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# Citizen Centric Smart Cities: A Systematic Review On Potential Profiles Using Linked Open Data

*Completed Research Paper*

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## Abstract

This paper describes a systematic review's results that aimed to verify the state of the art about potential consumer profiles of linked and open data in smart cities. An initial screening of 300 papers was carried out, which underwent a criteria's selection aiming to identify the papers that deal with the application of open data and linked data in any domain of smart cities or that carry out a more theoretical evaluation of the subject matter involving end-users in smart cities. As a result, it was noticed that the semantic web studies are still concerned with technical issues, but that there are already researchers concerned with Computer-Human Interaction perspectives for data access that profiles of citizens present in smart cities. Based on this, a profile's taxonomy was developed to assist the development of platforms focused on citizens, which can help in features' identification and knowledge mapping for each profile.

## Keywords

Smart Cities, Profiles, Linked Open Data.

## Introduction

The fast transition to a highly urbanized population has caused some governments to face new challenges in relation to key themes such as sustainable development, education, energy, the environment, security and public services, among others (Bolívar 2018).

According to Lemos (2013), the concept of smart cities appears in this context to stimulate the public environment in decision-making, to increase community ties and political participation. Despite all the benefits that the application of this concept can provide, there are difficulties and doubts about how to develop and use technologies to build and maintain smart cities (Marceau 2008).

The use of open data can enable greater community participation and inclusion in decision-making, and enable citizens themselves to be able to produce and use data for public and private purposes. As well as enabling them to produce their own initiatives based on the open data provided to solve or alleviate problems present in the different domains of smart cities (Belizario and Berardi 2019).

The use of ontologies, Linked Open Data (LOD) and other semantic technologies open up new possibilities in smart cities, as they can combine information from various sources for several purposes such as statistics, analysis, maps and publications, inform users when the information corresponds to their interests and describe products and services more accurately (Bischof et al. 2014).

Bizer, Heath, and Berners-Lee (2011) say that linked data is about using the Web to create links between data from different sources. Technically, linked data is data published on the web in such a way that it is

machine readable, that its meaning is explicitly defined, that it is linked to other external datasets, and that it can, in turn, be linked to more external datasets.

The citizen must be thought of as the central element of smart cities, who must have access to the data generated by them and capable of proposing new solutions (Giffinger and Pichler-Milanovic, 2007). Citizens here range from the citizens who use the public service of the city, for instance that use the public transport to go to a hospital, to citizens who are entrepreneurs and need to understand the dynamics of a city.

The problem is that the capture and consumption of linked open data is restricted almost entirely to the Semantic Web community. Although the usefulness of this data by people not experienced in technology is evident, the lack of technical knowledge and an understanding of the complexities about semantic technology limit these users in their ability to use the web of data (Dadzie and Rowe, 2011).

According to Klímek et al. (2019), there is a large number of data sets published as LOD. At the same time, there are also a large number of tools for publishing Linked Data. However, potential consumers of linked data find it difficult to discover, access and explore this data format. This is because, compared to the consumption of traditional data formats, there is a lack of tools for consuming linked data.

Therefore, there are big gaps in several areas of linked data consumption, especially for non-specialists, who still need the support of friendly tools that can fit their needs and expectations. This can allow data consumers to explore the benefits of working with linked data, which, in turn, would motivate more data publishers to publish it (Klímek et al. 2019). A possible solution to overcome this obstacle is to allow the visualization of the linked data in a coherent and readable way. Thus, it allows non-specialist and non-technical audiences to have a good understanding of its structure and, therefore, compose queries, identify links between resources and discover intuitively new information (Dadzie and Rowe 2011).

In mind that the information needs, as well as the motivations and level of digital literacy of the profiles present in smart cities can be different, the main objective of this review is to verify the state of the art about potential consumer profiles of linked and open data in smart cities. Besides identifying the different perspectives, motivations and how this kind of information should be used to develop suitable tools for citizens in smart cities, regardless of their technical knowledge.

