Show me the Data! A Systematic Mapping on Open Government Data Visualization

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ABSTRACT

During the last years many government organizations have adopted Open Government Data policies to make their data publicly available. Although governments are having success on publishing their data, the availability of the datasets is not enough to people to make use of it due to lack of technical expertise such as programming skills and knowledge on data management. In this scenario, Visualization Techniques can be applied to Open Government Data in order to help to solve this problem. In this sense, we analyzed previously published papers related to Open Government Data Visualization in order to provide an overview about how visualization techniques are being applied to Open Government Data and which are the most common challenges when dealing with it. A systematic mapping study was conducted to survey the papers that were published in this area. The study found 775 papers and, after applying all inclusion and exclusion criteria, 32 papers were selected. Among other results, we found that datasets related to transportation are the main ones being used and Map is the most used visualization technique. Finally, we report that data quality is the main challenge being reported by studies that applied visualization techniques to Open Government Data.

CCS CONCEPTS

• **Human-centered computing → Information visualization**;

KEYWORDS

Open Government Data, Visualization Techniques, Systematic Mapping, Literature Review

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1 INTRODUCTION

During the last years, more and more countries started to make their data publicly available as part of the Open Government Data (OGD) movement [48]. The data being published by government entities is often related to education, health, budget classification, political boundaries, transportation and crime reports.

Since there is more than a million of OGD datasets available [26] that could provide insights for the society, the OGD movement created many opportunities and challenges to its stakeholders [15]. As stakeholders we can highlight government employees, journalists, researchers and citizens. In other words, there is a big interest from people willing to use OGD to perform different types of tasks such as city dashboards, environmental alerts, predictive studies about public health, transportation and so on.

However, as described by Graves and Hendler [15], the availability of the government datasets is not enough to some people to make use of it due to lack of technical expertise such as programming skills and knowledge on data management. In order to ease this problem, different data visualization tools are often used as a way to consume, share and interact with data [15].

The use of different types of visualization techniques has proven useful for understanding large quantities of data in multiple fields such as economics [33], basic science [46] and history [29].

In order to provide deeper understanding about the usage of visualization techniques applied to Open Government Data, this study aims to identify which areas of government are being served by the visualization tools proposed by previously published studies, describe the most used data visualization techniques as well as classify the challenges that are commonly reported by other researchers when applying visualization techniques to OGD.

To achieve this goal, we conducted a systematic mapping study on this subject. As part of the study, we found and analyzed 32 papers dealing with Open Government Data Visualization.

This paper is organized as follows. Next two sections contextualize Data Visualization and Open Government Data. In the Research Method section, we detail the protocol that was followed during this systematic mapping study and define the research questions that we aimed to answer. In Results we present the analysis of the results found during this study in order to answer the research questions. Finally, in Conclusion section, we present our conclusions and future work.

2 DATA VISUALIZATION

Data visualization is the graphical display of abstract information for two purposes: sense-making (also called data analysis) and communication [9]. The visualization must communicate complex ideas

with clarity, accuracy and efficiency [43]. Although, it is usual to see tools more concerned in providing an artistic visualization than visualizations that actually communicate information efficiently. This may lead to a misunderstanding of visual representations reducing them to simple decorative tools [27].

A dataset may contain important information and data visualization is a powerful tool to discover and understand these information, and then to share it with others. For centuries humans have used data visualizations to consume and understand large amounts of data [9], since they provide a method to analyze and understand such data in a better way [10].

The use of visualizations allows us to discover trends and outliers that would be hard to detect if we analyze the raw data. This gets more critical when the users do not know exactly what they are looking for and the visualization tool is responsible for providing insights to them. This is one of the main reasons why the use of visualizations is widely spread in science, finance, and other data-intensive areas. In this sense, the use of visualization techniques applied to OGD can help people to have a better understanding of it [15].

