Collaborative Mapping and the Reliability of Volunteered Data

Christian Voigt
Technology & Knowledge
Centre for Social Innovation
Vienna, Austria
voigt@zsi.at

Susanne Dobner
Technology & Knowledge
Centre for Social Innovation
Vienna, Austria
dobner@zsi.at

Manuela Schmidt
Research Group Cartography
Technical University Vienna
Vienna, Austria
manuela.schmidt@tuwien.ac.at

***Abstract*— Participation platforms, such as OpenStreet Map.org or Wheelmap.org represent a shift from a world defined by the few to a world where almost everyone can participate voluntarily. Emerging cultures of participation offer powerful mechanisms to raise awareness of some of today's most pressing societal problems. However, just because citizens could contribute to these platforms, does not mean that they will actually do it. Engaging volunteers and offering straightforward means of participation whilst simultaneously ensuring that volunteers meet the necessary quality standards remains a known challenge. In this paper, we explore the robustness of a collaborative mapping process, specifically collecting accessibility data of cities' built environment. The paper combines theoretical considerations from the field of participatory design and actual data from the authors' recent experiences with crowdsourcing open accessibility information. Finally, the paper makes the case for enhancing a categorical approach to mapping with a stronger consideration of a map's purpose and a healthy scepticism towards overly simplified crowdsourcing mechanisms.**

Keywords- participation platforms; digital maps; volunteered geographic information; participatory design.

I. INTRODUCTION

Participation platforms, such as Wikipedia.com (creating knowledge collectively), Thingiverse.com (sharing digital designs) or Wheelmap.org (collecting accessibility information on a map) represent a shift from a world defined by the few to a world where almost everyone can participate [1]. Accompanying these platforms are emerging cultures of participation that offer powerful mechanisms to raise awareness of some of today's most pressing societal problems. For example, people have been successfully engaged through the volunteering of geo-referenced data about the scale of an environmental disaster or the level of noise pollution [2] [3].

Fischer [1] makes the point that improving participation platforms requires a shift from 'design for use' to continuously involving users in the development of a service, even if that service is already in use. Put differently, participation platforms depend on their ability to massively engage prosumers (i.e., people who provide parts of the services they consume for free) and deliver the aggregated results of participants in the needed quality [4]. A critical success factor in this effort are users as co-designers (i.e., users who directly participate in the design of the service so that emerging needs are met as soon as they are identified). The focus of our paper is on the design and use of participation platforms that are open source and create open data, thereby adding to the creation of informational commons.

Centerpiece of this paper is Wheelmap.org, a participatory platform and online map service to find and categorize wheelchair accessible places. However, just because citizens have the opportunity to actively contribute to this platforms, does not mean that they will actually do it. Ongoing engagement of existing and new citizens is a known challenge to participation platforms [5] and we cannot simply assume that our theories about interaction, group formation or motivation in the off-line world will also hold in virtual or hybrid worlds. The need for good engagement strategies is clear, more users and more long-term users increase not only the *quantity* of contributions (i.e., the number of places with accessibility attributes) but also the *quality and consistency* of contributions (i.e., the reliability of indicated accessibility conditions). This paper explores the potential of participatory design (PD) as a means to co-design *mapping criteria* in order to increase the quality of mapping initiatives. From its very beginnings, PD in organizations aimed at balancing power relations in order to ensure technology serves all stakeholders. Global participation systems, such as Wikipedia or OpenStreetMap, however, are not so much shaped by managerial, top down decisions but live and evolve through the active participation of those who use the systems. The open source equivalent to centralized management are democratic governance structures, which process users' critical reflections and comments. Nonetheless, the methods of PD are still applicable; interviews, user diaries and visual artifacts (photos or drawings) bring people in and make their voices heard.

Our paper is based on recent experiences with initiatives promoting the mapping of open accessibility information [ref. authors of this paper]. One of these initiatives involved 55 cartography students, who, over the course of three months, mapped places on wheelmap.org. Wheelmap, founded in 2010 by the German non-profit organisation 'Sozialhelden', is an online map service to find and categorize wheelchair accessible places based on a traffic light system: red (not wheelchair accessible), yellow (partly wheelchair accessible), green (wheelchair accessible). The service is based on OpenStreetMap (OSM) project, an open source digital map of the world. OSM contains, among many other things, information about the accessibility of specific points-of-interest, ranging from hospitals and train stations to playgrounds and bars. OSM's growth relies on the ongoing crowdsourcing effort of its community.

There are a number of issues that need to be investigated in order to better understand what influences the quality of collaborative mapping and to what extent participatory design can be a remedy.

