

A Tale of Open Data Innovations in Five Smart Cities

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Abstract

Open Data initiatives are increasingly considered as defining elements of emerging smart cities. However, few studies have attempted to provide a better understanding of the nature of this convergence and the impact on both domains. This paper presents findings from a detailed study of 18 open data initiatives across five smart cities – Barcelona, Chicago, Manchester, Amsterdam, and Helsinki. Specifically, the study sought to understand how open data initiatives are shaped by the different smart cities contexts and concomitantly what kinds of innovations are enabled by open data in these cities. The findings highlight the specific impacts of open data innovation on the different smart cities domains, governance of the cities, and the nature of datasets available in the open data ecosystem.

1. Introduction

The proliferation of Smart City initiatives around the world is part of the strategic response by governments to the rise of cities as the nexus of human and societal development. Smart Cities programs in general seek to harness their physical infrastructures, Information Communication Technologies (ICT), knowledge resources, and social infrastructure towards economic regeneration, greater social cohesion, better city administration and infrastructure management [1].

Starting from a select few and well known Smart Cities (such as PlanIT Valley, Curitiba in Brazil, Masdar City in United Arab Emirates, and Songdo in Korea) with comprehensive well-articulated development program, many Cities nowadays with one or more ICT-enabled urban innovation initiatives are labeled as Smart Cities. A positive consequence of this bottom up approach to the development of Smart Cities is the reduced risk and lower barrier to the uptake that has enabled less affluent cities and communities to undertake Smart City programs. For instance, Nairobi County in Kenya is already selected as one of the top 21 Intelligent Communities for 2014 [2].

Even more interesting in this newly emerging class of smart cities is their growth from traditional sustainability-related initiatives to open data [3]. While massive data collection through sensors attached to physical infrastructures (or Big Data) had always been a characteristic feature of first generation smart cities, publishing such data as open data or integrating with the open data published by city authorities on different aspects of city management and life, is a relatively recent phenomenon.

Open Data initiatives are part of the efforts by governments at all levels to open up to enhance transparency, better empower citizens, foster innovation, and reform public services [4][5]. For example, in 2014 the direct economic benefits from open data (or Public Sector Information) in the European Union was valued around Euro 40 billion and over Euro 140 billion annually across the whole EU27 economy [6]. In addition, the availability of open data is considered as critical to improving the functioning of cities [4]. For instance, Chicago's SmartData Vision includes building a predictive analytics platform for municipal government to transform the city's operations [7].

This convergence of smart cities and open data initiatives is fast unfolding across a number of cities like New York, Amsterdam, Helsinki, Chicago, Barcelona, Quebec City, Rio, Dublin, Nairobi and Manchester, albeit at different paces and scales [3][8]. However, there has been no systematic or rigorous study to understand how these open data initiatives are different from the traditional ones launched earlier by national and other levels of governments. Specifically, there is little literature on how open data initiatives are shaped by the smart city context and the kinds of innovations enabled by open data in smart cities. The study presented in this paper addresses this gap.

The paper investigates the impacts of open data innovation on the different smart cities domains and on the governance of these cities. It examines how open data enables open innovation and engagement of residents and stakeholders in addressing city challenges. Furthermore, it looks at how the smart city

context enriches the open data ecosystem and dynamics in terms of data resources and actors.

The rest of the paper is organized as follows: Section 2 provides the theoretical background for the study. The methodology for the study is presented in Section 3, with findings in Section 4. Discussion of findings is presented in Section 5 and concluding remarks in Section 6.

2. Theoretical Background

This section develops the theoretical frame for understanding Open Data as a smart city innovation. Section 2.1 elaborates smart cities first as an innovation based on innovation theory, while Section 2.2 provides a conceptualization of open data as a smart city initiative. The last section examines the need for aligning open data innovations within a smart city context. This is important to distinguish open data in the general context from open data initiatives enacted within smart cities context.

