# Urban Crowdsourcing Platforms across the World: A Systematic Review

ALESSANDRO FORNAROLI, EPFL and Idiap Research Institute, Switzerland
DANIEL GATICA-PEREZ, Idiap Research Institute and EPFL, Switzerland

Urban crowdsourcing platforms are becoming increasingly important, especially considering the relevance of citizen-centricity in smart cities. This systematic review aims at analyzing existing academic literature on urban crowdsourcing platforms to gather citizen-generated data and shed light on the state of research and development of these tools. Studies describing data-gathering urban crowdsourcing platforms were selected following the PRISMA protocol, for a total of 30 studies, corresponding to 32 platforms. After analyzing the studies at large, this review then proceeds to examine and catalogue the platforms, focusing on their location, purpose, and public data availability. While providing valuable information on existing platforms, the catalogue is subject to different types of bias, including a geographical one, which derive primarily from the chosen methodology to identify platforms worldwide. The article also discusses the implications of such choices.

CCS Concepts: • **General and reference** → **Surveys and overviews**; • **Information systems** → **Collaborative and social computing systems and tools**; **Crowdsourcing**; • **Applied computing** → **Computing in government;**

Additional Key Words and Phrases: Urban crowdsourcing, citizen sourcing

**ACM Reference format:**
Alessandro Fornaroli and Daniel Gatica-Perez. 2023. Urban Crowdsourcing Platforms across the World: A Systematic Review. *Digit. Gov. Res. Pract.* 4, 3, Article 15 (September 2023), 19 pages.
https://doi.org/10.1145/3603256

## 1 INTRODUCTION

Crowdsourced data generated by citizens has become increasingly relevant for the development of so-called smart cities: Data availability is paramount to the functioning of a city, and therefore platforms allowing to collect data generated by people represent a key element in the transition towards more citizen-centric cities [10]. The concepts of citizen sourcing and urban crowdsourcing are becoming particularly relevant for the public sector, as local, state, and national governments have promoted projects and made use of this kind of platform in the past decade [27]. Citizen-generated data platforms can be very useful as part of the digital transformation of certain processes in cities, as they can be an efficient and effective way to gather urban data to ultimately improve citizen-oriented services [13].

However, both the notion of urban crowdsourcing and citizen sourcing are blurry, without having a unique definition. Hilgers and Ihl describe citizen sourcing as *"The design and configuration of a new relationship*



D. Gatica-Perez was partly supported by the IcARUS project, funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 882749.
Authors' addresses: A. Fornaroli, École Polytechnique Fédérale de Lausanne, Rte Cantonale, Lausanne, Switzerland and Idiap Research Institute, Rue Marconi 19, Martigny, Switzerland; email: alessandro.fornaroli@alumni.epfl.ch; D. Gatica-Perez, Idiap Research Institute, Rue Marconi 19, Martigny, Switzerland and École Polytechnique Fédérale de Lausanne, Rte Cantonale, INN 138, station 14, Lausanne, Switzerland; email: gatica@idiap.ch.

2639-0175/2023/09-ART15 $15.00
https://doi.org/10.1145/3603256

*between a government and its people, based on a set of emerging practices and principles applied from the private sector"* [20], while Linders considers it to be *"Citizens' support of government to increase its responsiveness and effectiveness"* [26]. The domain of what can be referred to as urban crowdsourcing is quite broad and encompasses a broad range of applications, including urban mobility, participatory budgeting, and urban reporting [33]. It is possible to classify urban crowdsourcing into two macro-areas: *citizen participation*, in which citizens take a more active role, proposing new ideas and projects for the city or taking part in participatory budgeting initiatives; and *data gathering*, whereby the main role of citizens is to communicate (more or less actively) certain types of data to the platform for various purposes. This article will focus on the latter [39].

**The relevance of a literature review.** Having considered the importance of urban crowdsourcing in the context of the transition to smart cities, it is important to map existing research on the broader topic of data and crowdsourcing in the city. Several papers with this general goal exist in the literature. Niu and Silva [33] conducted a systematic review of studies concerning methods for data mining for crowdsourced data in urban contexts, highlighting both the diversity and heterogeneity of the crowdsourced data that can be used for different types of analyses (including tweets, images, and geographic information), as well as the broad range of applications that urban crowdsourcing can have. Costa and Teixera [10] carried out another systematic review of the ways that applications for smart cities can be developed and empirically tested. Liao et al. [25] explored how crowdsourcing methods can be utilized for urban planning. Pereira et al. [35] analyzed tools and initiatives to increase citizen participation in cities. Finally, Marzano et al. [29] conducted a review of studies describing crowdsourcing-based methods and initiatives for the purpose of urban mobility.

One aspect that remains open is the systematic examination of the existing scholarly research that directly describes *platforms for urban crowdsourcing*. The goals of this systematic review are to analyze studies directly concerning urban crowdsourcing platforms whose main purpose is data gathering (rather than increasing citizen participation); compile a catalogue of them; and conduct a comparative analysis around relevant dimensions, including geographic distribution, specific platform purposes, and availability of platform data for possible further use. The analysis also highlights a number of biases that researchers in the smart city domain need to be aware of. Overall, our review contributes to a more coherent understanding of the current state of affairs, reveals key trends in urban crowdsourcing platforms, and identifies topics of future interest.

The article is organized as follows: Section 2 describes the methodology and sources used in the review. Section 3 presents our analysis of the literature from a study-centric perspective. Section 4 extends the analysis of the literature from a platform-centric perspective. Section 5 discusses limitations encountered as well as future directions. Section 6 offers final remarks.

## 2 METHODS AND SOURCES

### 2.1 Methodology and Study Identification

This systematic review follows the PRISMA Statement for systematic reviews [30], and it is entirely based on a database search. The scientific databases that have been considered are Elsevier's Scopus,[1] the **Social Science Research Network (SSRN)**,[2] Wiley Online Library,[3] ACM Digital Library,[4] and IEEE Xplore.[5] For the purpose of this analysis, solely peer-reviewed academic articles retrievable in academic databases have been taken into account. Mendeley[6] has additionally been used as software for the removal of duplicate articles. All records were retrieved in October 2021.

[1] https://www.scopus.com/
[2] https://www.ssrn.com/
[3] https://onlinelibrary.wiley.com/
[4] https://dl.acm.org/
[5] https://ieeexplore.ieee.org/
[6] https://www.mendeley.com/

Table 1. Eligibility Criteria for Platforms

| | |
|---|---|
| **PLATFORM** | It is about (or it describes) a platform (at least one). |
| **IMPLEMENTED** | It has to be a permanent infrastructure, not an academic project or proposal. |
| **URBAN** | It is focused on one (or more) specific urban areas. |
| **LOCAL** | It is either managed or officially endorsed by a local government or developed by a local organization with a strong relationship with a city. |
| **DATA GATHERING** | There needs to be the ability to generate reports from the gathered data; users need to be actively involved/informed of the data gathering procedure. |

Given that this article aims at analyzing the current state of urban data gathering, urban crowdsourcing, and citizen sourcing platforms in the world, for all the aforementioned databases a search has been performed using *data* and either *urban crowdsourcing* or *citizen sourcing* as filtering keywords. Subsequently, all the articles containing this combination of keywords in either their title or abstract have been retrieved for initial screening.

For a study to be selected for inclusion, the following eligibility criteria were used:

(1) Be an academic and peer-reviewed article.
(2) Be written in English.
(3) Contain at least a short description of an urban crowdsourcing platform that would adhere to the eligibility criteria for platforms, which are described in Table 1.

During the screening procedure, every article has been examined, and it has been checked whether it described a platform satisfying all the five criteria in Table 1. These criteria were applied sequentially and will be explained and justified in more detail in Section 2.2.

