming hybrid, cyber-physical-social [53].

Appendix 3.1: Smart City Projects by City and Ecosystem

Source Based on city reviews included in the book "Smart City Emergence: cases from around the world".

City	Sector/ecosystem	Projects
Evora (Portugal) Smart City of Evora	Energy	• Smart meters, smart homes
		• Smart grid
		• Public lighting
		• EV charging
		• Data collection & modelling of energy system
	Environment	• Reduction of CO_2 emissions
		• Building retrofitting
		• Solar thermal and solar PV
		• Recycling
		• Promotion of cycling
		• Traffic restrictions
		• Biofuel buses
Torino (Italy) Smart City of Torino	Mobility	• Bike-sharing
		• Plan bicycle path
		• EV sharing
		• Car-sharing service
		• Car-pooling
		• Traffic zone regulation (restriction)
		• monitoring
	Environment	• District renewal
		• Smart squares
	Startups, innovation, skills	• Social innovation/startup support
		• Youth employment
		• Support for public goods and services
	Living, safety, health	• Citizen awareness solutions
		• Safety solutions
		• Active aging
	Tourism	• Information sharing
		• Points of interest, city tourism • Torino as a platform

(continued)

(continued)

City	Sector/ecosystem	Projects
	Governance	• Health services from home • Opening of public spaces to citizens • Co-designing public services
	Energy	• Energy action plan: retrofitting, PV panels, RES, LED • IoT in schools for energy metering and saving
Leuven (Belgium) Smart City Leuven	Mobility (under optimization of streams)	• Last mile delivery vehicles
		• Semi-autonomous bus shuttle
		• Bike-sharing
		• Policing of shop and parking by sensors
	Energy (under optimization of streams)	• Smart city lights and sensor network
		• Smart energy grid—interoperability
		• Smart energy in building
	Governance	• Data platform for city administration
		• Open data to share data with citizens and entrepreneurs
		• Digital Citizen: a digital profile of each citizen
	Health	• Living Lab for health(care) innovations
		• E-Health site
		• Vital City-innovative initiatives for active lifestyle
		• Testing wearables to improve health
	Education	• University student collaboration
		• Working environment for knowledge workers
		• Startups in residence
Vienna (Austria) Smart City of Vienna	Energy	• ICT integration for buildings and electrical grid Wien-Aspern (Grid, RES, and storage)
		• Wien energy. Use of block-chain for transactions
		• Clean heat, stable power grid. Excess electricity to heat

(continued)

(continued)

City	Sector/ecosystem	Projects
		• Energy monitoring and intelligent plant control in Airport
		• Urban Cool Down. Summer cooling in urban districts
	Education	• Make your city smart: toolkit for do-it-yourself building
		• Vocational orientation of future jobs, robotics, apps, RES
		• Digital agenda Vienna. Interactive development of ideas
		• Digital city: ICT education
	Governance	Sag's Wien application. Report to the city administration
		• e-Government online services, registration, e-signature
	Mobility	• Smart traffic lights
		• Car sharing, e-cars
	District renewal	• Renovation of former industrial sites, central station, Danube bank, residential areas, and other
Amsterdam (The Netherlands) Amsterdam Smart City (hundreds of initiatives at https://amsterdamsmartcity.com/ A few are included)	Digital city	• IoT and sensors
		• Digital infrastructure
		• Promotion of various advanced technologies (Blockchain, 5G, AI, Drones)
	Energy	• Energy atlas. Open data map and RES usage
		• Energy transition
		• Smart grid
		• Energy saving at home in city neighbourhoods
		• Next-generation renewable energy digital platform
	Mobility	• Mobility as a service
		• City logistics
		• Bicycle sharing
		• Autonomous vehicles
		• Crowd monitoring
		• Electric vehicles
	Circular city	• Building and construction

(continued)

(continued)

City	Sector/ecosystem	Projects
		• Public awareness
		• e-Waste
		• Make the circular economy and the upcycle visible
		• Design-driven solutions to waste and consumerism
		• New products from used pieces of plastics & metal
	Governance and education	• Transition from smart to inclusive city
		• Up-scaling
		• Input–output modelling for smart city development
	Citizen and living	• Public participation
		• Living labs
		• Healthy urban living
		• Sharing economy
		• Social entrepreneurship
		• Clean air monitoring
Trikala (Greece) Smart City of Trikala	Mobility	• Smart parking and parking analytics
		• Municipal fleet management
		• Fleet analysis with vehicles position and routes
		• Traffic lights monitoring for malfunction
	Energy	• Smart lighting, upgrade to LED and motion sensors
	Waste	• Smart bins with sensors installed
	Water	• Smart water metering
	Environment	• Sensor-based monitoring and metering
	Governance	• Public wi-fi
		• End-to-end city management system
		• GIS geospatial information
		• Complaint registration and mobile app
		• Public consultation
		• Digital payments
Smart Cities in Korea A common model for all cities: ICT based growth ecosystems in cities	Governance	• Gov with government agents