3 OPEN GOVERNMENT DATA

Open Government Data is data produced by the government with public funding and provided with no restrictions on its usage or distribution [18]. It is currently the latest practical manifestation of the government transparency ideal [41]. It has eight principles as described below [1]:

- **Complete:** The entire dataset is made available. It is not subject to privacy, security or privilege limitations.
- **Primary:** Data should be collected at its source with no aggregation nor modifications with the highest possible level of granularity.
- **Timely:** The data must be made available as quickly as necessary so the value of the information is preserved.
- **Accessible:** Data should be made available on the Internet so anyone with any purpose has access to it.
- **Machine processable:** Data should be structured so machines can process it.
- **Non-discriminatory:** Anyone is allowed to access the data. No registration is needed.
- **Non-proprietary:** No entity has exclusive control over the format that the data is published.
- **License-free:** Data is not subject to copyrights, patents, trademarks or trade secret regulations.

The information available in the published datasets vary across levels of government and government agencies [31]. Data commonly refers to public transit schedules, environmental measurements, consumer complaints, and educational scorecards and the most used formats are CSV, Excel and plain text [31].

There are some reasons why governments want to make their data publicly available: increased government transparency, citizen participation, the possibility of innovation, and potential economic benefits are some of the examples mentioned by Yang and Kankanhalli [48].

Although publishing the government data has some benefits, the OGD movement is not fully adopted yet. According to the data and charts available on the Global Open Data Index portal [2], we can assume the countries from the African continent have few government data made publicly available, while North America appears as a great contributor to this movement.

4 REVIEW METHODOLOGY

A Systematic Mapping Study is a secondary study meant to provide an overview for a given research field by evaluating and analyzing all its relevant available research data [22]. The guidelines for conducting systematic mapping studies described by Petersen [34] were followed to conduct this study. According to the author, there are three different phases that must be followed while performing a systematic mapping study: planning, conducting and reporting.

In the next subsections we provide details on how planning and conducting phases were performed. The reporting phase will be detailed in the Results section.

4.1 Planning

Before conducting the mapping study, it is necessary to define the review protocol. According to Kitchenham [22], besides reducing the chances of researcher bias, a review protocol is meant to specify:

- research questions intended to answer;
- methods that will be used to perform the review;
- selection criteria;
- data extraction strategy.

Next, we describe the creation of the review protocol.

4.1.1 Research Question. The main objective of this study is to provide an overview about the visualization studies using Open Government Data. Thus, we defined the following primary questions:

- RQ1: Which public areas have visualization for its published data?
- RQ2: What are the most used visualization techniques?
- RQ3: What are the common challenges being faced?

By answering these questions, this study identifies what data visualization studies are being conducted with Open Government Data.

4.1.2 Search Strategy. In order to cover the largest number of relevant publications, we identified and used the following databases to conduct our search:

- ACM Digital Library;
- IEEE Xplore Digital Library;
- Science Direct;
- Scopus.

Based on the research questions, we conducted a preliminary search in order to obtain a list of pilot studies [15][4][8][37]. The list of pilot studies were then used to find the search terms which would best answer our research questions: Open data, government data, visualization, visual, analytics, government and smart cities.

With the purpose of automating the search in the selected databases, the following search string was built using the terms found in the pilot studies as keywords:

Table 1: Search String variations for each database

Database	Search String
IEEExplore	(((“open data” OR “government data”) AND (visualization OR visual OR analytics)) AND (government OR “smart cities”))
ACM	(((“open data” OR “government data”) AND (visualization OR visual OR analytics)) AND (government OR “smart cities”))
ScienceDirect	TITLE-ABSTR-KEY((open data OR government* data) AND (visualization OR visual OR analytics) AND (government OR {smart cit*})) OR TEXT(({open data} OR {government* data}) AND (visualization OR visual OR analytics) AND (government OR {smart cit*}))
Scopus	TITLE-ABS-KEY((“open data” OR “government data”) AND (visualization OR visual OR analytics) AND (government OR “smart cities”))

(“open data” OR “government data”) AND (visualization OR visual OR analytics) AND (government OR “smart cities”)

Since each database has its own search engine, the search string needed to be adapted for each one. Table 1 shows the search string variations for each database.

4.1.3 Selection Strategy. Although we used a list of pilot studies to build the search string, some of the results obtained using the described search strategy were irrelevant for our research questions, even if some of the search terms appeared in the title, abstract or keywords. For that reason, a manual study selection needed to be performed with the purpose of retaining only those studies which are relevant to our research questions. In a first filter, some papers were excluded based only on titles and abstracts. In a second filter, we ensured a full text reading.