## 2.2 Eligibility Criteria for Platforms

Considering the broad diversity of platforms and applications that can be referred to as *urban crowdsourcing platforms*, it was necessary to define more strictly which kinds of platforms could be considered for this study. More specifically, it was important to identify aspects that could potentially lead to ambiguity regarding inclusion; these were identified as the following:

(1) **Type and Purpose**: The first step consisted in defining what would count as a *citizen sourcing* or *urban crowdsourcing platform* for the purpose of this study. In fact, such definitions are not necessarily clear, as they could encompass city government's websites incorporating basic data gathering (such as feedback and contact forms) and independent websites and apps with no connection whatsoever to a city. With respect to this point, it was also to be determined whether to include applications such as instant messaging apps or social networks that are used by city governments to connect with citizens. Moreover, it was also necessary to consider the scope of the platforms to be included and whether to restrict the study to only certain scopes (such as mobility, urban reporting, citizen participation, or socialization).
Given the macro-level differentiation between citizen participation and data gathering platforms for urban crowdsourcing (see Section 1), for the purpose of this article, we will only consider those whose main purpose is to obtain data generated by citizens (and citizens need to be voluntarily contributing to these data collection efforts). Hence, a platform will be eligible for this study if it permits to generate reports of the data obtained from citizens.
(2) **Official Status and Link to the City**: Another important aspect to consider is the link that the platform should have with the city and also how to define a city: whether it should be strictly a municipality or an urban area and whether this area needs to exceed a certain population threshold. In any case, as argued by Crooks et al. the peculiarity of urban crowdsourcing platforms is the way that they integrate with and complement the complex urban landscape, which includes physical, digital, and human aspects [11]. Given

that this study solely focuses on platforms analyzed in the academic literature, it was not deemed necessary to impose a minimum population. Nonetheless, only those platforms that have a specific connection to one or more cities (or urban areas) will be considered in the review, as the review is aimed to analyze *urban* crowdsourcing.

In addition to this, it is also necessary to define the official status of the platform, as it could be officially adopted or endorsed by the city government or have no relationship with it whatsoever, i.e., without any specific connection to the local administration. To exclude those platforms not having any relationship with a specific city despite their urban nature (such as Waze, the mobility app), this review will only include platforms that are either adopted or endorsed by a local government or that are developed by groups with a strong connection to the city (without necessarily having any official relations with the city administration).

(3) **Nature and Current State of the Platform**: Finally, besides its purpose, it is also essential to consider the nature of the platform and its creators: whether it is aimed at being a long-term infrastructure supported by the city or a purely academic project with minimal features, such as a research prototype. For this review, platforms developed for purely academic and research purposes will be considered as out of the scope of the analysis. To be taken into account, platforms need to have been practically implemented and functioning, hence beta-tests and prototypes cannot be considered. Nonetheless, discontinued or dormant platforms may be included in the review, provided that they satisfy the other eligibility criteria.

### 2.3 Data Collection and Synthesis

Once the studies to be included in the review have been selected, it is necessary to extract the data for analysis. In this article, two different analyses will be conducted: The first will cover directly the articles that have been identified, exploring how papers approach the analysis of the different platforms. Subsequently, there will be a second analysis, focusing on the identified platforms.

Besides collecting the basic bibliographical data on the papers and the platform(s) they describe, this review considers the approach that each of the articles adopts to analyze the platform, which is classified as either primarily **qualitative** or **quantitative**. Moreover, since for a study to be eligible for inclusion it is sufficient that it contains a short description of a platform abiding by the criteria in Table 1, studies are also divided in three categories, according to the relevance that the platform takes within each study, to discern whether (1) it is at the core of the study; (2) it describes the platform in one paragraph (or more); and (3) it describes it only briefly.

After this step, for each of the studies, the data on the platform is collected. These include the main characteristics indicated in Table 2.

Subsequently, the data collected from each of the studies and platforms will be aggregated to extract general considerations and trends. Furthermore, one of the main objectives of this study is to compile a catalogue of urban crowdsourcing platforms featured in previous academic studies, which will be analyzed in Section 4.

## 3 RESULTS: STUDY-CENTRIC ANALYSIS

### 3.1 Study Selection

In this section, we consider the papers selected by following the PRISMA framework and methodology, described in Section 2.1. Figure 1 shows the flowchart of all the records that have been identified, screened, and selected during this process. After the initial database search with the keywords *urban crowdsourcing* OR *citizen sourcing*, AND *data*, a total of 1,688 records have been identified. After the removal of duplicates, these were reduced to 1,488, which were later screened. A further 1,193 records have been excluded on the basis of their title and abstract, as they did not satisfy the eligibility criteria, which led to 295 studies being sought for retrieval. Of these, 264 were actually retrieved. At this point, each article was checked to verify whether it was describing one or more eligible platforms. The exclusion criteria were applied sequentially, meaning that if an article did not

Table 2. Data Collected with Respect to Each Platform Mentioned in the Selected Studies

| | |
|---|---|
| **Name** | Official name of the platform, in the original language (untranslated). |
| **Website** | URL to the official website. |
| **City** | City in which it is based. This strictly depends on the description as given by the study to which it corresponds. |
| **Country and Continent** | Country and continent, to identify the main location of each platform. |
| **Purpose** | Main purpose of the platform. Four main categories have been selected: Urban Reporting, Mapping, Mobility, and Other. |
| **Availability of Data** | This indicates whether it is possible to publicly access the data collected by the platform, and if so, how to access it. |
| **Format of the Data** | When it is possible to download the data, this corresponds to the format in which the datasets are obtained (e.g., JSON, CSV). |
| **Data Retrieval** | When the data can be downloaded, this indicates how it is possible to access the data, which is generally either via API or direct dataset download. |
| **License** | The license used to distribute the data—whether it is a proprietary dataset, part of the public domain, or distributed with an open data license. |
| **Privacy** | Information on whether or not any personal data from users are stored on the platform and whether the datasets are publicly available. |

describe any platform, then it was immediately excluded, otherwise, the assessment went on, checking whether the platform had been actually implemented, and so on. Ultimately, 30 studies were selected for inclusion in this review, as can be seen in Figure 1. The full list of studies is included in Appendix I, Table 4.

### 3.2 Description and Analysis of Selected Studies

In this review, only peer-reviewed studies published in English have been considered. From a temporal point of view, articles span a decade, as can be seen in Figure 2, with the oldest one being written in 2011. This shows how the topic of urban crowdsourcing has been increasingly emerging in the past years, and especially since the mid-2010s. This increased academic interest in the area could be attributed to the increasing number of urban platforms worldwide.

As part of the eligibility criteria, each of the articles describes at least one urban crowdsourcing platform, but some articles describe or mention more than one platform. For example, Aguilera et al. [2] describe two different platforms in Spain, the Complaint and Suggestions portal of the city of Zaragoza, and the *Bicicas*, a mobility platform of the city of Castellón.

As mentioned in Section 2.3, all articles are classified as *quantitative* or *qualitative*, depending on the main methodology used to describe and analyze the platform. A study is considered quantitative if it contains a detailed quantitative analysis of the platform, considering aggregate statistics and usage data; otherwise, the approach is classified as qualitative, meaning that the description or analysis of the platform is purely descriptive or qualitative—this can range from a short description to a longer analysis. Overall, 22 of the selected articles adopted a qualitative approach, while only 8 were quantitative analyses. This highlights a relative scarcity of peer-reviewed papers that contain in-depth quantitative analyses of urban crowdsourcing platforms.

Subsequently, the studies were also divided into three other categories to highlight the relative importance that the platform(s) referred to by each article had with respect to the article itself:

(1) **Articles whose *primary focus* is a platform**: These are the articles whose primary focus is the description and analysis of the platform itself, independently of the specific type of analysis that was conducted.