2.1. Smart Cities as Urban Innovation

While there are different definitions and conceptualizations for the concept of smart cities in research literature, extensive experience from practice clearly indicate that the concept represent attempts by various city governments to exploit different kinds of innovations to make cities function better and be more livable. Along this perspective, Nam et al. in [9] conceptualizes a “Smart City” as an interplay among technological innovation, organizational innovation, and policy innovation. The essence of smart city initiatives according to [1] include increasing access to information, enabling social inclusion and economic development, sustainable economic growth and urban development, and higher quality of life. Sectors typically impacted by smart city initiatives include [1] [8]: Environment, Transportation, Energy, Governance, People and Life Style, Technology and Built Infrastructure (e.g. roads).

As urban innovation, smart cities initiatives implicitly share the core attributes of any innovation. These attributes include [10]: relative advantage, compatibility, complexity, and trialability. In addition, [11] adds cost-efficacy and feasibility, evidence and risk. These characteristics are directly linked to the successful adoption and implementation of the innovation in question. In the context of a smart city, these characteristics are described below:

- *Relative Advantage* – the degree to which the smart city initiative is perceived as enabling better functioning city and city life. This can be measured in terms of the impact of the initiative on the different smart city domains.

- *Compatibility* – the degree to which a smart city initiative is consistent with the existing city stakeholder values, or interests, and the city context.
- *Complexity* – the degree of difficulty involved in implementing the initiative and communicating the associated benefits to stakeholders.
- *Trialability* – the degree to which experimentation is possible with the initiative.
- *Cost Efficiency and Feasibility* – the cost effectiveness of the initiative with respect to existing comparable practices.
- *Evidence* – availability of research evidence and practice efficacy of the initiative.
- *Risk* – the level of risk associated with the implementation and adoption of the initiative.

In addition, from the Diffusion Of Innovation (DOI) perspective, a smart city as an innovation must be communicated among relevant city stakeholders (so-called adoption units) [10]; in particular the different city authorities or departments that are expected to contribute to smart city initiatives. Such communication can happen through several channels such as events, briefings or explicit directives from city administrators.

2.2. Open Data as Smart City Initiative

Open Data is been increasingly acknowledged as a defining element of smart cities [12][13][14], and thus could be conceptualized as a smart city initiative. Based on Section 2.1, open data initiatives constitute urban innovation, and thus are expected to deliver relative advantage (in particular cost), be compatible with existing practices in the city management, and be inherently complex. In addition, it should be possible to implement open data initiatives as a trial or on a pilot basis as they are inherently risky activates.

However, given the paucity of rigorous research in the area of open data [5], evidence to support the efficacy of open data in the smart city context is very limited. Developing a formal evidence base for open data initiatives is dependent on the availability of Smart City Initiative frameworks such as those described in [1] and [8]. The Smart City Initiative Development (SCID) framework described in [1] provides a simple framework for linking smart cities initiatives to the associated impacts they generate on different smart cities domains and how these impacts address specific stakeholder and transformation outcomes. See Figure 1.

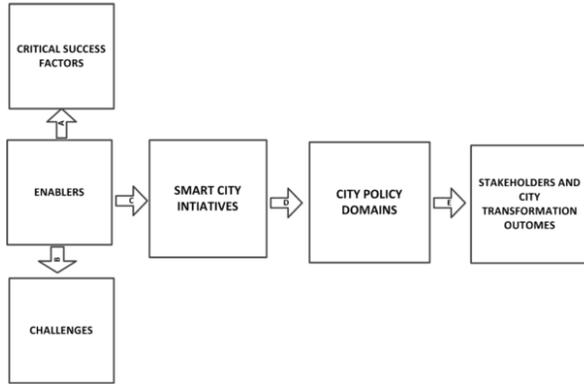


Figure 1: Smart City Initiative Design Framework [1]

The framework in [8] identifies the major components of a smart city initiative. Specifically, the model describes a smart city initiative as an interplay of technology, policy, and organizational innovation that is shaped by and at the same time impact external factors like the people communities, economy, built infrastructure, natural environment, and governance.