- *Semantic issues:* Crowdsourcing physical attributes of geographic places is based on interpretation work, which is inherently plagued by ambiguity. Hence, common sense is an insufficient base for mapping and establishing protocols for action is one of the measures taken to limit ambiguity [2]. The question here is how far can these protocols go and what role can learning and community membership play to help with disambiguation.
- *Digital divide*: Technologies used during online mapping range from paper maps and Apps on Smartphones to Image Databases and more advanced OSM Editors. However, open-source mapping is only effective if people have the physical and social means to access the technology. For example, people need smartphones with appropriate data plans in order to connect to online groups where they can access the latest information and help [6].
- *Internet literacy issues:* Closely related to the issue of 'access to technology' is the fact that people need a minimum of knowledge in order to get connected and use online mapping services. This leads to the question of whether design can inscribe knowledge to minimize the required learning curve for using the technology. Yet, a minimum level of Internet literacy is needed, e.g., understanding the hypermedia structure of the Internet and having a basic orientation in order to navigate between the different sides and services [7].

'*Semantic issues*' and related quality issues with mapping results have been the main motivation to explore volunteer participation, participatory design, semantic issues and mutual learning as a possible solution. The potential role of PD is conceptualized by using Star and Griesemer's notion of 'boundary objects' [8], which conveys succinctly what we need from collaborative processes: consistency of results (i.e., the mapping of reliable accessibility information) and variability in utilizations (i.e., the ongoing refinement of our mapping criteria, co-evolving with our understanding of accessibility and barriers). The paper is organized as follows: In section 2, we discuss collaborative mapping platforms and the role participatory design could take to improve participation quantitatively as well as qualitatively. Section 3 continues with an in-depth discussion of a specific collaborative mapping case, focusing on the operational and conceptual dimensions of the mapping process. Finally, in section 4 we elaborate a non-trivial trade off between the need for a simple yet intuitively compelling categorization system for accessibility mapping. Section 5 concludes with a brief summary of findings and their implications for future crowd-based accessibility maps.

II. COLLABORATIVE MAPPING PLATFORMS

One way of creating engagement is letting users participate in the design or refinement of crowd-based data collections. In the case of volunteering geo-located accessibility data, co-design can have a double motivating aspect: (a) optimizing intuitive use increases mappers perceived self-efficacy and (b) improving the coherence of mapping categories makes a difference for everyone using the map, hence, mappers sense the importance of their actions [5]. It's clear that not every mapping activity can lead to changes in the design of the mapping application, but it can well entail a rethinking of how we design mapping events and what advice to give mappers along the way.

A. Participatory Design for Mapping Applications

We start with Simonsen and Robertson's [9] definition of participatory design as mutual learning situations based on collective reflection. The need to reflect on design decisions and learn from these reflections applies to participation platforms as well. Also DePaula's description of PD as a balancing effort between different actors' needs, motivations, and values in order to create "socio-technical-political conditions that reduce the gap between design practices and use practices" [10, p. 162], holds for participation platforms, at least to some extent. Eventually PD is also evaluated against the degree of empowerment people get from a process that takes on their goals and values. A process that is highly iterative, integrating feedback on design changes and their impacts [11].

B. Digital Maps

Digital maps as participation platforms have become enormously effective tools for raising awareness and influencing power relations [12]. Maps have shifted from representing stable knowledge about territories to data collection platforms enabling the creation of multiple maps on the fly. A trend supporting the uptake of digital maps is the steady increase of mobile communication, which enables completely new ways for citizens to engage with online services in an ad-hoc fashion, wherever they are. 85 per cent of touchscreen phones released from 2010 onwards can use the global navigation satellite system (GNSS) [13]. A well-known example is the *OpenStreetMap* project, founded in 2004 at the University College London with the goal to create a free database with geographic information of the entire world. A plethora of spatial data, such as roads, buildings, land use areas, or points of interest is entered into the project's database. Similar to other community-based projects on the Internet, any user can start contributing to the project and editing data after a short online registration.

III. CASE DESCRIPTION

A. The Purpose of Collaborative Mapping: Open Accessibility Information

An increasingly aging population, as well as a change in awareness of the needs of people with mobility impairments raises the importance of having open information on accessibility. In Vienna alone, 24% of the city's population will be aged 65 plus by 2030 [14]. Open accessibility data include information about geo-located entrances, parking spots or toilets and their accessibility. However, in a wider context, the location of other points of interests (POIs), such as lifts or characteristics of pathways, e.g., their slope and width, also form part of an informational ecosystem that increases the mobility of people with mobility constraints. OpenStreetMap makes these data openly available and free of charge.

Over the last 4 years (2012 - 2015), over 8.800 places on average were tagged each month according to their accessibility using the wheelchair tag (wheelchair={yes, limited, no}) [15]. However, even major tourist destinations, such as London, Vienna or Paris show relatively low percentages (less than 8%) of accessibility related information in OSM like whether a street has sidewalks or not [16]. Hence, even though OSM has a rapidly growing community and has proven to deliver good spatial data quality, completeness of area coverage and longevity of volunteer engagement are remaining challenges for OSM [17].

Geographic information in terms of streets, buildings and other spaces is mostly complete in larger cities, however, this is not the case with open accessibility data. Multiple stakeholders have covert or explicit interests in the mapping of barriers. For example, there is some political brisance to exposing a city's lack of accessibility. This is not a concern if the platform is primarily driven by citizen activism, but gets problematic if a collaboration with city officials, e.g., urban planning or public transport departments, is sought after [18].