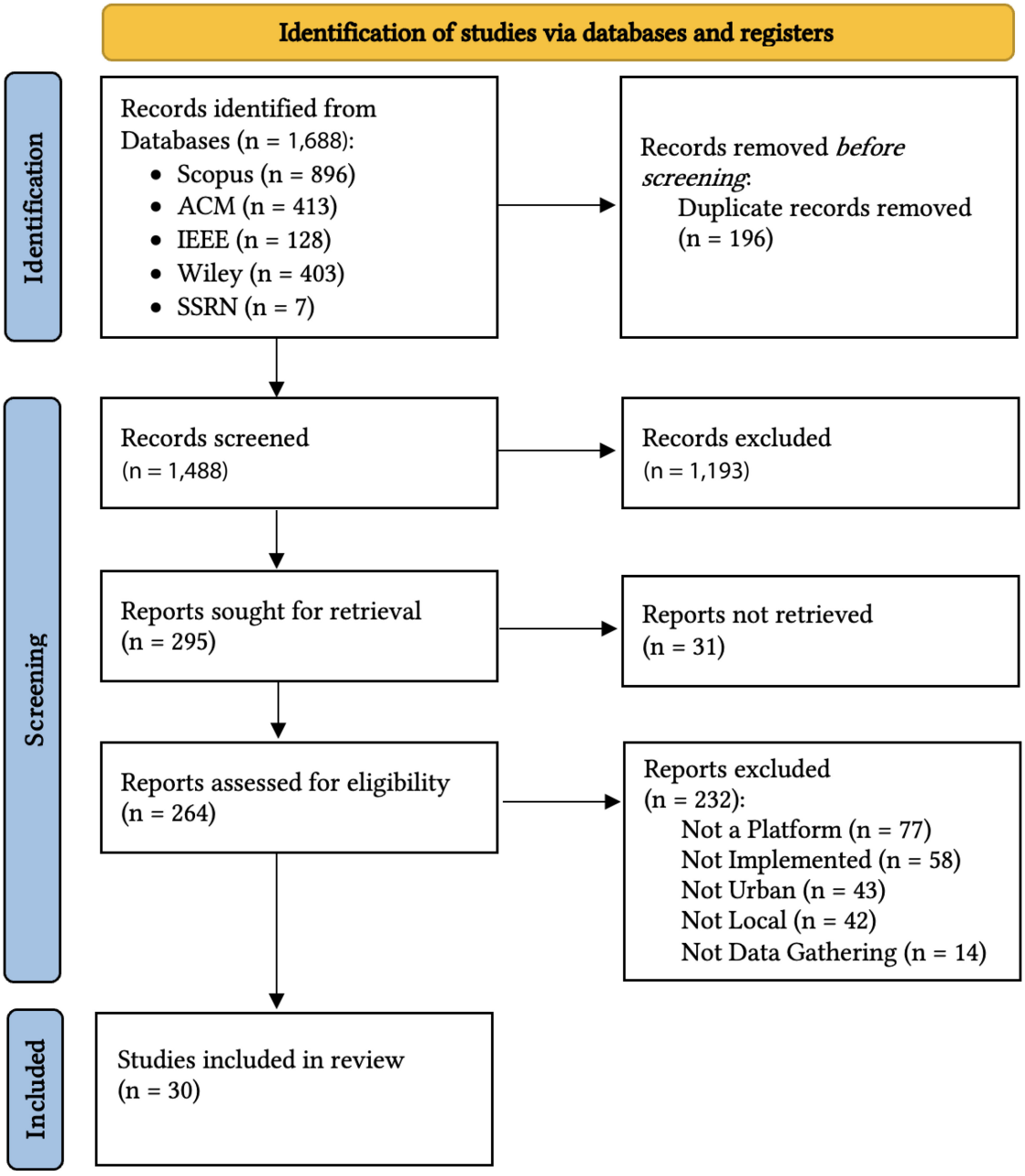



Fig. 1. Flow diagram of identification of eligible articles for review.

In these cases, the name and purpose of the platform are clearly stated in the abstract. Overall, there are 15 of these articles in the sample, corresponding to exactly half of the total.

(2) **Articles whose *secondary focus* is a platform**: In these cases, the primary focus of the study is not the description or analysis of the platform *per se*, but the platform is still an important and relevant part of the

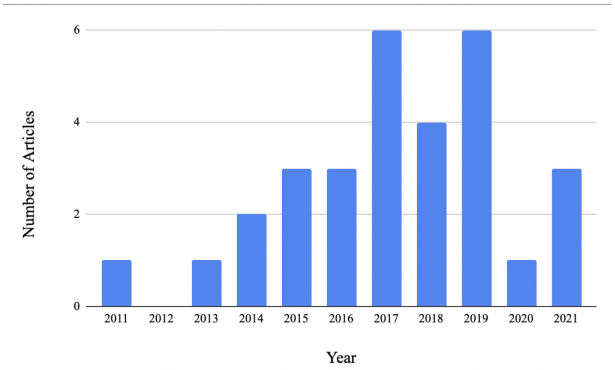



Fig. 2. Studies included in the review by year of publication (*number of platforms = 32*).

Table 3. Studies Included in the Review Divided by the Approach towards the Platform (*Number of Articles = 30*)

| | **Primary Focus** | **Secondary Focus** | **Mentioning Platform** |
|---|---|---|---|
| **Qualitative** | 8 | 9 | 5 |
| **Quantitative** | 6 | 2 | 0 |

article. In these papers, at least one paragraph is dedicated to the described platform, which often acts as a case study or example from which other conclusions are drawn. A total of 11 articles belong to this group, making up 36% of the full sample.

(3) **Articles *mentioning* a platform**: These are articles that only shortly describe a platform, using a few sentences, and usually as an example, or in the description of existing research. A total of 4 of the identified studies correspond to this group, i.e., 13% of the sample.

It is also possible to observe a connection between the relative importance of the platform and the type of analysis, as illustrated by Table 3. In fact, of the 8 studies that adopt a quantitative analysis, 6 are entirely about the platform that they are describing. This observation is also quite intuitive, as a quantitative analysis can be considerably more intensive and longer than a simple description of the platform. Similarly, this is the reason why all the studies that simply *mention* a platform are classified as adopting a qualitative approach.

Finally, it is also important to analyze the main thematic area on which each article is focused, especially in the case of the articles that are not centered on the description of the platform. Articles have been grouped into five main areas, which identify the main research goal of each publication. These are:

(1) **Urban Crowdsourcing and Smart Cities**: These studies analyze the topic of urban crowdsourcing and smart cities at large. They are mainly about different aspects of the management of data at the urban level, explaining in different ways how a city can be improved with the help of urban crowdsourcing platforms.
(2) **Urban Crowdsourcing Platform**: This refers to articles whose primary focus is a specific urban crowdsourcing platform, meaning that the article is mainly about the corresponding platform(s) included in Table 5.
(3) **Urban Mobility**: The main topic of these papers is to describe strategies for improving mobility at the urban level, often with the use of digital tools and data models.
(4) **Research Prototype**: These describe primarily a research prototype (i.e., an application that has been developed solely for academic purposes). Such platforms have not been considered in this study and are

therefore not included in Table 5, as they are excluded by the eligibility criteria in Table 1. Nonetheless, the articles have been taken as part of the analysis whenever they mention other platforms that do satisfy the eligibility criteria.

(5) Then, there are other types of articles, with only one occurrence per thematic area, which have been labelled as ***others***. These comprise urban planning, flood management, an analysis of noise, privacy, and an ethnographic analysis.

The results of this analysis are also included in Appendix I, Table 4. Only 8 out of the 30 papers directly address the topic of an urban crowdsourcing platform as their core.

## 4 RESULTS - PLATFORM-CENTRIC ANALYSIS

### 4.1 Platforms from Selected Studies

We now move to the platform-centric analysis, which considers platforms described by and identified from the studies included in the review. The 30 studies mentioned in Section 3.1 correspond to a total of 32 platforms, shown in Table 5 in Appendix II. All these platforms match the criteria explained in Section 2.2, meaning that they are all permanent platforms with a strong connection to a specific city (either because of a city government's official endorsement or because the platform is managed with a specific focus on a certain city) and aimed at obtaining citizen-generated data.

Most of these platforms are specific to a city, which gives them a strong local connotation. However, there are also certain platforms present in more cities; these have been included in the review, as they corresponded to the eligibility criteria. These platforms, such as FixMyStreet, have an international reach and might not be specific to one single city, but always have a relation with local authorities, making them satisfy the criteria. In these cases, multiple entries may be present for the same platform: one entry for the platform as a whole, which may be classified as an *international* platform, and one for each of the city-specific versions of the platform that are present in the selected studies. Therefore, the combination of platform and city is unique. In other words, the same platform can appear multiple times, in relation to multiple cities, and the same city might appear multiple times with different platforms—such as in the case of Boston, which appears two distinct times.

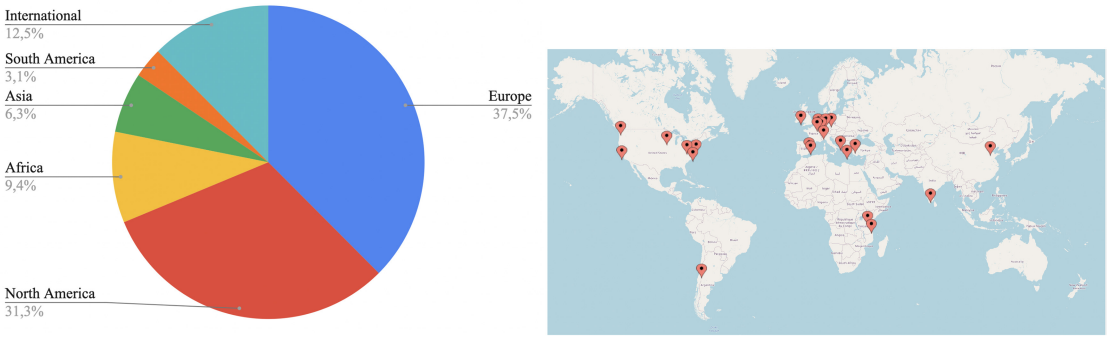
The platforms are then classified into one of four main categories to identify their main scope. These are:

(1) **Urban Reporting**: This category refers to those that allow users to report to the city administration or local authorities whether there are issues with the city that need to be addressed. Some examples are potholes, garbage, or broken public objects that need to be collected or fixed by the government.
(2) **Mapping**: Platforms that fall into this group aim at creating maps with data generated and/or provided by the users. Maps can either be general-purpose maps, especially in cases where accurate and up-to-date maps are difficult to obtain or non-existent; or specific maps aimed at highlighting certain events or areas.
(3) **Mobility**: This category refers to platforms aimed at using crowdsourced data to improve mobility within the city, either with public or private transportation.
(4) **Others**: All other platforms would fall into this category.