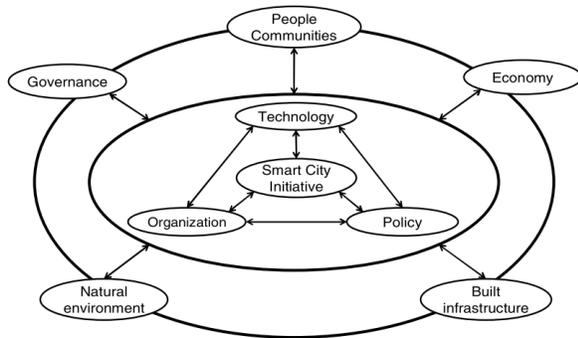


Figure 2: Smart City Initiatives Framework [8]

These two models are complementary, since the SCID Framework [1] is value driven, focusing on the impacts of initiatives on domains and how they address challenges and opportunities in the environment, while the model in [8] suggests that the impact areas in SCID Framework actually shapes the initiatives and thus sources of the challenges and opportunities to be addressed. Another implication of the model [8], albeit not elaborated in the model description; is the need to align smart city initiatives with the four outer components shown in Figure 2. We elaborate on this alignment in Section 2.3.

2.3. Smart City as Context for Open Data

The external system for any innovation includes: the external environment, government policy and regulation, social network and incentives among others [11]. This external system shapes and is impacted by the innovation under consideration. In our case, we

conceptualize the overall smart city program as a context for the open data initiatives. See Figure 3. Specifically, the alignment requirement can be framed as the two questions below:

1. How do open data initiatives impact the smart city context? In answering this question, we are interested in: a) the smart city domains impacted by open data initiatives, b) the kinds of open engagement activities enabled by open data in the associated smart city and c) the impact of open data on the governance of the smart city.
2. How does the smart city program shape its associated open data initiatives? Here our interest is in how the smart city as context determines the kinds of datasets that are published and the additional actors participating in the open data ecosystem.

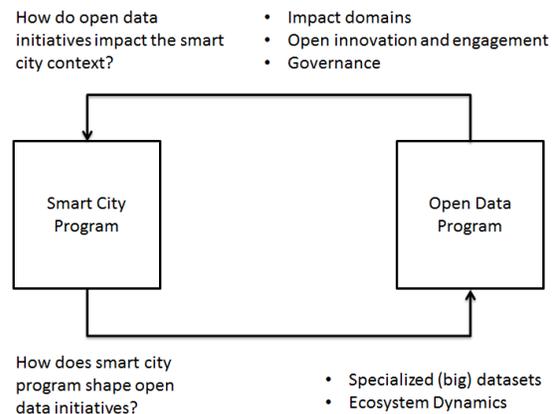


Figure 3: Aligning Open Data to Smart City Context

3. Method

This section describes how the five smart city and the 24 associated open data initiatives were selected (Section 3.1) and how data on these cases were obtained (Section 3.2). Section 3.3 elaborates the Content Analysis [15][16] approach employed in analyzing the data collected.

3.1. Case Selection

The cities selected for study were identified based on three criteria. The first criterion for selecting a city is that it must have a well-developed smart city program. This is indicated by the availability of documents describing the city's various smart cities initiatives. The second criterion is that the city strongly promotes and situates open data initiatives as smart cities initiatives. The third criterion is that significant information on the open data initiatives is available in the public domain. The third criterion is necessary since the study relies on secondary information. Few

cities satisfied these criteria, which include: Helsinki, Manchester, Amsterdam, and Barcelona in Europe and Chicago in the United States.