But apart from the political dimension of designing and using participation platforms addressing accessibility issues in cities, there is also the challenge of engaging a sufficiently large community that can carry the OSM mission to create a digital map of the world - we would add - including accessibility information. Crowdsourced or volunteer-based services depend on people's interest- and preference-driven decisions of where and when to spend their time. There is a rich body of literature dedicated to 'volunteerism in non-profit organizations', studying the decisions of volunteers in terms of 'engagement', 'commitment' and 'well-being' [19] or using similar concepts describing psychological empowerment of volunteers, including 'sense of community', 'perceived self-efficacy' (i.e., the possibility to master the task at hand) and 'causal importance' (i.e., the understanding that volunteering serves the common good) [5].

The following sections are describing a mapping action, which we organized in collaboration with a group of cartography students. The mapping action had a twofold objective: (a) gaining a better understanding of the current traffic light design for categorizing the accessibility of places and (b) boosting mapping engagement and create awareness around urban accessibility.

B. *Collaborative Mapping Technology: Wheelmap*

The specific application we used for accessibility mapping was Wheelmap.org, an open-source mapping application aiming to support the cause of better wheelchair-accessibility. Once the application is installed, everyone can contribute information about the accessibility of a point of interest (POI). Additionally, if mappers register, they can upload photos and add more specific comments on why a place is not or only partially wheelchair accessible. Registration is kept as simple as possible, only requiring a self-chosen user name and a password. No additional personal information is requested. The goal is to involve as many people as possible and avoid privacy issues or cumbersome registration procedures.

The tagging follows a traffic light metaphor (Fig. 1). Grey indicates places with an unknown status, that is we cannot say whether the place is wheelchair accessible or not. Places shown in green have been tagged as accessible, i.e., one can enter the building with wheelchairs, and for buildings where one would expect a public toilet to be available, the toilet would be accessible as well. Places in red are not wheelchair accessible, that would be the case if the entrance has a step higher than 7 cm and no ramp [20]. When viewing a map, the user will be shown all available POIs from a set of 12 categories, e.g., shopping, sport or tourism.

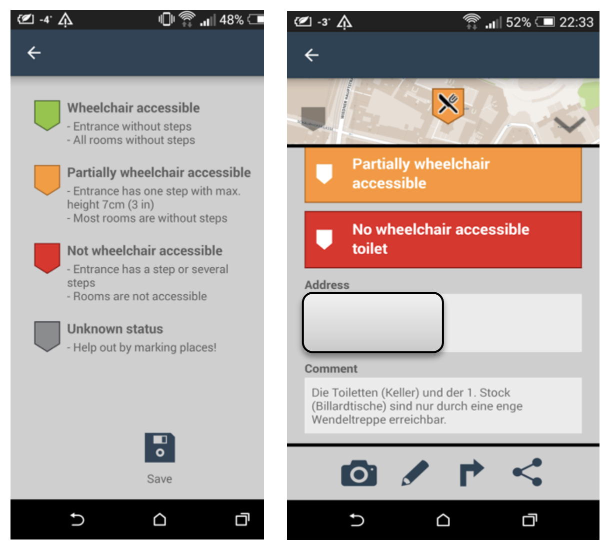

Figure 1. Mapping accessibility on the Wheelmap.

Clicking on the yellow icon for a restaurant (cf. Fig. 1) will open a pop-up window with the address and additional comments.

C. *The collaborative mapping process*

Together with a major university in Vienna, we organized a mapping action following a critical cartography approach [21]. Critical cartography implied that students reflected on the functionality of the digital map, as well as on ways in which the map influenced their views on accessibility. Altogether 55 students (about half of the class, 47%) participated in the voluntary task to map places on the Wheelmap. Two thirds were female students and one third male. We did not record the age of participants, but they resembled a typical, rather homogenous, group of students in their second year at university (approx. 20 - 25 years). The mapping action was introduced during a course called 'Thematic Cartography in Regional Planning' (October to December 2014). Students could obtain bonus points for their

 ISBN: 978-1-61208-517-3

participation, those could be of help if they had missed the better grade by just a few points. Their task included (a) their feedback on their experience when using the Wheelmap and (b) their feedback on their mapping experience, specifically when deciding between the color codes of the mobile mapping application (cf. Fig. 1). In concrete terms, students were asked to:

- categorize at least five places without accessibility information. These places appeared in grey on the Wheelmap.
- revisit at least three places, which have been categorized as 'partially wheelchair accessible'. These places appeared yellow on the Wheelmap.
- consider the appropriateness of the place's categorization and change its status if necessary.

Additionally, we explained that the purpose was to address the non-trivial challenge inherent in a categorization system needed to be simple enough to engage as many volunteers as possible but also meaningful enough to be of help to people searching accessible places. Students recorded their experiences in a mapping protocol consisting of a discussion of places visited including a place's conditions that could explain a categorization (task 1) or a change in categorization (task 2). Almost all students included photographs of the places visited in their protocols and a reflection on how their mapping influenced their views on accessibility in the city of Vienna.

