

# **PITFALLS AND PROGRESS IN PARTICIPATORY MAPPING**

Addressing accessibility and representation through the novel application of  
alternative interfaces and development of an Open Science framework

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## ABSTRACT

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Participatory Mapping has been used for many years as a way of collecting and collating views on spatial questions from citizens, be it specific stakeholders in a planning decision or the wider public on matters of local importance. The data collected can provide unique insights into spatial challenges that may not be available through other means. With the current climate crisis and need for rapidly updated energy and transport infrastructure in the UK, collaborative knowledge is critical in creating plans that are both effective and acceptable to local people. Whilst there has been a rapid growth in the use of Participatory Mapping since the development of Web 2.0, the methods with which it is conducted have not advanced simultaneously to the technological potential. Challenges including ineffective spatial representation, accessibility barriers and a lack of transparency have restricted replicability and progression in the field. This thesis investigates both the current state of Participatory Mapping as a wide-ranging and rapidly growing field, and also begins to address these issues raised in the literature. The transparency of the field is assessed through the first large-scale systematic review of Participatory Mapping (following the PRISMA Protocol), from which an Open Science framework for best practice in future research is produced. Two novel Public Participatory GIS interfaces are then introduced to demonstrate how citizens' views might be better represented through the use of more complex spatial units, which support and contextualise participant choices to challenge the reliance upon overused and under-considered spatial primitives. Finally, to illustrate how participant accessibility can be improved whilst maintaining high data standards, a case is presented for using notitative sketch mapping, ensuring that the technological requirements remain the responsibility of the researcher and not the participant. The two empirical papers are supported by a case study exploring the potential for local energy and transport planning developments in the Outer Hebrides, UK.

It is clear from the systematic review that there are a number of areas of weakness in how Participatory Mapping research is reported, including a lack of transparency around participant numbers, demographics and incentivisation. This research presents a clear milestone, from which the issues articulated can be addressed through use of the subsequent framework, ensuring future work is more transparent and replicable. The empirical studies further demonstrate how the field might advance, both in regard to representation of spatial entities and accessibility in participation. The examples given in this thesis successfully demonstrate that there is real scope for alternative methods to shake up the stagnation in the field without placing further technical requirements on the general public. In a rapidly changing and challenging world, meaningful and inclusive public engagement is critical in ensuring sustainable energy futures, therefore it is of vital importance the methods through which this is done are both effective and veracious to ensure the best outcome for all.

## **DECLARATION**

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For the past four and a half years I have been  
Under the supervision of the  
Champions that are Jonny and Sarah,  
Killing it in their fields.

The process has been neither smooth nor easy  
However, it has come to an  
End.

Thank you to all who have helped  
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Really appreciate all the brews, bakes and mango.  
I should also shout out to my main girl Phoebe, and  
Extra props to the lads along the way.  
Smashed it.

# 1.

## INTRODUCTION

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### 1.1 Background

Public participation has the potential to access hitherto unknown data and information, unable to be captured by traditional sources and incorporating the knowledge and values of citizens (Godwin and Stasko, 2017). One such form of involving the public in decision making is through Participatory Mapping. Participatory Mapping is an umbrella term, covering a multitude of methods used for collecting and compiling spatial data from the wider public, such as Public Participatory Geographic Information Systems (PPGIS), Sketch Mapping and Mental Mapping. Participatory Mapping has become an established subfield of geography, used to collate individual views and ideas from a range of non-expert stakeholders in the decision-making process, and enhance engagement from historically marginalised groups (Czepkiewicz et al., 2018; Anderson et al., 2009; Elwood, 2006; Bozeman & Sarewitz, 2005). It is widely accepted that to include multiple different parties is advantageous in the decision-making process, and provides a more comprehensive understanding of the ways in which people interact with the world around them (Huck et al., 2016; Carver et al., 2009; Anderson et al., 2009; Perkins, 2007; Evans & Waters, 2007 & Montello et al., 2003).

The field of Participatory Mapping experienced an initial flurry of activity in the early 2000s with the proliferation of Web 2.0 and advances in computer technologies, however there has been very little progress in terms of advancing the methods being used. Researchers persist in

using outdated methods that are more reflective of historical cartographic practice and the limitations of early computers than of their suitability for the task of collecting and representing the ideas and opinions of citizens affected by the decision-making process (Huck et al. 2019). The widespread use of such methods results in an over-reliance on familiar tools and methods used to collect spatial data from the public, with the easiest option being favoured as opposed to the most effective or appropriate for each individual situation, for example using simple point markers to identify areas. Whilst the field as a whole is in need of reinvigorating, this thesis is framed specifically around the two key challenges highlighted by Huck et al., (2017) that limit the potential success of Participatory Mapping: the effective representation of spatial features; and maximising accessibility for participants. With increased popularity of the use of public consultation in a wide range of sectors, it is critical to use the most appropriate methods not only to obtain the most informative data, but also strengthen community engagement and support.

## **1.2 Representation in Participatory Mapping**

As with all Cartesian mapping systems, Participatory Mapping relies on the simplification and generalisation of spatial features into reproducible features on a 2D map surface in order to represent the real world in a usable format. Representation, for the purposes of this thesis, refers to the ways in which geographical features are shown on a map, and stored in databases. Participatory Mapping examples in the literature tend to rely on spatial primitives (i.e. basic points and polygons) to represent complex spatial thoughts and feelings into readable and replicable formats (Brown, 2012). Used uncritically, these basic forms can fail to provide those participating with the appropriate means to express nuanced ideas adequately, resulting in participatory data being collected but neglected in decision-making

(Huck et al., 2018). Whilst it is frequently acknowledged in the literature that these traditional approaches are unsatisfactory when it comes to representing non-expert opinion, their usage persists and consequently restricts the veracity of participatory data in decision-making (Brown & Kyttä, 2018; Robinson et al., 2017; Huck et al., 2014 & Goodchild, 2011). To address this requires a shift from the normative approach of collecting complex information based on basic spatial primitives, and instead considering more specialised spatial representations, supported by bespoke interfaces (e.g. Huck et al., 2014; Evans & Waters, 2007). These alternative spatial units can then be specifically designed to generate information which is better targeted at the specific situation, as opposed to being predicated on convenience, convention and availability.

### **1.3 Accessibility in Participatory Mapping**

As public participation is increasingly used for governance and associated decision-making across multiple scales, progress needs to be made in ensuring methods are not only providing appropriate representations for the question being asked, but also accessible to all who wish to participate. Accessibility, for the purposes of this thesis, refers to the ease of physical and intellectual access for a wider audience to participate and move towards more equitable methods of data collection. Whilst few would dispute that engaging with communities and encouraging public participation in decision making can reduce levels of conflict and increase depth of knowledge, certain groups are still vulnerable to omission. In particular, the increased use of web-based forms of Participatory Mapping, can exclude those who may not have the necessary skills, inclination, access to computer technologies or access to high-speed internet (Gottwald et al., 2016). Whilst there are clearly advantages to using online platforms and digital mapping tools, such as the ability to collect spatial data rapidly, remotely and

whenever the participant chooses; highly technical solutions are not appropriate in every situation (Huck et al., 2014). For example, older adults may have physical difficulties such as visual impairments or reduced fine motor skills, which become barriers to the use of digital mapping technologies (Gottwald et al., 2016; Vrenko and Petrovic, 2015). As a number of studies have found that those who participate in participatory research predominantly fall into the older age brackets, it is vital to ensure that the tools used are accessible (Brown, 2017; Haworth et al., 2016; White and Selwyn, 2013; Kyttä et al., 2013). Although older adults are not alone in the potential difficulties accessing participatory research, increasing accessibility to meet their needs can improve the user experience for the wider public as a whole (Gottwald et al., 2016; Meng & Malczewski, 2010).

#### **1.4 Significance and Scope**

Rather than simply acknowledge the challenges around representation and accessibility in Participatory Mapping (as has been done widely in the literature), this thesis aims to present new methods and a novel framework with which they can be addressed. Funded by the EPSRC Power Networks CDT, this research is conducted in the discourse of addressing future energy challenges, an emotive and ever developing subject area. In this sector, participatory forms of mapping provide a valuable method to conduct trade-off analysis whilst simultaneously co-designing suitable and sustainable energy landscapes with local communities (Stremke & Picchi, 2017). To meet an ever increasing demand for energy coupled with an increased need for clean energy sources to meet emissions targets, it is necessary to create new renewable power infrastructure such as wind turbines. The siting of new infrastructure of this scale can be a source of concern for members of the public, who often predict negative impacts upon themselves, the environment, or both. Whilst public

opinion is gaining increasing recognition as a valuable source of information for decision makers, the methods by which those opinions can be collected are often quite rudimentary and poorly suited to the representation of complex spatial thoughts and feelings. The result of this is that public dissatisfaction with power installations is often high and planners miss out on opportunities to engage the public in the decision-making process.

This research presents novel methods of spatial data collection, designed to support public involvement in decision-making. In partnership with Barra and Vatersay Community Ltd., the isles of Barra and Vatersay in the Outer Hebrides, UK are used as a case study, as residents have collaboratively produced a local energy plan in preparation for future energy challenges. This pre-existing engagement in and understanding of energy challenges, coupled with the remote island location and a prevalence of natural beauty over infrastructure means that working with the local residents to obtain the best results for all parties involved is critical. Using a case study (see section 3.2) is not only an effective means of demonstrating the bespoke Participatory Mapping tools, but it also, critically, supports the intellectual arguments within each chapter. The arguments have wider academic and practical relevance which go beyond the case study location itself.

By providing real world examples to demonstrate how the arguments in each chapter might be applied, the potential for improved participatory decision making can be realised. It is hoped that in doing so, participatory spatial data will be more readily used in informing policy, rather than merely a box-ticking exercise. With this, more informed decisions can be made which benefit the decision-makers by improving long term outcomes, reducing costs and minimising local challenges, as well as benefiting those who participate by being able to

more effectively inform the policy or infrastructure developments in question. Although the arguments are supported with case evidence, the intention is that the frameworks and methods presented are easily transferable into other sectors and geographical locations.

## **1.5 Research Questions**

To address the key challenges of representation and accessibility in Participatory Mapping, the overarching aim has been broken down into three distinct but interconnected research questions:

1. Who is it that participates in Participatory Mapping research and how?
2. How can PPGIS better support the researcher in the question they are asking, and the participant in the answers they are providing to better represent spatial information?
3. To what extent can the use of a non-digital interface improve accessibility for participants whilst still producing data that can be rigorously analysed in order to inform policy?

The first question (Chapter 4) determines the extent of the problems around representation and accessibility in the field of Participatory Mapping which, although identified, are not fully defined in the literature. Using a desk-based systematic review of the literature, this chapter reports who exactly it is that tends to participate in these surveys and how they are carried out. This is done following the Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) Protocol, a framework for the systematic extraction of data from an extensive literature review, to minimise sampling bias and ensure that the literature is collected and reviewed in a formalised and efficient manner. Once it is ascertained who

exactly takes part in these Participatory Mapping surveys (i.e. is it specifically targeted social groups) and what methods are used, measures can then be taken to ensure their ideas are effectively represented and methods used are accessible or appropriate for the specific situation. Through conducting a systematic review of the field, the original contribution to knowledge is the production of a set of recommendations endorsing an Open Science approach to Participatory Mapping.

The second question (Chapter 5) addresses the issue of spatial representation in Participatory Mapping, looking at how researchers might better support both those asking and answering the questions under investigation. This chapter makes an intellectual argument for researchers to consider creating specialised interfaces and alternative spatial units to ensure that participants can get their point across effectively. It also highlights the importance of designing the interface to ensure that the nature of the question being posed is one which the general public can be reasonably expected to answer without requiring specialist skills or knowledge. These points are demonstrated by trialling two bespoke PPGIS interfaces which utilise alternative spatial units to answer two considered questions. The contribution to knowledge presented in this chapter is the conclusion that both the tools *and* questions need to be carefully designed in order to best support the researcher and the participant in producing usable data.

The third question (Chapter 6) then considers the issues around accessibility, particularly in terms of ensuring methods used retain the ability to be spatially analysed whilst enabling a wider cross section of the population to participate. This is then demonstrated using a paper-based tool for collecting and compiling participatory spatial data to ensure that not only

those who are familiar with, or have access to computer technologies are able to participate, without sacrificing the quality of the resulting dataset or user experience. The contribution to knowledge from this chapter is in the demonstration of how a novel paper-based software can improve accessibility of Participatory Mapping without limiting the capacity for spatial analysis that could be replicated in wider research or used alongside digital equivalents.

Through answering these three questions, this thesis addresses the challenges of representation and accessibility in Participatory Mapping by rigorously defining the nature of the problem. It then presents a practical solution that demonstrates how each intellectual argument can be illustrated in the real world and provides a framework for future work to be developed. By asking the same geographical questions in both, the results from the second and third papers can then be compared with one another in the discussion (Chapter 7) to draw out the limitations that may come from using more specialised methods and how these might be overcome in further work and to better influence policy.

## **1.6 Thesis Outline**

This thesis is written using the ‘alternative’ format, in which the central chapters are written in the style of journal articles and intended for publication as such either preceding submission of the thesis or following it. This introduction has presented a brief introduction to the subject area, as well as the scope and significance of the research, the outline for the remainder of the thesis is as below:

- Chapter 2 provides a comprehensive literature review on existing theories and practices in Participatory Mapping and the wider context in which this sits;

- Chapter 3 gives details on the overarching methodological approach and individual methods used in addressing issues revealed by the literature review as well as a comprehensive overview of the case study used;
- Chapter 4 addresses the first research question through a systematic review of the literature on Participatory Mapping using the PRISMA Protocol to identify issues in the reporting of Participatory Mapping and presents an Open Science framework to minimise them;
- Chapter 5 addresses the second research question using a case study to highlight the benefits of ensuring the question being asked and means to answer it are appropriate for the audience whilst obtaining representative data for the researcher;
- Chapter 6 addresses the third research question, by demonstrating a paper-based method of Participatory Mapping with a case study that balances accessibility with capacity for spatial analyse;
- Chapter 7 summarises the novel findings from each of the three papers collectively, presents conclusions arising from the research, limitations in the methods used and suggests directions for future research.

Chapters 4, 5 and 6 are empirical papers written in journal format. Chapter 4 has been published in the *Annals of the American Association of Geographers*; Chapter 5 has been published in *Transactions in GIS*; and Chapter 6 has been published in *The Journal of Geographical Systems*.

## 2.

### LITERATURE REVIEW

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#### 2.1 Introduction

In order to identify gaps in the field, this literature review first sets out how Participatory Mapping was established then considers a number of issues that have been raised in two fundamental elements: the people, and the technology.

##### 2.1.1 Participatory Mapping

It is widely agreed that involving more views and ideas in decision-making allows for a better understanding of the way people interact with the space around them (Huck et al., 2016; Carver et al., 2009; Anderson et al., 2009; Evans & Waters, 2007 & Montello et al., 2003). The use of public participation is aligned with Ulrich's (1983) concept of 'Boundary Critique', which is built upon the idea that because people conceive ideas and form opinions based on personal experiences, the more parties are involved in a decision, the more solutions will be found. This has the benefit of expanding the boundary of what is considered relevant to a particular decision. These boundaries constructed from differing personal views and understanding are not necessarily fixed, and can overlap or change following interactions with other system boundaries. Whilst systems can become more complex and the task of analysis more demanding as a wider range of opinions are added, the consideration of more possible solutions increases the capacity for problem solving by opening up the solution space. Akin to this is the concept of 'Crowd Wisdom', whereby collective intelligence is used

to harness a variety of solutions to a superior problem, which can then be used to ensure decisions satisfy the needs of multiple stakeholders and garner wider acceptability (Brown et al., 2015 & Surowiecki, 2005). As such, spatial data collected from different stakeholders can benefit decision-makers by gauging satisfaction and identifying concerns early in the decision-making process, which can then reduce objections and maximise utility further down the line (Maquil et al., 2015; Huck et al., 2014).

Geographic Information Science (GIS) is constantly developing to balance contradicting technologies and social practices, diversifying its uses and theoretical frameworks to address concerns regarding access, power structures and representation (Elwood, 2006). GIS is not only used to translate spatial data into cartographic form, but to represent the connections between people and their environment, elucidating these complex patterns and relationships (Obermeyer, 1998).

In the early 1990s, heated debate took place over the future of GIS, with geographic journals providing a platform for provocative essays condemning or supporting the progression of the field. Human geographer, Taylor (1990) instigated by declaring GIS overtly positivist, naively empirical and incapable of achieving anything more than describing the world in an imperialistic manner. Goodchild (1991) responded to this claim by arguing that geography and GIS are well matched to develop one another simultaneously, with the critical perspective of the geographer providing an opportunity to understand and address the biases in digital systems, and GIS providing a means for exploring “profound geographical thought” (Goodchild, 1991; pg 336). Openshaw (1991), took a more defensive stance, intimating GIS users were censored by the “misinformed speculation about what GIS is and does” of human

geographers (Openshaw, 1991; pg 621). Swiftly rebuffed by Taylor & Overton (1991), Openshaw went on to suggest that in fact both sides were raising the same issues, but through different lenses and that “it is particularly important that those who comment on GIS should be properly informed and base their comments and criticism on some knowledge and experience of what GIS can and cannot do” (Openshaw, 1991; pg 465). Despite this, the battle continued through the 1990s following Pickles' (1995) publication of ‘Ground Truth’ which garnered further combative reactions from Openshaw (1997) amongst others making the case for improving the field of GIS instead of trying to dismantle it. Critically, Openshaw (1997; 8) acknowledged the capacity for improvement in the ways in which GIS was being used and the impact it could have, stating: “There is no denying a need for the practitioners of GIS to be more aware of the possible social consequences[...] of the potential role of GIS as an agent in transforming society, and the limitations in the range and nature of the representations that GIS can handle.”

This critique of GIS in the mid-1990s snowballed, with the practice being labelled as techno-cratic and elitist with inconsistent access rights, a myriad of financial barriers and top-down methodologies imposing external perspectives on local problems leading to a distrust and ineffective outcomes (Weiner et al., 1995; Sawicki & Craig, 1996; Craig & Elwood, 1998; Rundstrom, 1995; Harris et al., 1995). Alongside this, an increased enthusiasm for GIS in decision-making placed a level of responsibility on the visual output that could be abused and manipulated to benefit those in power (Dunn, 2007). This meant that the use of GIS may not only exclude those unfamiliar with Cartesian forms (often the people directly affected), but also that valuable knowledge might not be captured effectively, if at all (Sheppard, 1995).

As a reaction to the criticism, more inclusive and participatory GIS techniques evolved in order to better acknowledge the social, epistemological and power implications the process of conducting such research may have (Elwood, 2006). The focus shifted towards providing marginalised communities a voice, using an integration of place-based, non-expert knowledge to aid in addressing issues such as land use disputes (Brown & Kyttä, 2018; Radil & Jiao, 2016; Kar et al., 2016 & McCall & Dunn, 2012). Web 2.0 and the ‘Geoweb’ have been key in the development of GIS, with a wide range of branches developing for different purposes and in different fields (Huck et al., 2014). Due to the broad nature of and scope in applications, a range of often overlapping or contradictory terms are used to refer to the methods used (see Section 4.2.1). Such terms include (but are not limited to) sketch mapping, mental mapping, community mapping, bottom-up GIS (BUGIS), participatory GIS (PGIS) and public participatory GIS (PPGIS) and Digitally Mediated Participatory Mapping (DGPM) to name but a few (Huck et al., 2014; Kar et al., 2016; Godwin and Stasko, 2017 & Brown & Kyttä, 2018; Nicolosi et al., 2020). All have contributed to changing the relationship between researcher and participant, with the underlying goal of combining the qualitative, experiential knowledge of communities with the space around them in order to allow alternate views on the same issue to be mapped and analysed (Huck et al., 2014 & Kar et al., 2016). To refer to the breadth of methods collectively, Participatory Mapping is used as an umbrella term for the collecting and compiling of participatory spatial data (Brown & Kyttä, 2018). Although defined originally by Schroeder (1996) as a multitude of approaches to make GIS and spatial decision-making tools available to all with a stake in the decision-making process, there is some debate over what it entails. For example with some authors describe it as a product of volunteered geographic information (VGI) (e.g. Nicolosi et al., 2020), and others considering it to be the process of producing it (e.g. Brown & Kyttä,

2018). Participatory Mapping in this thesis however can be understood as a multi-agent practice, through which people can communicate their knowledge of, and opinions on, spatial questions utilising cartographic visualisation. Participatory Mapping can therefore be used to incorporate a wide range of views into the decision-making process, narrowing the divide between people and policy (Brandt et al., 2019).

### **2.1.2 Participatory Mapping in Power Networks**

The use of Participatory Mapping is particularly relevant to the field of power networks. With increased decarbonisation, electricity is likely to be used more heavily for heating and transport, which in turn requires the development and siting of new infrastructure (DECC, 2011). A key driver in transforming landscapes has always been energy demand and creation, and as such, the concept of ‘energy landscapes’ has emerged (Pasqualetti & Stremke, 2018). Previously, energy landscapes have been in remote areas away from population centres and scepticism (out of sight and out of mind) however they have now accumulated to such a degree that this is no-longer the case. It is now common therefore, to involve the local population in the decision-making process with the siting of energy infrastructure becoming a co-construction of space and society rather than merely a spatial question (Stremke & Picchi, 2017; Pasqualetti & Stremke, 2018).