3.2. Data Collection

The study completely relied on secondary information published on the five selected smart cities online. The authors independently searched for all available information on each city in the period February to May 2014 and consolidated the information obtained. The consolidated information produced a total of 24 initiatives. However, after a round of review of the 24 initiatives, the authors unanimously agreed to include only 18 that clearly addressed the use of open data in one or more smart cities domains. The 18 selected comprised 5 initiatives from Helsinki, 4 from Manchester, 4 from Amsterdam, 2 from Barcelona, and 3 from Chicago. The difference in number of initiatives across the cities in our sample does not pose any threat to the validity of our results since our goal is to consolidate and analyze patterns of open data adoption across these cities to answer our research questions in Section 2.3.

The identified open data initiatives across these five smart cities are described in Table 1. The different sources of information available on each of the initiatives are provided in the reference column of Table 1.

Table 1: Open Data Initiatives in Selected Smart Cities

Initiative	Description	Ref.
Helsinki City		
Smart Kalasatama	Utilizes raw open data made available for free by the public administration, businesses, organizations and private individuals. Offers a platform to utilize open data.	[17], [18], [19]
Helsinki Region Infoshare	Provides web service access to over 1,000 data sources for the cities of Helsinki, Espoo, and Vantaa. Datasets cover public transport, decision-making and service points.	[20] [18] [21] [22] [23] [24] [25]
Apps4Finland	To utilize open data datasets to produce applications.	[18] [26], [23]
CitySDK	Develops tools to help cities open up their data in formats easy for developers to reuse. This is the basis for a sustainable city app ecosystem.	[27] [28] [29]
Helsinki Loves Developer	Arranges events for developers and organizing local challenges based on available open data.	[28] [30]

Manchester City		
CROSS: Citizen Reinforcing Open Smart Synergies	Establish European-wide strategy for enabling a new generation of digital services targeted to the social services sector based on open data.	[31] [32]
The Greater Manchester Data Synchronization Programme	Creates tools to enable free flow of data between public sector organizations, whilst creating a public facing mechanism for the release of open data.	[33] [34] [35]
Greater Manchester Datastore	A platform to make public data open and accessible to use for the developer community. Resulted in numerous apps that help the city function better.	[36], [37]
Transport for Greater Manchester	Aims at releasing their bus time data for developers or interested organization or companies to use to build Apps helping people to find information.	[38]
Amsterdam City		
Apps for Amsterdam	Use open data to develop apps related to one of six themes; safety, mobility, vacancy, energy, tourism & culture, and democracy.	[39] [40] [41]
Park Shark	Connects developers with city's open data including parking data to help Amsterdam drivers find parking spaces.	[42]
FietsFinder	Publishes a comprehensive list of bike shops and provides applications that show the closest bike and cobbler shops from any location.	[43]
Code4Europe	Aims to solve local civic challenges by enabling agile temporary teams of developers to create solutions that are easily reusable in other European cities utilizing available open city data.	[44] [45]
Barcelona		
Open Cities	Aim to foster open and user driven innovation in the public sector by leveraging open data, open sensor networks, and existing crowdsourcing platforms and tools.	[46] [47]
iCity	Aims to foster co-creation of digital public services by third-parties (developers and businesses) based on utilizing available open data.	[48] [49]
Chicago		
Data Science Chicago	Utilizing data in identifying opportunities to improve many aspects of the city's operations with anticipated impact on cost	[50]

	of operations, public safety, transportation, and quality of city services in general.	
Chicago School of Data	Provides leadership and clarity on how data could be used to improve lives in Chicago. Provides services describing and interpreting data for different constituents in the city.	[51],
Cook County Open Data	Creating an open county that goes beyond just opening up data to include publishing the internal methods and processes (including financial) required for the effective functioning of the county.	[52], [53], [54]

3.3. Analysis

The study employed a content analysis approach [15], [55], [16] to analyzing all the documents and webpages describing the 18 initiatives guided by the constructs in models presented in Section 2. Specifically, we adopted a mixed strategy involving two related approaches to content analysis described in [15]: the conventional approach and directed approach. In conventional content analysis, coding categories are derived directly from the text data. In the directed approach, analysis starts with a theory or relevant research findings as guidance for initial codes. Our goal for employing a mixed strategy is to be enable us harness the existing constructs in the SCID framework (Figure 1) to analyze the initiatives as top level codes while allowing discovering of specific categories of codes under each of these top level codes.