Finally, an important piece of information that has been considered is the availability of data to the public. This has been divided into three macro-categories: *Fully Available*, when all the data obtained by the platform can be freely accessed on the web; *Partly Available*, when the data can be obtained with limitations—in most cases this is because it is necessary to make a request to the platform owners or managers to access the data; and *Not Available*, when the data cannot be accessed by unauthorized individuals, and there is no specified procedure to inquire or ask for the data. This will be further discussed in Section 4.4.

### 4.2 Geographical Distribution

We now proceed to analyzing the platforms included in Table 5. As shown in Figure 3(a), the platforms are very unevenly distributed geographically, as around 70% of all the platforms included in the studies are either in




(a) Distribution of the platforms by continent

(b) Cities with at least one of the selected platforms [7]

Fig. 3. Geographical distribution of platforms (*number of platforms = 32*).

Europe or North America. In addition to this, around 10% of the platforms have been classified as *international*, meaning that they do not refer to any specific city but are present in many countries spanning different continents; examples of these are the mapping and urban reporting platform Ushahidi, or SeeClickFix, also used for urban reporting. Therefore, there is a high level of geographic imbalance in this platform catalogue. While this could be in part an indicator of the fact that urban crowdsourcing platforms are more often developed in North America or Europe, it is also in part attributable to a selection bias derived from the fact that the platforms have been selected solely from academic studies written in English.

This imbalance can also be seen in Figure 3(b), which shows all the cities in which there is at least one urban crowdsourcing platform identified from the studies. In fact, of all the platforms, 10 of them are based in the United States, corresponding to about 30% of the total, with 2 platforms in Boston. At the same time, only 3 platforms are based in Africa, 2 in Asia, and only 1 in South America. However, the geographical distribution of platforms within Europe is moderately more even.

### 4.3 Purpose of the Platform

As explained in Section 4.1, all platforms were assigned to one or more of four macro-categories that indicate the main platform scope: urban reporting, mapping, mobility, and other.

As seen in Figure 4, the most popular category is that of **urban reporting**.

This is an indication of the relevance and popularity of urban reporting platforms, which create a direct connection between citizens and city government.

Some of these platforms are programmed and maintained by companies that provide the same platform to different city governments, such as *SeeClickFix* or *FixMyStreet*, while others are integrated within the main city website, such as *Zaragoza Quejas y Sugerencias* (*Zaragoza Complaints and Suggestions*) or Vancouver's *311* service. In any case, a common characteristic of urban reporting platforms is that there is always a connection with the local government, an administrative office, or an official agency, so the city can intervene to solve the problems that are reported by citizens.

A second group is that of **mapping platforms**, whose main goal is to utilize the provided data to generate or improve maps. Within this category, we can observe different types of platforms: Map Kibera and Dar Ramani Huria, based in Nairobi and Dar Es Salaam, respectively, aim at using citizen's volunteered geographic information to create maps of certain neighborhoods that, because of irregular housing and poor official reporting, are poorly mapped in official maps. However, apps such as Reusing Dublin or Hush City in Berlin use data generated

[7]Source for the map: https://www.mapcustomizer.com/

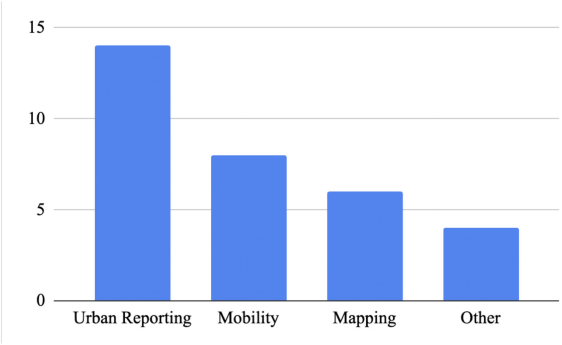



Fig. 4. Number of platforms for each of the purposes (*number of platforms = 32*).

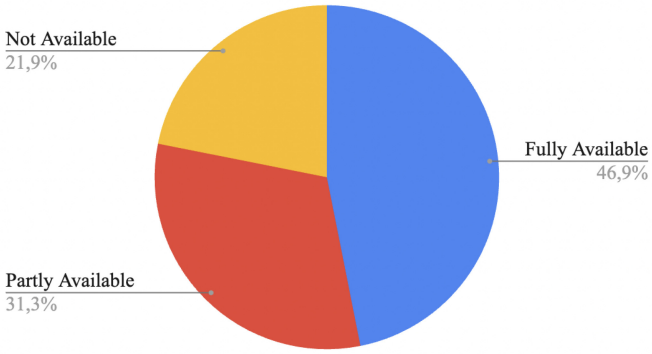



Fig. 5. Platforms divided into macro-categories by availability of data (*number of platforms = 32*).

by users to map certain areas of particular interest within the city (such as vacant properties in the former case or quiet areas in the latter).

A third category of platforms is **mobility**, whose main purpose is to improve mobility within the city. These are also of different types: For example, IBB CepTrafik in Istanbul uses citizens' data to provide the real-time state of traffic, while other platforms like Tiramisu Transit in Pittsburgh use the users' data to monitor the state of public transportation.

Finally, there are the platforms classified as ***other***, which did not fit into the previous categories. The purposes of these platforms include flood management, smell detection, or noise detection.

One general consideration to make is that, in different forms, platforms from all the four aforementioned categories contain a geo-localization aspect: Nearly the totality of the analyzed platforms contain, to some extent, geographic information. For example, in the case of urban reporting, this corresponds to the location of the problem that needs to be solved, while in an application for smell detection like Smell Pittsburgh, the map is a fundamental component of the platform.

## 4.4 Availability of Data

The public availability of data is another important aspect of urban crowdsourcing platforms, as publicly available datasets enable research, innovation, and transparency. Table 5 indicates to which extent the data is available, dividing platforms into three macro-categories:

(1) For platforms with **fully available data**, all data generated by the users and gathered by the platform can be accessed online via the official website of the platform or with the use of APIs. The formats in which

the data can be obtained, accessed, or downloaded differ across platforms. In certain cases, such as in Budi Odgovoran, based in Podgorica, all data are accessible on the website, but not directly downloadable, so the data could be scraped from the website to be downloaded. Most platforms directly allow downloading a dataset or accessing it via API.

(2) Platforms are categorized as having **partly available data** when the data generated by users is not entirely or directly accessible. In most cases (7 out of 10 of partially available data), this is because it is necessary to contact the platform managers to obtain access to the data or to the API keys necessary to download the data. This definition also applies to international platforms whereby each individual deployment has the right to administer the data independently, as in the case of Ushahidi or FixMyStreet. A different case is that of Dar Es Salaam-based Dar Ramani Huria, where the data is indicated as partly available, because some of the download links were not functioning at the time of writing this review, meaning that it is necessary to contact the organization to access the data.

(3) The rest of the platforms do not grant access to the data and are labeled as having **not available data**. These can occur for two reasons: either the platform has been discontinued and the dataset is no longer available (such as in the case of BeCity) or the managers of the database do not allow for unauthorized individuals to download the data.

As seen in Figure 5, close to half of the platforms fall within the category of Fully Available data, followed by those classified as containing partly available data. Table 5 includes detailed information on the availability of the data of each platform, including the links from which it is possible to access data. It also shows which data can be accessed via API and which can be downloaded, as well as the format of the data that can be downloaded.

A majority of the analyzed applications allow obtaining JSON data, while other popular data formats are CSV and XML. Moreover, most platforms with publicly available data have APIs that can be used for queries.

### 4.5 Licensing and Privacy

We can observe that the large majority of the platform managers have made the decision to distribute the data collected with open data licenses of different types, meaning that anybody can make use of the data under certain conditions. There are a few exceptions, which coincide with platforms that do not share their data publicly and which retain all the rights over the datasets, requiring any potential data user to sign confidentiality agreements to use the data, thereby preventing redistribution.

Finally, we notice that all the applications taken into consideration in this study have a strict privacy policy in the way that they handle personal data. It is noteworthy to point out a divide between platforms that store users' personal data for log purposes (even though these data are not publicly distributed, but only an anonymized version of the datasets is made available), while others do not store any personal data in the first place. Generally, larger and more well-established platforms will tend to store and process data such as the name, email address, and phone number of the users.