Further information was obtained by two of the authors analyzing the 55 mapping protocols we got. Primarily quantifying students' reasoning about their mapping decisions. All in all, we scanned the protocols for the following information (I) How many barriers had been considered when categorizing a place?; (II) What types of barriers had been considered when categorizing a place?; and (III) In what ways were photos helpful in understanding the categorization of a place? All three types of information were then analyzed in relation to specific mapping decisions, namely (i) changing the categorization of a place; (ii) leaving a place's categorization as is and (iii) categorizing a place for the first time. Options (i) and (ii) were most interesting as we were interested in the effects of considering more than one barrier, possibly broadening the range of barriers or taking a picture of a barrier.

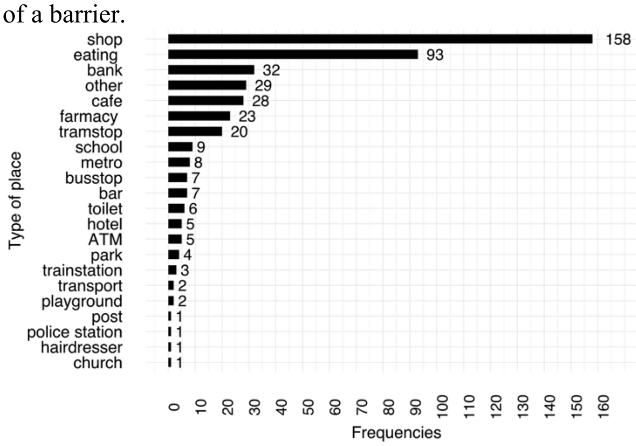

Figure 2. Type of mapped places (n=445).

However, some of our quantifications could be incomplete. For example, a mapper might have contemplated four types of barriers but reported only one in his or her mapping protocol. We believe that this is a limitation inherent to most self-reported data and difficult to prevent, if there is no other, more reliable data source to compare with.

Altogether, 279 new places had been categorized using the Wheelmap App and another 166 places had been reviewed and partly re-categorized (Fig. 2). Mappers found 168 completely accessible places and 277 places with barriers. Out of the 166 revisited places with limited accessibility, 51% remained unchanged and 49% changed, either to completely accessible or not accessible. Shops and restaurants were most prominent among the types of places that had been mapped. Access points to public transport received comparatively little attention.

IV. CASE DISCUSISON

An underlying issue of our case not yet discussed is the 'accountability aspect' when providing accessibility data. Put differently, the question is whether lay people, i.e., volunteers, can be trusted with providing this information and should not trained members of public authorities assume this task. In a review of the adoption of participatory geographic information systems (PGIS), Brown [18] lists several reasons for the fact, that participation in data collection has been promoted more by academics than by government agencies, including fear of the public, lack of experience in participatory processes and distrust in lay knowledge. At the core of these concerns is mostly a misunderstanding in that volunteers are not to be seen as a replacement for technically qualified experts but as a way to add local knowledge or lived experience. Both forms of knowledge, technical and experiential should be considered valuable sources of information to inform users of GIS.

Yet, our initial question was whether accessibility mapping done by lay people was problematic or controversial due to ambiguous or fuzzy classification systems. Since we did not want to compare the accuracy of lay mapping with expert mapping, we focused on the replicability of mapping results. In the end, we found two main conditions that triggered changes of mapped barriers: (1) a place contained multiple, aggregated barriers and (2) the mapper expanded his or her very notion of what a barrier is. The following discusses the mapping process on two different levels [22]:

- The *operational level*: How to apply mapping criteria to more complex buildings (shopping centers, train stations, museums, etc.)?
- The *conceptual level*: How can we make the concept of accessibility more tangible in order to ensure a sufficiently high quality of mapping outcomes?

These levels also reflect the semantic challenges of mapping categories outlined earlier in the introduction of the paper.

A. *Operational Level: How many Barriers are there?*

When assessing the accessibility of more complex structures, e.g., a supermarket, a train station or a bank, we will often find that multiple types of barriers exist. For example, there is an ongoing debate whether supermarkets are acces-

 ISBN: 978-1-61208-517-3

sible if they have no steps at the entrance and sufficient space between shelves, but lack a payment option at the exit that is mounted at a height accessible for wheelchair users.

Hence, before starting the mapping project we emphasized the need to attempt a functional mapping rather than a categorical approach. Functional mapping would start with the question of 'What is the purpose of this place?' and could lead to a discovery of barriers not previously considered. On the contrary, the approach followed by the Wheelmap app (cf. Fig. 1) suggests a categorical approach (steps not higher than 7 cm and sufficient spaces within a location). The height of credit card readers, counters or door handles for example, is not explicitly mentioned.