In line with the directed approach, we mapped the four major phenomena of interest in the source documents describing initiatives to the following core constructs of the SCID Framework: 1) aims and objectives of the initiative, 2) potential impacts of initiative, 3) the city domains that will be impacted by the initiative, 4) the stakeholders involved in the initiatives and benefits expected to accrue to these stakeholders.

To determine lower-level concept categories under each of the four top-level codes, we employed the conventional content analysis (CA) approach. The conventional CA was carried out in three phases. In the first phase, we started by highlighting the keywords and phrases in the source document considered to be associated with the top-level codes. In the second phase, we labeled these keywords and related them to produce a tuple consisting of the sub-category codes for specific objectives, the impact, domain and stakeholders. In the third phase, we consolidated the sub-category codes to determine the core patterns for impact, stakeholders and related domains.

4. Findings

We present the results of our analyses in this section. Section 4.1 presents the types of impacts anticipated from the open data initiatives on the city policy domains identified from the source documents. This is followed in Section 4.2 by descriptions of the identified patterns of applications of open data initiatives to the governance of smart cities and the roles of stakeholders. Lastly, Section 4.3 presents how the open data ecosystem is enriched through additional smart city specific data resources and the participation of new stakeholder roles in the ecosystem.

4.1. Impact on Domains

Our analysis of the open data initiatives associated with impact or policy domains across the five smart cities produced seven impact areas: Economy, Education, Energy, Environment, Governance, Tourism and Transportation. The identified domains are similar to the domains already captured in existing literature, e.g. in [1], [8] and [56]. The potential impacts identified from the descriptions of the initiatives are described below:

Economy – 10 out of the 18 initiatives are designed to impacts the economy domain. These impacts include: 1) Creation of an ecosystem of open data-based apps; 2) Creation of a civic-technology marketplace of societal relevant apps; availability of open data services and products by business exploiting open data resources related to city operations; 3) Establishing the foundations for an open data industry, 4) Creation of a marketplace for innovative digital services in the social sector by leveraging open data; and 5) Scaling up open data innovations across a network of cities by providing tools. From these, three impact patterns have been identified and are presented in Table 4.

Education – The only impact identified for this domain is the availability of co-created digital services for education. This impact is associated with the CROSS initiative.

Energy – The availability of co-created digital services is also the only expected impact for the Energy domain. This impact is associated with the CROSS initiative.

Environment – The Dutch’s FietsFinder initiative potentially leads to a greener environment, through promotion of environment-friendly transport options.

Table 2: Patterns of Governance Mechanisms employed in Initiatives

Collaboration	Participation	Communication	Data Exchange	Service and App. Integration
<ul style="list-style-type: none"> - Collaboration between city, developers, SMEs and residents. - Collaboration among smart cities initiatives. - Collaboration between school and city. 	<ul style="list-style-type: none"> - Inspire participation of residents, developers in creating applications and new services. - Promote idea sharing among residents. 	<ul style="list-style-type: none"> - Improving policy outcomes with increased communication between city and residents and other stakeholders. - Designing communication plans. 	<ul style="list-style-type: none"> - Data exchange between government, residents and other stakeholders for purpose of city development. - Data exchange among city authorities (CA). - Data exchange among CA and developers. - Data exchange between sensor infrastructure and CA. - Data exchange among cities. 	<ul style="list-style-type: none"> - City SDK for developing city applications.