## 5 DISCUSSION

### 5.1 General Trends

Overall, while there is a certain diversity both across studies and platforms, there are certain characteristics that are commonly shared. First and foremost, the urban connotation is reflected in the fact that all the selected platforms rely, at least partly, on location and geographic data. This aspect highlights the strong link that exists between data-gathering urban crowdsourcing platforms and cities themselves, showing how they can generally be used as data sources for understanding the behavior of citizens with respect to the urban context of interest to the platform/city. Therefore, considering that the majority of the selected platforms had all their data publicly available, these platforms offer a potentially significant data source for a broad range of applications, which could span from research on citizens' urban reporting habits to informing policymaking actors.

## 5.2 Limitations

While this review has given insights into existing data-gathering urban crowdsourcing platforms, it has certain limitations. First, the only included platforms were those on which academic studies in English had been conducted. While this choice was useful to understand the current state of urban crowdsourcing academic research, it also introduces bias, which is particularly evident when looking at their geographical distribution. As described in Section 4.2, the selected studies primarily referred to platforms based in cities in North America and Europe: This phenomenon is likely partly caused by a language bias, as only studies published in English were considered, thus possibly discarding papers that could have been included in the review but were written in a different language [24]. Language bias is particularly relevant for this research because of the importance of geo-localization of the platforms, which is directly related to culture and language. Furthermore, besides the inaccessibility of relevant research in different languages, there is also another problematic issue: the possible non-existence or scarcity of research on platforms in certain regions, compared to others.

Given the type of literature selection that was carried out, it is not possible to determine exactly why so few platforms were identified in Asia, Africa, and South America, although the results show that there might be lack of research, lack of research in English, lack of urban crowdsourcing platforms in these regions, or a combination of these factors [17]. The inability to clearly establish the main drivers of the existing geographical bias is another limitation of the current analysis. In fact, the definition of urban crowdsourcing platform for data gathering that was adopted in this article might not be relevant in certain countries, e.g., under authoritarian regimes, whereby there might be an absence or quasi-absence of data protection laws, leading to the possibility of government and other agents to exploit other user-generated data more freely, without the need for these platforms.

A further point relates to the selection of keywords for the identification of studies in scientific databases. Given that the concepts of citizen sourcing and urban crowdsourcing are relatively vaguely defined, and not all researchers utilize unequivocally these concepts in their work [32], this review might have possibly failed to identify a number of studies that would otherwise have satisfied the eligibility criteria for inclusion. This potential limitation in the identification phase of the study selection process is related to the lack of clarity regarding the concept of *urban crowdsourcing*. Hence, it is not simple to determine a compact yet precise list of words that could be used for another database search without having an exceedingly large number of results.

Finally, this review classified studies into the broad categories of *quantitative* and *qualitative*, or *primary focus on a platform*, *secondary focus on a platform*, and *mentioning a platform*. While this classification certainly simplified the process, grouping all articles into two and three categories tends to flatten them, possibly failing to capture certain nuances. This also applies to the second part of the analysis, which focused on the platforms themselves: Trying to obtain some general characteristics that could be applied to all the entries might have resulted in oversimplification, therefore increasing the risk of overlooking potentially important aspects and features.

## 5.3 Directions for Future Work

First, as mentioned in the previous section, our analysis may have been limited by certain choices with respect to the selection of articles. Future work could broaden the systematic review so a larger range of keywords is utilized to identify relevant studies from scientific databases, such that additional studies that do not directly refer to the concepts of *urban crowdsourcing* or *citizen sourcing* can be included in a review.

Second, this review analyzed academic studies on platforms using citizen-generated data for cities, solely considering platforms that have been mentioned in academic and peer-reviewed studies. For future research, it would be desirable to expand the current catalogue of urban crowdsourcing platforms to include those that are not featured in academic papers, therefore constructing a larger, worldwide database of platforms. Needless to say, there are important complexities associated with this task, such as finding a method to systematize the search outside scientific databases and to obtain information documented in a very diverse range of languages. A possible approach would be to launch a collaborative and dynamic database of urban crowdsourcing platforms that scholars from different areas of the world could contribute to. However, considering the limitations of current

scholarly research and the discussion in Section 5.2, it is likely that even such database would be subject to a representation bias. Nonetheless, even though it is unlikely that it would accurately reflect the state of urban crowdsourcing in the whole world, such expanded catalogue could be a useful tool for research and possibly the design and development of new platforms.

Third, it would also be possible to extend the research (both with respect to a systematic review and the creation of a catalogue database) to platforms whose main scope is not that of gathering data on and for the city, but that collect people's suggestions and ideas on the city and that increase citizen engagement; those can be described as *citizen participation platforms*.

Fourth, the analysis in Section 3.2 highlighted the need for more quantitative research based on crowdsourced data from existing urban platforms. This review showed how most of the studies tended to adopt a more descriptive, qualitative approach. To better assess the quality and variety of the data gathered, it could be useful to conduct more quantitative research on the analyzed platforms.

Finally, an open topic in urban crowdsourcing research entails the definition of theoretical models and frameworks that could be used to better classify and analyze digital platforms within the urban context. The existence of such theoretical frameworks would help to identify (and reason about) currently under-explored elements of existing urban crowdsourcing platforms and to envision how to conceptualize new platforms.

## 6 CONCLUSION

This systematic review investigated the state of research on existing urban crowdsourcing platforms for data-gathering, selecting a list of 30 studies with the PRISMA framework. After a study-centric analysis, which showed how most of the existing papers tend to be largely descriptive rather than quantitative, thus indicating an opportunity for more quantitative research, the review compiled a platform catalogue, highlighting some of their main features, including the platforms' location, purpose, and data characteristics. A key result has been the geographical distribution of the platforms, which showed a great imbalance towards the United States and Europe. This result can be the result of a study selection and language bias, but is also a possible indication of an uneven distribution of these platforms worldwide. Despite these limitations, we believe that the patterns and insights that emerged from this review can be used as a starting point for further research, toward the creation and analysis of a more inclusive catalogue of urban crowdsourcing platforms worldwide.

## APPENDICES

## APPENDIX I: STUDIES INCLUDED IN THE REVIEW

Table 4. Studies Included in the Analysis

| Study | Platform(s) | Type of Analysis | Description of Platform | Main Topic |
|---|---|---|---|---|
| Gebremedhin et al. 2020 [18] | Dar Ramani Huria | Qualitative | Primary Focus | Urban Crowdsourcing and Smart Cities |
| Crowe et al. 2016 [12] | Reusing Dublin | Qualitative | Secondary Focus | Other: Urban Planning |
| Poggiali 2017 [36] | SeeClickFix | Qualitative | Secondary Focus | Other: Ethnography |
| Borges et al. 2016 [6] | SeeClickFix | Quantitative | Secondary Focus | Urban Crowdsourcing Platform(s) |
| Ballatore et al. 2021 [5] | Litterati | Quantitative | Secondary Focus | Urban Crowdsourcing and Smart Cities |
| Pak et al. 2017 [34] | FixMyStreet | Quantitative | Primary Focus | Urban Crowdsourcing Platform(s) |

(Continued)