Renewable energy initiatives often face opposition from local citizens, conservationists and other stakeholders due to concerns over the trade-off between cultural (the right to the landscape) and provisioning services (renewable energy supply) (Nadaï & van der Horst, 2010). As Stremke & Picchi (2017) state, participatory forms of mapping techniques are a

key practice to conduct trade-off analysis whilst simultaneously co-designing suitable and sustainable energy landscapes with local communities to meet local, regional or national objectives. Participatory Mapping can be used to identify areas of conflict (Huck et al., 2014; Plieninger et al., 2018), hotspots for landscape metrics (Brown and Reed, 2012) as well as obtain qualitative data on existing or proposed infrastructure (Stremke & Picchi, 2017). Huck et al. (2014) for example, used a PPGIS tool to collect local opinions on where best to site wind turbines. The system allowed participants to provide reasoning behind areas highlighted on the map as either particularly suitable or particularly unsuitable, giving greater depth to the data and resultant maps showing areas where the most/least conflict would arise. This system therefore provided valuable insights for planners and decision-makers, whilst helping to limit grievances from the local community.

In order to meet future energy demands of a growing population, whilst also hitting carbon emission targets set within the Paris Climate Agreement, the nature of energy production is changing (Mander et al., 2007). Chu and Majumdar (2012) go as far as to suggest a new industrial revolution will be required to ensure a global energy supply that is sustainable, affordable, accessible and decarbonised. To address the future energy challenges, a complex mix of renewable technologies will be required, such as wind turbines, solar panels and hydroelectric plants, as well as the infrastructure to support an increasingly electrified network (Ghanem et al., 2016). Hein (2005) and Dorian et al. (2006) both highlight the importance of public participation in ensuring the best possible outcome from such developments. The tools currently used such as tally sheets and voting can be effective in creating a decision; however it is unlikely the results fully reflect local knowledge to any great extent in a fair and reliable manner (Stelzle et al., 2017). Engaging with citizens and

obtaining local knowledge in such a way provides the opportunity to ensure such large-scale energy landscape alterations are feasible as well as limiting potential conflicts between stakeholders.

Despite a clear progression since the mid-1990s, Elwood (2006) argued that participatory forms of GIS still fell foul to the same limitations and criticisms as their predecessors, such as representation and inclusion. More than 15 years has passed since this point was first made and whilst significant technological advances have taken place and the limitations often acknowledged, little has been done to address the issues in PPGIS (Robinson et al., 2017; Brown & Kytä, 2018). This chapter will therefore identify gaps in the current field of knowledge before considering how these might be overcome.

## **2.2 The Pitfalls of Participatory Mapping**

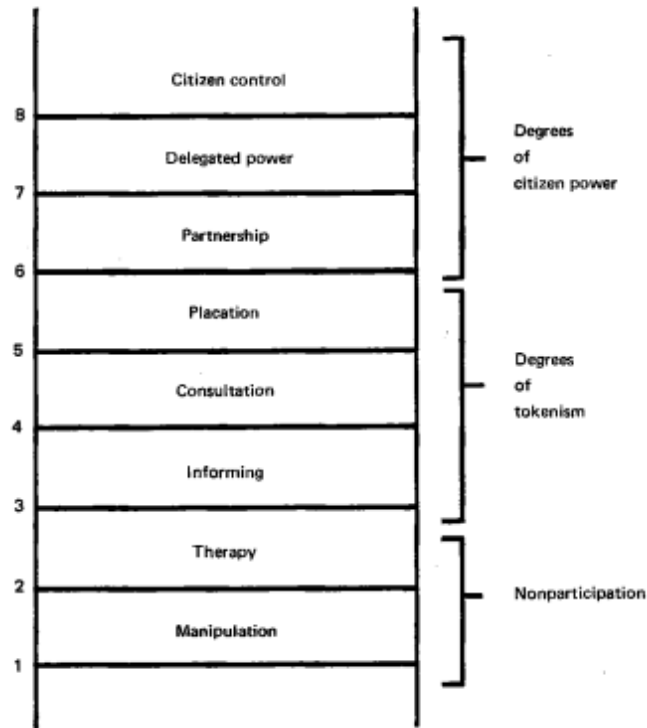
Whilst there are clear advantages to including members of the public in the decision-making process, it is not without issue. Barriers to the effective use of PGIS include (but are not limited to) digital divides (Gottwald et al., 2016), participation inequalities (Haklay, 2016), and ineffective representation in the data produced (Huck et al., 2019). The following section will assess the current literature surrounding barriers to effective Participatory Mapping, firstly by considering those involved, and secondly the technologies.

### 2.2.1 Challenges in Public Participation

At its core, Participatory Mapping has long been intended as a democratising practice celebrating the multiplicity of geographical realities, used to instigate social change and improve policy-making (Sieber, 2006; Schlossberg & Shuford, 2005; Dunn, 2007). It is therefore important to consider exactly who these stakeholders are and how they will be involved.

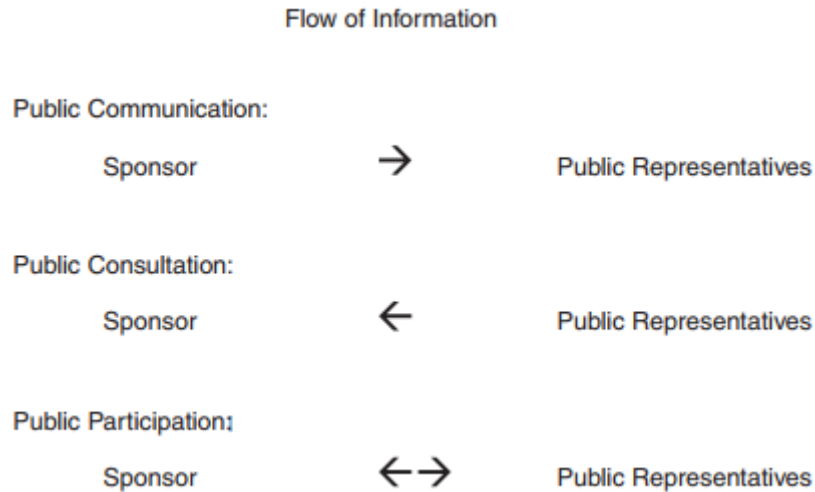
#### 2.2.1.1 Participation

A broad definition of public participation is *“the practice of involving members of the public in the agenda-setting, decision-making, and policy-forming activities of organisations/institutions responsible for policy development”* (Frewer and Rowe, 2005 p253). However whilst providing a general definition, it is arguably too general a statement with no indication as to what level of participation is actually involved. In 1969, Arnstein published “A Ladder of Citizen Participation” (Figure 1) to highlight the importance of redistributed power in citizen participation. The model divided participation into eight ‘rungs’ starting from mere tokenism (for example when hits on a GIS web page are counted) through collaboration (which could involve a meeting with stakeholders to identify issues), to full citizen control with active participation in decisions that benefit a specific locality (Arnstein, 1969).



**Figure 1** Arnstein's Ladder of Participation. Reproduced from Arnstein (1969)

Following Arnstein's lead, other categorisations of participation hierarchies have emerged such as Callon's (1999) three way model. It starts with the lowest ranked 'public education' a one way process, secondly 'public debate' a two way process, and finally 'co-production of knowledge' which actively involves lay people in the production of knowledge. Similarly, Frewer and Rowe's (2005) three types of participation seeks to categorise the term depending on flows of information as shown in Figure 2.



**Figure 2** Frewer and Rowe's Three Types of Public Engagement. Reproduced from Frewer and Rowe (2005)

It is not necessarily true that, as the hierarchical approach suggests, to be on the top most rung is always desirable however, with factors such as culture and politics also having an influence. It is worth noting that involving everyone in a decision may not always be the most appropriate course of action as increasing the level of democracy slows down the speed at which a decision can be made. However, this may just highlight that there is a need for new procedures to be developed that enable quick, reliable and community supported decision-making (Stelzle et al., 2017). The term ‘participation’ can therefore mean markedly different levels of input and power depending on who is defining it and their desired goal (Whitman et al., 2015). The development of participation has taken place across multiple disciplines such as socio-ecological systems (Gunderson, 2001), science and technology studies (Wynne, 2003) and geography (Kindon et al., 2007), for a multitude of purposes. As such, participation holds numerous ideological, methodological and political meanings (Lawrence, 2006).

Sieber (2006) argues that the incorporation of the term ‘participatory’ is immediately problematic as it implies the need for an intermediary to initially involve participants. Whether an academic, decision-maker or software developer, someone must instigate the process for participation, which creates a power dynamic and prevents a truly bottom-up approach. The intermediary will also bring their own assumptions and biases, based on previous experience and beliefs which again can influence outcomes. Whilst it could be understood from this that rather than taking a role of leadership, the instigator should act as a facilitator to encourage collaboration and knowledge sharing in a more organic manner, in practice, this is not often neither feasible nor desirable.

The related approach of Participatory Action Research (PAR) attempts to minimise the impact of the researcher or instigator and potential biases from the outset, rather than simply acknowledging their presence. It offers an alternative mode of science, involving collaboration and co-production of research from defining specific research questions, through to producing outcomes (Whitman et al., 2015). PAR provides a democratic model of precisely who is able to create, own, use and benefit from knowledge; it is driven by participants rather than an outside sponsor or academic (although they may be invited to assist); it is collaborative at all stages, involving discussion and working together, and is intended to result in some form of action, or improvement on the issue being researched (Torre et al., 2012; Whitman et al., 2015). Historically, PAR has been used to research environmental issues in marginalised communities, particularly in the global South (Gavin et al., 2007; Martin and Hall-Arber, 2008). However, there has been a movement in recent years to increase the use of participatory action in other fields and regions. For example, Whitman et al., (2015) used PAR methodologies to address issues in the basin of the River Lune,

Northwest England. This work highlighted a number of difficulties with the approach, however, such as the greatly increased time required to obtain commitment from participants as well as reach decisions on topics and then more specific questions that were of interest to the group. Whilst supported by strong core values around local knowledge, the real-world practicalities of PAR such as funding and time constraints make application difficult. These also introduce sampling biases, limiting the pool of participants to those with a considerable amount of time available and enthusiasm/capacity to commit, leading to outcomes being significantly skewed towards particular demographics.

A more practical approach to take is that of Brown & Kytä (2018) who suggest that whilst the role of the researcher will inevitably impact the outcome of the project, it is not necessarily problematic providing it is acknowledged and steps are taken to understand or respond to positionality. They argue that the success of a project depends more upon the researchers' ability to build and maintain trust with participants as well as understand the power dynamics at play (Brown & Kytä, 2018). Who it is that participates in such research is also therefore of great importance, as well as understanding what might be impacting participation and the social context within which the research is conducted.

#### *2.2.1.2 The Participants*

Without sufficient up-take of participatory decision-making services the potential benefits can not materialise (Viitanen & Kingston, 2009). Who actually takes part in Participatory Mapping is therefore equally as important and also as open to interpretation as how participation is carried out (see Section 4.4.3). 'The public' for example, is often viewed as

an amalgamation of all affected stakeholders which can range from a specific community group engaged in a decision-making process, to a city with multiple interest groups and government bodies, to every resident of a country interested in viewing or contributing to national spatial data (Schlossberg & Shuford, 2005). It is important to identify the scale at which a project applies to then enable the identification of those that may be interested or affected. When the scale is set, it then needs to be decided who within that range will be included in the sample to ensure a broad representation and to capture the knowledge held within different age groups, levels of skill, levels of wealth and different genders for example (Kyem, 2001). This is not to imply that the goal of Participatory Mapping is to simply digitise all local knowledge but rather organise and display key information that would not be otherwise available, in a form that benefits the community (Jordan, 1998).

Public participation is a complicated process with multiple interpretations that lead to numerous expectations and as such, clear aims need to be identified at the outset as well as the methods by which these will be approached as well as the intended purpose of the resultant dataset (Craglia & Onsrud, 2003). Although there has been much evidence to support the use of public knowledge, there is the danger that participatory data is not actually used in decision-making and remains simply a box-ticking exercise (Brown & Kyttä, 2018). Stelzle et al. (2017), found little in the way of validated participatory tools or methods to support decision-making, with most established methods focussing on decisions by single persons. Brown et al. (2015) state that a critical barrier to the use of Participatory Mapping is an uncertainty amongst decision-makers about the quality of the spatial data produced. With certain spatial attributes, the precision of collectively mapped landscape features to the physical realities has been used as a benchmark for the accuracy of the participatory spatial

data (Zolkafli et al., 2017). However, this is often not applicable to the type of questions asked in Participatory Mapping research. Studies have also successfully assessed the ability of non-experts to accurately identify suitable habitats for native species or areas of specific conservation importance demonstrating the validity in the method through comparison to expert-obtained data (Cox et al., 2014; Brown et al., 2014 respectively). However, the basis of collecting spatial data from the public is to explore what is not obtainable from 'expert' sources. As such, if the goal is for the public view to match expert opinion or else be deemed as inaccurate, then the point of obtaining public opinion on the matter is redundant. Zolkafli et al. (2017) suggest that the level of accuracy from such participatory spatial data may be indeterminate and necessitate judgement on the part of the analyst to accept or reject the data as 'valid'. This suggestion again raises concerns over the purpose of using Participatory Mapping however; as if the data produced by the public are not deemed acceptable by the researcher then it may not be the most appropriate method of data collection. Taking this approach opens up the data to bias in interpretation and imposition of the positionality of the researcher influencing the outcome and consequential decisions being made. It is clear to see that there is a need for more credible forms of Participatory Mapping system to maximise the utility of public knowledge in decision-making and ensure the data are given sufficient value, however doing so should not minimise the voices of those involved and ultimately impacted. As it currently stands, whilst some public bodies use participatory mapping to collect spatial data and local knowledge, most do not give adequate consideration to the results and therefore limit the potential success of resultant decisions (Brown & Kytä, 2018).

### *2.2.1.3 Participation Inequalities*

Once the participants have been determined, it is important to consider whether the way in which this is done is equitable. Participation inequality, first recognised by Hill (1992), is the phenomenon that a very small percentage of participants produce the largest proportion of data. Participation inequalities can occur spatially (i.e. cultural factors influencing who participates in certain places) as well as temporally, as those who have been able to contribute over a longer period of time may be able to contribute the 'better' or 'easier' content (Neis & Zipf, 2012). Whilst competition is often thought to increase participation for example by using a leader board, it can also create temporal inequalities between those with more time to contribute or those who signed up earlier. Those lower down the leader board may be put off contributing as they can never hope to 'catch up' with those who began contributing years before (Haklay, 2016). Temporal inequalities can also be linked to social inequalities in participation, for example, not everyone will have the means or time to actively contribute even if they desire to, which is often forgotten when focussing purely on the data and not the metadata of who provided it (Haklay, 2016). Parker (2006) found that the identities of individual participants led to a reduced likelihood of inclusion from people of different identities, where the process itself of defining goals and steps to take, could lead to the exclusion of certain groups and make the aim unclear or not the consensus.

Whilst Participatory Mapping does allow non-professionals to input into decision-making, their views may be over-represented in the output at the expense of others through the system and methods used in data collection (Huck et al., 2014; Dunn, 2007). This can result in false authority being placed on a specific group who are the most able or keen to participate, leaving the results not as representative of the community as they may suggest (Green,

2010). For example when Whitman et al., (2015) conducted PAR in the Lune estuary, Northwest England, their participants were exclusively from the local rivers trust group which is unlikely to accurately represent a cross section of the population. False authority can be present in both the social and technological sides of Participatory Mapping, such as when a specific group or opinion dominates, or an attribute represented in a manner not reflective of reality (Huck et al., 2014; Green, 2010). One case where false authority was highly apparent was the Muncie Action Plan (MAP) project in Indiana, which used a series of public meetings to ask participants to highlight on a map the positive and negative features of the city (Radil & Jiao, 2016). These maps were then subsequently used to identify possible initiatives. However, there was a geographic inequality in the data as the meetings were predominantly located in more affluent areas where participants repeatedly highlighted the less affluent areas as negative. This was noticed at a later date and an additional public meeting was arranged in the less affluent area of town. However, as only a sixth of the overall participants were from the more deprived area, they were still not adequately represented on the map. As the bias wasn't identified at the time, (only highlighted in later academic criticism) the resulting plans favoured the wealthy side of town (Radil & Jiao, 2016). It is therefore not just the responsibility of the researcher/decision-maker to ensure that the community is fairly represented, but also the data once obtained to prevent bias seeping into policy.

It is critical for participation to be carefully considered, designed and implemented (Radil & Jiao, 2016), particularly as participation inequality is not just an online phenomena but also occurs with projects that are predominantly offline (Haklay, 2016). It should be remembered that whilst high contributors receive most attention, they are in fact statistical anomalies,

making up a tiny percentage of the overall population and therefore may not accurately represent the view of a population (Haklay, 2016).

### **2.2.2 Challenges with Technology**

It is apparent that the process of conducting Participatory Mapping is not as straightforward as it may at first seem. Once the challenge of establishing participants has been overcome, the next task is to ensure an effective as well as ethical approach is used that best represents the needs and goals of stakeholders. Although the methods used to facilitate this may vary spatially and culturally, it is clear from the literature that the more effectively the sample represents the specific population as a whole, the greater impact possible (Elwood, 2006; Schlossberg & Shuford, 2005; Carver et al., 2009; Montello et al., 2003; Evans & Waters, 2007; Radil & Jiao, 2016). This section will therefore focus on the barriers to ensuring a fully inclusive Participatory Mapping, focussing initially on ‘digital divides’, before challenging the status quo of spatial representation.

#### *2.2.2.1 Digital Divides*

One of the key issues in Participatory Mapping is a lack of understanding as to how the specific technology selected can influence usability and user behaviour (Brown & Kyttä, 2018). The use of PPGIS in particular evolved rapidly alongside the development of web-based platforms and affordable software (Green, 2010). Dunn (2007) amongst others considers the internet to have opened up the field for web-based public participation in GIS, as well as facilitating discussions, feedback and supporting the decision-making process.

Using a web-based PPGIS means that participants can provide information rapidly, without confrontation or any discouraging atmosphere and whenever they choose (Huck et al., 2014).

It is not always feasible (or desirable) however, to use hi-tech solutions to spatial problems such as web-based mapping platforms like Google Maps API (Google, 2022). Although widely popular due to the easy online access and familiar slippy-map interface, there is an inbuilt assumption that all stakeholders not only have access to high speed internet but the skills and inclination to use it (Huck et al., 2017). Whilst creating a number of advantages through removing temporal and geographical limits, as well as creating a more anonymous environment to air opinions, it does exclude those without the skills to use or ability to access the internet (Gottwald et al., 2016). Whilst the number of people connected to or using the internet continues to grow, as of April 2020 40% of the global population remains offline with vast inequalities apparent that are in many cases worsening (Statista, 2020; Robinson et al., 2015). These digital inequalities exist across a broad range of macro-level and micro-level domains, including age, gender, race and class, and fall under the banner of the ‘digital divide’ (Robinson et al., 2015; Tsai et al., 2015). It is the assumption of universal high quality web-access that leads to a divide between those with and without, and introduces inequalities to PPGIS (Goodchild et al., 2007; Riddleston and Singleton, 2014). Philip et al. (2017) dispute the use of the term ‘digital divide’ suggesting it creates a dichotomous image which implies a distinct boundary between the haves and have-nots, which in reality is considerably more nuanced (see Section 6.1.1). In a similar vein, Blank & Groselk (2015) propose that the digital divide (instead of considering purely the technical inequalities) should consider those able to make use (or not make use) of the benefits the internet offers, especially with the proliferation of smartphones. As there are numerous forms of digital divide, it is certainly

important to address the suggestion of dichotomy, and acknowledge that the issue is often one of relative difference also, depending on societal group and location as well as simply physical access or means (Philip et al., 2017). In reality these differences are considerably more nuanced, therefore, it is now deemed more suitable to refer to ‘digital divides’, to account for the multifaceted reasons behind digital inequalities (van Dijk, 2020).

There are numerous barriers that restrict participation by certain stakeholders in addition to internet access, for example technical expertise or knowledge of map projections (Radil & Jiao, 2016). Research around digital divides often focuses on indigenous or rural communities in developing countries, yet there are a range of other groups who may also have limited or no access to online platforms such as the elderly, disabled citizens and those living in poverty (Rundstrom, 1995; Geertman, 2002; Chambers, 2006; Huck et al., 2014). Although efforts to narrow the divides could on occasion be applied to all groups, there is little research into more differentiated solutions. Due to the high start-up costs of individualised technology and the invisibility of citizens with disabilities in participatory settings, they are often not considered in digital design (Watling, 2011). This can also be the case with the elderly (particularly those with no close relatives) who may be unable to keep up with technological developments or access training in online skills (Hwang & Nam, 2017). Consequently, both groups may find themselves unable to actively participate in decision-making, particularly with the increasing number of services that are now web-based.