## Methodology

The digital libraries IEEE Xplore Digital Library, ACM Digital Library, Scopus, Springer, Periódicos Capes and Google Scholar were searched to support the systematic review of the literature on how the use of linked and open data in smart cities happens. This search was carried out in March 2021, and was guided by the protocol presented by Kitchenham (2004). The research involved the general expression of search (keywords) ("smart cities") or ("interactive workspaces"), ("linked open data"), ("stakeholders") or ("user centric") or ("end users") or ("citizen centric") and ("exploration") or ("storytelling") or even ("visual exploration") present in any part of the work.

When using these expressions, it is possible to have access to papers that use the most diverse approach related to Linked Open Data consumer platforms in smart cities with a central focus on the user, thus generating more variety for the research and then verifying the state of the art in this area.

Publications were considered between the years of 2011 and 2021. This period was stipulated because the relevant approaches, methods and research of the last ten years on the subject are sought. In total, 300 papers were returned, as highlighted in Table 1.

Paper Repository	Papers	Search String
IEEE Xplore Digital	10	("smart cities" OR "interactive workspaces") AND ("linked open data") AND ("stakeholders" OR "user centric" OR "end users" OR "citizen centric") AND ("visual exploration" OR "storytelling" OR "exploration")
Periodicos Capes	0	
Google Scholar	257	
Springer	25	

Scopus	2	
ACM Digital Library	6	+ ("smart cities" "interactive workspaces") + ("linked open data") + ("stakeholders" "user centric" "end users" "citizen centric") + ("visual exploration" "storytelling" "exploration")

**Table 1. Papers Per Repository**

In the first phase of the protocol, 36 papers were excluded because of the first criterion, the duplicity (i). That is, they were present in more than one digital library, the second (ii) criterion is the language used to write the papers, only selected papers that were in Portuguese and English. And by this criterion, 9 papers were excluded. In the third (iii) criterion, the studies published since 2011 were selected, excluding 25 papers.

The reading of the papers' title and abstract was the fourth (iv) criterion for work's exclusion. In the title or abstract it should be clear that the work refers to open data, linked data or linked open data applied to smart city domains aimed at the use of citizens. In this filter 124 articles were discarded. From this preliminary selection, we had 106 remaining papers. And as the last criterion (v), the introduction of the work must present solutions for the visualization and exploration of linked open data, present the possible users to which the solution was applied and the domains to which it refers in a smart city. In this filter were discarded another 78 papers. After the adoption of the preliminary selection criteria, the remaining 32 articles were then subjected to broader filtering criteria, which were verified by reading the full paper, resulting in the maintenance of 25 articles in the body of this work. Finally, we selected 25 papers, which deal with the visualization and exploration of linked open data for different domains in smart cities.

**Research Questions**

With the papers selected, this review intends to answer the following questions: a)What are the consumers' profiles of linked open data in smart cities?; b)What are the characteristics and particularities of each of these profiles in a smart city?; c)What are the features presented in the tools and platforms present in the literacy for consumption of linked open data in smart cities?

Regarding the main objective of the paper we can link the questions in this way: the question (a) focuses on to verify different profiles present in the literature. The question (b) helps to identify what makes these profiles different and why we should take this in consideration in the development process for linked open data tools, and the question (c) serves to evaluate the solutions and approaches already present in the literature for visualization and exploration of this type of data by all kind of users in smart cities.

**Results**

From a historical perspective, there is a growing number of works related to this research topic since 2011. Figure 2 shows the publications over years for the selected papers. As a result of the process of selection and identification of the papers, twenty five papers met the methodological requirements described previously. Figure 3 shows the publication's year of the papers that were selected for the systematic review after the selection criteria. We can see that there has been a constant growth of publications on this topic since 2011, reaching the peak in 2020 with nine publications.

A clear difference between the types of publications on this topic over the years is that until 2018 the papers had very technical objectives and interests in the use of tools, technologies and the production of linked open data. Since 2018, they begin to present a social approach that is concerned with the level of technical knowledge required to manipulate this type of data and investigate ways of visualization and interaction that can allow greater popular participation in decision making in smart cities.

As a way of organizing the reading and classifying the selected papers, they were grouped into four different categories perceived while reading the papers: Frameworks or APIs, approaches or models, platforms and surveys.