Table 4. Continued

| Study | Platform(s) | Type of Analysis | Description of Platform | Main Topic |
|---|---|---|---|---|
| Young et al. 2021 [44] | Ushahidi | Qualitative | Secondary Focus | Urban Crowdsourcing and Smart Cities |
| Chang et al. 2011 [9] | Ushahidi; 311 NYC | Qualitative | Mentioning Platform | Prototype of a Platform |
| Hsu et al. 2019 [22] | Smell Pittsburgh | Qualitative | Primary Focus | Urban Crowdsourcing Platform(s) |
| Hsu et al. 2017 [23] | Smell Pittsburgh | Quantitative | Primary Focus | Urban Crowdsourcing Platform(s) |
| Drosatos et al. 2014 [16] | NoiseTube | Qualitative | Secondary Focus | Other: Privacy |
| Tempelmeier et al. 2019 [40] | MiC | Qualitative | Primary Focus | Urban Mobility |
| Ashby et al. 2015 [3] | SeeClickFix; Map Kibera; FixMyStreet; Cyclopath | Qualitative | Mentioning Platform | Urban Crowdsourcing Platform(s) |
| Aguilera et al. 2017 [2] | Zaragoza quejas y sugerencias; Bicicas | Qualitative | Secondary Focus | ICT in Smart Cities |
| Mainka et al. 2018 [28] | Kölner Service-App | Qualitative | Secondary Focus | Urban Crowdsourcing and Smart Cities |
| Myrovali et al. 2019 [31] | MOTIVATE | Qualitative | Primary Focus | Urban Mobility |
| Desouza & Bhagwatwar 2014 [14] | Textizen | Qualitative | Mentioning Platform | Urban Crowdsourcing and Smart Cities |
| Torres et al. 2016 [41] | BeCity | Qualitative | Primary Focus | Urban Mobility |
| Hong et al. 2020 [21] | 311 | Quantitative | Primary Focus | Other: Analysis of Noise |
| Post et al. 2018 [37] | 311 | Qualitative | Secondary Focus | Urban Crowdsourcing and Smart Cities |
| Carrera et al. 2013 [8] | StreetBump | Qualitative | Primary Focus | Urban Crowdsourcing Platform(s) |
| Helmrich et al. 2021 [19] | STORM | Qualitative | Secondary Focus | Other: Flood Management |
| Dılek & Ayözen 2016 [15] | IBB CepTrafik | Quantitative | Primary Focus | Urban Mobility |
| Bulatović et al. 2017 [7] | Budi Odgovoran | Quantitative | Primary Focus | Urban Crowdsourcing Platform(s) |
| Radicchi 2018 [38] | Hush City | Qualitative | Primary Focus | Urban Crowdsourcing Platform(s) |
| Gatica-Perez et al. 2019 [17] | Ma3Route | Quantitative | Primary Focus | Urban Crowdsourcing and Smart Cities |
| Traut & Steinfeld 2019 [42] | Tiramisu Transit | Qualitative | Primary Focus | Urban Mobility |
| Zhou & Long 2016 [45] | Beijing City Lab | Qualitative | Secondary Focus | Urban Crowdsourcing and Smart Cities |
| Atreja et al. 2018 [4] | ichangemycity | Qualitative | Mentioning Platform | Prototype of a Platform |
| Abu-Tayeh et al. 2017 [1] | Zueri wie neu | Quantitative | Primary Focus | Urban Crowdsourcing and Smart Cities |

## APPENDIX II: PLATFORMS INCLUDED IN THE REVIEW

Table 5. Platforms Described in the Selected Studies Selected and Included in the Analysis

| Name | City | Continent | Type | Availability of Data | Data Format | Data Retrieval | License and Privacy | Citation |
|---|---|---|---|---|---|---|---|---|
| Dar Ramani Huria[8] | Dar Es Salaam, Tanzania | Africa | Mapping | Partly Available: Broken Links[9] | OSM (XML) | Direct Download | [10] | [18] |
| Reusing[11] Dublin | Dublin, Ireland | Europe | Mapping | Not Available: Not Public Data | | | | [12] |
| SeeClickFix[12] | | Global | Urban Reporting | Fully Available[13] | JSON | API | [14, 15] | [3, 36] |
| SeeClickFix[16] | Oakland, United States | North America | Urban Reporting | Fully Available[13] | JSON | API | [14, 15] | [6] |
| Map Kibera[17] | Nairobi, Kenya | Africa | Mapping | Fully Available[18] | OSM (XML) | API or Direct Download | [19, 10] | [43] |
| Litterati[20] | Amsterdam, Netherlands | Europe | Urban Reporting | Fully Available (with limitations)[21] | CSV | Direct Download | [22, 15] | [5] |
| FixMyStreet[23] | | Global | Urban Reporting | Partly Available: Depending on City[24] | JSON | | | [3] |
| FixMyStreet[25] | Brussels, Belgium | Europe | Urban Reporting | Fully Available[26] | JSON | API | [27, 15] | [34] |
| Ushahidi[28] | | Global | Urban Reporting | Partly Available: Depending on City | JSON | API | | [9, 36, 44] |
| Smell // Pittsburgh[29] | Pittsburgh, United States | North | Other: Smell | Fully Available | CSV | API or Direct Download | [30, 31] | [22, 23] |

(Continued)

[8] https://ramanihuria.org/en/
[9] The link for the download is broken; Necessary to contact organization to download the data.
[10] No personal data is stored.
[11] http://www.reusingdublin.ie/
[12] https://seeclickfix.com
[13] Use http://dev.seeclickfix.com/ for API; there is a maximum of 20 requests per minute. For more information, consult https://seeclickfix.com/open311/v2/docs
[14] Open Data License (Creative Commons Attribution-Noncommercial-Share Alike 3.0 United States License).
[15] Personal Data is stored but not publicly available.
[16] https://seeclickfix.com/oakland/
[17] https://www.mapkibera.org/
[18] The download and API are done through the OpenStreetMap platform; https://www.mapkibera.org/theme/download/; https://wiki.openstreetmap.org/wiki/Downloading_data
[19] Open Data Commons Open Database License (ODbL).
[20] https://litterati.org/
[21] Direct download until March 2022 and 50000 reports; Need to request data directly otherwise; https://opendata.litterati.org/.
[22] Open Data License (Creative Commons BY-SA 4.0 license).
[23] https://www.fixmystreet.com/
[24] The data are not managed directly by FixMyStreet, but by each city individually.
[25] https://fixmystreet.brussels/
[26] https://datastore.brussels/web/
[27] Open Data License (Creative Commons CC-0 license).
[28] https://www.ushahidi.com/
[29] https://smellpgh.org/
[30] Open Data License (Creative Commons Legal Code).
[31] Personal Data is not stored; Location data is skewed.

Table 5. Continued

| Name | City | Continent | Type | Availability of Data | Data Format | Data Retrieval | License and Privacy | Citation |
|---|---|---|---|---|---|---|---|---|
| NoiseTube[32] | | North America | Noise | Partly Available: Upon Request[33] | CSV | API | [14] | [16] |
| MiC[34] | Hannover, Germany | Europe | Mobility | Not Available: Not Public Data | | | [35, 36] | [40] |
| Zaragoza quejas y sugerencias[37] | Zaragoza, Spain | Europe | Urban Reporting | Fully Available[38] | JSON/ XML/ CSV | Direct Download | [39][15] | [2] |
| Kölner Service-App[40] | Köln, Germany | Europe | Urban Reporting | Not Available: Not Public Data | | | [35, 10] | [28] |
| CycloPath[41] | St. Paul, United States | North America | Mobility | Not Available: Discontinued | | | | [3] |
| MOTIVATE[42] | Greece | Europe | Mobility | Partly Available: Upon Request[33] | CSV | Direct Download | | [31] |
| Textizen[43] | United States | North America | Other: Citizen Engagement | Partly Available: Upon Request[44] | JSON | API | | [14] |
| BeCity[45] | Santiago, Chile | South America | Mobility | Not Available: Discontinued | | | | [41] |
| Bicicas[46] | Castellón, Spain | Europe | Mobility | Not Available: Not Public Data | | | [35, 15] | [2] |
| 311[47] | Vancouver, Canada | North America | Urban Reporting | Fully Available[48] | JSON/ CSV | API or Direct Download | [49, 15] | [21] |
| 311[50] | New York City, United States | North America | Urban Reporting | Fully Available | JSON | API | [51, 15] | [9, 37] |
| 311[52] | Boston, United States | North America | Urban Reporting | Partly Available: Upon Request | JSON/ XML | API | [53, 54, 15] | [37] |

(Continued)

[32] http://www.noisetube.net/
[33] Need to contact the organization to have access to the API.
[34] https://www.mic-app.org/
[35] Proprietary Dataset.
[36] Data is Pseudonymised; Confidentiality agreement for the use of the dataset.
[37] https://www.zaragoza.es/sede/servicio/tramite/4022.
[38] https://www.zaragoza.es/ciudad/ticketing/enlace/servicios/mapa-quejas-y-sugerencias.html
[39] Open Data License.
[40] https://www.stadt-koeln.de/artikel/06903/index.html
[41] Discontinued
[42] http://motivate.imet.gr/
[43] https://www.textizen.com/
[44] Need to contact the organization to have access to the API; https://textizen.com/api
[45] Discontinued
[46] https://www.bicicas.es/
[47] https://www.311canada.ca/vancouver-bc/
[48] Available at https://opendata.vancouver.ca/
[49] Open Data License (Open Government License - Vancouver)
[50] https://portal.311.nyc.gov/
[51] Available upon registration; https://portal.311.nyc.gov/article/?kanumber=KA-01336;https://api-portal.nyc.gov/
[52] https://311.boston.gov/
[53] Open Data License (part of Open311 project)
[54] API access available upon request; https://mayors24.cityofboston.gov/open311