Ghanem et al., (2016) raise this point in relation to recent flooding in Lancashire which left a number of homes without electricity for a sustained period. Residents without power were unable to find out information over the phone, and were simply re-directed to the DNOs

(Distribution Network Operators) website. Those with limited mobility or no access to the internet were cut off with no knowledge of when the power would return or advice on what to do. As the DNO had not considered digital divides in its flood plan, residents had to rely on the help from neighbours who, in some cases, they previously didn't know. With the onset of climate change, the number of extreme weather events such as this are on the rise, so ensuring effective online training and facilities are provided or putting community-based systems in place could ensure the safety of those most vulnerable (Klinger & Owen Landeg, 2014). These experiences could both serve to shape and be shaped by Participatory Mapping. In knowing where vulnerable citizens reside (though this brings with it complex data protection issues) or creating networks of assistance, spatial information can be presented to the emergency services and care providers to reduce the impact of such events. Although web-based PPGIS do allow non-expert input to the decision-making process, their viewpoints may be over-represented as those without the access to computers or the skills to participate online are excluded and therefore not heard (Huck et al., 2017; Dunn, 2007).

There is, however also the argument that digital tools may in fact be able to reach user groups that are in other ways excluded from traditional forms of participation, be it for geographic, social or cultural reasons, providing that the selected software is adapted to each different context or user group (Brown & Kyttä, 2018; Stelzle et al., 2017). One of the pitfalls of more conventional participation events such as workshops or public presentations is that they suffer from being limited in size and often access only a small, motivated participant group. Digital tools on the other hand hold the potential for vastly higher levels of participation by being available to anyone with access to the internet (Stelzle et al., 2017). With increased proliferation however, it is prudent to be aware that the creators and owners of the apps or

websites used bring with them their own limitations and agendas which in turn should be considered for analysis (Kar et al., 2016).

A common alternative to digital methods is the use of paper-based methods such as Sketch Mapping, wherein a paper base map or satellite image is provided for participants to manually draw on with pen or pencil, or add markers too such as stickers (Boschmann & Cubbon, 2014). Whilst demonstrably more accessible, the fixed format introduces alternative challenges such as scale and generalisation. The flexibility of a digital, slippy map interface is lost (for example, being able to zoom in on a certain area), with instead a fixed scale and physical size being required which therefore limits the precision and accuracy with which participants can contribute (Yabiku et al., 2017). One way to address this is to use larger maps, permitting a larger geographical area to be covered (i.e. Haworth et al., 2016, Yabiku et al., 2017; Usher et al. 2020), however there is a limit to which this is feasible and practical in the field. This can not only limit the level of detail in the dataset, but also influence the scope of the question being asked (as the spatial scale of the question will define how generalised the dataset produced is), creating a tradeoff between the depth of insight and generalisability of results (Gunderson & Watson, 2007). It is clear that digital participation is not necessarily better or more effective than low-tech options nor vice versa, but instead that the appropriateness of the method for the specific situation is key (Brown & Kyttä, 2018). As Participatory Mapping places a heavy emphasis on the importance of local knowledge, it is seen as a necessarily place-specific technique and therefore should be relevant to that place to achieve optimal results for both researchers and participants (Radil & Jiao, 2016).

Digital divides are not a technological issue alone, but also impacted by geographic, economic and social barriers. Digital inequalities exist across multiple scales including age, gender, race and class (Robinson et al., 2015). The challenges older adults face in engaging with digital technologies are much covered in the literature (e.g. Gottwald et al., 2016; Vrenko & Petrovic, 2015; Barnard et al., 2013). Whilst there is agreement that physical barriers exist, there are also concerns over high upfront costs creating slower uptake of new technologies amongst older adults (Barnard et al., 2013; Carpenter & Buday, 2007; Lam & Lee, 2006). Rather than being a simple economic reason, the upfront cost was more of a deterrent due to issues around technological self-efficacy (Barnard et al., 2013; Tsai et al., 2015; Carpenter & Buday, 2007; Lam & Lee, 2006). For example, Hill et al. (2015) for example, found that one of the main concerns for older adults engaging with new technology was unintentionally damaging expensive equipment.

Efforts to address these challenges are apparent, for example in the UK free wireless internet (and often computer training) is available in all public libraries (Berry, 2011), however despite going some way to tackle the physical aspect of the digital divides; this does not address the attitudinal barriers such as low technological self-efficacy, for example fears of 'getting lost' in the computer (Hill et al., 2015). When contrasting online and offline participation, White and Selwyn (2013) and Gottwald et al. (2016), found older participants preferred an offline option as they were less likely to use a computer at home (although numbers are increasing). Conversely, a PPGIS study in Helsinki found those in the older age bracket to be over-represented when compared with census data and younger people under-represented due to fewer time constraints (White and Selwyn, 2013; Kytä et al., 2013).

In providing online services to a select group of people, governments and agencies miss out on the opportunity to interact with other societal groups, and a more representative proportion of the population (Bélanger & Carter, 2009). For example it has been noted that there is a gap in empirical studies looking into the exclusion of those lacking computer literacy from PPGIS studies (Steinmann et al., 2005). Whilst it can be true that provisions made for one social group (such as older adults) may benefit another, there is little literature available on specialised tools or methodologies for these other groups. The internet is increasingly being used as a new political sphere for participation in decision-making. Whilst creating a number of advantages through removing temporal and geographical limits, as well as creating a more anonymous environment to air opinions, it does exclude those without the skills to use or ability to access the internet (Gottwald et al., 2016).

#### *2.2.2.2 Spatial Representation*

Blackstock et al. (2006) argue that the validity of public involvement of any type depends on credible, accountable and transparent methods of representation which connect individuals and groups to the decision-makers. In turn, these ensure a broad range of interests are taken into account and presented accordingly (see Section 5.1.1). Much of the Participatory Mapping in the literature uses the traditional spatial representations (i.e. simple points and polygons that have become synonymous with the field over the past three decades) to simplify complex social and geographic features into readable formats. Brown (2012) suggests that using points either on a paper map or online platform is the simplest way to collect spatial data whilst yielding the highest response rates, reduced levels of bias and greater participation. This seems a very simplistic approach however considering the imprecise manner in which people interact with the physical world and is disputed in the

literature on ‘vague’ or ‘fuzzy’ geographies (Huck et al., 2014; Fisher, 2000; Varzi, 2001; Montello et al., 2003). It could certainly be argued that what people perceive to be true should not be simplified and mapped in the same way as a building or point with very specific boundaries. Whilst in some situations the use of such representations are valid and appropriate, the uncritical use of spatial primitives can result in poor representations of the complex relationships between people and place, particularly in Participatory Mapping which is focussed on human perceptions and experience (Huck et al., 2019). Although their limitations are widely recognised, their uncritical use is still prevalent (Brown & Kytä, 2018; Huck et al., 2014 & Goodchild, 2011).

It could be argued that the spatial thoughts and feelings of an individual cannot be adequately reduced to a precise point or boundary in the same way as a building or landmark. The geographical uncertainty with which people perceive and experience the world moves it away from being purely spatial, but also to incorporate societal and cultural values (Mackaness & Chaudhry, 2013; Goodchild, 2011). Humans do not typically refer to precise boundaries in their environment, instead using notions of place, connecting emotion and experience to spatial entities (Huck et al., 2014; Evans & Waters, 2007). As a means of collecting valuable and nuanced socio-spatial data, Participatory Mapping similarly should enable the effective representation of these interactions (Evans & Waters, 2007). For example, Brown et al.'s (2014) PPGIS to assess the value of public lands provided participants with point markers to indicate areas used for recreation (i.e. where they like to walk) could be better represented by a line or polygon than a point. With the technological advances that have taken place since the millennium, it seems inopportune that the methods used in Participatory Mapping have not advanced simultaneously. Huck et al. (2014) begin to address this through the

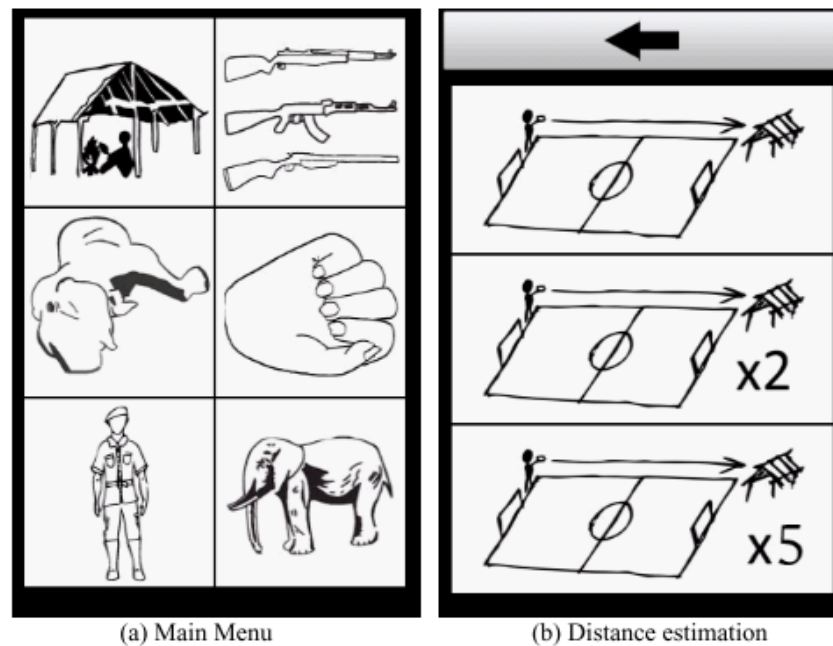
development of the ‘Spraycan’ tool (see <http://map-me.org>) which allows the unclear boundaries to be represented, rather than enforcing ‘artificial precision’ (after Montello et al., 2003). Enabling participants to represent a ‘vague’ area rather than precise bounds permits the collection of empirical data from the public that embraces inherent vagueness without the imposition of artificial precision in the data-collection process (Huck et al., 2019). Although this goes some way to break away from the uncritical use of spatial primitives or applying false boundaries, there is considerably more that could be done to take advantage of the technology now available, and that has been commonplace in desktop GIS for a number of years.

If the human experience is not being visualised and represented adequately, and representations are instead selected only for ease of analysis, it minimises the impact of and justification for involvement of the public in the process. The current over-reliance on familiar methods being used in the collection of nuanced and complex data dictates the nature of representation used, instead of ensuring it is the most suitable for the question being asked (Huck et al., 2019).

### **2.3 Progress in Participatory Mapping**

Whilst it is clear from the above that there are still a number of issues with Participatory Mapping, there have been attempts made to overcome challenges such as digital divides, and developments towards more bespoke systems. Stevens et al. (2013) for example, developed a mobile application specifically to use with Mbendjele hunter-gatherers in the Congo basin rainforests to gather information regarding the activities of commercial poachers. Stevens et

al. (2013) used mobile phones with a specialised graphical interface (using images of the activity spotted and approximate distances based on football fields as shown in Figure 3) to side step language barriers and illiteracy amongst the indigenous group.



**Figure 3** Graphical interface for the collection of poaching data. Reproduced from Stevens et al. (2013)

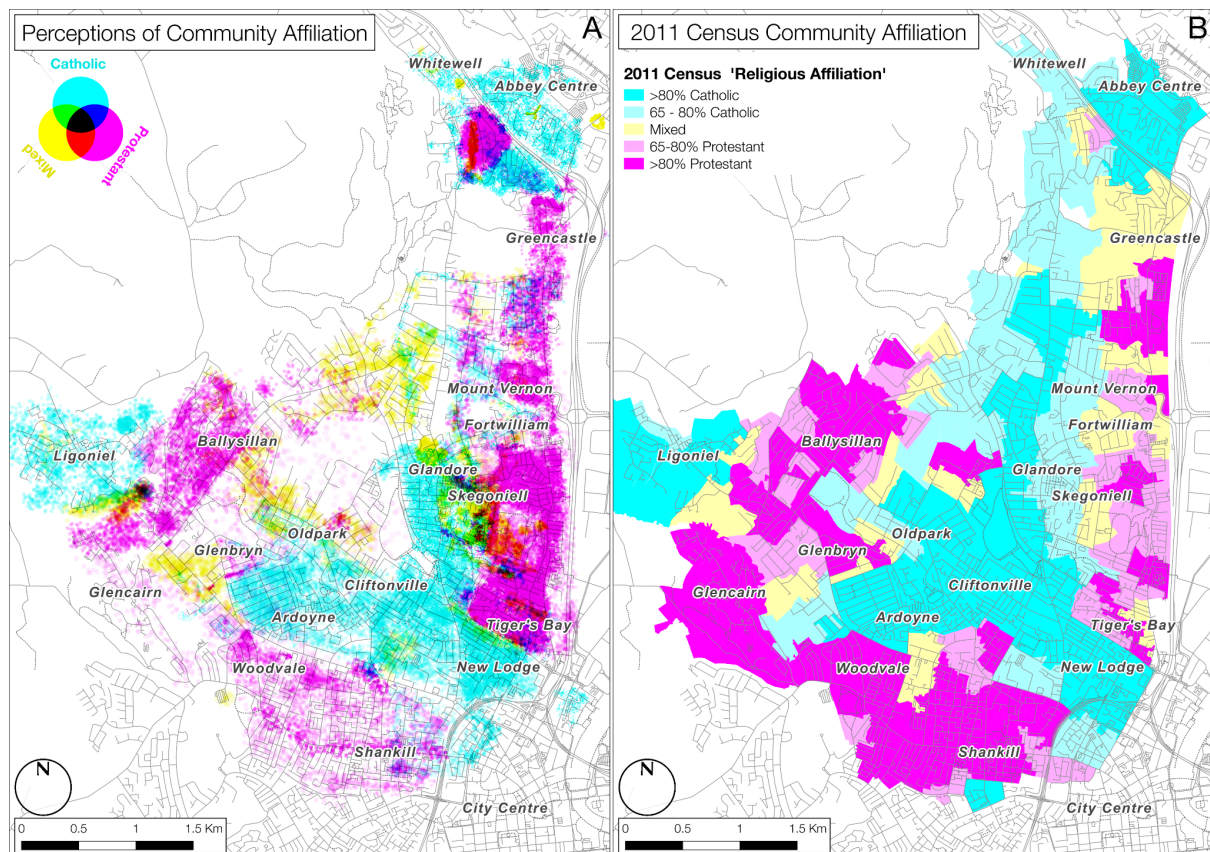
Whilst succeeding in addressing barriers regarding language and digital familiarity, the tool requires specific mobile phones that can withstand the elements in a rainforest environment as well as additional hardware for charging the phones using cooking pots (Stevens et al., 2013). Although innovative, the method required significant financial input and therefore may not be feasible in other contexts. The use of graphics instead of cartography or text

however could be transferable and increase usability of less familiar technologies to cross other divides.

In a Western context, the body of literature on the use of technology amongst older adults has been steadily increasing. One strategy in particular that appeared a number of times was that of using tablets rather than desktop computers (Delello & McWhorter, 2017; Tsai et al., 2015; Wu et al., 2015; Winstead et al., 2013). Cisco (2010) found that physical barriers such as not being able to press down on keys or small buttons, or understand complicated interfaces prevented many older adults from engaging with computer technology. As tablets have smooth touch screen controls and icon-based interfaces, these offer a solution. Tsai et al. (2015) also found that tablets reduced the issue of self-efficacy, by appearing smaller and less intimidating to older adults thus reducing concerns over breaking them or 'getting lost'. This uses a similar logic to that of Stevens et al. (2013), and suggests a move towards more specialised software that enables a clear, simple user experience without relying on complex instructions or overwhelming options.

With regard to the issues around representation of spatial features, Huck et al.'s (2019) research on segregation in Belfast, Northern Ireland provides an example of progress in the field. The research sought to create a novel methodology that would permit the collection of empirical socio-spatial data from the public that embraced the inherent vagueness and perceived form of the areas in question without imposing artificial precision at any stage. By using a 'spraycan' tool combined with data from GPS trackers, the perceptions of residents were effectively visualised and represented on the map. Figure 4 shows the difference between formal census data and Huck et al.'s (2019) approach and clearly suggests that the

local experience differs from the census data in a number of areas, demonstrating the importance of using the most suitable tool for the question, rather than just relying on what has been done previously.



**Figure 4** Map of perceived community affiliation contrasted with small area census data.

Reproduced from Huck et al. (2019)

Godwin and Stasko (2017) present a similar study, contrasting spatial data on nodes, paths and edges collected from sketched mental maps of local residents, with official crime data in three cities across the USA. By considering both the nodes and the paths between them, the results can be used to support crime prevention in more precise areas as the official crime

data is based on points rather than lines. The use of lines in Participatory Mapping, particularly PPGIS, is not as common as conventional GIS, with the dominance being with points and polygons. However studies such as this highlight the potential value to be found with lines or other more specialised representations if used in an appropriate manner.

## **2.4 Conclusion**

Through the literature assessed in this review, a number of key challenges can be drawn out to highlight the gaps in the field and identify where further study is required. Despite thirty years of Participatory Mapping research having taken place since Carver (1991) suggested the use of public participation through customised GIS, issues of representation and accessibility are still as prevalent today as at its inception (Obermeyer, 1998; Elwood, 2006; Robinson et al., 2017; Brown & Kyttä, 2018). As it is becoming more commonplace for Participatory Mapping to be used in governance and associated decision-making, it is essential to minimise these barriers and draw from the experiences found in the literature to improve practice in future work. In order to conduct any Participatory Mapping research it is vital to consider who is participating and what level of involvement is required, so that both the researcher and participants are clear on the matter.

Ensuring methods used are accessible to different societal groups (for example though minimising the influence of digital divides) enables a wider viewpoint to be obtained, ultimately leading to more effective decision-making. Omission of certain groups can also lead to the production of inaccurate representations of communities and lending false authority and bias to those who have access (not only to the technology but also sufficient

and relevant data) and the ability to participate. These issues must not only be addressed in the literature, but also in practice if the ethos of empowering marginalised groups with Participatory Mapping is to be maintained. The researcher/decision-maker also is a key part of the process and should act as a facilitator rather than leader, encouraging collaboration and knowledge sharing but also acknowledging how their positionality might impact outcomes (Brown & Kytä, 2018).

Despite vast technological advances since the origins of Participatory Mapping and some evidence of new techniques in spatial representation emerging (e.g. Huck et al., 2019; Godwin and Stasko, 2017), the uncritical use of point-based map interfaces still dominates (see Section 4.2.2) . This can limit the representativeness of the data collected and effectiveness of the resulting outcomes. By ensuring that social, cultural and geographic requirements are taken into account when designing the tool/methods to be used, more comprehensive and thus successful data collection can take place. This should in turn account for those groups left vulnerable to omission, though this assumption is yet to be thoroughly tested. Although this suggests more specialised, unique tools and approaches will be required for each new study, Participatory Mapping is context specific and therefore it could be argued that generalisation is not an option (Sieber, 2006). Encouraging the production of any new tools/systems to be open source in terms of both software and methodologies could minimise these barriers whilst simultaneously enhancing knowledge sharing and transparency in the field.

This review has explored two key challenges in the field of Participatory Mapping: the accessibility of the methods used and the way in which participant knowledge and perception

is represented. Whilst these issues are frequently identified, little is done to address them. This thesis will therefore begin to do so, by considering how Participatory Mapping tools can be more effectively produced and the subsequent research reported in order to obtain a more representative understanding of local knowledge, adding value for both the participants and the researcher.

### 3.

## METHODS

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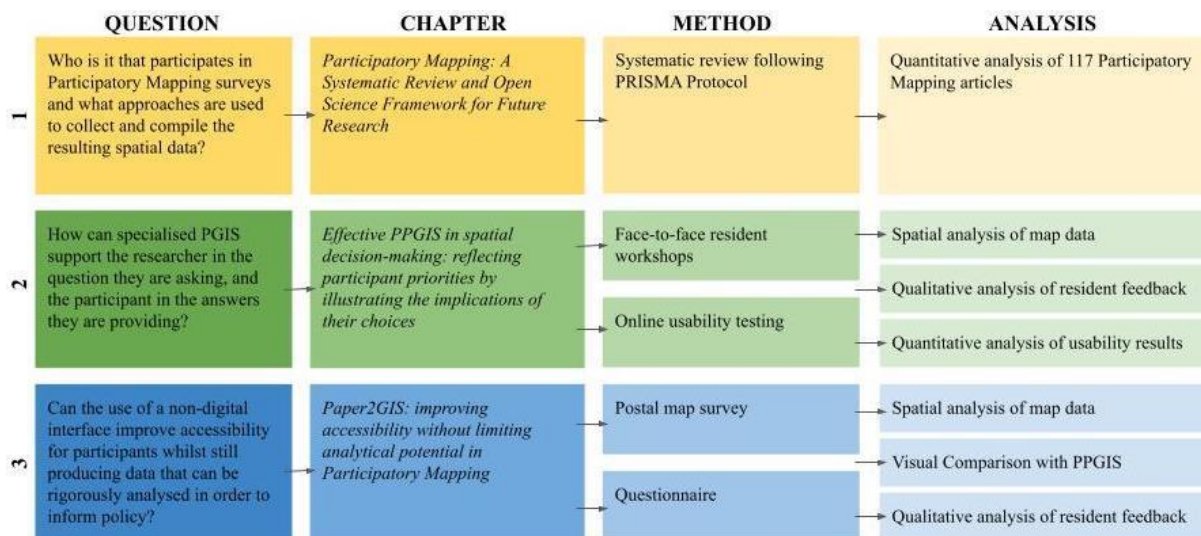
### 3.1 Introduction

This PhD research provides a much needed stock-take of the field of Participatory Mapping and investigates how it might be improved given the persistent challenges identified in Chapter 2. The main focus for the research process is to use bespoke tools for spatial data collection to promote better public engagement in decision-making around power network infrastructure, as a detailed case study. To fill in the emergent gaps in knowledge that arose from the literature review, three research questions have been developed:

1. Who is it that participates in Participatory Mapping research and how?
2. How can PPGIS better support the researcher in the question they are asking, and the participant in the answers they are providing to better represent spatial information?
3. To what extent can the use of a non-digital interface improve accessibility for participants whilst still producing data that can be rigorously analysed in order to inform policy?