We are aware that reducing a rather complex concept, such as 'accessibility' to a number of physical properties is a compromise a crowdsourcing platform has to make in order to keep things feasible and draw in as many volunteers as possible. But what consequences does it have if we switch from a categorical to a functional approach for mapping? Fig. 3 compares places with multiple, aggregated barriers with places that had been categorized taking a single barrier into account. As highlighted with the slightly darker bar, if mappers revisited a place already categorized, chances that they were to change the existing categorization were twice as high if they took into consideration multiple barriers (24% compared to 12%).

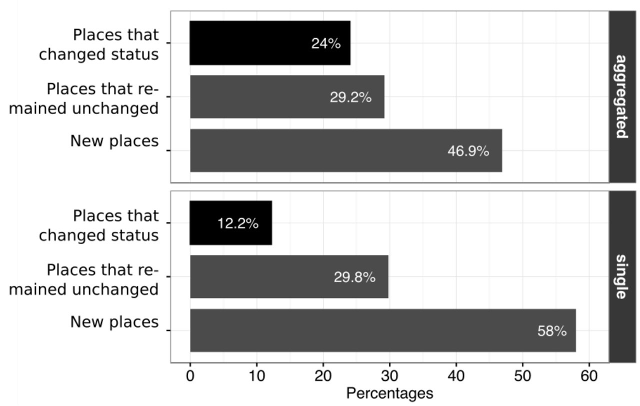

Figure 3. Mapping of aggregated or single barriers (n=277).

However, we cannot tell whether the places that changed their mapping status had already been mapped with multiple barriers in mind or whether the mappers revisiting the place simply saw a combination of barriers where previously only single barriers had been checked. Comments on changes from green to yellow (e.g., non-accessible toilet in a restaurant with an accessible entrance) or on changes from yellow to red (e.g., a movie theatre with accessible entrance but no wheelchair place in the cinema hall) seem to suggest that considering more possible barriers led to the changes.

Fig. 4 compares changes from yellow ('partially accessible') to red ('not accessible') depending on whether multiple or single barriers had been considered. Again the likelihood of a place to change to 'not accessible' is almost twice as high (25% versus 47%) if mappers take into account multiple barriers.

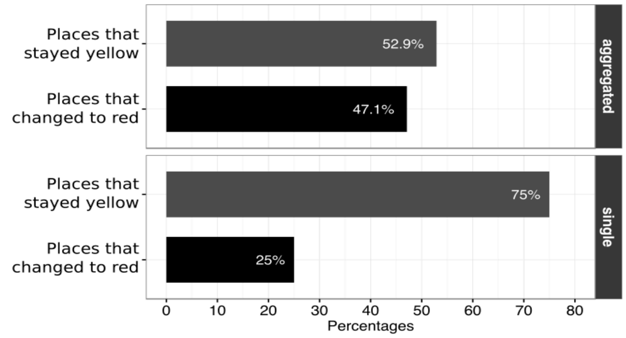

Figure 4. Impact of aggregated barriers on categorization changes (n=127).

Still, the objective of a categorization system cannot be to consider as many potential barriers as possible and thereby reduce the availability of accessible places if this is not absolutely necessary. Students became aware that striking a balance between mapping existing barriers, as well as producing useful accessibility information was a challenge not yet completely solved.

The relatively recent increase of Linked Open Data could provide a solution to his issue in the long term. Rather than trying to capture all accessibility related information through a single application, needed information could be combined accessing different sources. Ding et al. [23] conducted a survey of open accessible information, and found that different sources of similar accessibility information used different levels of aggregation. For example, whereas the accessibility of train stations in the Wheelmap is mostly based on tagged entrances and toilets, similar accessibility information included in the national rail station dataset (UK), is based on tags, such as 'ramp for train access' or 'accessible ticket machines'. Rather than trying to establish an all-embracing standard of tags, Ding and colleagues suggest to link open data. Linked data principles would allow for integrating data sets using different data structures, as ontology matching is a known approach to overcome semantic heterogeneity [23]. One possible first step in that direction could also be to direct users of the Wheelmap to another site, if that site offers additional information to the place the user had just inquired.

B. Conceptual Level: Our Notions of Barriers and the Role of Photos

The right to personal mobility is recognized globally as a human right, as reflected in the Convention on the Rights of Persons with Disabilities of the United Nations, which states that nations: "must take measures to ensure that persons with disabilities have equal access to the physical environment, to transportation, to information and communications, and to other facilities open or provided to the public" [24]. Following from this statement, it becomes clear that mobility and physical accessibility is a precondition to having choices in life, be it the school that is accessible or not, the workplace or the means of transport people with disabilities can or cannot use.