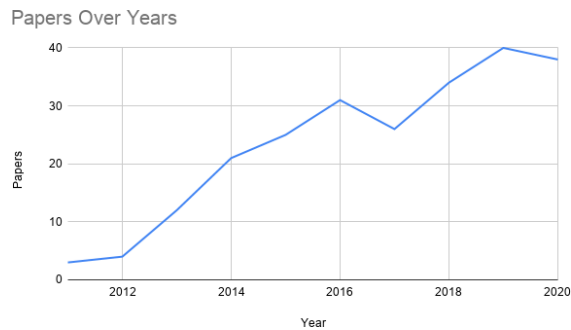


Figure 2. Papers over years

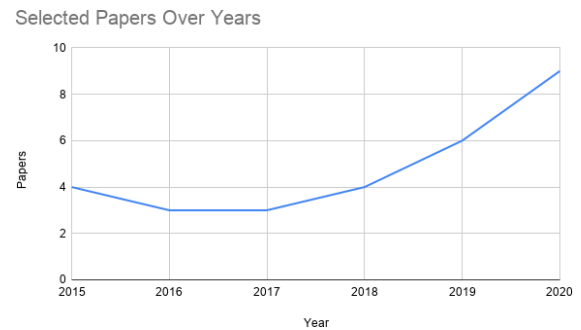


Figure 3. Corpus papers years

The frameworks and APIs represent 6.9% of the studies accepted in this systematic review, they refer to blocks of code or programming interfaces for access and use of linked open data. Platforms account for 13.8% of the selected works, and refer to studies that intend to develop platforms for consumption of open data and linked data. Approaches and models are 27.6% of the works and present approaches to treatments, manipulation, distribution and visualization of open data and linked data, or refer to theoretical models of platforms and systems that use open and linked data in smart cities.

The largest number of papers are classified as surveys, totaling 51.7% of papers. These works deal with research on visualization of open and linked data by citizens in smart cities and on how they can be used by the community. Including references from the areas of human-computer interaction and design.

### ***Common Features for Linked Open Data Platforms in Smart Cities***

The works use different words to describe the same features and profiles. For example, the work of De Santo and Holzer (2020), cites users with technical skills and non-technical users, besides domain experts. The cited features are query, visualize and browse. But can all the lay users or domain experts perform a technical query to consume linked open data? The visualization for technical users, or even web semantic specialists is the same as for non-technical users since the knowledge level is different?

Thus, there is a need for standardization to understand what the differences are between functionalities and profiles in the literature. Five common features were identified for platforms in smart cities: Visualization, exploration, export, manipulation and publishing. They are presented below.

- **Visualization:** Feature that allows the user to view the data present on the platform, whether in the form of lists, documents or graphs. The key to fulfilling this functionality is to allow visual access to linked open data.
- **Exploration:** Functionality that allows the user to interact with the data present on the platform, through filters, maps, flowcharts or endpoints for queries. It does not refer to data changes, but organization and search for data of interest.
- **Export:** Feature that allows the user to export data from the platform for their own use, using formats such as Comma-separated values (CSV), Resource Description Framework (RDF), Web Ontology Language (OWL), Portable Document Format (PDF) among others.
- **Manipulation:** Functionality that allows the user to change data present on the platform, make changes, corrections, add data and even remove if necessary.
- **Publishing:** Feature that allows the user to publish and interlink structured linked open data for access by both humans and machines via the use of the RDF (Resource Description Framework).

### ***Potential Profiles to use Linked Open Data in Smart Cities***

Given the difficulty of other studies in defining who are the data users in smart cities, a table was constructed that summarizes sixteen different profiles present in smart cities that are also potential consumers of linked open data. These profiles were identified based on the systematic review of the literature. Their definitions emerged from the capture of their motivations and technical levels of

knowledge present in the papers. Thus, it was possible to join profiles that were synonymous in different studies and to group them in a taxonomy according to the observed classifications. Table 2 presents the result of the definition of profiles in smart cities and also answers the first research question carried out: What are the consumers' profiles of linked open data in smart cities?