To answer the research questions, three individual chapters are presented. The first research question is answered using a desk-based, systematic review of Participatory Mapping literature, providing an unprecedented overview of the field, whilst the second and third

research questions utilised a real-world case study and purpose-built systems (Figure 5). The outcomes of each are then evaluated in order to advance the field.



**Figure 5** Methodological approach to the three research chapters

It was clear from the literature that there are considerable research gaps in the field surrounding issues of representation and accessibility, yet little action to improve the *status quo* in academia. The chapters within this thesis not only provide a rigorous analysis of the current state of the field but make practical steps to begin to address the issues embedded within it.

### 3.2 Case Study

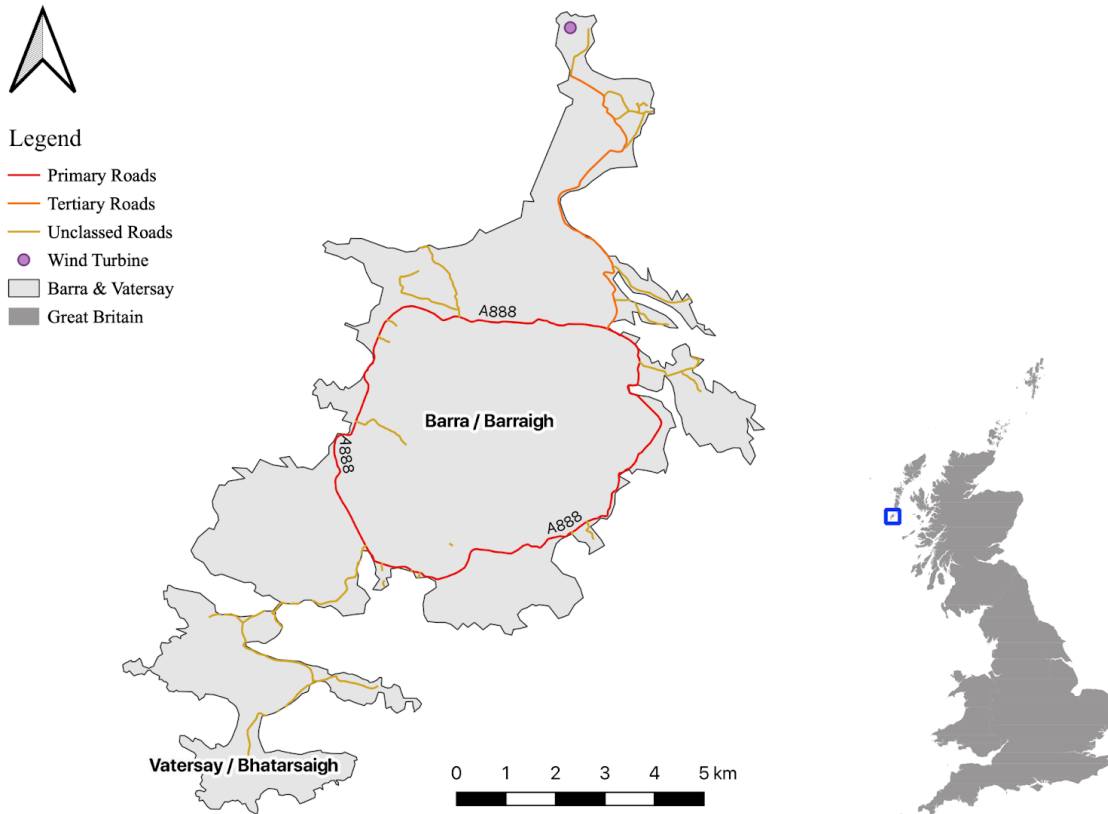
Chapters 5 and 6 both use a case study to test the theoretical arguments made within them. Case studies are used to explore new processes in a holistic manner (considering both the

processes being investigated and context simultaneously) without the limitations of strict guidelines, enabling an open and flexible approach to data collection (Meyer, 2001). For this research to address the gaps found in the literature review, specific criteria were required for the case study:

- a location that faced specific energy related challenges that required spatial solutions
- a small population with pre-existing awareness and engagement regarding the energy challenges
- a demographic that would likely be adversely impacted by digital divides
- a natural geographic boundary e.g. an island population

A case study approach is an appropriate method for exploring the above research questions as it enables meaningful answers to be obtained from participants to which the questions being asked are relevant in a way that would not be possible with a non-place based study. Other methods could have been used to collect data on the systems presented in this thesis, such as an ‘in the wild’ approach where users are able to use the systems for their own research (for example as used by Huck et al., 2014), however as the systems are compared to one another (in Chapter 6) it was necessary to have control over how they were applied. Through analysis of pre-existing networks, the isles of Barra and Vatersay, Outer Hebrides, UK were identified as the case study location as they meet each of the criteria required of a case study for this research as set out above.

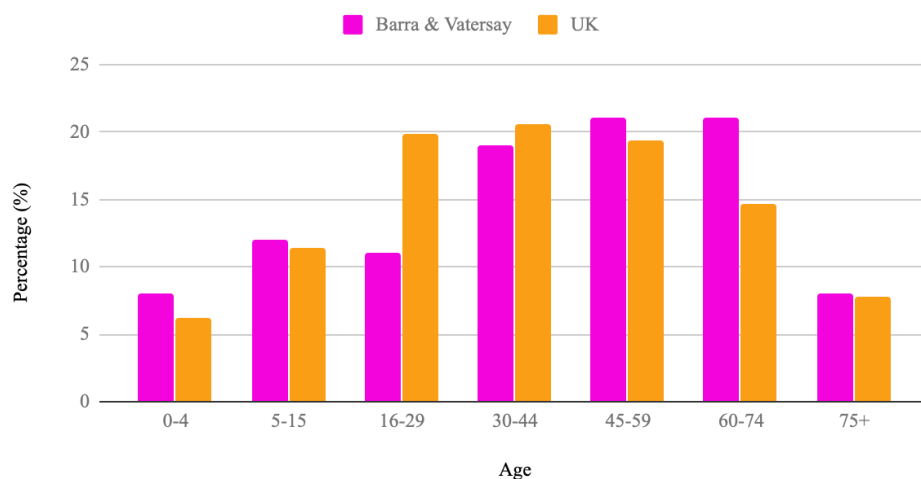
The isles cover a combined area of approximately 70 km<sup>2</sup> and host a population of approximately 1,300 (CNE Siar, 2011). Barra and Vatersay (two separate islands joined by a short causeway) consist of machair (low-lying grassy plains), hills and small lochs (illustrated in Appendix 1). The majority of the population resides in hamlets and crofts along the coastline, leaving the centre of the isles largely uninhabited. Residents of the isles have recently produced a 'Local Energy Plan' (referred to as 'the Plan') to assess their current and future energy needs, opening up opportunities to obtain local views on challenges already identified as important (Local Energy Scotland, 2018). The Plan specifically identifies the production of electricity and limited infrastructure for active transport infrastructure as two areas of concern. These issues are largely due to the remote location of the isles, which makes importing fuels of any kind challenging and expensive. The isles also provided a good opportunity to explore the use of alternative approaches to participatory mapping as not only were there spatial questions that needed addressing and a population already engaged in energy provision, but also in the landscape of the isles themselves. The fact that the only restriction on the sample area was the physical boundary provided by the Atlantic Ocean, removes any biases that might be caused by sample areas selected based on arbitrary administrative boundaries, such as county limits or postcode zones. To this end, the isle of Barra and Vatersay, Outer Hebrides, UK presented an excellent case study (Figure 6).



**Figure 6** The isles of Barra and Vatersay, Outer Hebrides

The energy infrastructure on the isles is currently very restricted, comprising a single mains connection to the grid and a one wind turbine at the North of the isles. The majority of the energy used domestically is produced through oil-powered boilers, requiring oil to be shipped in from mainland Scotland, at high cost to the user. Just one, single track, primary road (A888) circumnavigates the island of Barra which, coupled with an extremely small number of footpaths and pavements, means that the transport systems on the isles are no longer adequate. This problem is compounded further during the summer months by high levels of cycle tourism since the opening of the popular Hebridean Way cycle trail in 2017, which uses the already overwhelmed network (Sustrans, n.d.). These factors have meant that the isles experience high levels of fuel poverty and have created an over-reliance on private transport for travelling even short distances (Local Energy Scotland, 2018). Although there is already

one community-owned 900kW wind turbine on the northern peninsula of Barra, the addition of further local renewable energy sources coupled with a network of new footpaths (to open up opportunities for movement across the isles) and pavements (along roadsides for the purposes of safety) could alleviate some of the pressure on the current system. Whilst there is clear demand for an increased renewable energy supply and development of the current active transport infrastructure, the almost complete absence of any existing industrial landscapes on the isles means that any new developments will have a high impact. This, coupled with an economic reliance on tourism brought about by the prevalence of natural beauty on the isles, means therefore that community input is critical in ensuring the most suitable solutions can be identified.



**Figure 7** Percentage of the population in different age groups on the isles of Barra and Watersay compared to the UK based on the 2011 Census (data source: Gov.uk, 2011; Local Energy Scotland, 2018)

Figure 7 shows the age demographic of the isles, which indicates an older than average population when compared with the rest of the UK. Anecdotal evidence from officials on the isles suggests that the population has aged further since the last census (which was carried out

almost a decade ago) due to young families moving away from the isles to greater job opportunities in mainland Scotland. This therefore increased the potential impact that taking alternative approaches to participatory mapping may have in accommodating the needs of older residents impacted by digital divides as highlighted in the literature review. In order to maintain a strong relationship with residents on the isles, and ensure that their time will not be taken for granted when participating in this research, all results found were presented back to the isles for use at their discretion.

### **3.3 Data Collection**

To answer each of the three research questions identified in Chapter 1, different approaches were used. Research question 1 (Chapter 4) required desk-based research, whereas answering research questions 2 and 3 (Chapters 5 and 6 respectively) required primary data from participants both from the case study location and the wider public (Figure 5). For Chapter 5, face-to-face workshops were conducted in November 2019 on the isles at three different locations (Vatersay, Northbay and Castlebay) to minimise the distance participants were required to travel to attend. An exploratory trip was taken initially to the isles to discuss what research questions might prove most useful to the residents with Euan Scott, Project Officer at Barra & Vatersay Community Ltd. (the main contact on the isles), locate potential locations for workshops, gain an understanding of the landscape and begin to build relationships with the local community. Participants were then recruited through a local social media group, the local newsletter, and poster advertisements around the isles to attend face-to-face workshops where the website was used on laptops. The website was piloted by members of the Mapping: Culture and GIScience (MCGIS) research group prior to use on the isles as well as undergoing perpetual beta testing during the data collection phase. Face-to-face workshops

are a popular method of participatory data collection, creating a space for collaboration, discussion and learning between participants (Kpamma et al., 2016; Storvang & Clarke, 2014). Whilst the workshops could have been conducted remotely, the face-to-face element enabled a conversational and relaxed atmosphere, ensuring participants felt comfortable talking about their choices and were often prompted to add further data following discussions with other participants. Additionally, being able to be on the isles in-person allowed for a better understanding of the landscape and deeper understanding of the challenges faced by their residents. A participant information sheet was available for participants to review on the website and consent was required before beginning the mapping tasks (Appendix 6).

The usability testing for Chapter 5 was conducted remotely in January 2021 using cloud-based video conferencing. It was conducted firstly with a group of expert GIS users to locate any bugs in the system (such as links directing users to the incorrect webpage), and then with a mixed-ability sample of the general public who were recruited through snowball sampling. Residents were not used to conduct the usability testing so as to avoid participant fatigue in the small population, and prevent the introduction of bias through participants having done both the testing and on-location data collection. The aim of usability testing is to assess the extent to which a system is effective, efficient and elicits positive responses from the intended users (Bastien, 2010). Usability testing directly enables the participants to provide feedback on the software developed and explore the degree to which the general public are able to use it. Dumas & Redish (1999) present five characteristics of usability testing, four of which were achieved in this research:

- 1) The purpose is to improve the usability of the software
- 2) The participants are engaged in authentic tasks

- 3) The participants' actions and words are recorded
- 4) The collected data was then analysed to identify problems in the software design that could be addressed

Whilst the participants of the usability testing exercise were not the actual users of the software as they were not residents of the isles (the fifth characteristic according to Dumas & Redish, 1999), the results give an indication of how the wider public might respond. The questions asked of participants are detailed in Chapter 5 using a series of Likert-style questions. The questionnaire was developed based on Balletore et al.,'s (2019) Participatory GIS Usability Scale (PGUS), a specifically designed questionnaire to assess non-expert opinions of a PGIS. The questionnaire is designed to standardise the assessment of usability studies in PGIS specifically, assessing user interface, spatial interface, learnability, effectiveness and communication. Following this, participants could clearly define whether they found a range of different features to be more usable in the more traditional system or the newly developed system. To limit bias towards one system over the other, the order in which they appeared for participants was randomised and no indication was given as to which system was intended for use on the isles.

For the remote, paper-based data collection in Chapter 6, research packs comprising two A3 maps, instructions, consent form (Appendix 5), participant information sheets (Appendix 6), questionnaires (Appendix 7) and stamped addressed return envelopes were sent to 525 households on the isles between November 2020-March 2021. The questionnaire that followed the instructions first asked participants to circle their age and gender from multiple

choice categories. The same options were given in both the paper questionnaire and the digital PGIS system in Chapter 5. Participants were then asked (with free text boxes) to explain the routes they drew, their reasons for not wanting a wind turbine in the areas they marked and any further feedback on the method itself. Whilst not directly linked to the research aim of Chapter 6, by obtaining an understanding of why participants mapped the specific routes/areas a more rounded insight into the data, increasing its value in the ‘real world’ when presented back to the isles.

### 3.4 Software Development

The website [barramapper.co.uk](http://barramapper.co.uk) was built specifically for this research. The styling of the website was designed to be modern and user friendly, with large clear fonts and photographs of the isles, based on the *Road Trip* HTML template<sup>1</sup>. Instructional videos were provided alongside written instructions so that users had multiple options to learn how to take part. It is important to note that the development of software was not the purpose of this thesis, presenting instead an application and critical analysis to demonstrate how such approaches might benefit both researchers and participants. The research therefore used preexisting, open source systems. The javascript for the A\* and viewshed map interfaces were developed by my supervisor Dr Huck (<https://github.com/jonnyhuck/ppgis-interfaces>) for the purposes of this thesis. The Paper2GIS software was developed by Dr Huck (<https://github.com/jonnyhuck/Paper2GIS>) prior to the commencement of this thesis, and has previously been referred to in a conference abstract (Huck et al. 2017), though neither its usability nor data arising from it have been formally analysed. The design and styling of the

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<sup>1</sup> available at <https://templatki.com/template/html-templates/item/2043-road-trip.html>

Paper2GIS basemap was a modification of the ‘OSM Bright’ style by MapBox (<https://github.com/mapbox/osm-bright>), undertaken collaboratively by myself and Dr Huck in order to ensure sufficient detail was visible and key landmarks would be recognisable to residents of the isles.

### **3.5 COVID-19 Impact**

Due to the restrictions caused by the global COVID-19 pandemic, fieldwork on the isles of Barra and Vatersay scheduled to take place in April 2020 was cancelled. This and an additional fieldwork trip would have been used to collect further data for Chapter 5 and to carry out all data collection for Chapter 6. The requirements of conducting participatory research during a pandemic posed numerous challenges however, both ethical and logistical (as reviewed by Hall et al., 2021) and consequently, the research for both chapters had to be adapted. To complete Chapter 5 (and compensate for the small number of participants obtained on Barra prior to the pandemic), the additional usability study was designed to assess how the wider public found the informed interfaces in direct comparison to more conventional PPGIS tools. This required designing a second website ([www.usability.barramapper.co.uk](http://www.usability.barramapper.co.uk)) including additional mapping interfaces for comparison and subsequent questionnaires, and conducting the online workshops, as well as additional data analysis.

Chapter 6 was intended to be conducted again through in-person workshops and walking interviews with residents to experience first hand the landscape being mapped and obtain a more holistic understanding of the issues being investigated. Data collection was instead

conducted remotely through the above-described postal method. Whilst this meant the research could still go ahead, it did extend the time frame to complete the data collection phase significantly to enable the procurement of the necessary materials. Fortunately a six month extension was awarded (taking the PhD deadline from 30th September 2021 to 30th March 2022) which has allowed time to complete this adapted data collection as well as make revisions to submitted papers without compromising completion of the thesis.

### **3.6 Ethics**

Ethics approval was granted for the face-to-face data collection of Chapter 5 (review reference 2019-6162-9691). Due to the nature of the data being collected being that of ‘market research’ (i.e asking non-identifiable preference related questions as opposed to personal information), ethics approval was not required for the virtual data collection of Chapter 5 or that of Chapter 6. No incentive was offered for participation in any of the data collection stages.

## 4.

### **Participatory Mapping: A Systematic Review and Open Science Framework for Future Research**

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This chapter has been published as:

*Denwood, T., Huck, J. J., & Lindley, S. (2022). Participatory Mapping: a systematic review and open science framework for future research. Annals of the American Association of Geographers, 1-20. <https://doi.org/10.1080/24694452.2022.2065964>*

A small part of the research was published in an earlier form as:

*Denwood, T., Huck, J. J., & S. Lindley. (2022) An Open Science approach to Participatory Mapping. Proceedings of the GIS Research UK 20th Annual Conference. Liverpool University.*

## **Abstract**

Participatory Mapping emerged from a need for more inclusive methods of collecting spatial data with the intention of democratising the decision-making process. It encompasses a range of methods including mental mapping, sketch mapping and Participatory GIS. Whilst there has been a rapid increase in uptake of Participatory Mapping, the multidisciplinary nature of the field has resulted in a lack of consistency in the conducting and reporting of research, limiting further development. In this paper we argue that an Open Science approach is required to enable the field to advance, increasing transparency and replicability in the way Participatory Mapping research is both conducted and reported. This argument is supported by the first large-scale systematic review of the field, which identifies specific areas within Participatory Mapping that would benefit from an Open Science approach. Four questions are used to explore the sample: (1) How are different Participatory Mapping methods being used and reported? (2) What information is given on the data collected through Participatory Mapping? (3) How are participant demographics being recorded? (4) Who is conducting the research and where is it being published? From a total of 578 academic research articles, we analysed a stratified sample of 117. The review reveals a significant lack of reporting on key details in the data collection process, restricting the transparency, replicability, and transferability of Participatory Mapping research and demonstrating the urgent need for an Open Science approach. Recommendations are then drawn from the results to guide the design of future Participatory Mapping research.

**Keywords:** *PGIS, PPGIS, Sketch Mapping, Mental Mapping, PRISMA Protocol*

## 4.1 Introduction

Participatory Mapping is an umbrella term that encompasses a wide range of methods for the collection and compilation of local, spatial information; including, but not limited to participatory GIS (PGIS), sketch mapping and mental mapping (Brown & Kyttä, 2018). We define Participatory Mapping as a multi-agent practice, through which citizens are required to communicate their spatial thoughts, feelings or knowledge in support of a specific research aim or decision making goal, utilising a cartographic visualisation. It was developed as a way of empowering citizens by incorporating nuanced, non-expert knowledge into the decision-making process and enhancing opportunities for democracy within communities (Sieber, 2006; Carver, 2003). By enabling the views of multiple, often competing stakeholders' voices to be heard, acceptable and democratic solutions can often be found (Anderson et al., 2009). As a result, Participatory Mapping research can also assume an advocacy role, acting as a voice to marginalised groups to provide a visual representation of places with specific community value, political conflict or legal custody (Corbett, 2009). Participatory Mapping therefore holds the potential to provide an effective means of incorporating citizens' views into the decision-making process, bridging the gap between policy and people (Brandt et al., 2019).