Table 5. Continued

| Name | City | Continent | Type | Availability of Data | Data Format | Data Retrieval | License and Privacy | Citation |
|---|---|---|---|---|---|---|---|---|
| StreetBump[55] | Boston, United States | North America | Urban Reporting | Partly Available: Upon Request | | | [56] | [8] |
| STORM[57] | Norfolk, United States | North America | Other: Flood Management | Fully Available[58] | JSON/ XML/ GeoJSON | API or Direct Download | [10] | [19] |
| IBB CepTrafik Dublin[59] | Istanbul, Turkey | Europe | Mobility | Partly Available: Upon Request[60] | XML | API or Direct Download | [61, 62] | [15] |
| Budi Odgovoran[63] | Podgorica, Montenegro | Europe | Urban Reporting | Fully Available[64] | HTML/ CSV | Dashboard/ Webscraping | | [7] |
| Hush City[65] | Berlin, Germany | Europe | Mapping | Fully Available[64] | HTML/ CSV | Dashboard/ Webscraping | | [38] |
| Ma3Route[66] | Nairobi, Kenya | Africa | Mobility | Fully Available[67] | JSON/ CSV | API | | [17] |
| Tiramisu Transit[68] | Pittsburgh, United States | North America | Mobility | Not Available: Discontinued[69] | | | | [42] |
| Beijing City Lab[70] | Beijing, China | Asia | Mapping | Fully Available[71] | GIS Shapefile | Direct Download | | [45] |
| ichangemycity[72] | Bangalore, India | Asia | Urban Reporting | Fully Available | CSV | Direct Download | | [4] |
| Zueri wie neu[73] | Zurich, Switzerland | Europe | Urban Reporting | Fully Available[74] | JSON/ XML | API | [75] | [1] |

## REFERENCES

[1] G. Abu-Tayeh, O. Neumann, and M. Stuermer. 2018. Exploring the motives of citizen reporting engagement: Self-concern and other-orientation. *Busin. Inf. Syst. Eng.* 60, 3 (2018), 215–226. DOI: https://doi.org/10.1007/s12599-018-0530-8

[2] Unai Aguilera, Oscar Peña, Oscar Belmonte, and Diego López-de Ipiña. 2017. Citizen-centric data services for smarter cities. *Fut. Gener. Comput. Syst.* 76, C (Nov. 2017), 234–247. DOI: https://doi.org/10.1016/j.future.2016.10.031

[55] http://www.streetbump.org/

[56] Personal data policy not specified

[57] https://data.norfolk.gov/Public-Safety/STORM-System-to-Track-Organize-Record-and-Map/a22j-f5hs

[58] https://data.norfolk.gov/Public-Safety/STORM-System-to-Track-Organize-Record-and-Map/a22j-f5hs

[59] https://uym.ibb.gov.tr/hizmetler/ibb-cep-trafik

[60] Depending on the specific dataset needed, it might be required to contact the organization; https://data.ibb.gov.tr/dataset/trafik-indeks-degeri-web-servisi

[61] Open Data License (Istanbul Metropolitan Municipality Open Data License)

[62] Personal data may be stored but kept confidential

[63] http://www.budiodgovoran.me/

[64] The website provides an interface with all the reports in an unstructured form; For more structured data, it is necessary to contact the organization.

[65] https://www.opensourcesoundscapes.org/hush-city/

[66] https://www.ma3route.com//

[67] Access through API available upon registration. https://bitbucket.org/ma3route_team/ma3route-api-documentation/wiki/Introduction

[68] http://www.tiramisutransit.com/

[69] The app was terminated in March 2022

[70] https://www.beijingcitylab.com/

[71] Three levels of data access: free download, email request, shared among research fellows. https://www.beijingcitylab.com/data-released-1/

[72] https://www.ichangemycity.com/bangalore/

[73] https://www.zueriwieneu.ch/

[74] At most 1000 items per query; https://www.zueriwieneu.ch/open311/

[75] Open Data License (part of Open311 project).

[3] S. Ashby, T. Vieira, J. Hanna, F. Abreu, I. Oakley, and P. Campos. 2015. Citizen X: Designing for holistic community engagement. In *ACM International Conference Proceeding Series*, Vol. 28. 178–181. DOI: https://doi.org/10.1145/2808435.2808438

[4] Shubham Atreja, Pooja Aggarwal, Prateeti Mohapatra, Amol Dumrewal, Anwesh Basu, and Gargi B. Dasgupta. 2018. Citicafe: An interactive interface for citizen engagement. In *Proceedings of the 23rd International Conference on Intelligent User Interfaces (IUI'18)*. Association for Computing Machinery, New York, NY, 617–628. DOI: https://doi.org/10.1145/3172944.3172955

[5] A. Ballatore, T. J. Verhagen, Z. Li, and S. Cucurachi. 2021. This city is not a bin: Crowdmapping the distribution of urban litter. *J. Industr. Ecol.* 26, 1 (2021), 197–212. https://doi.org/10.1111/jiec.13164

[6] J. De Melo Borges, T. Riedel, and M. Beigl. 2016. Urban anomaly detection: A use-case for participatory infra-structure monitoring. In *ACM International Conference Proceeding Series*, Vol. 24. 36–38. DOI: https://doi.org/10.1145/2962735.2962757

[7] Nikola Bulatović, Nikola Ćarić, Slobodan Djukanović, Igor Radusinović, and Milica Pejanović-Djurišić. 2017. An example of human-centric sensor network: Be responsible platform. *Wirel. Pers. Commun.* 92, 1 (Jan. 2017), 237–250. DOI: https://doi.org/10.1007/s11277-016-3848-x

[8] F. Carrera, S. Guerin, and J. B. Thorp. 2013. By the people, for the people: The crowdsourcing of "streetbump," an automatic pothole mapping app. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, Vol. 40. 19–23.

[9] Y.-C. Chang, C.-T. Lu, H. Morris, P. Murray-Tuite, and Q.-B. Nguyen. 2011. Community situational awareness and resilience through mobile applications. In *Proceedings of the 8th IEEE International Conference on e-Business Engineering (ICEBE'11)*. 185–192. DOI: https://doi.org/10.1109/ICEBE.2011.36

[10] Alex Costa and Leopoldo Teixeira. 2018. Testing strategies for smart cities applications: A systematic mapping study. In *Proceedings of the Brazilian Symposium on Systematic and Automated Software Testing (SAST'18)*. Association for Computing Machinery, New York, NY, 20–28. DOI: https://doi.org/10.1145/3266003.3266005

[11] Andrew Crooks, Dieter Pfoser, Andrew Jenkins, Arie Croitoru, Anthony Stefanidis, Duncan Smith, Sophia Karagiorgou, Alexandros Efentakis, and George Lamprianidis. 2015. Crowdsourcing urban form and function. *Int. J. Geogr. Inf. Sci.* 29, 5 (2015), 720–741. DOI: https://doi.org/10.1080/13658816.2014.977905

[12] P. R. Crowe, K. Foley, and M. J. Collier. 2016. Operationalizing urban resilience through a framework for adaptive co-management and design: Five experiments in urban planning practice and policy. *Environ. Sci. Polic.* 62 (2016), 112–119. DOI: https://doi.org/10.1016/j.envsci.2016.04.007

[13] Auriol Degbelo, Carlos Granell, Sergio Trilles, Devanjan Bhattacharya, Sven Casteleyn, and Christian Kray. 2016. Opening up smart cities: Citizen-centric challenges and opportunities from GIScience. *ISPRS Int. J. Geo-Inf.* 5, 2 (2016). DOI: https://doi.org/10.3390/ijgi5020016

[14] Kevin C. Desouza and A. Bhagwatwar. 2014. Technology-enabled participatory platforms for civic engagement: The case of U.S. cities. *J. Urban Technol.* 21, 4 (2014), 25–50. DOI: https://doi.org/10.1080/10630732.2014.954898

[15] Esma Dilek and Yunus Emre Ayözen. 2016. Smart mobility in Istanbul with "IBB CepTrafik." In *Proceedings of the IEEE/IFIP Network Operations and Management Symposium (NOMS'16)*. IEEE Press, 1273–1278. DOI: https://doi.org/10.1109/NOMS.2016.7503002

[16] G. Drosatos, P. S. Efraimidis, I. N. Athanasiadis, M. Stevens, and E. D'Hondt. 2014. Privacy-preserving computation of participatory noise maps in the cloud. *J. Syst. Softw.* 92, 1 (2014), 170–183. DOI: https://doi.org/10.1016/j.jss.2014.01.035

[17] D. Gatica-Perez, D. Santani, J. Isaac-Biel, and T.-T. Phan. 2019. Social multimedia, diversity, and global south cities: A double blind side. In *Proceedings of the 1st International Workshop on Fairness, Accountability, and Transparency in MultiMedia, co-located with MM'19 (FAT/MM'19)*. 4–10. DOI: https://doi.org/10.1145/3347447.3356749

[18] E. T. Gebremedhin, L. Basco-Carrera, A. Jonoski, M. Iliffe, and H. Winsemius. 2020. Crowdsourcing and interactive modelling for urban flood management. *J. Flood Risk Manag.* 13, 2 (2020). DOI: https://doi.org/10.1111/jfr3.12602

[19] A. M. Helmrich, B. L. Ruddell, K. Bessem, M. V. Chester, N. Chohan, E. Doerry, J. Eppinger, M. Garcia, J. L. Goodall, C. Lowry, and F. T. Zahura. 2021. Opportunities for crowdsourcing in urban flood monitoring. *Environ. Model. Softw.* 143 (2021). DOI: https://doi.org/10.1016/j.envsoft.2021.105124

[20] Dennis Hilgers and Christoph Ihl. 2010. Citizensourcing: Applying the concept of open innovation to the public sector. *Int. J. Pub. Partic.* 4, 1 (2010).