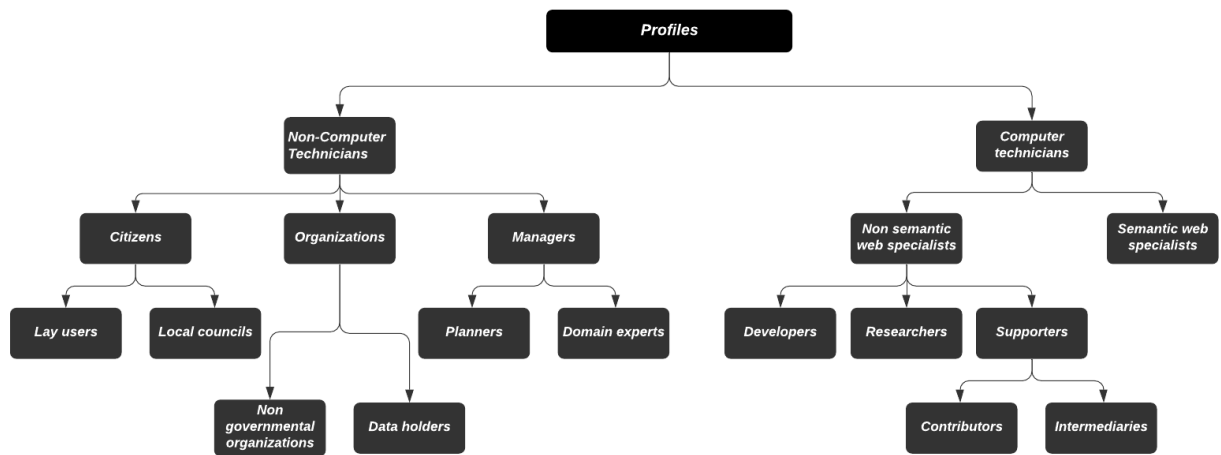
Profile	Definition
Computer Technician	People with the necessary skills to achieve digital competence, supported by basic skills in ICT and in the use of computers, in order to retrieve, evaluate, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet.
Semantic Web Specialists	People capable of using and understanding technologies such as Resource Description Framework (RDF) and Web Ontology Language (OWL). These technologies are used to formally represent metadata.
Non-Semantic Web Specialists	People that are not capable of using and understanding technologies such as Resource Description Framework (RDF) and Web Ontology Language (OWL). But they might have knowledge about Comma-separated Values (CSV), tables, graphs or different formats of data representation and visualization.
Researchers	Someone who studies a subject, especially in order to discover new information or reach a new understanding. This person might be interested in using linked open data to support its research.
Developers	A programmer or designer that creates new products, especially computer products such as software. Might use linked open data in the creation of a new solution for smart cities.
Supporters	People responsible for supporting the platform and the data present on it. They may be responsible for feeding the platform with more data or helping other users to interact with the platform and the data.
Intermediaries	People responsible for helping profiles with less technical skills to use linked open data consumer platforms and use the necessary data for their purposes.
Contributors	People responsible for feeding the platform with more open data, correcting data with possible inconsistencies and making changes to connections if necessary.
Non-Computer Technicians	People that do not have the necessary skills to achieve digital competence, supported by basic skills in ICT and in the use of computers, in order to retrieve, evaluate, store, produce, present and exchange information
Managers	Main executive and administrative officers of a municipality under a council-manager system of local government. They may be interested in linked open data to provide better services for the city or to investigate local problems.
Organizations	Group of people who work together in an organized way for a shared purpose. Can be a company or a social organization that can provide more valuable data or use the platform for some particular purpose.
Citizens	An inhabitant of a particular town or city. They may be interested in open linked data about the city they live in or the services they use.
Domains Experts	Person who is an authority on a specific area or topic. They may be interested in how the data in their area has been linked, they may be able to feed the platform or consult it for specific studies.
Planners	Professional responsible for creating and developing solutions aimed at improving or revitalizing certain aspects within a given domain with the main objective of providing the inhabitants with an improvement in the quality of life.
Data Holders	Data holders collect or generate data that can serve a product or a main product. It is quite likely that entities belonging to this group exploit their data for decision making. Not only companies but also, for instance, academic institutions or government bodies may be data holders.