Over the past decade, Open Science approaches have gained momentum in numerous fields of enquiry, including in the closely related field of GIS (e.g. Brunsdon & Comber, 2021; DeLyser & Sui, 2014). Open Science is a “disruptive phenomenon” intended to increase openness and connectivity in the way research is designed, conducted and assessed, both socio-culturally and technically (Vicente-Saez & Martinez-Fuentes, 2018; p.428). When research is replicable, scientific progress can be accelerated by making it simpler and more

cost effective for researchers to build on previous work (Kedron, Fotheringham & Goodchild, 2021; Singleton et al., 2016). Singleton et al. (2016) presented a framework for an Open Science approach to GIS, maintaining that research should make data accessible; software should be open; workflows should be public; that the peer review process should require workflows; and that where these are not possible due to commercial software or data sensitivity, that as many aspect of an Open framework should be adopted as possible. Despite these arguments having been made for GIS, there has been no consideration of how open the field of Participatory Mapping currently is and whether there is a requirement/potential for it to become more open in the future. As Participatory Mapping is a nuanced and diverse field, covering a wide range of methods, there may be aspects that this pre-existing framework does not cover. This paper seeks to address this gap by making the argument for the adoption of an Open Science approach in Participatory Mapping, in order to promote the unification of an at present disparate field. The need for this approach will be demonstrated through a systematic review of academic literature, which will identify areas unique to the field that could be advanced through increased communication. Finally, we present a clear set of recommendations for effective, rigorous and open reporting in future Participatory Mapping research through which the field can become more open for the benefit of researchers and research users.

## **4.2 Background**

The legitimacy of public participation depends on credible, transparent and accountable methods to ensure that the views of all are heard and to link decision makers to those whose realities they will be impacting (Blackstock et al., 2006; Carver, 2003). Participatory Mapping takes numerous forms, as a product of the multidisciplinary of the field and its

applications (Corbett, 2009; Elwood, 2006). The difference between participatory maps and more traditional cartography is the process involved in their production, as well as their subsequent use. Their production is not necessarily confined by formal media, with approaches ranging from drawing with sticks in sand to complex, bespoke online platforms (Corbett, 2009). The choice of method used to gather spatial information from a local population often depends on the social, political and technological practices of the case in question, with key considerations including the needs, priorities and spatial knowledge of those involved (Elwood, 2006). The choice of method also affects, and is affected by, the type of knowledge that is desired (Brown & Fagerholm, 2015; Raymond, et al., 2014). Such methods can be grounded in different epistemologies, employ a range of engagement approaches, and be instigated from a grassroots organisation or carried out as part of an external research project. Furthermore, methods can be physical, digital or a combination of both; conducted remotely in the form of a survey or facilitated in focus groups or individual interviews; targeted at a specific group (e.g. older adults) or broadcast to the general public. However, this breadth of variation brings with it a number of challenges when it comes to both conducting and reporting Participatory Mapping research. As there is no standard approach which can be readily referred to, it is important to understand the principles and practice used in each case for transparency and to bring the benefits of open working to this field.

#### **4.2.1 Differing definitions**

As might be expected given the wide range of methods that fall under the banner of Participatory Mapping, there are a variety of terminologies used (Brown, 2017). Digital approaches to Participatory Mapping are often referred to as 'PGIS', a term that encompasses

an array of different practices enabling citizens to participate in GIS based decision making (Elwood, 2006). However, PGIS can be distinguished from Public Participation GIS (PPGIS), which is often used to refer to the case where participation is open to the general public, as opposed to being restricted to specific groups of stakeholders or decision-makers. However, in many instances, the two terms are conflated, or referred to collectively as '*P/PGIS*' (Kar et al., 2016) or '*PPGIS/PGIS*' (Brown & Fagerholm, 2015), for example. For the purposes of this research, PGIS will be used in a manner that includes PPGIS, recognising that the differences between the two terms are "highly fluid given the pace of global technological and social change" (Brown & Fagerholm, 2015; p119). Paper-based approaches to Participatory Mapping are typically referred to as 'sketch mapping' or 'mental mapping', depending whether they make use of a base map (sketch mapping) or not (mental mapping; Boschmann & Cubbon, 2014). Again, these definitions are not universally accepted, with sketch mapping used interchangeably with both mental mapping and PGIS in the literature (Boschmann & Cubbon, 2014 and Huck et al., 2017 respectively).

This is not to suggest that any of these definitions are incorrect, but rather that there is a lack of clarity and consistency across the literature, which may in part be due to the multidisciplinary (as opposed to interdisciplinary) nature of the field. With Participatory Mapping being applied for a range of purposes across a number of industries, government agencies and academic fields that traditionally operate independently, it is no surprise there is little agreement (Huck et al., 2014). However, a clear taxonomy is important for enabling transferable and replicable research. For this purposes of this research we adopt three widely used terms as defined in three prominent papers to ensure a broad range of methods is included: PGIS, referring to digital tools that enable the collection of spatial data (Brown,

2017); sketch mapping, a non-digital but spatially contextualised mapping technique (Boschmann & Cubbon, 2014); and mental mapping being the creation of perceived space through freehand drawing without supporting spatial context (Green et al., 2005). The fundamental differences between each definition can be simplified depending on two key factors: Firstly, whether the method is digital (if so then it is PGIS), and secondly whether there is spatial context to support the participant such as a paper base map (if so then it is sketch mapping, otherwise it is mental mapping). We propose these three terms as simple, high-level classifications, as opposed to focusing on more detailed, nuanced ontologies (i.e. Pánek, 2015), in order to ensure that the terms are comprehensive yet simple, providing a clear way of communicating methodological approach.

#### **4.2.2 Representation**

The term ‘representation’ is used here in the cartographic sense, referring to the relationship between a feature and the data model and ontology that are used to represent it on a map (c.f. Goodchild et al., 2007). In Participatory Mapping, representation is one of the fundamental issues in the field (Huck et al., 2017), as this is the way in which the complex thoughts and feelings of the participant are captured. It is well recognised in the literature that the use of traditional forms of representation (such as points and polygons) in Participatory Mapping are often inadequate representations of human experience, yet their uncritical use is still prevalent (Brown & Kyttä, 2018; Huck et al., 2014 & Goodchild, 2011). As the representation selected by the researcher can directly influence the resulting dataset and subsequent analysis, understanding the usage of various modes of representation across the literature is of great value and transparency of data a core principle of Open Science.

There are two high-level modes of representation, *notation*: formalised communication such as writing; and *indication*: informal communication of ‘freehand’ gestures such as drawing (Ingold, 2007). PGIS approaches tend to rely on notation-based approaches, using specific spatial units such as points or polygons. Whilst specific notation can be instructed in sketch mapping studies, there is usually an element of freedom on the part of the participant as to the way in which they represent their spatial thoughts and feelings on the page. This goes further still with mental mapping where complete freedom of indication is available, limited only by the materials at hand. The difficulty with sketch mapping and (in particular) mental mapping, which allow greater freedom, is that the unrestricted nature of the input makes any quantitative analysis of the output challenging. Nevertheless, whilst posing challenges for the analyst, these less restrictive mapping methods can offer a more accessible environment for the participant, enabling a wider cross section of society to take part (Denwood et al., 2021).

#### **4.2.3 Accessibility**

The accessibility of any participatory research is vital, particularly when engaging traditionally marginalised groups of society or vulnerable citizens (Kar et al., 2016). Truly inclusive and accessible participatory methods are difficult to put into practice, though there have been attempts to facilitate certain social groups (Radil & Jiao, 2016; Gottwald et al., 2016). One of the most significant barriers to accessing participatory research is inequalities in access to computer technologies and high speed internet, known as ‘digital divides’ (van Deursen and van Dijk, 2011). There is often an assumption in the decision making process that citizens have equal access to computers and high-speed internet, which in turn places a

'false-authority' with those that do, enabling certain voices to be heard and others not, which introduces bias into the decision making process (Huck et al., 2017). Digital divides are far from binary, and can be broken down into four forms of access: experience (*mental access*), possession of computer technology (*material access*), digital skills (*skills access*) and usage opportunity (*usage access*) (van Dijk & Hacker, 2003). The challenge of accessibility is not just a technological one, with multiple factors impacting who may or may not be excluded (or exclude themselves) from participatory research based on gender, status or skill, dictated instead by the social and cultural context of the research (McCall, 2021). Regardless of the targeted social group, increasing accessibility is beneficial for all by both increasing participation and accuracy in the output (Gottwald et al., 2016). It is therefore vitally important to carefully consider not only the specific social and geographical context when selecting or creating the method of Participatory Mapping, but who it is that will be participating if effective outcomes are to be realised (Brown & Kytä, 2018). By adopting an Open Science approach by being transparent about specific methodological details and workflows, future research can learn from similar studies, benefiting both those who participate and better informing decisions.

#### **4.2.4 Purpose and intent**

Participatory Mapping grew from reflexive efforts of GIS researchers as well as through the work of less traditional users, to improve democracy in decision-making and include those whose voices were often excluded from governance (Radil & Jiao, 2016; Elwood, 2006). Participatory mapping has since been driven forward by decision-makers for the purpose of creating more realistic plans whilst minimising dissatisfaction by addressing disconnects between local views and the priorities of different stakeholders (Czepkiewicz et al., 2018;

Radil & Jiao, 2016). However, gauging the degree to which Participatory Mapping contributes to decision-making can prove challenging (Sieber, 2006). Although the internet is replacing more traditional processes for participation in decision-making, there has been little assessment of the decisions that are made through using Participatory Mapping or the impact they might have on the population involved (Radil & Jiao, 2016; Gottwald et al., 2016). Brown & Kyttä (2018) concur, highlighting the difficulties in analysing the success of participatory approaches as there are too many external factors involved, such as political pressure and the level of authority the various agencies have. Additionally, some authorities may be dismissive of results presented through participatory methods, or opt to use local knowledge to inform rather than necessarily influence the decision-making process (Rall et al., 2019; Brown & Kyttä, 2018). It is therefore of great importance that future research demonstrates rigour in order to promote integration with the decision making process. Despite global uptake, there is little in the way of guidelines for effective knowledge sharing of Participatory Mapping practices, and therefore only limited understanding as to their effectiveness (Radil & Jiao, 2016). Applying an Open Science approach to Participatory Mapping is one way to address these issues.

#### **4.2.5 An Open Science approach to Participatory Mapping**

Open Science is “transparent and accessible knowledge that is shared and developed through collaborative networks” (Vicente-Saez & Martinez-Fuentes, 2018; p.435), designed to bring about socio-technical change through transparency and connectivity in the way research is created and communicated. The Open Science Agenda has led to the development of data management systems such as the FAIR (Findable, Accessible, Interoperable, Reusable) Data Principles, designed to improve the reusability of research outputs and raw data (Wilkinson et

al., 2016). In the neighbouring field of GIS, it has been argued that scientific value is dependent on the degree to which methods used are transparent, specifically in regard to open data, open source software and transparent workflows (Singleton et al., 2016). However, an Open Science approach to *Participatory Mapping* must go beyond the technical and consider the more nuanced, contextual details and choices made by the researcher to be replicable (Kedron et al., 2021; Nüst & Pebesma, 2021). Regardless of the approach to Participatory Mapping that is taken (be it PPGIS or Mental Mapping) or the type of data produced (i.e. qualitative or quantitative), transparency and replicability are critical to the development of Participatory Mapping across all spatial contexts (Kedron et al., 2021). Should an Open Science approach be taken to Participatory Mapping and adopted across the field, it holds the potential to transform the way research is communicated and conducted; improving understandability, trust and innovation as has been reported in other fields (Nüst & Pebesma, 2021). Each of these is important in Participatory Mapping, however trust is of particular importance due to the nature of the research being intended to give voices to those who might normally not be heard.

#### **4.2.6 Research scope and objectives**

Whilst there have been a number of articles considering the positive impacts of an Open Science approach to GIS, (e.g. Nüst & Pebesma, 2021; Brunsdon & Comber, 2021; Singleton et al., 2016) there is yet to be any guidance of how this might be applied to the nuanced and broad field of Participatory Mapping. Elwood (2006) acknowledged the need to be critically reflexive in Participatory Mapping to best demonstrate the significance and capacity of the field, through the use of robust frameworks and best practices. Whilst a small number of frameworks for certain aspects of Participatory Mapping have been produced (e.g. focussing

on available tools (Corbett, 2009); data analysis (Fagerholm et al., 2021) and practical ethics (Rambaldi et al., 2006)), there is nothing to date that considers the field as a whole or proposes an adoption of the principles of Open Science. Indeed, even an understanding of the fundamental characteristics of how Participatory Mapping is currently being used, e.g. in terms of who is engaged, to what extent, and how, is similarly lacking. The fundamental knowledge gaps mean that both researchers and users of Participatory Mapping from wider disciplinary fields have little basis for evaluating their own data collection exercises with Participatory Mapping.

Kedron et al., (2021) propose that further research into the current degree to which geographic research is replicable would enable criticisms to be raised and addressed, and improve trust in the outcomes of future research. Systematic reviews are increasingly being used for this purpose, as well as to support decision-making and guide policy development (Behghadami & Janati, 2019). By following a specific set of principles, systematic reviews are regarded as producing high quality evidence, minimising bias whilst maintaining the capacity to be replicated (Gholizadeh et al., 2020; Moher et al., 2009). To date, only non-systematic reviews of smaller subsets of Participatory Mapping (generally PGIS) have been conducted (e.g. Brown, 2017; Brown & Fagerholm, 2015; Dunn, 2007; Sieber, 2006). This research therefore comprises the first systematic review to include all empirical, academic Participatory Mapping research; imposing no limitations on the method, application, location or intended purpose of the case study; and conducted following a strict systematic protocol. This presents a practical step toward expanding geographic ontologies and the effective sharing of analytical choices to better understand and replicate spatial analysis (Kedron et al., 2021). Four key questions will be used to explore the sample in order

to understand the compatibility of the existing body of literature with an Open Science agenda:

1. How are different Participatory Mapping methods being used and reported?
2. What information is given on the data collected through Participatory Mapping?
3. How are participant demographics being recorded?
4. Who is conducting the research and where is it being published?

Each question covers key aspects of Participatory Mapping research that could be improved through an Open Science approach and permits an overview of the field to be presented. This systematic review enables a novel insight into the challenges posed by the disparate and inconsistent nature of the field of Participatory Mapping, drawing on academic publication from a wide range of disciplines, conducted for a broad spectrum of purposes across a global scale, to advance towards a more coherent, transparent and definitive field.

### **4.3 Methods**

This systematic review of Participatory Mapping was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) protocol (Moher et al., 2009). This involves an extensive literature search to extract data from a selection of search engines, using specific keywords in a specified time frame. It is used to

provide an unbiased report on the literature by clearly stating exactly what has been reviewed and how this was done.

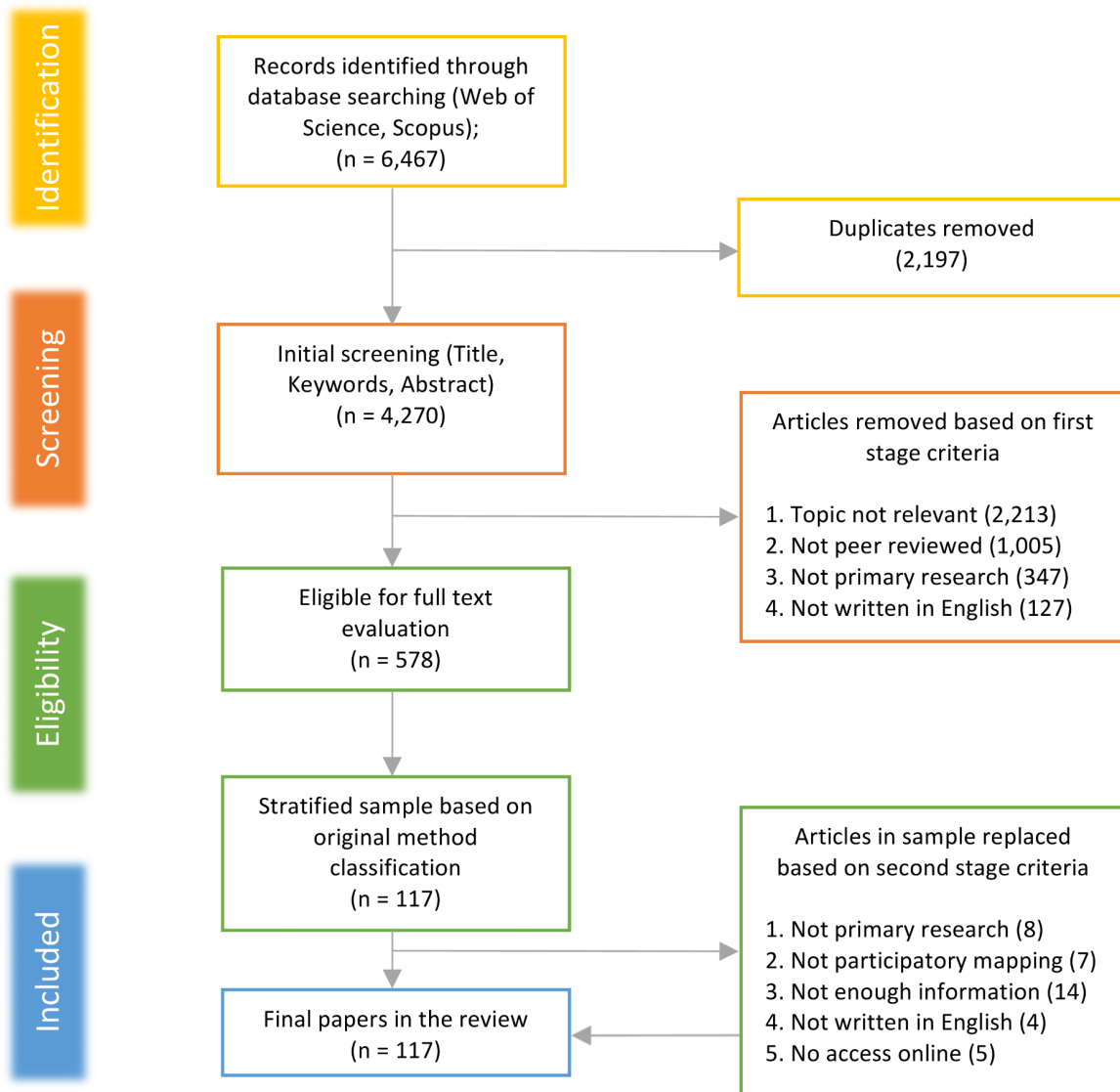
#### **4.3.1 Selection strategy**

The first step in the PRISMA protocol involved identifying all Participatory Mapping research articles from two search engines (Web of Science and Scopus) inclusive of all dates up to and including 16th June, 2020. These articles were found using a specific set of key terms that are often used to describe the dominant methods of Participatory Mapping. The full search string (*“Mental Map\*” OR “Sketch Map\*” OR “PGIS” OR “PPGIS” OR “Participat\* GIS” OR “Participat\* Map\*” OR “Participat\* Geographi\* Information” OR “Community Integrated GIS” OR “Collaborat\* GIS” OR “GIS for Participat\*” OR “GIS in Participat\*” OR “Bottom up GIS” OR “Community GIS”*) used Boolean logic to improve efficiency, enabling multiple keywords and phrases to be searched for concurrently. This initial search returned 6,467 results (2,441 from Web of Science and 4,026 from Scopus), of which 2,197 were duplicates and therefore immediately removed.

The second step (screening) requires all articles to be removed that do not meet specific eligibility criteria based on the title and keywords or the title and abstract in those cases where the title did not provide adequate information to distinguish relevance. Articles were excluded at this stage if they were: (1) not relevant, i.e. not actually about Participatory Mapping or within the scope of this research, (2) not peer reviewed journal articles (e.g. grey literature), (3) not primary research with a case study (e.g. review papers), (4) not written in the English language. Reasons for articles being classed as ‘not relevant’ include the acronym

PGIS being used with a different meaning in medical, geological and robotics settings; sketch maps referring to architectural drawings; and mental maps being used to refer to psychological phenomena. During this stage a further 3,689 articles were excluded, leaving 578 articles for analysis, which are referred to as the ‘eligible’ set.

Conventionally the next step in the PRISMA protocol is to review the full texts to ensure eligibility whilst extracting the required data for analysis. However, due to the unusually broad nature of the search and consequent high number of eligible papers, the remaining records were first sampled, to reduce them to a more manageable number. To obtain a representative sample, the eligible texts were first grouped by the dominant method of Participatory Mapping used (mental mapping, sketch mapping or PGIS). For those texts from which the title, abstract or keywords contained more than one of these terms, priority was given to the term that appeared first in the title, then keywords, then abstract. Those that did not specifically refer to the method used, instead referring to Participatory Mapping in general, were assigned to a fourth class: ‘uncategorised’. A reproducible, stratified random sample (based on the method class) of 20% was drawn from each of these groups (<https://github.com/jonnyhuck/literature-sampling>). Stratification ensured that the proportion of papers in each of the four categories was the same for both the sample and the original set. The resulting sample comprised 117 articles, which were then each read in full and assessed to confirm inclusion or replacement (the final stage of the PRISMA protocol). These articles are referred to as the ‘included’ set. During the process of reading the articles in full, 38 were replaced using the same sampling method as they did not meet the inclusion criteria, as listed in Figure 8.