[21] A. Hong, B. Kim, and M. Widener. 2020. Noise and the city: Leveraging crowdsourced big data to examine the spatio-temporal relationship between urban development and noise annoyance. *Environ. Plan. B: Urban Analyt. City Sci.* 47, 7 (2020), 1201–1218. DOI: https://doi.org/10.1177/2399808318821112

[22] Yen-Chia Hsu, Jennifer Cross, Paul Dille, Michael Tasota, Beatrice Dias, Randy Sargent, Ting-Hao (Kenneth) Huang, and Illah Nourbakhsh. 2020. Smell Pittsburgh: Engaging community citizen science for air quality. *ACM Trans. Interact. Intell. Syst.* 10, 4 (Nov. 2020). DOI: https://doi.org/10.1145/3369397

[23] Y.-C. Hsu, P. Dille, M. Tasota, B. Dias, R. Sargent, and I. Nourbakhsh. 2017. Smell Pittsburgh: A mobile crowdsourced application for reporting and visualizing pollution odors. In *Proceedings of the Air and Waste Management Association's Annual Conference and Exhibition (AWMA'17)*.

[24] Peter Jüni, Franziska Holenstein, Jonathan Sterne, Christopher Bartlett, and Matthias Egger. 2002. Direction and impact of language bias in meta-analyses of controlled trials: Empirical study. *Int. J. Epidemiol.* 31, 1 (02 2002), 115–123. DOI: https://doi.org/10.1093/ije/31.1.115
[25] Pinchao Liao, Yaolin Wan, Pingbo Tang, Chunlin Wu, Yumeng Hu, and Sichun Zhang. 2019. Applying crowdsourcing techniques in urban planning: A bibliometric analysis of research and practice prospects. *Cities* 94 (2019), 33–43. DOI: https://doi.org/10.1016/j.cities.2019.05.024
[26] Dennis Linders. 2012. From e-government to we-government: Defining a typology for citizen coproduction in the age of social media. *Govern. Inf. Quart.* 29, 4 (2012), 446–454. DOI: https://doi.org/10.1016/j.giq.2012.06.003
[27] Euripidis N. Loukis. 2018. Citizen-sourcing for public policy making: Theoretical foundations, methods and evaluation. In *Policy Analytics, Modelling, and Informatics*. Springer, 179–203.
[28] Agnes Mainka, Tobias Siebenlist, and Lisa Beutelspacher. 2018. Citizen participation: Case study on participatory apps in Germany. In *Proceedings of the The Web Conference (WWW'18)*. International World Wide Web Conferences Steering Committee, 915–918. DOI: https://doi.org/10.1145/3184558.3191518
[29] Gilberto Marzano, Joanna Lizut, and Luis Ocha Siguencia. 2019. Crowdsourcing solutions for supporting urban mobility. *Procedia Comput. Sci.* 149 (2019), 542–547. DOI: https://doi.org/10.1016/j.procs.2019.01.174.
[30] David Moher, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G. Altman. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *PLoS Med.* 6, 7 (2009). DOI: https://doi.org/10.1371/journal.pmed.1000097
[31] G. Myrovali, M. Morfoulaki, B.-M. Vassilantonakis, A. Mpoutovinas, and K. M. Kotoula. 2020. Travelers-led innovation in sustainable urban mobility plans. *Period. Polytech. Transport. Eng.* 48, 2 (2020), 126–132. DOI: https://doi.org/10.3311/PPtr.11909
[32] Taewoo Nam. 2012. Suggesting frameworks of citizen-sourcing via government 2.0. *Govern. Inf. Quart.* 29, 1 (2012), 12–20. DOI: https://doi.org/10.1016/j.giq.2011.07.005
[33] Haifeng Niu and Elisabete A. Silva. 2020. Crowdsourced data mining for urban activity: Review of data sources, applications, and methods. *J. Urban Plan. Devel.* 146, 2 (2020), 04020007. DOI: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000566
[34] Burak Pak, Alvin Chua, and Andrew Vande Moere. 2017. FixMyStreet brussels: Socio-demographic inequality in crowdsourced civic participation. *J. Urban Technol.* 24, 2 (2017), 65–87. DOI: https://doi.org/10.1080/10630732.2016.1270047
[35] Gabriela Viale Pereira, Maria Alexandra Cunha, Thomas J. Lampoltshammer, Peter Parycek, and Maurício Gregianin Testa. 2017. Increasing collaboration and participation in smart city governance: A cross-case analysis of smart city initiatives. *Inf. Technol. Devel.* 23, 3 (2017), 526–553. DOI: https://doi.org/10.1080/02681102.2017.1353946
[36] Lisa Poggiali. 2016. Digital futures, analog pasts? Technology and ethnicity in Nairobi. *Proc. Afric. Fut. Conf.* 1, 1 (2016), 6. DOI: https://doi.org/10.1002/j.2573-508X.2016.tb00009.x
[37] A. E. Post, A. Agnihotri, and C. Hyun. 2018. Using crowd-sourced data to study public services: Lessons from urban india. *Stud. Compar. Int. Devel.* 53, 3 (2018), 324–342. DOI: https://doi.org/10.1007/s12116-018-9271-4
[38] A. Radicchi. 2018. From crowdsourced data to open source planning: The implementation of the Hush City app in Berlin. In *Proceedings of the 47th International Congress and Exposition on Noise Control Engineering: Impact of Noise Control Engineering (INTER-NOISE'18)*.
[39] Lisa Schmidthuber and Dennis Hilgers. 2018. Unleashing innovation beyond organizational boundaries: Exploring citizensourcing projects. *Int. J. Pub. Admin.* 41, 4 (2018), 268–283. DOI: https://doi.org/10.1080/01900692.2016.1263656
[40] Nicolas Tempelmeier, Yannick Rietz, Iryna Lishchuk, Tina Kruegel, Olaf Mumm, Vanessa Miriam Carlow, Stefan Dietze, and Elena Demidova. 2019. Data4UrbanMobility: Towards holistic data analytics for mobility applications in urban regions. In *Proceedings of the World Wide Web Conference (WWW'19)*. Association for Computing Machinery, New York, NY, 137–145. DOI: https://doi.org/10.1145/3308560.3317055
[41] S. Torres, F. Lalanne, G. Del Canto, F. Morales, J. Bustos-Jimenez, and P. Reyes. 2016. BeCity: Sensing and sensibility on urban cycling for smarter cities. In *Proceedings of the International Conference of the Chilean Computer Science Society (SCCC)*, Vol. 2016-Feb. DOI: https://doi.org/10.1109/SCCC.2015.7416587
[42] E. J. Traut and A. Steinfeld. 2019. Identifying commonly used and potentially unsafe transit transfers with crowdsourcing. *Transport. Res. Part A: Polic. Pract.* 122 (2019), 99–111. DOI: https://doi.org/10.1016/j.tra.2019.02.005
[43] A. D. Yilma. 2019. Volunteer geographic information in Africa. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, Vol. 42. 1615–1620. DOI: https://doi.org/10.5194/isprs-archives-XLII-2-W13-1615-2019
[44] J. C. Young, R. Lynch, S. Boakye-Achampong, C. Jowaisas, J. Sam, and B. Norlander. 2021. Volunteer geographic information in the global south: Barriers to local implementation of mapping projects across Africa. *GeoJournal* 86, 5 (2021), 2227–2243. DOI: https://doi.org/10.1007/s10708-020-10184-6
[45] Y. Zhou and Y. Long. 2016. SinoGrids: A practice for open urban data in China. *Cartog. Geog. Inf. Sci.* 43, 5 (2016), 379–392. DOI: https://doi.org/10.1080/15230406.2015.1129914

Received 20 December 2022; revised 24 March 2023; accepted 10 May 2023