Matthews [25] surveyed different user groups (in regards to age and types of wheelchair) and listed the following most frequently mentioned barriers: steps, high curbs, deep gutters, gravel surfaces, lack of dropped curbs, narrow pavements, steep gradients and cobbled surfaces. Even though this might be already a fairly comprehensive list, given the methodology applied, types of barriers can be differentiated into normative (i.e., prescriptive) barriers and positive (i.e., descriptive) barriers [26]. Since we did not use an a-priori normative framework for our mapping action, we were particularly interested in the formulation and use of descriptive barriers. Fig. 5 shows the types of barriers that had been mapped. The most frequently mentioned barriers were steps (48.8%) and narrow spaces (22.8%). Next were barriers related to height (10.5%) and a category other (7.7%). 'Other barriers' included things like double doors, doors too heavy or ramp too steep.

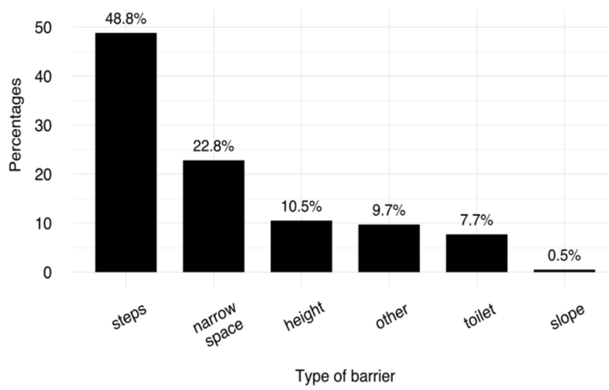

Figure 5. Types of barriers mapped (n=391)

Next, we wanted to see whether the explicit reference to a new type of barriers would influence the possibility that an existing categorization would change.

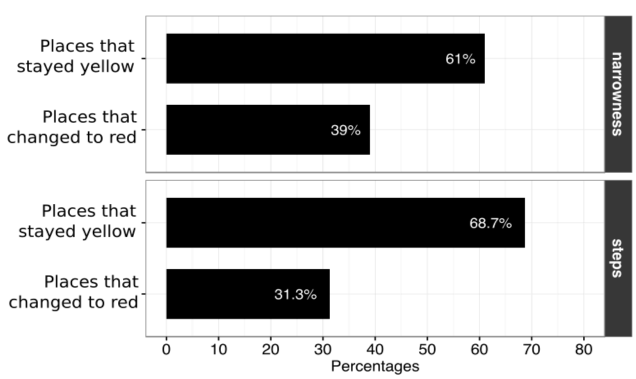

Figure 6. Impact of 'steps' and 'narrowness' on categorization changes (n=124).

For that, we compared 124 places that were tagged 'partially wheelchair accessible' either because they had steps or narrow spaces inside (Fig. 6). We would argue that 'steps' as it is mentioned on Wheelmap's mobile app interface is a prescriptive category and 'narrowness' an emerging, descriptive category. What we can see in Fig. 6 then, is that both categories have similar effects, in 39% of the cases the 'new', emerging category 'narrowness' co-occurred with changing a place into 'not accessible'. Since the majority of the places that changed into 'not accessible' were cafes, bars or restaurants, having emphasized the functional approach to mapping could be another reason for the relatively high impact of 'narrowness' as a new type of barriers.

Throughout the mapping action participants were encouraged to take pictures of the barriers they analyzed. Our initial hypothesis was that photos would help the specification of barriers and therefore enhance clarity and transparency of the mapping decisions. Hence, two of the authors looked through the 215 photos taken during the mapping project and classified them according to their effect on understanding mapping decisions (Fig. 7).

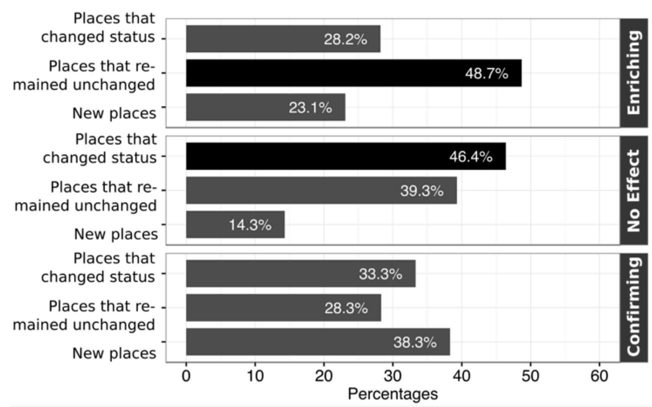

Figure 7. The effect of photos on status clarity (n=215).

A photo was said to be 'enriching' whenever the photo showed more then what was expressed in the verbal description of a barrier.

Figure 8. A clear picture of barriers

For example, rather than having to speculate whether double doors at the entrance might be a barrier that could be overcome, a photo such as in Fig. 8 supports the visualization and individual evaluation of a barrier, be it the shape of the curb or the steepness of the slope that can make a difference. If a photo just showed a panoramic view of a location without a clear focus on a barrier, we decided that the photo had 'no effect' on our understanding of the accessibility of a

 ISBN: 978-1-61208-517-3

place. 'Confirming' photos were similar to Fig. 8, only that they represented less complex situations of single stairs or steps. They are still useful as they help to avoid surprises if users go by verbal descriptions only.