**Figure 8** Flow diagram of the PRISMA protocol steps followed in this systematic review of Participatory Mapping research

### 4.3.2 Sampling

The following information was extracted from the abstract, title and keywords of all 578 eligible articles prior to sampling: year of publication, journal of publication, intended participants, method of Participatory Mapping, case study location, lead author location. To

ensure the final 20% stratified sample is representative of the whole 578 population of eligible articles and can be expected to follow the trends presented above in a statistically significant way, a  $\chi^2$  test has been conducted based on the year of publication, (<https://github.com/jonnyhuck/denwood-chi-sq>). As  $\chi^2$  requires each category to have a frequency greater than five, the eligible articles have been grouped into five year interval groupings from 2005 (the creation of Web 2.0) onwards, before which has been grouped as one. The difference between the observed and expected frequency distributions that were compared in this analysis indicate a very close match between the sample (observed) and the population (scaled to produce expected values; Appendix 2). The  $\chi^2$  test produced a result of  $p=0.78$ , confirming that the sample is representative of the overall population in terms of year of publication. Once the sample was confirmed as representative, all 117 articles in the ‘included’ set (Appendix 3) were read in full, with key findings presented in the next section.

#### **4.3.3 Data Extraction**

Data (Appendix 4) was extracted from the stratified sample through independent reading as well as using key search terms, then entered into a categorised spreadsheet in Microsoft Excel for analysis. The lead author individually identified the articles suitable for inclusion, extracted and analysed the data from those eligible. The second and third authors assisted in research design, production of Python code for analysis and sampling, and oversaw the analysis of extracted data.

## 4.4 Results

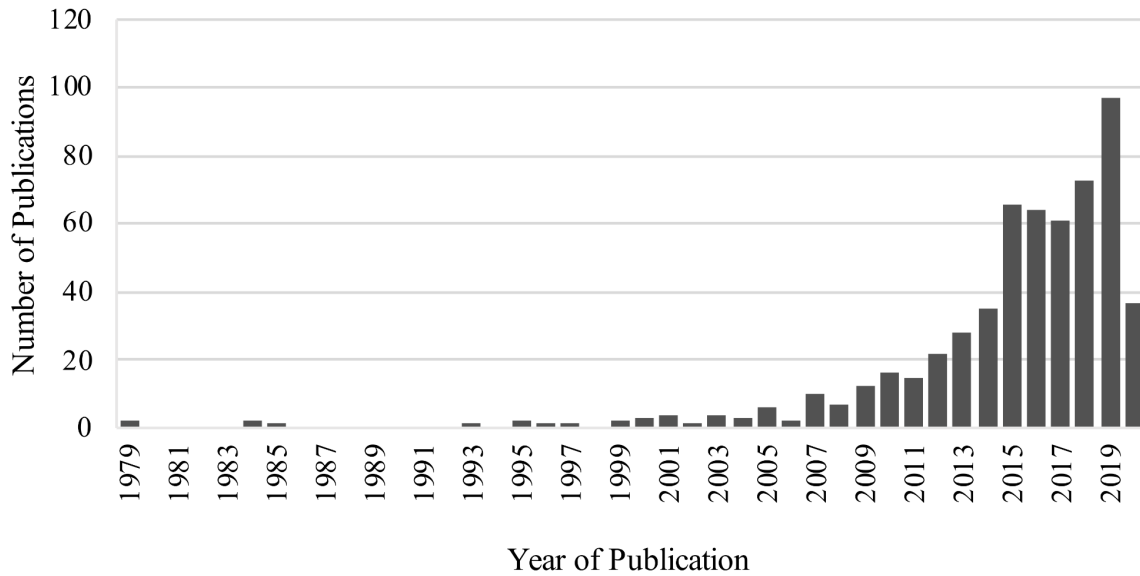
In this section, we deal with each research question individually using data both from the ‘eligible’ set of articles (n = 578) and the ‘included’ set of articles (n = 117).

### 4.4.1 How are different Participatory Mapping methods being used and reported?

This section first presents the distribution of articles over time, followed by the re-categorisation of the stratified sample. An analysis of how Participatory Mapping research is carried out is then presented, including whether research is facilitated or remote, how it was conducted and whether there was any incentive to participate.

#### 4.4.1.1 Method of Participatory Mapping

A steady increase can be seen in the number of Participatory Mapping articles published across all categories over time in the *eligible* set, with a significant increase from 2015 onwards (Figure 9). This was also present in the *included* set as confirmed by the  $\chi^2$  test.

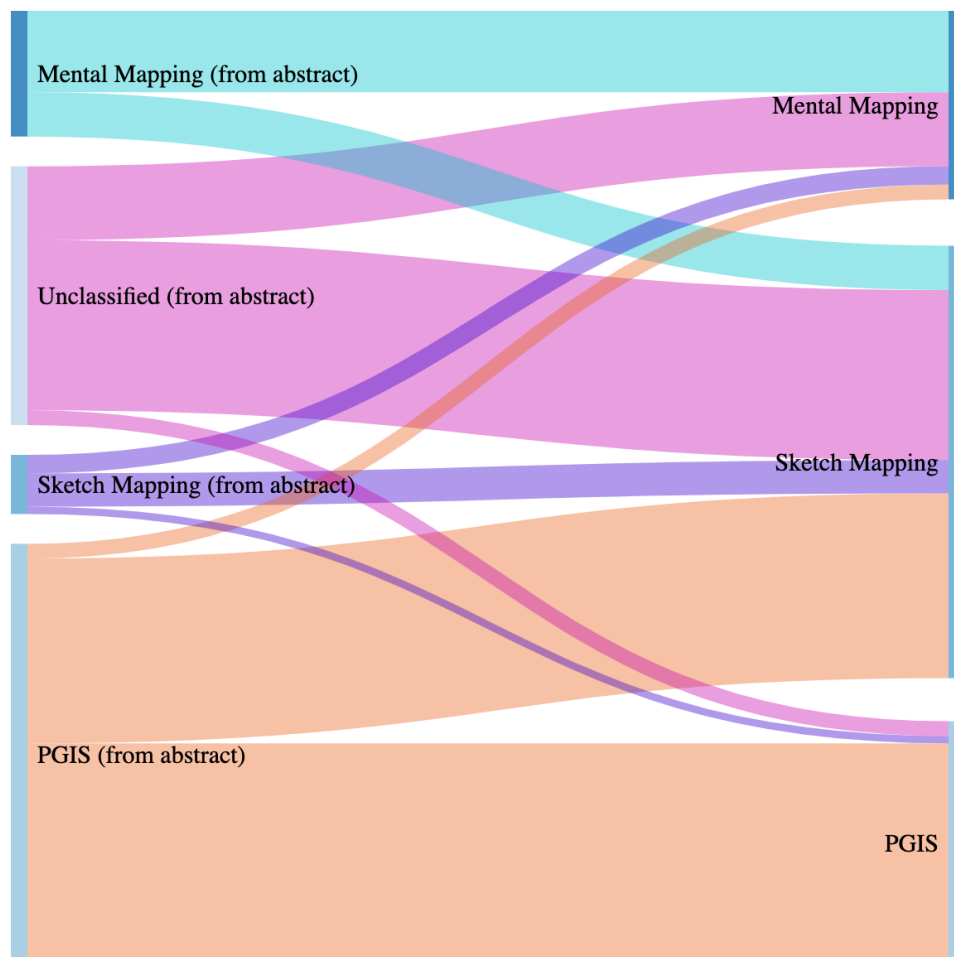


**Figure 9** Distribution over time of Participatory Mapping articles published up to 16th June 2020

#### 4.4.1.2 Method of Participatory Mapping - Recategorised

To address the lack of a standard ontology across the field of Participatory Mapping, each *included* article was re-categorised using a high-level, simple ontology to be either ‘mental mapping’ (freestyle creation without an underlying base map); ‘sketch mapping’ (manually drawing on a base map); ‘PGIS’ (computer based mapping onto a digital base map) (as per Green et al, 2005; Boschmann & Cubbon, 2014; and Brown, 2017 respectively); or as a combination of multiple categories. In instances where a method presented fell between two of the defined categories or used multiple methods, the total percentage was shared evenly between said categories. For example, Gorokhovich et al. (2014) uses a digital PGIS style interface but a digital pen to add features as you would in Sketch Mapping, and as such is classed as being split between the two categories. Those that did not include sufficient methodological detail in the title, abstract or keywords were initially categorised as ‘unclassified’.

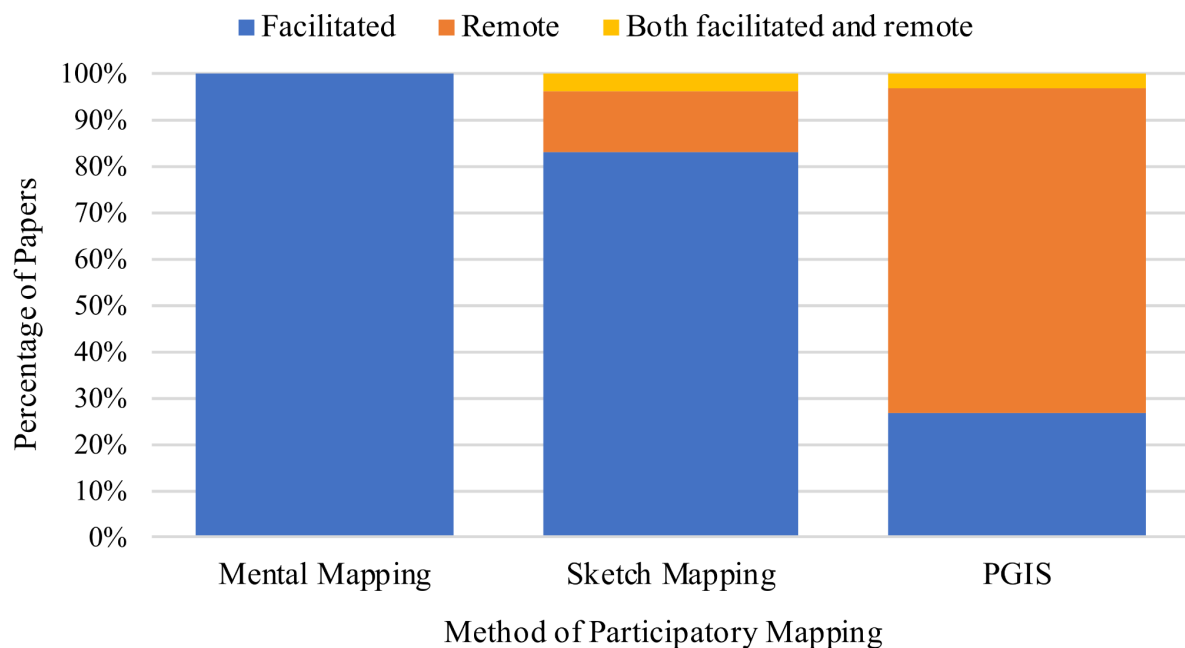
Figure 10 illustrates the lack of a unified taxonomy in Participatory Mapping. There is a clear dominance of articles referring to the method as PGIS, however a significant proportion of these were referring to non-digital methods. Sketch mapping is by far the most prevalent method but also the least defined in the title, keywords and abstract. Whilst PGIS studies (by our definition) were sometimes categorised as mental mapping, this did not occur in the other direction, with no articles that used mental mapping being referred to as PGIS.



**Figure 10** The reclassification of the Participatory Mapping methods from how they were referred to in the 117 included articles, into the three high-level definitions of PGIS, sketch mapping and mental mapping

#### 4.4.1.3 Facilitation of Remote Data Collection

Each type of Participatory Mapping can be carried out either remotely or in a facilitated setting, yet there are clear preferences for engagement in each case (Figure 11). All research that used mental mapping conducted case studies in a facilitated setting ( $n = 25.5$ ), in comparison to 84% ( $n = 47.5$ ) of those using sketch mapping and just 28% ( $n = 9$ ) of those that used PGIS. A small percentage of those using sketch mapping and PGIS utilised both facilitated and remote data collection settings to capitalise on the advantages of each.



**Figure 11** Type of data collection setting used in each category of Participatory Mapping

Whilst most Participatory Mapping case studies were facilitated, it was the remote studies that exhibited the highest numbers of participants (Table 1), with the mean number of participants being more than ten times that of facilitated studies. All articles in the top 5% in terms of participant numbers achieved were conducted remotely using PGIS, with remote studies being on average an order of magnitude larger than facilitated studies.

**Table 1** Participation numbers in facilitated and remote settings for conducting Participatory Mapping research

<b>Method of data collection</b>	<b>Total Participants</b>	<b>Number of Articles</b>	<b>Mean</b>	<b>Median</b>	<b>Lowest</b>	<b>Highest</b>	<b>Range</b>
Facilitated	6,130	58	106	46	4	731	727
Remote	22,818	28	815	325	10	7,656	7,646
Both	1,116	2	558	516	67	533	466
All Included	30,064	88	1,479	67	4	7656	7652

However, results suggest that conducting research remotely does not necessarily guarantee large numbers of participants. Furthermore, due to the nuanced nature of Participatory Mapping and associated varied target audiences and intentions, large numbers of participants may not necessarily be desired. Additionally, 22% (n = 26) of articles failed to provide any information regarding the number of participants and 2.5% (n = 3) did not state whether the research was conducted in a facilitated or remote setting.

#### 4.4.1.4 Data Collection Approach and Incentivisation

The majority of PGIS studies (76%,  $n = 25$ ) were conducted as part of a questionnaire, in comparison to sketch mapping studies which were split between focus groups (42%,  $n = 24$ ), interviews (31%,  $n = 17.5$ ) and questionnaires (19%,  $n = 11$ ). Mental mapping studies were conducted predominantly through either focus groups (56%,  $n = 13.75$ ) or interviews (36%,  $n = 8.75$ ). A small number of studies were conducted outside these arenas, in school lessons, community meetings or as part of on-street activities, the majority of which used sketch mapping. Regardless of method, those that offered an incentive for doing so (and provided participant numbers) achieved higher numbers of participants than those that did not, by roughly one order of magnitude (Table 2). Only 11% ( $n = 13$ ) of articles in the stratified sample provided data on both incentivisation *and* the number of participants. The incentives varied from meals and postage stamps to being entered into a lottery to win \$500.

**Table 2** Participant numbers by use of incentives

<b>Incentive used?</b>	<b>Total Participants</b>	<b>Number of Articles</b>	<b>Mean</b>	<b>Median</b>	<b>Lowest</b>	<b>Highest</b>	<b>Range</b>
Yes	4,522	8	565	290	95	2,499	2,404
No	310	5	62	42	10	151	141
Did not report	25,602	81	316	60	4	7,656	7,652

#### 4.4.2 What information is given on the data collected through Participatory Mapping?

This section first presents the question being asked of participants, including the nature of the question and the research domain; and secondly, the interface being used and subsequent

mode of representation used to enable participants to elucidate their spatial thoughts and knowledge.

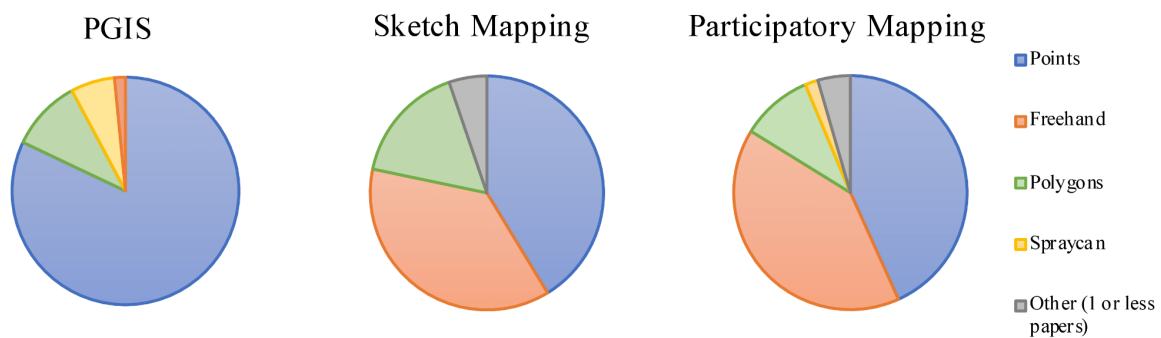
#### *4.4.2.1 The Questions Being Asked*

With each different type of Participatory Mapping method, the questions being asked of participants were largely split between activities/practices (e.g. “*where do you do...?*”) and values/perceptions (e.g. “*how do you feel about...?*”), being 50% (n = 54) and 45% (n = 49) respectively. The remaining 5% (n = 6) sought participants’ preferences about future developments (e.g. “*where would you like to see...?*”). However, only 56% (n = 66) of articles provided a detailed explanation of the question posed to participants, of which just 36% (n = 24) disclosed the exact wording used, whereas 7% (n = 8) provided no detail at all. The questions asked of participants covered 22 different research domains, with 19% (n = 22) of all articles relating to issues around land use and planning; predominantly utilising PGIS and sketch mapping approaches (44% and 47% respectively). The most popular domain for mental mapping was health (16%, n = 4), closely followed by farming and agriculture (14%, n = 3.5).

#### *4.4.2.2 The Interface and Mode of Representation*

All PGIS methods were conducted with an online map interface (as per the definition); sketch mapping typically with a printed base map (65%, n = 31) or satellite image (25%, n = 12); and mental mapping with freehand drawing on blank paper (95%, n = 21). Relatively few studies (<5%) used alternative interfaces such as sticks and earth (e.g. Chirowodza et al., 2009).

Whilst a range of options could be expected of PGIS due to the digital interface, the use of points to represent spatial knowledge and opinion dominate, being used in 82% (n = 26) of articles (Figure 12). Sketch mapping is more equally split between freehand indication (37%, n = 20) and point representation (41%, n = 22). In some instances, alternative forms of representation also featured, such as the ‘Spraycan’, an airbrush type interface used to denote vague areas rather than imposing precision (e.g. Huck et al., 2019). Whilst 95% (n = 111) of the articles provided details on the type of representation used in the data collection stage, just 6% (n = 7) provided any justification for the type of representation used. The ‘other’ category included the use of lines, which was only found in articles that used sketch mapping. Polygons are sometimes used but only comprise 10% (n = 11) of all Participatory Mapping articles, split between those categorised as PGIS and Sketch Mapping.



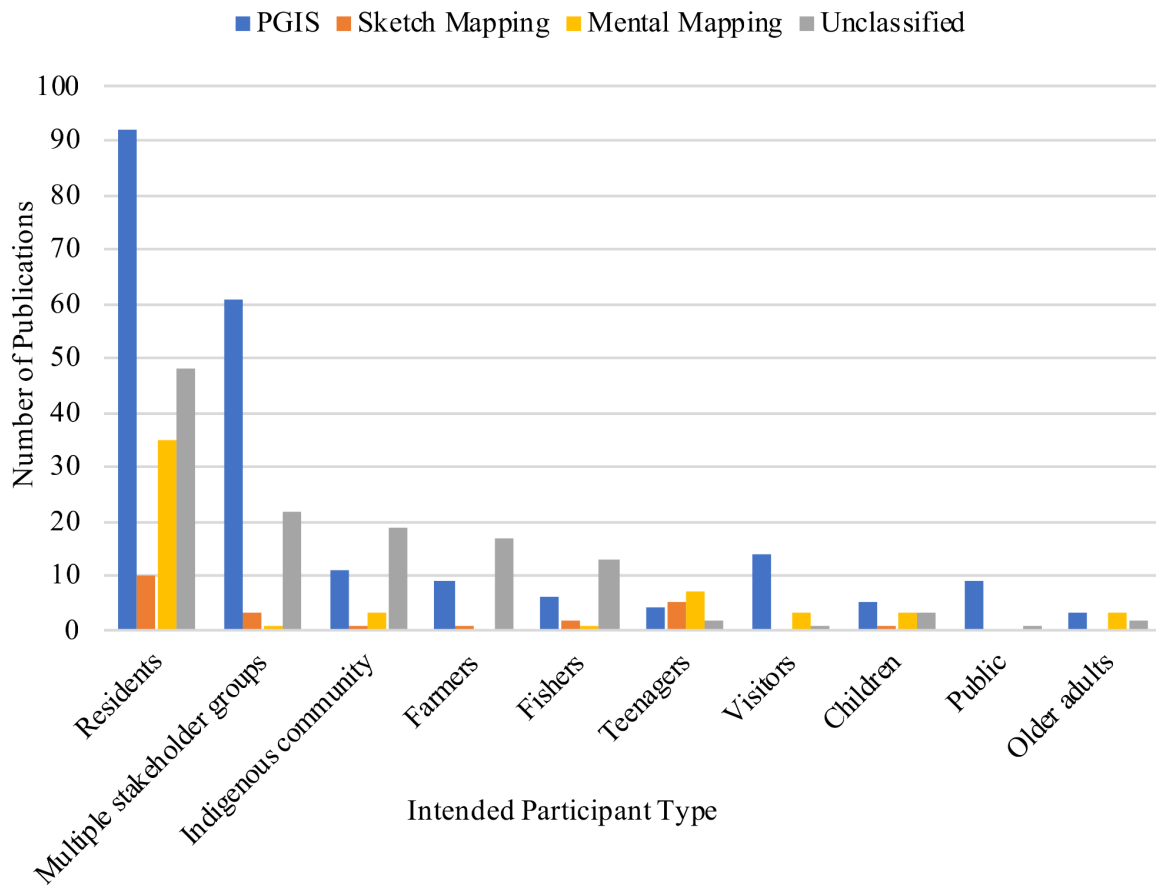
**Figure 12** Type of representation used by the Participatory Mapping category

#### **4.4.3 How are participant demographics being recorded?**

In this section an analysis of the information provided regarding who participates is presented, including whether participants have been specifically targeted or are members of the general public; and standard demographics.