(continued)

(continued)

City	Sector/ecosystem	Projects
		• Citizen cooperation
		• Public–private partnership
		• Integrated policy legal system
	Startups, innovation, skills	• Innovation led sustainable growth
		• Innovative start-up
		• Spaces for innovative job creation
		• Clustering
		• Spread of innovative ideas
	Education	• Innovative education
	Mobility Energy & Environment Health Safety Welfare	• ICT infrastructure • Smart city technologies • Integrated infrastructure with ICT • Open data • Big data • Data sharing and integration
Hangzhou (China) Dream Town Internet village	Startups, innovation, skills	• Attraction of high-quality overseas talents in ICT, biomedicine, RES, financial services
		• Applications of e-business, software design, information services, big data, security, animation design
		• Start-up support
		• Start-up incubators and mentoring
		• Grants: creative digital tickets (vouchers)
		• Angel village, interaction with VC
		• Collaboration and use of Alibaba infrastructure
Changsha (China)	Government	• e-Services for social insurance, taxation, police
	Mobility	• e-Services for information and ticketing
		• Transport cloud for information, coordination, service delivery
	Commerce	• e-Services for shopping and online payment

(continued)

(continued)

City	Sector/ecosystem	Projects
	Health	• e-Services in hospitals for medical service, payment
	Tourism	• Hotel reservation, tourism venues, e-payment
	Safety	• Fire protection
		• Police cloud big data platform
		• Police analytics and prediction
Pune (India) Smart City of Pune	Energy	• Smart grid and solar panels
	Water	• Smart metering
	Mobility	• e-Buses
		• Electric Rickshaw/Electric Tuk-Tuk in Pune
		• ICT-enabled bus
		• Smart parking
		• Adaptive traffic management
	Safety	• CCTV
		• IT connectivity
Nara (Japan) Smart City of Nara	District renewal	• Smart campus
		• Smart housing district
		• Smart grid and solar panel
		• Solar thermal
		• Energy management platform
		• Data centre
Singapore (Singapore) Smart City of Singapore	Health	• Elderly mobility using robotics
		• App citizen wearables encouraging exercise
		• Health monitoring at home
		• Health related analytics
	Living	• App: User engagement on environmental issues
		• App: Understand living conditions at home
	Mobility	• Access to public transportation
		• Mobility analytics
		• Smart parking
		• Autonomous mobility testing
	Government	• Citizen database platform-interaction with gov
		• Access to numerous public services

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City	Sector/ecosystem	Projects
		• Open datasets
		• Platform for sharing ideas
	Startups, innovation, skills	• Financial database of business opportunities
		• Digital transactions for citizens and businesses
		• Digital training programs and fellowships
		• Digital tools for innovative development
		• Platforms for academic collaboration
		• Business grants portal
Newark (US) Smart city of Newark	Government	• Data analytics platform (B2B, B2C, open gov data, crime, vacant lots, employment)
		• Industrial analytics platform • Smart city governance analytics
Quayside Toronto (Canada) Sidewalk Labs' Waterfront Toronto (before being abandoned)	District renewal	• Self-driving shuttles
		• Robot delivery
		• Spaces showcasing new technologies
		• Dynamic, reconfigurable pavement, allowing different uses and activities throughout the day
		• Building envelope technologies (raincoats)
		• Responsible Data Use Framework
Porto Alegre (Brazil) Porto Alegre Smart City	Governance	• Integrated command centre
		• GIS data centre
		• Bio-monitoring (trees, plant, pollutants)
		• Training telecentres for literacy and digital inclusion
		• Smart city innovation centre
	Health	• Real-time monitoring of hospital bed occupation
		• Sharing patient information
		• Telemedicine, primary diagnoses

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City	Sector/ecosystem	Projects
Johannesburg (South Africa) Smart city of Johannesburg	Safety	• Crime reporting application
		• 911 response application
		• Kitestring—check-up and emergency alert
	Mobility	• Intelligent Transport System
		• Interactive application—real time transport
Tunis (Tunisia) Smart City of Tunis	Startups, innovation, skills	• Digital entrepreneurship
		• Digital innovation services
		• Offshoring—place promotion
		• IT promotion
	Governance	• Administrative services to citizens
		• User-centric governance
		• Platform for data exchange and interoperability

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