C. Learning with Boundary Objects and Probabilistic Models

One reason to go through a detailed evaluation of a mapping process on an operational and conceptual level was to make a case for learning the pros and cons of mapping categories, as well as learning when a good description of the place is more needed than a general debate about the 'right' mapping categories.

Spinuzzi suggests a methodology that aims to understand 'knowledge' by doing, i.e., "the traditional, tacit, and often invisible ways of how people perform their everyday activities and how those activities may be shaped productively" [11]. Categorization work of volunteer mappers can be researched under just the same premise: What are the often tacit perceptions that shape mapping decisions? Hence, a conceptual extension to PD is the notion that collaborative mapping involves learning, similar to communities-of-practice, where the transition from peripheral to genuine participation requires changes in doing, talking, thinking and feeling [4]. If we think of collaborative mapping as the production of socially constructed knowledge, i.e., a shared knowledge creation experience, then Star and Griesemer's 'boundary objects' [8] can be a useful paraphrase of 'flexible mapping categories'. Boundary objects are " objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use" [8].

If we continue with the metaphor of the 'robust core' of mapping decisions, a prescriptive set of barriers could serve just this purpose. However, Fig. 5 presented only a relatively small data set of 391 barriers and 'narrowness' became an example for a barrier, previously not much considered. What if we were to analyze the accessibility of thousands of places? How many additional types of barriers could we discover and how would we want to map them? We can assume that a very long list of barriers would be impractical in the context of crowdsourcing. When relying on volunteer contributions, we would suggest that the categorization of 'accessibility' couldn’t be managed through a checklist of accessibility-defining attributes, no matter how comprehensive. We would rather aim for mappers to develop a mental model of accessibility in order to decide whether a place is accessible or not.

In such situations, mappers need to be able to adapt their categorization procedures and develop new categories of accessibility in accordance to the place they want to map. Barsalou [27] suggests two ways for how we acquire new categories: (a) we learn from exemplars (several objects have overlapping characteristics and therefore suggest a category) and (b) we learn by recombining features of existing categories. An example for the latter would be the combination of an attribute like 'width of passage' with 'available space in front of a door' to form a new category 'maneuvering space'. In a shop that has just one long corridor, wheelchair users should be able to turn around at the end of the corridor, especially if they use an electric wheelchair. The underlying idea would be that it is not enough if a wheelchair can move ahead, if in fact the user of a wheelchair needs to make a turn.

V. Conclusion: Co-Design Drives Engagement

The paper started with the claim that large scale participation platforms offer new possibilities for addressing long-standing societal problems, such as creating awareness for the accessibility of cities. We then presented collaborative mapping and digital maps as a typical instance of a participation platform which in many aspects is already a success story, offering an open source alternative to commercial products, such as Google Maps. Next, we linked collaborative mapping to the case of Wheelmap.org, an accessibility mapping platform built on top of the OSM. Using wheelmap.org as a case study, we concentrated on issues around the operational and conceptual foundations of the mapping process. The case discussion made clear that 'conceptualizations of barriers' and 'rules of mapping' are critical components of an application's design and impact the quality of the mapping done.

Being foremost concerned with ambiguities and reliability issues of accessibility mapping, we focused on identifying issues with mapping complex places and - often tacitly hold - concepts of accessibility and barriers. We found that efforts to raise awareness of accessibility barriers often faced the challenge that the public cannot relate to accessibility data if they are not able to relate to the meaning of accessibility, either because they think it does not apply to their lives or because they cannot make the link to the personal context of their daily experiences [28]. Yet, if we want people to challenge their believes and to contribute to improving the accessibility of their cities, we need mechanisms that allow people to contextually relate with accessibility. Research on awareness raising through crowd-based accessibility maps by Goncalves [28] has shown the effectiveness of contextual cues when people are asked to relate with past experiences or memories. Moreover, without implying causation, Goncalves showed that people who took pictures during an accessibility-mapping event reported considerably more places than those participants who did not take pictures.

Yet, the implicit engagement strategy in this paper has been to make crowdsourcing also a co-design and mutual learning activity. To summarize, this paper (a) highlighted the need for switching from a categorical to a functional approach for mapping; (b) demonstrated the value of involving volunteer mappers as co-designers in order to optimize designs at the operational and conceptual level; and (c) suggested an explicit learning component as part of the collaborative mapping process, using a boundary objects metaphor in order to balance flexibility and feasibility when collaboratively mapping accessibility.

ACKNOWLEDGMENT

This research has been supported by cap4access, a project funded by the European Commission in the 7th Framework Program.

REFERENCES

[1] G. Fischer, "Understanding, fostering, and supporting cultures of participation", *interactions*, vol. 18, no. 3, pp. 42–53, 2011.

[2] M. F. Goodchild, "Citizens as sensors: the world of volunteered geography", *GeoJournal*, vol. 69, no. 4, pp. 211–221, 2007.

[3] E. Hornecker et al., "UbiComp in opportunity spaces: challenges for participatory design", in *Proceedings of the ninth conference on Participatory design: Expanding boundaries in design-Volume 1*, pp. 47–56, 2006.