##### *4.4.3.1 Types of Participant*

Of the 578 eligible papers 82% (n = 475) provided details in the title, keywords or abstract regarding the specific groups of intended participants. Of those that gave this information 39% (n = 186) focussed on specific groups defined by occupation, age or distinguishing characteristics pertinent to the context of the case. For instance indigenous communities, farmers, fishers and teenagers were all common participant types, each targeted in 3-7% of papers. Figure 13 presents a more detailed breakdown of the ten most common types of intended participants, categorised by method of Participatory Mapping. A clear dominance of PGIS can be seen in the more generic categories such as residents, multiple stakeholder groups (i.e. multiple specifically targeted groups for the same objective), public and visitors, with a more balanced use of methods in the age-defined categories such as children, teenagers and older adults. However, 18% (n = 103) of articles failed to identify a specific intended participant type.



**Figure 13** Most common intended participants type as referred to in the title, abstract or keywords

#### 4.4.3.2 Targeted Participation

Participants in each method of Participatory Mapping were either recruited for being part of a specific group (i.e. age, job or location) or the general public (i.e. through crowdcasting). For the included articles using mental mapping, 67% ( $n = 17$ ) of participants were targeted groups, similarly with sketch mapping at 65% ( $n = 38$ ). Articles using PGIS however were largely addressed to the general public (64%,  $n = 21$ ). As shown in Table 3, research targeted

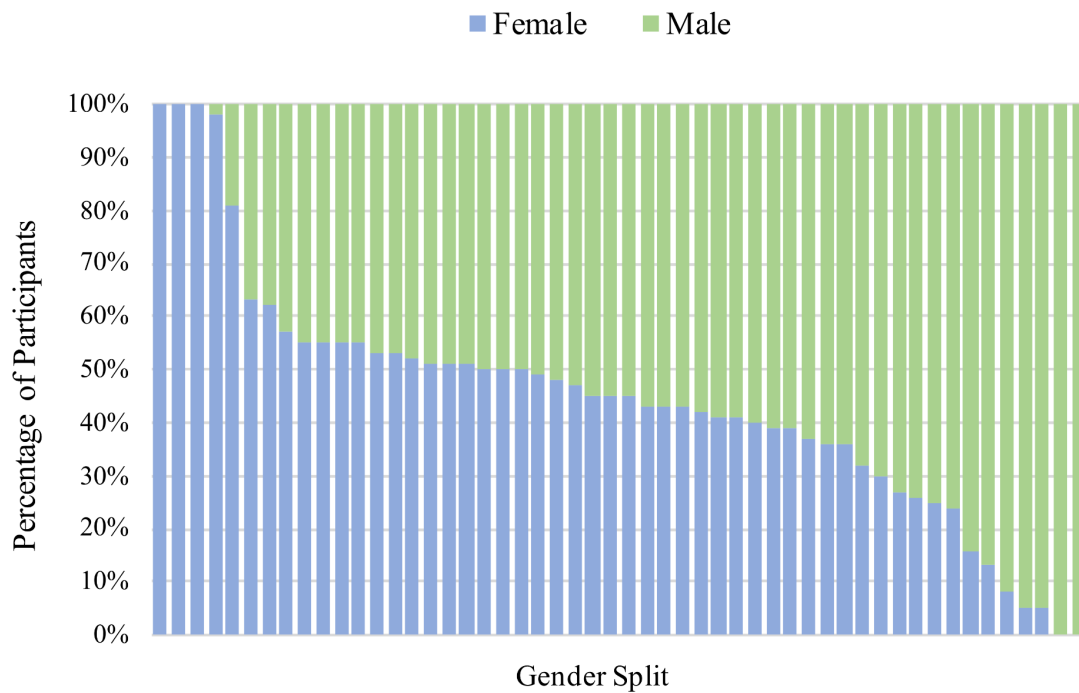
at specific groups got considerably fewer responses than that aimed at the general public, which is to be expected as they are being drawn from a significantly larger pool. It should be noted that just 80% (n = 94) of papers reported both the participant numbers and whether the participants were specifically targeted or not.

**Table 3** Impact of participant recruitment on participation numbers in the 94 Participatory Mapping articles that reported the number of participants

<b>Participant Recruitment</b>	<b>Total Participants</b>	<b>Number of Articles</b>	<b>Mean</b>	<b>Median</b>	<b>Lowest</b>	<b>Highest</b>	<b>Range</b>
Public	24,703	43	574	150	25	7,656	7,631
Targeted	5,731	51	112	46	4	731	727

#### *4.4.3.3 Participant Demographics*

Just 44% (n = 52) of articles reported the participant gender demographic (Figure 14). Of those that did report the gender demographic, none quantified any gender imbalances in the contribution to the study (i.e. whether most data was produced by male or female participants). There were no discernible patterns in gender balance over time, location or method.

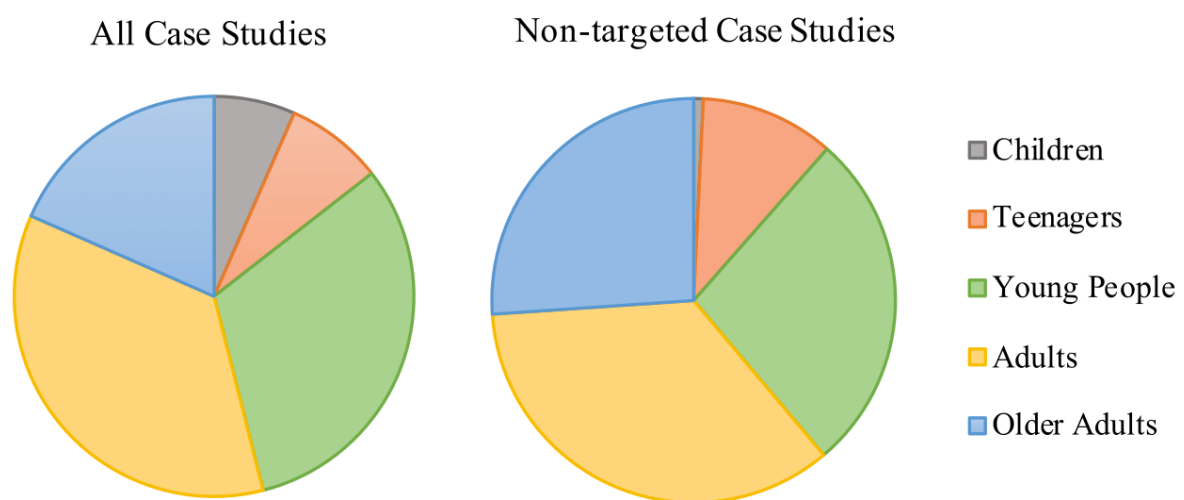


**Figure 14** Participants identifying as female/male in each article

Similarly, only 60% (n = 70) reported the approximate age demographic of those that participated in the case studies. As different articles used different groupings, we will use the following classification: ‘children’ are <12 years, ‘teenagers’ 13-19 years, ‘young people’ 20-29 years, ‘adults’ are 30-64 years and ‘older adults’ 65+ years.

Figure 15 suggests that in those articles where the research does not target a specific type of participant (of those articles that also report age demographics), adults hold the largest proportion at 35% (n = 9), closely followed by young people and older people, each of which make up 27% (n = 7) of articles. Children account for just 1% (n = 0.2) of participants of non-targeted research, yet account for 9% (n = 6) overall, suggesting that they are

predominantly involved in Participatory Mapping when specifically targeted. Conversely, teenagers participate in 9% (n = 6) overall in comparison to 12% (n = 3) of non-targeted research. It should be noted that only 35% (n = 41) of articles indicated that they were aiming for a representative sample in the population in question, be it by gender, stakeholder type or age, of which 15% (n = 6) stated that they failed to achieve their goal.



**Figure 15** Age demographics of participants for all case studies (left) compared to non-targeted case studies (right)

#### 4.4.4 Who is conducting the research and where is it being published?

As would be expected in a survey of academic literature, across all types of Participatory Mapping, articles are predominantly produced independently by universities accounting for 72% (n = 84) overall, ranging between 71% (n = 41.5) for sketch mapping, to 75% (n = 19) for mental mapping. The majority of those remaining were produced by universities in

collaboration with a government agency, totalling 10% (n = 2.5) of mental mapping, 21% (n = 12) of sketch mapping and 23% (n = 7.5) of PGIS.

Although there is a clear increase in the number of articles that use Participatory Mapping since 2005, a dominant journal of publication has not yet emerged. The most frequently seen journal of publication across the 578 eligible articles is 'Applied Geography' which published 6% (n = 35) of all Participatory Mapping articles up to 16th June 2020, however 79% (n = 455) of articles were published across a broad range of journals that each contained less than 2% of all published articles (i.e. fewer than 10 papers per journal).

Of the 5% (n = 6) of articles that reported they were intended to influence policy, just 2% (n = 2) of articles implied they might have succeeded in doing so, however the remaining four gave no indication as to whether this intention was realised or not. A further 33% (n = 39) mentioned the use of Participatory Mapping in policy, but gave no indication that the research was used to this end.

## **4.5 Discussion**

The above findings identify a number of incompatibilities with the principles of Open Science. Here we present a detailed discussion on the nature and importance of incompatibilities, before presenting a framework through which an Open Science approach may be adopted in Participatory Mapping research.

Despite the increasing popularity of Participatory Mapping over the past decade, there is little evidence of emerging cohesion within the field, or attempts to make studies more open in nature, limiting replicability and development. The lack of a clear taxonomy for the varied methods is likely a symptom of the multidisciplinary nature of the field, exacerbated also by the lack of a clear ‘home’ journal for the publication of empirical and critical Participatory Mapping research. This confusion is further compounded by the lack of an agreed definition for many of these terms, as is illustrated by the variety of definitions for the term PGIS given by Godwin and Stasko, (2017); Huck et al., (2014) and Elwood, (2006). We propose the simple, high-level taxonomy of PGIS, sketch mapping and mental mapping to better accommodate the heterogeneity of approaches in this multidisciplinary field without imposing restrictions based on the individual nuances. By clearly communicating the methods under these high-level terms to break down the distinguishing features (i.e. digital or not, and whether a base map is present or not), these simple categories would facilitate more effective knowledge sharing both within and between disciplines.

It is widely recognised that transparency and accountability are key in conducting Participatory Mapping research (Blackstock et al. 2006). However, the poor levels of reporting across all aspects of the research demonstrated in this study demonstrate a clear need for an Open Science approach. Without sufficient information about who is participating and to what end, the validity of publicly collected information is brought into question (Brown, 2017). Neither age nor gender demographics were consistently reported in publications (just 60% and 44% respectively), with even fewer indicating whether a representative sample of a given population as a whole or specific gender balance was desired. The representativeness, credibility and relevance of the participants is central to

effective outcomes in Participatory Mapping (Brown, 2017). It is vital therefore, for future research to report participant numbers, demographic information, whether (and how) participation was incentivised, and the context in which the research was conducted (i.e. locations and institutions).

Within an Open Science framework, specific details such as these are required to be reported, which adds veracity to the data produced as well as value to the decisions made using it. Whilst all eligible articles in the systematic review gave an indication of the type of participant recruitment that was used (e.g. targeted or crowdcast), many of the included articles lacked even basic information on participant demographics. Reporting the age and gender demographics of those who participate is vital context required in order to identify and understand the results. Similarly, whilst being reported more frequently than demographic data, the total number of participants was only reported in 78% of articles. As transparency, sharing and trust are critical for defensible and robust spatial data (Brunsdon & Comber, 2021), omitting such data brings into question the representativeness of the participants and consequently the validity of the research as well as losing out on more nuanced insights into local knowledge (McCall, 2021). Participatory Mapping research is necessarily collaborative, which Kedron, Fotheringham & Goodchild (2021), suggest makes it computationally intensive and susceptible to ethical limitations, and therefore difficult to maintain transparency. However, as Nüst & Pebesma (2021) argue, this is more a challenge in the way that academic research is communicated, and one which would be remedied by taking an Open Science approach through the inclusion of workflows and open data. Like GIS, there may be situations where the data is of a sensitive nature. In these cases researchers should adopt all elements possible in the given circumstance (Singleton et al., 2016).

To further enhance knowledge sharing and replicability in Participatory Mapping, as well as maintain the empowering and democratic intentions, the methods used in collecting complex socio-spatial data and reasons for doing so should also be made clear (Elwood, 2006; Carver, 2003). Whilst all of the methods identified in this review hold the potential to be conducted remotely, PGIS is particularly well suited to this approach (Carver, 2003), as is reflected in our findings, with greater numbers of PGIS studies conducted remotely than the other methods. The lack of reporting on specific data such as the number of participants and use of incentivisation limits the potential to thoroughly interrogate the impact differing methods and approaches may have on citizen buy-in with Participatory Mapping research. Although there are generally higher participant numbers for research conducted remotely, this does not necessarily imply that remote research is more successful and should be used in place of facilitated research. Rather, the two approaches present different opportunities for complementary data to be collected in support of the spatial data. The number of participants that take part in facilitated research tends to be smaller as these methods can be used in tandem with interviews or ethnographic approaches, whereas questionnaires are more likely to be used in conjunction with remote research. For example, one article using sketch mapping to examine the distribution of a species of fish in Brazil had only 6 participants, which was appropriate for the situation given those who participated required specific experiences and allowed for a rich dataset to be produced (Gerhardinger et al., 2009). In comparison, a remotely conducted PGIS study into urban forestry obtained the views of 1,403 participants as the research was intended to understand the views of the population of Helsinki, the capital city of Finland (Wang et al., 2019). In all cases, it would be beneficial to include the target sample size or participation rate to add meaning to the participant numbers

within the wider context of the research and enable other researchers to learn from what may work well in similar case studies.

The interface being used to collect spatial data from participants is inextricably linked to not only the chosen method but also the mode of notation or indication with which participants are able to elucidate their thoughts. Despite the variety and subjective nature of the questions being asked, the way in which participants are then able to represent their spatial thoughts and opinions through the various interfaces is dominated by discrete points. The interface and notation used appear restricted by focussing on the perceived advantages in precision of discrete points (i.e. Brown et al., 2017), rather than capitalising on the variety of options that both digital and paper-based methods could present. One example that demonstrates this issue is a sketch mapping study that required participants to identify walkable neighbourhoods using points, rather than shaded areas or polygons to ensure the data was standardised and could facilitate spatial analysis (Bereitschaft, 2018). The use of a discrete point in this case cannot adequately convey the participants' understanding of neighbourhood extent, which will be different for each individual that takes part (Huck et al., 2014). The majority of articles offered no justification for their choice or representation, conforming instead to the norm of relying on points to convey complex and nuanced data. Overall, there is minimal justification provided for the notation or indication used to represent participants' spatial thoughts and opinions. This lack of critical engagement restricts the capacity to learn from previous research and highlights the need to normalise the development of more bespoke interfaces designed to gather different types of Participatory Mapping data. Ensuring that more participatory mapping software is made open source will help to stimulate innovation in the development of both new interfaces and more suitable notations. Not only

can this act as a catalyst for the development of the field, open source software also improves methodological rigour and accountability by permitting both researchers and participants to obtain a deeper understanding of how exactly the data is being collected and analysed.

Similarly, in being transparent about the intentions or purpose of the research (such as the intention to influence policy) a better understanding of the direction the field has taken and will take in future research can be obtained. In this paper we have focused on understanding a defined set of characteristics associated with the use of Participatory Mapping methods in empirical studies. We recognise that there is considerable variation in approach, processes of engagement and modes of participation according to the epistemological contexts of individual studies (Raymond et al., 2014). These affect the types of knowledge generated and how decisions are informed. Although an interesting line of enquiry, a direct investigation of these nuances was beyond the scope of this particular investigation.

It is well cited in the literature that Participatory Mapping is used as a means to increase democracy in policy and the decision-making process (Czepkiewicz et al., 2018; Radil & Jiao, 2016; Elwood, 2006). However, and as previously identified by Sieber (2006), it is difficult to actually gauge the influence or impact that Participatory Mapping has, as just 5% of articles stated their intent to influence policy, none of which confirmed whether this had been successfully achieved. It should be noted, however, that this study comprises a review of academic publications, and that a review of ‘grey literature’ or policy reports, for example, might yield a different result. This apparent lack of policy influence is therefore a reflection on the academic applications of Participatory Mapping, and not necessarily the efficacy of

Participatory Mapping itself. The advantage of an Open Science approach in this regard is that the intentions of the research must be transparent, therefore ensuring replicability and enabling any specific motivations (i.e. research that is intended to influence policy) to be identified and their success or failure evaluated. This therefore also increases the legitimacy of the evidence base for decisions which are based on Participatory Mapping research, which in turn would influence grey literature.

The analysis of the included articles revealed that Participatory Mapping is largely being used to ask questions regarding values/perceptions about a certain places (such as identifying areas of perceived risk and vulnerability to natural hazards e.g. Kienberger, 2014 and Ruin et al., 2007), or to identify spaces used for specific activities/practices (such as identifying particular routes taken, or frequently used green spaces e.g. Wolf et al., 2015 and Luz et al., 2019). However, just 21% of articles presented the exact wording posed to participants. The wording of a question directly influences the answer given and can greatly influence the results of a survey (Fowler & Fowler, 1995). Therefore, a simple description does not provide sufficient detail required for scientific rigour or replicability of the research. To ensure that future Participatory Mapping research is considered a legitimate and scientifically valid method, and not just a “box-ticking exercise” the precise wording of the research question must be included (Brown & Kyttä, 2018; p5).

#### **4.5.1 Recommendations for an Open Science approach to Participatory Mapping**

Singleton et al., (2016) reported an urgent need to reconsider how GIS data, tools and methods can be made more open and scrutable, engendering improved scientific transparency

and replicability. In the case of Participatory Mapping, this has not yet taken place, as has been revealed in the results of this systematic review. Although a challenging and multidisciplinary field, plurality of methods should not impact the degree to which they are transparent or replicable, with both quantitative and qualitative research capable of benefiting from an Open Science approach. We have therefore developed a set of best practice recommendations in order to advance Participatory Mapping towards a unified and open field following the principles of Open Science. These recommendations include general good practice (e.g. Singleton et al., 2016), as well as specific areas unique to the field of Participatory Mapping that we have identified through systematic review. Kar et al., (2016) propose that three key components of Participatory GIS are the *technology*, the *people* and the *purpose*, however in applying this to the wider field of Participatory Mapping a more holistic inclusion of the *methods* (rather than technology alone) is required, and so we adopt the *methods*, the *people* and the *purpose* as a structure. These recommendations address all of the challenges that we have identified in the reporting of Participatory Mapping research. Implementation of the recommendations (Table 4) as a framework for engendering an Open Science approach to Participatory Mapping will enhance replicability and transparency, helping to unify the field and ensure rigorous reporting of methods. Not only would this benefit those who conduct the research, but also produce datasets with greater influence in decision-making for the benefit of those who participate.

**Table 4** Recommendations for an Open Science approach to Participatory Mapping research

<b>Methods</b>	<i>Selection</i>	<p>Provide specific details regarding the method selected, including:</p> <ul style="list-style-type: none"> <li>• whether it is PGIS (digital), sketch mapping (non-digital but with spatial context) or mental mapping (non-digital with no spatial context)</li> <li>• why that method is appropriate for the specific context/location/participants</li> <li>• why that method is suitable for the purpose of the research</li> <li>• the precise wording of the questions being asked of participants</li> <li>• the mode of representation being used (i.e. point/lines/polygons/ bespoke/freehand)</li> </ul>
	<i>Disclosure</i>	<p>Provide details on the approaches used in collecting and compiling the data, including:</p> <ul style="list-style-type: none"> <li>• whether participation was incentivised or not,</li> <li>• how participants were identified;</li> <li>• whether there were any issues in doing so;</li> <li>• whether or not they were a specifically targeted group and</li> <li>• the target number of participants, including a justification for this target</li> <li>• the interface used, including a justification of why it is appropriate</li> </ul>
	<i>Access</i>	<p>Where possible, links should be provided to open access repositories containing:</p> <ul style="list-style-type: none"> <li>• anonymised data collected from participants (for example using the FAIR Data Principles)</li> <li>• software or scripts used for the collection and analysis of data</li> <li>• workflows detailing the procedures followed for replicability</li> </ul>
<b>People</b>	<i>Participants</i>	<p>Specific details of those who took part in the research should be reported including:</p> <ul style="list-style-type: none"> <li>• total number of participants</li> <li>• demographic information, including age/gender, and where appropriate to the research ethnicity/educational</li> </ul>

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		level/related experience to the research and any other categories that were collected
	<i>Researcher</i>	Consider the positionality of the researcher and report: <ul style="list-style-type: none"> <li>• how this might impact the research</li> <li>• how this was accounted for</li> </ul>
	<i>Institution</i>	Ensure that funding bodies as well as all agencies involved are reported (including if there was no funding body/affiliate agency involved)

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<b>Purpose</b>	<i>Location</i>	Justify why the specific case study location was selected
	<i>Intentions</i>	Include details on: <ul style="list-style-type: none"> <li>• why participation is required to answer the research questions</li> <li>• how the input given by participants will be used</li> <li>• whether the output is intended to inform policy</li> <li>• and, where possible, the extent to which the output was successful in doing so</li> </ul>

## 4.6 Conclusion

This paper has presented the first systematic review of empirical Participatory Mapping research across a diverse range of disciplines. Our results identify areas of weakness in which adopting an Open Science approach could advance the field. A number of inconsistencies have been revealed in how methods are both defined and reported, which impacts the replicability and rigour of published research, as well as on the potential for the cross-fertilisation of ideas and sharing of best practice between disciplinary silos. A significant number of Participatory Mapping research articles fail to report participant demographics; participant numbers; the use of incentives; and even the wording of questions posed to participants. This makes it not only difficult to learn from previous research, but also limits the potential impact of the participatory data collected and raises issues around transparency in the subsequent decision-making. There is a clear dominance in the use of

discrete points to articulate participants' spatial thoughts and feelings with little justification for their selection (or apparent consideration as to whether they are the most suitable way to collect such complex data). Further, the inconsistent taxonomy used to refer to each method is confusing and limits transferability.