Table 3: Sector specific Datasets available in Open Data Ecosystems of the 5 Cities

Cities	Transportation & Mobility	Health & Wellbeing	Environment	Education	Tourism
Helsinki	Traffic Accidents in Helsinki; Current journey times; Traffic disorders; Status of road stations.	Vantaa social and health care statistics; Social Welfare	Environmental objects; Camera data	Espoo Adult Education Centre statistics	Helsinki: Culture and Leisure 2013.
Manchester	OpenStreetMap Data; Survey of Passengers.	Drug Treatment Statistics, England; UK food hygiene rating data	Flood Map - Flood Zone 2; National Parks Key Figures for Crime and Safety; Road Accident Data	List of students in Greater Manchester	
Amsterdam	Current Car parks availability; information on Guarded bicycle; Electric Charging Points; Borough Centre, Bicycle Network data.	Health care and welfare in West district	Planned Roadworks; Energy labels in Amsterdam; Location of Heat Cold Storage.	Open Education Data.	Activities.
Barcelona	Biking Stations; Bus stops; Car parks; Street sections relations of the public road; Traffic incidence notices.	Number of disability and retirement pensions by neighborhood.	Environmental administration: Activities and policies.	List of education equipment in city of Barcelona.	List of tourist accommodation in the city of Barcelona"
Chicago	Information on Car park locations.	Public Health Statistics.	Energy Usage 2010; Crimes - 2001 to present.	Cook County - Public Schools; Cook County - Private Schools; Chicago Public Schools.	

Governance – 12 initiatives are designed to impact on the governance of cities. These include: 1) Better information sharing across local authorities through data standards; 2) Improved services across major sectors like transportation and public safety; 3) Enhanced transparency; 4) Co-created services that better addresses citizen and business needs; 5) Enabling open innovation in City Administration involving third-party developers; 6) Enhanced inter-operation among network of cities by sharing tools and methods (standardization); 7) Improved capacities of citizens and stakeholders to leverage open data; 8) Open engagement of citizens in policies; and 9) Significant improvement in internal decision-making.

Tourism – The “Apps for Amsterdam” and “Helsinki Loves Developers” initiatives aim to enable co-created services that better addresses citizen and businesses needs through innovation in the Tourism domain through the availability of open data based applications.

Transport and Mobility – 3 initiatives including Apps for Amsterdam, Park Shark, and Transport for Greater Manchester will create the following impacts on the transport domain: 1) Better city park management through the use of open data; 2) Co-created services that better addresses citizen and business needs; and 3) Improved transit time and traffic flow by exploiting data on bus schedules.

Table 4: Summary of Impacts on City Dimensions

Domain	Impact Patterns
Economy	<ul style="list-style-type: none"> - Creation of marketplace for society relevant applications; - Availability of data products and services based on city operational data and; - Scaling up the adoption of open data innovations across city functions through tools provision.
Education	<ul style="list-style-type: none"> - Availability of innovative digital services for the education domain.
Energy	<ul style="list-style-type: none"> - Availability of innovative digital services for the education domain.
Environment	<ul style="list-style-type: none"> - Greener environment.
Governance	<ul style="list-style-type: none"> - Better information sharing. - Open innovation for co-created services - Open engagement in policy and decision-making - Interoperation within city-network.
Tourism	<ul style="list-style-type: none"> - Co-created services based on available open data.
Transportation	<ul style="list-style-type: none"> - Better City Park Management; and - Shorter transit time for commuters.

4.2. Governance

This section presents the various governance mechanisms enabled by the open data initiatives in the smart cities. Based on [1][56], we identified patterns of smart city governance mechanisms enabled through the open data initiatives. The patterns are related to collaboration, participation, communication, data exchange, and service & application integration.

In the area of collaboration, the open data initiatives were designed to enable collaboration between city and stakeholders like software developers, residents, and SMEs in identifying needs. The open data initiatives were also designed to enable collaboration among different smart cities initiatives.

In the area of participation, the goals of the initiatives included enabling participation of residents and developers in developing applications and new services as well as sharing ideas among residents.

In the communication arena, some of the initiatives were designed to enable better policy outcomes through the publication of relevant data and information for residents based on communication plans. Data exchange objectives of the initiatives include enabling data sharing among city authorities and network of cities. It also includes the exchange of data between sensor data infrastructure providers and city management.