The following inclusion criteria were applied in the first filter:

- studies should be published in the Computer Science area;
- studies should present the subject on Open Government Data and Data Visualization.

Publications that meet any of the following criteria are excluded from the review:

- duplicated papers;
- books;
- studies that were not written in English;
- studies presenting workshops, tutorials, panels, poster or sessions;
- conference covers, table of contents.

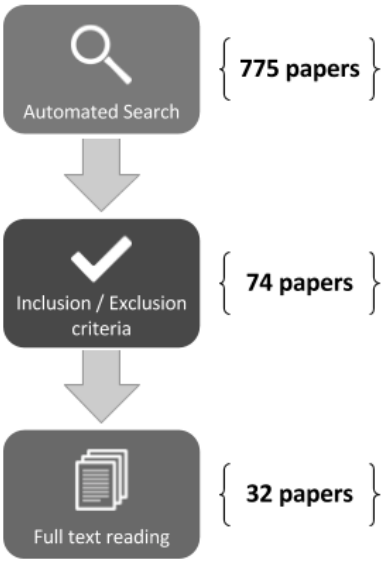


Figure 1: Paper selection process

During the full text reading stage, the list of studies were subjected to a more severe scrutiny. The goal of this stage was to select only the studies that met at least one of the following inclusion criteria:

- present visualization techniques for open government data;
- propose tools for generating visualization from open government data;
- provide an overview of the usage of visualizations combined with open government data;
- review an existing tool that uses open government data and data visualization.

4.1.4 Data Extraction Strategy. The data extraction strategy was based on providing groups of answers for RQ1 and RQ2. Regarding RQ3, we had to first analyze the entire process described in each study so we could try to identify the challenges reported by the authors. It was also part of the data extraction strategy to identify whether the data published by the government and used to create visualizations was combined with any other sort of data (such as social media, company data, user feedback, devices or sensors) as well as identify which country was the open data from.

4.2 Conducting

The search on the selected databases was conducted during July 2017. As part of the automated search step, we found a total of 775 studies. From this list, we applied the exclusion and inclusion criteria from the first stage, where only title, abstract and keywords were considered. After applying inclusion and exclusion criteria, a total of 74 studies were selected. Lastly, after the full text reading phase, 32 publications were selected. The selection process is documented in Figure 1 and the selected papers are presented by year of publication in Table 2.

Next section reports the results found during the review process.

Figure 2: Word cloud based on the number of publications for each author

Table 2: Selected papers per year

Year	Selected Papers
2011	[17]
2012	—
2013	[37] [15] [20] [19]
2014	[12] [8] [5] [16] [40] [13] [7]
2015	[14] [24]
2016	[21] [3] [6] [23] [32] [36] [4] [42] [30] [47] [28] [39] [38]
2017	[44] [35] [11] [45] [25]

5 RESULTS

Before answering the research questions, it is important to describe the current scenario of the usage of data visualization techniques combined with Open Government Data. Next subsections provide an overview about the usage of visualizations with Open Government Data and present the analysis of the results for each research question.

5.1 Open Government Data Visualization Scenario

As presented in Table 2, studies in the Open Government Data Visualization area were heavily published in 2016. Although only 5 studies were published in 2017, it is convenient to remember that this systematic mapping study was conducted in July.

From the final list of 32 selected papers, 26 studies focused on either proposing or evaluating a visualization tool which was based on Open Government Data. There were also 5 papers ([5, 13–15, 36]) that aimed to propose applications or tools to generate visualization models for any generic Open Government Data based on the data type, and another paper that provided an overview of Open Government Data for a future visualization tool proposal [16].