Non Governmental Organizations	A non-governmental organization (NGO) is a non-profit group that functions independently of any government. NGOs, sometimes called civil societies, are organized on community, national and international levels.
Local Councils	A local council is a universal term for community, neighborhood, parish and town councils. They are the first tier of local government and are statutory bodies. These councils are concerned with community needs and goals.
Lay Users	The users who have limited or no training in a particular area, like web semantic or technology, however they are likely to have personal interests or special needs in that area.

**Table 2. Profiles' definition**

According to the common characteristics on technical and social perspective in Table 2, the Profiles were organized as a Taxonomy as Figure 4 shows. The profiles presented can be divided into two groups according to their technical knowledge of computing: Technical profiles in computing and non-technical profiles in computing. The classifications, from a social perspective, cannot be as rigid as the developed taxonomy, because in reality they function as spectra. For example, it is possible to have a local council with technical knowledge about computing, or even domain experts and managers who can be specialists in the semantic web at the same time.



**Figure 4. Profiles' taxonomy**

However, it is necessary to have knowledge of the existence of these isolated profiles and how to meet their needs to allow them to participate in decision making in their cities. Technology must adapt to the motivations and needs of these people and not the other way around. The paper's analysis together with the taxonomy shown in Figure 5 are able to answer the second proposed research question: What are the characteristics and particularities of each of these profiles in smart cities?

To answer the last research question, a map was built by grouping the profiles according to their classifications. It demonstrates the ideal functionalities that an open linked data platform should offer for each of these profiles. Figure 5 shows the developed map.

According to the reviewed literature, the classification of citizens is a group that may have the lowest technical knowledge about applied computing. And their interests when looking for data and platforms related to the topic of these studies refer to the visualization and exploration of the data to solve specific doubts about personal and community problems in the regions where they live.

Personas			Features	Personas			Features
Non-Computer Technicians	Managers	Planners	Visualization Exploration	Computer technicians	Semantic Web Specialists		Visualization Exploration Manipulation Export Publish
		Domains Experts	Visualization Exploration Manipulation		Developers	Visualization Exploration Export	
	Organization	Data Holders	Visualization Exploration Publish			Non Semantic Web Specialists	Researchers
		Non Governmental Organizations	Visualization Exploration		Contributors		Manipulation Publish
	Citizens	Local Councils	Visualization Exploration		Supporters	Intermediaries	Visualization Exploration Manipulation Export Publish
		Lay Users	Visualization Exploration				

**Figure 5. Features map per profile**

Regarding the classification of organizations, the difference lies in the data holders, who in addition to viewing and exploring the data may be interested in publishing their own data on the platform. Non-governmental organizations, as well as citizens, are interested in viewing and exploring data, but they may have people with higher technical skills.

The group of managers can use the data to improve the quality of services offered to the population of a city. Domain experts may be interested in manipulating the data, as they have specific knowledge of a particular area and may be able to correct problems or inconsistencies in the platforms and data.

Within the group of computer technicians, the profile of greatest attention is that of specialists in the semantic web, who may be interested in all functionalities: visualization, exploration, manipulation, export and publication. Developers and researchers may have different motivations for using the platforms and using the data, but in general the functions of visualization, exploration and export meet their needs.

Supporters play a very important role in maintaining platforms and data. Contributors can manipulate the data and publish new data on behalf of organizations or social groups. On the other hand, intermediaries can help other less technical profiles in the realization of all the other features that the platforms allow.

An analysis of selected papers was carried out, described in Table 3. This table contains the reference of the work analyzed (Paper), the abstraction for the different features observed in other works (Features Abstraction) and the last column refers to an abstraction of the profiles cited in the paper (Profiles Abstraction).