Lastly, in the area of service and application integration, the initiatives seeked to provide software development tools (such as CitySDK) for building open data-based applications. The patterns are highlighted in Table 2.

4.3. Data Ecosystem

This section highlights the specific datasets that are associated with major smart cities domains. The study identified a number of datasets across the following five sectors – Transport & Mobility, Health & Wellbeing, Environment & Safety, and Education & Tourism across the five cities. As shown in Table 3, there is a lot of focus on the “Transportation & Mobility” and the “Environment & Safety” domains. The datasets for the Transport domains cover car park availability, locations of electric charging points, locations of bicycle stations, traffic accidents, and passenger satisfaction survey. Environment and safety datasets cover surveillance camera data, crime figures for different districts, planned road works, road accidents, and flood maps.

In addition to these datasets, the Open Data Ecosystems in these cities have the active participation of residents, different city authorities, software developers, and SMEs in providing, curating and consuming the datasets described in Table 3.

5. Discussion

The object of the study is to investigate the nature of the convergence between smart cities and open data initiatives. We have sought to analyze this convergence as a form of alignment (see Figure 3) in which we expect open data initiatives to directly support smart cities objectives and the smart cities context to shape the open data initiatives enacted within them.

The analysis of the potential impacts of open data initiatives on smart cities domains presented in Section 4.1 shows that these initiatives have significant impact on the Economy, Governance, Education, Environment, Tourism, and Transport & Mobility domains of the studied cities. In particular, we note that Governance, Economy, and Transport & Mobility are the three core domains that are expected to be most impacted by open data initiatives. *Specifically, the Governance and Economy domains clearly stand out as the two domains that will be most impacted by open data initiatives in these smart cities.*

When we compare these findings with the results presented in [1], which shows that Environment, Energy, and the Transportation & Mobility domains are primarily targeted by smart cities initiatives, we see strong opportunities enabled by open data initiatives implemented within the smart city contexts. These are channeled through the anticipated impact of open data on the governance and economy domains of the associated cities.

We also noted a somewhat recurring pattern in which open data initiatives concomitantly impact both the Governance and the Economy domains. *A closer examination of these impacts shows an inherent open data innovation pattern which potentially creates an “open innovation economy” enabled by the participation of city residents, civic society, software developers and SMEs in smart cities.* In this context, open data business models [57] will play a major role as a mechanism for understanding and creating values for these different stakeholders. These results are generally consistent with the anticipated benefits of open data, specifically considering the political and social and the economic dimensions as presented in [5].

Our findings on the published datasets across these cities show they in general cover the innovation and social clusters of the so-called datasets of high-value provided in [58]. *However, we observe more focus on Transport & mobility as well as Environment & Safety datasets, which are both characterized as innovation cluster data.* This finding is somewhat consistent with and in fact supports *our earlier notion of open data oriented smart city as an “open innovation economy”.*

In general, there are clear evidences of alignments of these open data initiatives to their contextual smart city programs.

6. Conclusion

This study contributes to a better understanding of the emerging convergence of smart cities and open data initiatives. Relying on existing smart cities initiative frameworks, we have framed this convergence phenomenon as a form alignment in which open data initiatives would be expected to directly impact smart cities domains and at the same time be shaped by the smart city context. Our findings have revealed the several potential impacts of open data initiatives on smart cities domains as well as revealed an inherent “open innovation economy” impact pattern. We also showed that the nature of datasets published by these cities is supporting innovation. A plausible conclusion from this study is that emerging smart cities that are driven by open data like Chicago can be characterized as “*Open Innovation Economies*”.

Our future work will address the limitation of our studies that solely relied on secondary data obtained from cities websites and literature. Given that three of five cities involved in the studies may have non-English language content, it is difficult to guarantee that we did capture all available information on the initiatives. Guided by the results from this study, we intend to carry out in-depth interviews in two of the four European cities considered here in addition to Dublin [59] and Chicago to better understand the results from this study and better characterize our conception of smart cities as open innovation economies or ecosystems.

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