Table 3: Selected papers grouped by the country that published the data used in the studies

Country	Papers	Total
Asia		
China	[47]	1
South Korea	[21, 24]	2
Taiwan	[6, 25]	2
Australia		
Australia	[35, 40]	2
Europe		
Austria	[37, 38]	2
Ireland	[23]	1
Italy	[11]	1
Romania	[42, 45]	2
Serbia	[28]	1
Spain	[30]	1
Sweden	[20]	1
Switzerland	[4]	1
United Kingdom	[19]	1
North America		
Canada	[44]	1
Mexico	[12]	1
United States	[3, 32]	2
South America		
Brazil	[7, 8]	2
Peru	[39]	1

While reviewing the papers that proposed or evaluated a visualization tool based on OGD, we also grouped the papers based on the author. Figure 2 shows that Graves is the author with the greater number of published papers: 4 ([13–16]),

Figure 3 shows the final list of papers grouped by the country that published the data used in each study. Darker countries published more papers than the lighter ones. Table 3 also shows the number of papers related to Open Government Data Visualization grouped by the country that published the data being used, however it also groups the studies by the continent. Although Figure 3 suggests North America as the main contributor to studies on the subject, Table 3 shows that the European continent has more studies on this area.

Although it is not visible on Figure 3 neither in Table 3, Hienert et al. [17] used data from multiple countries from the European continent, while Mijovic et al. [28] combined Open Data from Serbian government with public data from European open organizations.

Figure 3: Open Government Data combined with Visualization tools grouped by country

5.2 Public areas with visualization to its data

The final list of studies were grouped by the areas which the proposed visualization tools served to, as presented in Figure 4. At first glance, the following areas were served by the visualization tools proposed by the studies selected in this systematic mapping: Crime, election, finance, general/demographics, health, infrastructure and traffic.

Table 4 shows that most of the proposed tools are somehow intended to solve issues in the finance, infrastructure or traffic areas. Next items will enlighten what has been done with the public data in these areas as well as in crime, election, demographics and health areas.

5.2.1 Crime. Balasubramani et al. [3] proposed an Ontology-based crime map for the city of Chicago where user can select the specific area to filter, while Okamoto et al. [32] provided an overview of how New York City open data was being used. As part of the overview, Okamoto showed a map with felony offenses grouped by Community.

5.2.2 Election. Salvador and Sinnott [40] and Kalampokis et al. [19] proposed two different tools for the same segment. Salvador and Sinnott proposed a tool to provide visualizations (mainly about political donations) using different open datasets. The main use case was to show the correlation between election years and donations, and donations and contract awards. In the other hand, Kalampokis proposed a tool that revealed that there is a significant relationship between the probability one of the two main political parties to win in a UK constituency and the unemployment rate in the same constituency.

5.2.3 Finance. Rind et al. [38] developed a dashboard reporting on the flows of money from government to media.

Both Craveiro and Martano [7], González et al. [12] and Kim et al. [21] proposed tools to reveal how the government is classifying budget. Craveiro and Martano proposed a map tool for the city of São Paulo to provide users with the investments made by the government in each project/construction. While González implemented a tool to show how the Mexican government is using the budget, Kim developed an application that shows how the South Korean government is distributing the budget for government programs and the social issues that were previously filtered by the users.

5.2.4 General/Demographics. Pettit et al. [35] provided a review about AURIN, an Australian map tool that allows users to search for spatio-temporal demographics data. Spoiala et al. [42] combined Romanian public data with data from companies in order to provide a tool to show companies and their information in an interactive map. Lee et al. [24] designed and implemented a mobile application service to visualize various typed or formatted public open data with geo-based images on the mobile web.

5.2.5 Health. Mendonça and Maciel [8] presented a case study that involved the creation of a map to visualize the infestation of *Aedes Aegypti* in the city of Cuiabá, Brazil.

5.2.6 Infrastructure. Vaz et al. [44] developed the "environment injustice" map. The map was a combination of Open Government Data related to pollution to show how these conditions are affecting health and prosperity of low-income and racialized communities.

Gagliardi et al. [11] combined Open Government Data with users feedbacks in order to investigate how open data together with