Paper	Features Abstraction	Profiles Abstraction
(Desolda et al. 2020)	Visualization, exploration	Domain Experts
(González-Mora et al. 2020)	Export	Developers, citizens
(De Santo and Holzer 2020)	Visualization, exploration, manipulation	Citizens, domains experts, computer technicians
(Desimoni et al. 2020)	Visualization, exploration, manipulation, export, publish	Semantic web specialists
(Neves et al. 2020)	Don't apply	Data holders, organizations, researchers, intermediaries, contributors, domain experts
(Lnenicka et al. 2020)	Visualization, exploration, publish, export	Citizens, managers, researchers, Domain experts
(Lafia 2020)	Don't apply	Citizens, researchers, organizations, managers
(Desimoni and Po 2020)	Visualization, exploration	Citizens, organizations, managers



(Destandau 2020)	Visualization, exploration	Citizens, data holders, researchers
(Lytras et al. 2019)	Don't apply	Citizens, organizations, managers
(Wilson and Chakraborty 2019)	Don't apply	Citizens, organizations, managers, researchers, computer technicians
(Degbelo 2020)	Visualization, exploration	Citizens, organizations, managers
(Walker 2019)	Visualization, exploration	Domain experts
(Kolbe et al. 2019)	Don't apply	Citizens, organizations, managers, researchers
(de Assis Cunha et al. 2019)	Don't apply	Organizations, managers, researchers
(Cordasco et al. 2018)	Don't apply	Organizations, managers, citizens
(Petrova-Antonova and Ilieva 2018)	Visualization, exploration	Organizations, managers, citizens
(Lafia et al. 2018)	Visualization, exploration	Organizations, managers, citizens, researchers
(Maccani et al. 2018)	Visualization, exploration, manipulation, export	Organizations, citizens, local councils
(Diamantini et al. 2017)	Visualization, exploration, manipulation, export	Don't apply
(Desolda et al. 2017a)	Visualization, exploration, export	Computer technicians, developers, non-technicians in computing
(Desolda et al. 2017b)	Visualization, exploration	Computer technicians, non computer technicians, domain experts
(Degbelo et al. 2016)	Visualization, exploration, publish, manipulation	Citizens, developers, managers, urban planners, organizations
(Ardito et al. 2016)	Visualization, exploration, manipulation	Citizens, developers, domain experts
(Amugongo et al. 2016)	Export	Citizens, managers
(Desolda et al. 2015)	Visualization, exploration	Domain experts, developers, non computer technicians
(Psyllidis 2015)	Visualization	Urban planners, managers, citizens, organizations
(De Vocht 2015)	Visualization, exploration	Researchers, managers, organizations
(López-de Ipina et al. 2013)	Visualization, exploration, manipulation	Managers, citizens, organizations

**Table 3. Papers Analysis**

## Conclusion

In this paper, a systematic review of the literature was carried out to verify the state of the art about potential profiles to use linked and open data in smart cities. This survey is necessary since it is perceived that only a technical group can actually develop useful applications based on these types of data. In order to build Information Systems that actually enable the comprehensive use of this data, it is necessary to question who the potential users are and what functionalities they require.

To answer this question three research questions were developed. Initially, the aim was to understand the profiles of consumers of open data linked in smart cities. We answered this question by showing eighteen profiles according to the literature: Computer technicians, semantic web specialists, non-semantic web specialists, researchers, developers, supporters, intermediaries, contributors, non-computer technicians, managers, organizations, citizens, domains experts, urban planners and data holders.

The second research question aimed to understand the characteristics and peculiarities of each of these profiles. We answered it by showing the description of the motivation for data usage and what is the

typical technical level of knowledge for each one of the profiles identified - which has a high impact on the type of interaction with the platform and the visualization of the data. The third research question seeks to understand what features are presented in the literature for the consumption of linked open data. We answered this question by presenting the five general functionalities identified and their descriptions: Visualization, exploration, manipulation, export and publish.

This systematic review of the literature allows us to conclude that studies that take into account social motivations and levels of knowledge or that have approaches focusing on human-computer interaction are still recent. And that there is still no clarity in defining who are the end users for which linked open data consumption platforms are developed.

The differential of this work is in the definition of citizens' profiles present in smart cities that can consume linked open data, according to a literature review, and what are the motivations and which functionalities interest them in platforms for consuming this data.

With the results of this work, it is expected to help the development of Linked Open Data visualization and consumption interfaces in smart cities considering the diversity of motivations and technical knowledge of citizens. We hope that we have shown the importance of considering this diversity for the real scope of the data. Interfaces aimed at non-specialist citizens allow the data to be used outside the academic environment for the creation of new solutions, identification of problems in the urban environment and decision-making processes.

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