[4] P. Ehn, "Participation in design things", in *Proceedings of the Tenth Anniversary Conference on Participatory Design 2008*, pp. 92–101, 2008.

[5] J. Gonçalves et al., "Citizen motivation on the go: The role of psychological empowerment", *Interacting with Computers*, vol. 26, no. 3, p. 196-207, 2014.

[6] N. Selwyn, "Reconsidering political and popular understandings of the digital divide", *New Media & Society*, vol. 6, no. 3, pp. 341–362, 2004.

[7] A. J. Van Deursen and J. A. van Dijk, "Modeling traditional literacy, Internet skills and Internet usage: An empirical study", *Interacting with computers*, vol. 28, no. 1, p. 13-26, 2016.

[8] S. L. Star and J. R. Griesemer, "Institutional Ecology, `Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39", *Social Studies of Science*, vol. 19, pp. 387–420, Aug. 1989.

[9] J. Simonsen and M. Hertzum, "Participative design and the challenges of large-scale systems: Extending the iterative PD approach", in *Proceedings of the tenth anniversary conference on participatory design 2008*, pp. 1–10, 2008.

[10] R. DePaula, "Lost in translation: a critical analysis of actors, artifacts, agendas, and arenas in participatory design", in *Proceedings of the eighth conference on Participatory design: Artful integration: interweaving media, materials and practices-Volume 1*, pp. 162–172, 2004.

[11] C. Spinuzzi, "The methodology of participatory design", *Technical Communication*, vol. 52, no. 2, pp. 163–174, 2005.

[12] J. W. Crampton, "Maps as social constructions: power, communication and visualization", *Progress in Human Geography*, vol. 25, no. 2, pp. 235–252, 2001.

[13] M. Schaefer and T. Woodyer, "Assessing absolute and relative accuracy of recreation-grade and mobile phone GNSS devices: a method for informing device choice", *Area*, vol. 47, no. 2, pp. 185–196, 2015.

[14] Statistics Austria, "Population census und structure", 2016. [Online]. Available: http://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/bevoelkerung/index.html. [Retrieved: September, 2016].

[15] R. Spindler, "OpenStreetMap Wheelchair History: A subset of wheelchair tagged nodes of a Planet OSM-Full-History", in *Unpublished Database*, 2015.

[16] M. Bakillah et al., "Toward a collective tagging Android application for gathering accessibility-related geospatial data in European cities", in *Agile Conference*, pp. 21-26, 2015.

[17] M. Haklay, "How good is volunteered geographical information? A comparative study of OpenStreetMap and Ordnance Survey datasets", *Environment and planning B: Planning and design*, vol. 37, no. 4, pp. 682–703, 2010.

[18] G. Brown, "Public Participation GIS (PPGIS) for regional and environmental planning: Reflections on a decade of empirical research", *Journal of Urban and Regional Information Systems Association*, vol. 25, no. 2, pp. 7–18, 2012.

[19] M. Snyder and A. M. Omoto, "Volunteerism: Social issues perspectives and social policy implications", *Social Issues and Policy Review*, vol. 2, no. 1, pp. 1–36, 2008.

[20] Hans Voss, "D3.2 Technical Design, Collective Awareness Platforms for Improving Accessibility in European Cities & Regions", in *7th Framework Programme*, 2015.

[21] J. W. Crampton and J. Krygier, "An introduction to critical cartography", *ACME: an International E-journal for Critical Geographies*, vol. 4, no. 1, pp. 11–33, 2005.

[22] F. Barcellini, L. Prost, and M. Cerf, "Designers' and users' roles in participatory design: What is actually co-designed by participants?", *Applied ergonomics*, vol. 50, pp. 31–40, 2015.

[23] C. Ding, M. Wald, and G. Wills, "A survey of open accessibility data", in *Proceedings of the 11th Web for All Conference*, pp. 37-40, 2014.

[24] United Nations, "Convention on the Rights of Persons with Disabilities", 2007. [Online]. Available: http://www.un.org/disabilities/default.asp?navid=15&pid=150. [Retrieved: September, 2016].

[25] H. Matthews, L. Beale, P. Picton, and D. Briggs, "Modelling Access with GIS in Urban Systems (MAGUS): capturing the experiences of wheelchair users", *Area*, vol. 35, no. 1, pp. 34–45, 2003.

[26] A. Páez, D. M. Scott, and C. Morency, "Measuring accessibility: positive and normative implementations of various accessibility indicators", *Journal of Transport Geography*, vol. 25, pp. 141–153, 2012.

[27] L. W. Barsalou, "Deriving categories to achieve goals", *Goal Directed Learning. MIT Press, Cambridge MA*, pp. 121–176, 1995.

[28] J. Goncalves, V. Kostakos, S. Hosio, E. Karapanos, and O. Lyra, "IncluCity: Using contextual cues to raise awareness on environmental accessibility", in Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 17-24, 2013.