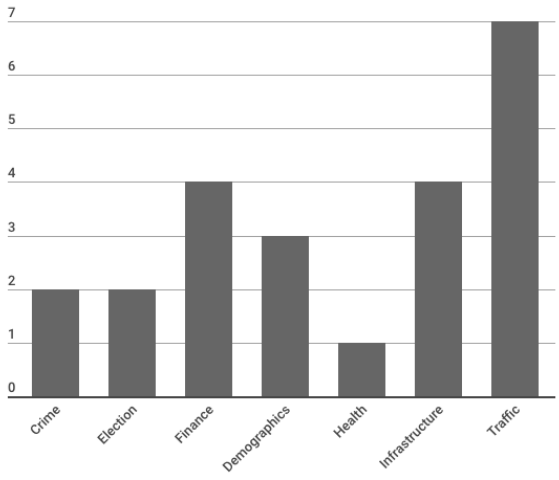


Figure 4: Papers grouped by public area served by their visualizations

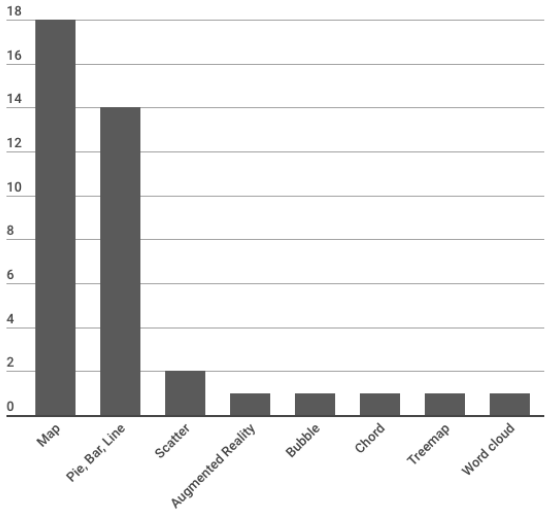


Figure 5: Papers grouped by type of visualization presented

Table 4: Public areas served by visualization tools

Area	Papers	Total
Crime	[3, 32]	2
Election	[19, 40]	2
Finance	[7, 12, 21, 38]	4
Demographics	[24, 35, 42]	3
Health	[8]	1
Infrastructure	[6, 11, 17, 44]	4
Traffic	[20, 25, 30, 32, 37, 39, 47]	7

simple and standardised elaborations and innovative visualisation techniques may be used to provide new and updated services to citizens and communities.

Chen et al. [6] provided a tool to manage energy system in Taiwan and Vert and Vasiu [45] created an augmented reality application that shows constructions sites and permits information to the users. Furthermore, users can contribute to the app by confirming whether a given construction is done or not.

5.2.7 Traffic. Okamoto et al. [32] presented a map tool to show the most dangerous roads in New York city based on car collisions.

Radl et al. [37] implemented a very interesting map that shows chestnut trees concentration for each street in the city of Vienna (Austria) so drivers can avoid parking near those areas.

Rocca et al. [39] and Lin and Tseng [25] proposed tools to help on the traffic accidents area. While the tool presented by Lin and Tseng shows the correlation of citizen potholes reports versus accidents reports on that same area, Rocca proposed a tool that combines Open Government Data and Machine Learning algorithms to predict car accidents in a given location.

Both Wang and Li [47] and Mrazovic et al. [30] published papers on the city routing segment. Wang and Li presented a map that provides routes based on the average speed of the region being visited by the drivers. Mrazovic proposed a tool where tourists set their interests in the current city, then receive an itinerary based on his choices versus current city mobility reported data. The mentioned tool also provides map reports about mobility, crime, and other useful information for tourists.

In the other hand, Kazemi et al. [20] presented and evaluated a decision support system based on open data and expert rules to help coast guard to detect anomalies on maritime surveillance.

5.3 Most used visualization techniques

The map visualization is the most used technique among the papers mapped in this study as shown in Figure 5. Table 5 shows examples of some of the visualizations listed in Figure 5.

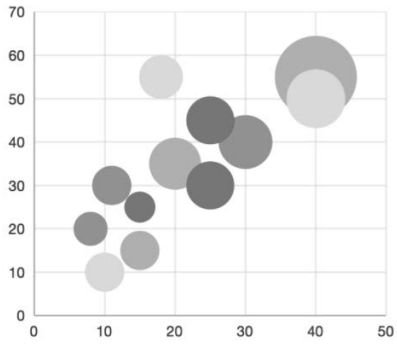
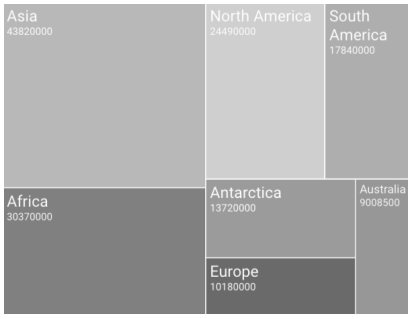
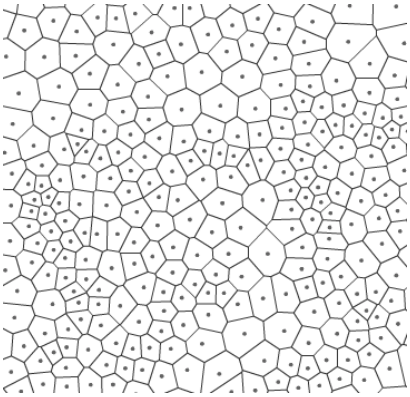
It is easy to see that, between the studies that presented tools based on map visualizations, Traffic is the public area that have the higher number of visualization proposals as demonstrated in Table 6.

There are some interesting visualizations for traffic issues like the ones presented by Radl et al. [37] and Rocca et al. [39]. Radl et al. [37] used pointers to show the highest concentration of chestnut trees in a map. Rocca et al. [39] also used pointers in a map, however the goal was to present the prediction of car accidents in a given location.

As noted in these examples and in Table 6, most map visualizations somewhow use map pointers to display exactly locations to the users. Choropleth is another technique that is commonly combined with map visualizations [44][32][35][28]. As an example, Okamoto et al. [32] reviewed how the New York City open government data was being used. It was found a choropleth map that showed felony offenses grouped by community.

Another interesting fact is that regular charts like pie, bar and line are also often used in combination with public datasets. However, these charts are commonly used as secondary resource for

Table 5: Visualization Examples

Choropleth Map	Pointer Map	Route Map
		
Bubble Chart	**Treemap**	**Voronoi Diagram**
		

other primary visualizations like maps, chord diagrams or treemaps, for example.

Vert and Vasiu [45] found a different way to display open data related to construction permits. They created an augmented reality application that shows permit information for constructions sites. With the application opened in a mobile device, the user can point it to a construction direction and the application displays available permit data over the edifice being built. The user can also interact with the application and mark constructions as complete.

Among the studies surveyed in this literature review, map is the most used visualization to show open government data and it is commonly used to present data related to transportation, crimes in a given area and demographic information.

5.4 Common challenges

Not all papers reported on the challenges faced during the project. Among the ones that did report, the most common challenges are data with poor quality, issues accessing the data, the gaps between Open Data initiatives and stakeholders, the disengagement of the users and tools that require too much skills.

Next, we provide a more detailed description on the commonly reported challenges.

As shown in Figure 6 and Table 7, among the studies that reported on the faced challenges, most challenges are somehow related to poor data quality.

The studies that faced problems with poor data quality [7, 13, 28, 36, 45] reported issues like unformatted data, too many generic values or even missing values as well as data not following standards.

Three papers [8, 40, 45] reported on the issues related to having access to Open Government Data.

Table 6: Papers that used map visualizations and the areas served

Paper	Map Type	Area
[37]	Pointers	Traffic
[39]	Pointers	Traffic
[30]	Pointers	Traffic
[25]	Pointers	Traffic
[20]	Pointers, Route	Traffic
[32]	Choropleth, Pointers	Crime, Traffic
[3]	Pointers	Crime
[42]	Pointers	Demographics
[24]	Pointers	Demographics
[35]	Choropleth	Demographics
[7]	Pointers	Finance
[12]	Bubble	Finance
[8]	Pointers	Health
[11]	Area, Voronoi	Infrastructure
[44]	Choropleth	Infrastructure
[17]	Pointers	–
[28]	Choropleth	–
[23]	Pointers, Heatmap, Route	All

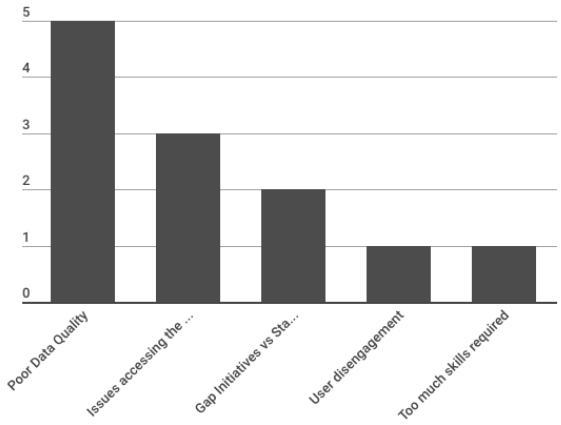


Figure 6: Papers grouped by the reported challenges that were faced during the project

Table 7: Common challenges reported in each paper

Challenge	Papers	Total
Poor Data Quality	[7, 13, 28, 36, 45]	5
Access to data	[8, 40, 45]	3
Gap Initiatives vs Stakeholders	[4, 15]	2
User disengagement	[21]	1
Skills required	[4]	1

While Mendonça and Maciel [8] reported that too much information is still documented on paper, Salvador and Sinnott [40] and Vert and Vasiu [45] raised problems with the available files and data formats.

Salvador and Sinnott [40] reported on the difficulties faced in harvesting public data because, in some cases, datasets were published directly in HTML format. Vert and Vasiu [45] also presented issues on trying to download data in bulk.

As for the gaps between open data initiatives and stakeholders, two studies [15][4] reported that the gap between the current open data initiatives and its stakeholders is a challenge.

Graves and Hendler [15] showed that this gap prevents the stakeholders from making extensive use of the publicly available due to lack of technical knowledge.

Brugger et al. [4] also reported that despite the general interest of the organizations, their existing routines and limited budgets currently do not allow for much experimenting in Open Government Data visualization.

About the user disengagement issues, Kim et al. [21] reported on their results that 14 out of 104 participants believed that budget programs were useless or wasteful.

Regarding the tools that require too much skills, Brugger et al. [4], who also reported a gap between the open data initiatives and its stakeholders, noted that lay users would need to invest considerable time to make the necessary learning steps to produce data visualizations that meet at least basic quality.

6 CONCLUSION

Considering the amount of government data that is being made publicly available during the last years [48], visualization tools for open government data became fundamental so users can extract the maximum information available from it.

In this study we provide an overview of the open government data initiatives inspected in our systematic search. The major contribution of this study is to provide an overview about the Open Government Data Visualization area and present the initiatives being conducted to visualize open government data, public areas that can take advantage from these visualizations and the challenges that have been faced while combining data visualization and existing government data.

To achieve this goal, we conducted a systematic mapping study. The first step of the process found 775 papers on the area and, during the process, we selected 32 studies that have useful information about the use of visualizations with open government data.

As part of this literature review, we analyzed several aspects of the papers that were selected during the paper selection process. After reviewing all of them, we presented results that answer our research questions.

The first research question was defined as *"Which public areas have visualization for its published data?"*. As part of the results, we presented that although there is space for more work to be done, there are some areas that have visualization proposals for its open data like crime, election, finance, general/demographics, health, infrastructure and traffic.

We then analyzed the selected studies grouped by the type of visualizations applied. This analysis was related to second research question, which was defined as *"What are the most used visualization techniques?"*. The results of this study showed us that the most used visualization techniques are maps and regular dashboards like pie, line and bar charts. This can be partially explained by the first research question because Traffic is the area with the highest number of visualization proposals. Also, about the regular dashboards, they are commonly used as secondary resources to other primary visualizations.

The last research question was related to the problems that are often faced when using visualization with Open Government Data. The research question was defined as *"What are the common challenges being faced?"* As part of the results, we found that data quality is the main problem reported in the selected studies. However, there are some others like poor data quality, issues accessing the data, the gaps between Open Data Initiatives and the Stakeholders, user disengagement and tools that require too much skills.

7 LIMITATIONS AND FUTURE WORK

One limitation of the presented research is that, during the planning phase, we defined that we would only consider studies written in English and published in the Computer Science area.

Another limitation is the fact that we did not consider books while conducting this review. Both limitations exist because we wanted to ensure and make easier the repeatability of this review study [22].

This study presents how the open government data is being combined with data visualization techniques. The next step is to extend our understanding by investigating the perception of the stakeholders about the insights provided by the visualizations that were applied to open data.

Moreover, it is also part of this future work to research on the impact of these visualizations in the society and whether citizens recognize actions taken by politicians based on the open government visualizations.

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