In response to these challenges, we argue that there is a need for an Open Science approach to Participatory Mapping research. To this end we present an associated reporting framework, the use of which will assist researchers to understand requirements, share knowledge and experience, stimulate innovation and ensure that the impact of information generously given by citizens can be maximised. The context-specific nature of the discipline and requirement for specific data protections means that the reporting and sharing of participatory research is not without complication. However, in following the recommendations set out above, a level of replicability and rigour can be ensured to a degree that has not been widely evidenced in the current body of literature. This would not only add value to the Participatory Mapping data used in decision-making, but empower citizens to exert greater democratic influence; the very reason for which the field was developed in the first place (Brown and Kytä, 2018; Sieber, 2006; Carver, 2003).

## 5.

### **Effective PPGIS in spatial decision-making: reflecting the priorities of the public by illustrating the implications of their choices**

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This chapter has been published as:

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*Denwood, T., Huck, J., & Lindley, S. (2019). Alternative Interfaces for Improved Representation in Web-Based PPGIS. In Proceedings of the 28th Annual Geographical Information Science Research UK Conference. Winner of ‘Best Paper’ award at GISRUK 2020.*

*Denwood, T., Huck, J., & Lindley, S. (2019) Intelligent Lines, a Novel PPGIS for Route Mapping. In the Book of Abstracts of the ISPM Conference "Let the People Map" Page 16. Aalto University 17-19th June 2019*

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## **Abstract**

The use of local knowledge adds value to the decision-making process, for which Public Participatory GIS (PPGIS) are widely deployed. However, there are often issues in the way that PPGIS are designed, particularly with respect to the type of spatial representation used. We propose ‘informed interfaces’ as a novel approach to PPGIS interface design, to ensure the system can effectively reflect the interests, priorities and values of participants in case-specific spatial decision-making. This paper introduces the concept before demonstrating the benefits of the approach using two examples of informed interfaces through an illustrative UK case study. Evidence was gathered from three face-to-face workshops and five multi-participant online usability tests, revealing that participants felt more confident in the datasets they produced using the informed interfaces. The results also confirm that informed interfaces hold the potential to provide richer, more veracious datasets for improved decision-making, revealing new insights into local perspectives.

*Keywords:* PPGIS, Participatory Mapping, Interface, Representation, Public Participation

## 5.1 Introduction

The development and use of any Geographical Information System (GIS) is a socio-technical process. GIS is not merely a method for translating spatial data into cartographic form but a representation of the connections, patterns and relationships between people and their environment (Obermeyer, 1995). In the early phases of development, traditional GIS were criticised as being elitist. Inconsistent access rights, financial barriers and top-down methodologies imposing external perspectives on local problems led to not only a distrust in the practice, but also produced ineffective outcomes (Craig & Elwood, 1998, Sawicki & Craig, 1996; Weiner et al., 1995; Rundstrom, 1995; Harris et al., 1995).

As a reaction to these criticisms, more democratic GIS techniques evolved in order to better acknowledge the social, epistemological and power implications the process may have (Elwood, 2006). The focus shifted towards providing marginalised communities with a voice, using an integration of place-based, non-expert knowledge to aid in addressing issues such as complex land use disputes (Brown & Kyttä, 2018; Radil & Jiao, 2016; Kar et al., 2016 & McCall & Dunn, 2012). Public Participatory Geographical Information Systems (PPGIS) encompass a wide array of practices in which social groups and individuals can participate in GIS-based spatial analysis, planning, knowledge production and decision-making (Elwood, 2006). PPGIS can be used to compile and present spatial data from a broad range of stakeholders in order to represent individual (or group) interests and priorities (Anderson et al., 2009). It is widely agreed that the inclusion of public, non-expert views in decision-making allows for a better understanding of the way people interact with the space around them and consequently enables more robust decisions to be made (Anderson et al., 2009; Evans & Waters, 2007). Accordingly, PPGIS are often used as part of Spatial Decision

Support Systems (SDSS) or other multi-method data collection approaches to obtain public perceptions (Keenan & Jankowski, 2019).

Including members of the public in GIS-based decision-making processes, brings both benefits and challenges. Barriers to the effective use of PPGIS include digital divides between those who can and cannot access the internet or computer technologies (Gottwald et al., 2016); participation inequalities in how much those who can participate actually contribute (Haklay, 2016); and data-related issues, e.g. quality, credibility and the effectiveness of representations (Huck et al., 2018). Despite progression in the field since the mid-1990s, Elwood (2006) argued that participatory forms of GIS still fall foul of the same limitations and criticisms as their predecessors, such as issues around representation and inclusion. Whilst further technological advances have since taken place and the limitations in the field often acknowledged, little has been done to address them (Radil & Anderson, 2019; Brown & Kyttä, 2018 & Robinson et al., 2017). As Blackstock et al. (2006) indicated, the validity of public involvement of any type depends on credible, accountable and transparent methods which connect individuals and groups to the decision-making process. In PPGIS, this requires the use of an appropriate interface, to enable the most effective transfer of information between the target population and the researchers or decision-makers.

### **5.1.1 Representation in PPGIS**

Many PPGIS interface examples in the literature use spatial primitives (normally basic points and polygons) to simplify complex social and geographic features into readable and replicable formats. Brown (2012) suggests that using point-based data collection is the

simplest way to collect spatial data whilst yielding the highest response rates, reduced levels of bias and greatest participation. However, the uncritical use of basic spatial units such as points, can in some circumstances offer a poor representation of the complex relationships between people and place compared to other units (Huck et al., 2018). Representing human opinion more effectively on a map requires a shift from the normative approach of collecting data based on simple points and polygons, to considering more specialised spatial units and associated interfaces (e.g. the interfaces presented by Huck et al., 2014; Evans & Waters, 2007). Such spatial units are designed to generate information which is better representative of the specific question at hand, as opposed to being predicated on convenience, convention and availability. With the technological advances that have taken place since the millennium, it hardly seems appropriate that the interfaces used in PPGIS should not have advanced simultaneously. Whilst it is often acknowledged in the literature that these traditional approaches are unsatisfactory, their use remains common practice in research and decision-making (Brown & Kytä, 2018; Robinson et al., 2017; Huck et al., 2014 & Goodchild, 2011). The continued use of spatial primitives in PPGIS has been described as the “*Hammer of Participatory GIS*” (Huck et al., 2019:5), referring to Maslow’s ‘Law of the Hammer’ (*if the only tool you have is a hammer, you’ll treat everything as if it’s a nail*; Maslow, 1966). This analogy highlights an over-reliance on familiar tools and techniques for the collection of nuanced and complex data, instead of ensuring that the question being asked is what influences the nature of representation used (Huck et al., 2019).

It is vital that the interface used in PPGIS reflects the values and priorities of both the participants and of the researchers or decision-makers. As such, new techniques in spatial representation are emerging that greatly expand the possibilities for both researcher and

participant, and which are critical for ensuring the public is engaging with PPGIS in a meaningful way (Godwin and Stasko, 2017; Huck et al., 2014). It is also important to ensure the questions asked with PPGIS can reasonably be expected to be answered by members of the general public, without requiring advanced analytical assessment. For example, as part of an energy infrastructure project, we might wish to gather public opinion on the location of a potential new wind turbine. We cannot reasonably expect the public to have the depth of knowledge and spatial thinking skills to identify a location from which a proposed turbine might be visible, or at least to be able to do that accurately. Neither can we expect them to have a detailed understanding of the many complex factors that determine the suitability of a location for a wind turbine. Such expectations might be one of the reasons that target audiences feel poorly qualified to comment in these sorts of decision-making consultations, and therefore do not participate (Firestone et al., 2020). In such situations, participants can benefit from the support of an underlying algorithm to provide contextual information or guide the user in a way that better reflects the real world situation.

### **5.1.2 Research Aim**

To address the reliance on simple spatial primitives in PPGIS, this research considers how the type of representation used might enable participants to engage more effectively in the decision-making process. Specifically, we ask the question:

*How might PPGIS interfaces be designed in a way that better supports the researcher (in the question they are asking) as well as the participant (in the answers they are giving)?*

In answering this question we introduce and demonstrate the concept of ‘informed interfaces’ in PPGIS: purpose built systems that utilise underlying algorithms to provide case-specific,

contextual information that supports and informs both the participant in making their choice, and the decision-maker or researcher in interpreting the resulting dataset. Such interfaces are commonplace in traditional GIS, yet rarely seen in PPGIS where the focus is on members of the general public providing their views on spatially explicit questions to support the decision-making process (as opposed to specific groups of stakeholders). Whilst there are numerous factors that influence the success of PPGIS such as geodesign (e.g. Burnett, 2020) or sampling design (e.g. Brown 2017), this research focuses on spatial representations and seeks to encourage the use of more considered spatial units to progress the field of PPGIS. The objective is to encourage the use of more informed interfaces to improve the veracity and value of data collected from the general public, as well as progress the field of PPGIS through more effective spatial representation.

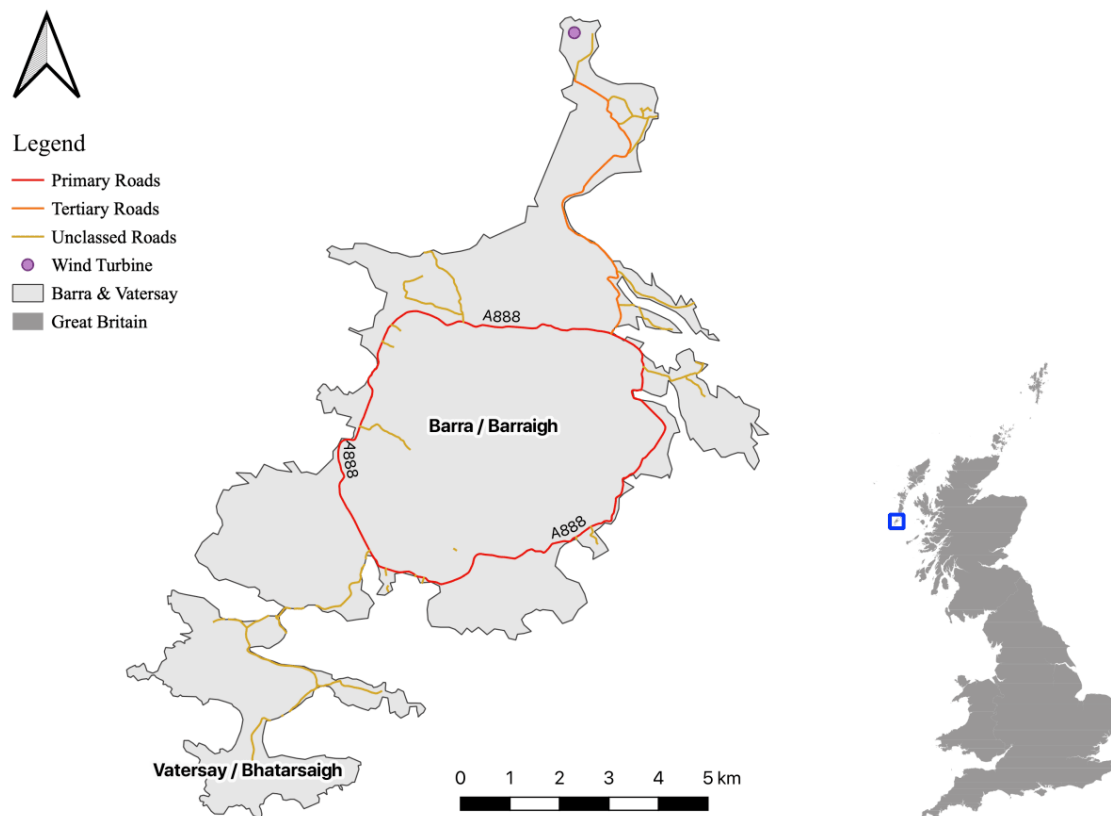
## **5.2 Methods**

We demonstrate the potential of informed interfaces through two examples: the first of which relates to the visual impact of wind turbines and the second to designing footpaths, using the isles of Barra and Vatersay, Outer Hebrides, UK as a case study. This section begins by detailing the case study, before explaining the interfaces designed and how they were assessed through both face-to-face focus groups and a remote usability study.

### **5.2.1 Case Study**

The isles of Barra and Vatersay (Figure 16) have an area of approximately 70 km<sup>2</sup> and a population of around 1,300 (CNE Siar, 2011). The interior geography of Barra and Vatersay (two islands joined by a short causeway) consists of machair (low-lying grassy plains),

uninhabited hills and lochs, with the population residing in hamlets and crofts along the coast. This location offers a unique opportunity to explore the use of informed interfaces in PPGIS as the residents have recently produced a Local Energy Plan enabling existing and future energy needs to be assessed, opening up further opportunities to obtain local views (Local Energy Scotland, 2018). The plan identifies electricity production and active transport as two key areas of concern, largely due to the remote location of the isles, which makes importing fuels both challenging and expensive.



**Figure 16** The isles of Barra and Vatersay, Outer Hebrides, UK

### 5.2.2 Informed Interfaces

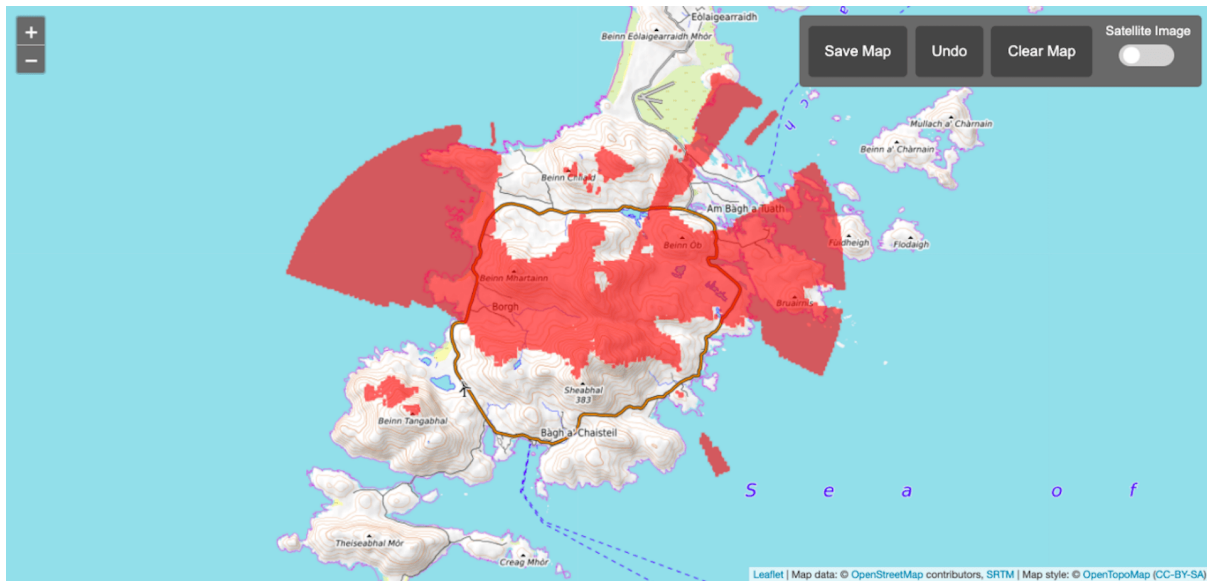
The algorithms underlying the two ‘informed interfaces’ used in this research are widely available in traditional GIS packages, but are not normally used as part of web-based PPGIS. To ensure transparency in the data collection process, both interfaces are available online at <https://gitlab.com/timna/informed-interfaces>. This not only gives those taking part in the research the opportunity to see exactly how their data are being collected (therefore increasing transparency and trust in the process) but also enables the tools to be integrated into research with only minor alterations i.e. the parameters of the algorithm or location.

#### 5.2.2.1 Using Viewsheds as an Informed Interface

The first interface uses viewsheds (a visibility structure that represents all visible points from the selected viewpoint) as a spatial unit; calculated and drawn in real-time in response to clicks on the map (Kaučič & Zalik, 2002). The viewshed indicates all of the locations from which a 50m tall wind turbine would be visible to an individual standing at the click location (with eye level set at 2m above the ground, a 360° field of view and a maximum visible distance of 5km). As participants click on multiple locations from which they would *not* wish to be able to see a turbine (e.g. their house, or a hill summit with a ‘nice view’), the map will then be populated with a cumulative viewshed delineating the areas in which a turbine should not therefore be placed in order to meet the desires of that individual participant. Asking participants to specify locations from where they would not wish to see a turbine is a question to which they can reasonably be expected to be able to answer without further information being provided. This contrasts with more traditional approaches to planning-based PPGIS, which have asked participants to identify locations they view as suitable or unsuitable for a wind turbine, or choosing from already designated areas (e.g. Huck et al. 2014 and Mekonnen

& Gorsevski, 2015 respectively). These are complex decisions for which a non-expert cannot be expected to provide an informed response. The approach presented here, however, is able to facilitate the asking of questions that better reflect how participants think they would experience the installation in real life, and also provides them with contextual information about the implications of their decisions (because they can see the viewshed as they add locations to the map, and choose to accept or reject them accordingly).

Within the interface, multiple viewsheds can be added to the same map, resulting in a composite viewshed of all of the locations at which each participant would not wish to see wind turbines, i.e. as a composite of viewsheds for homes, vantage points and other significant locations where seeing the turbine would have a negative impact for that participant (as shown in Figure 17). Over multiple viewsheds and users, an inverse suitability surface is generated, with the areas containing the fewest viewsheds - or none at all - being the most acceptable to the participants.



**Figure 17** Screenshot of the informed interface using viewsheds, with areas considered unacceptable locations shown in red

In this way, both the participant and the decision-maker gain a more comprehensive view of the expected visual impact of a wind turbine without increasing the level of effort or technical skill required. The use of the informed interface, together with a reframed question, means that the participant is more empowered to provide meaningful answers. In this case participants are asked the considerably more straightforward task of entering known point locations which denote places to shield from view (e.g. homes) as opposed to being asked to accurately assess point locations where turbines would be invisible from those places. From the perspective of the researcher, the dataset provides a meaningful insight into the participants' views on spatial variations in the visual acceptability of a wind turbine development across the isles; as opposed to a collection of somewhat arbitrary points indicating understandably ill-informed opinions on where a wind turbine should or should not go. From the perspective of the participant, they are able to provide more informed locations in their answers, using the viewshed to understand the implications of their choice, and in

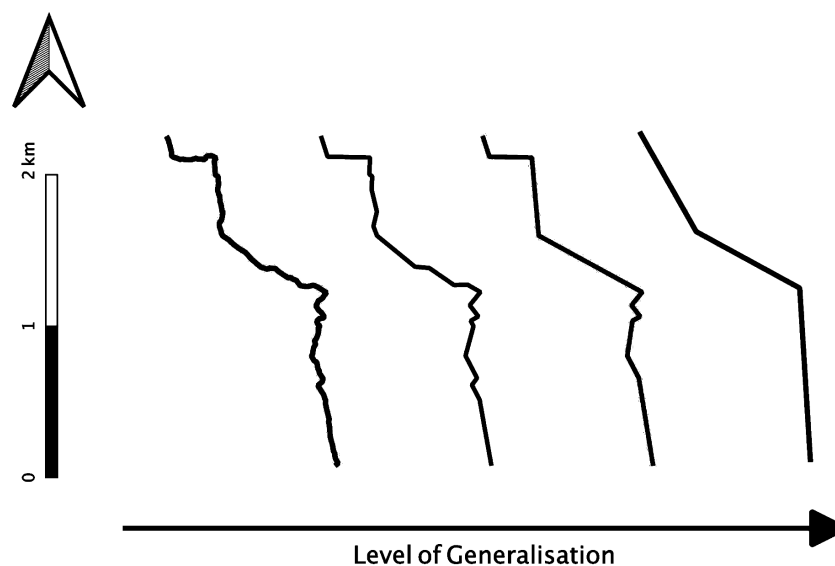
doing so better understand the decisions that they are making. As such, the proposed interface is better suited to support the question being asked by giving participants the opportunity to make better-informed decisions, and generating a more robust and useful dataset for the researcher.

#### *5.2.2.2 Using the A\* Algorithm as an Informed Interface*

The second interface uses a routing algorithm to generate least-cost paths between nodes (click locations) entered interactively by the participants to indicate where they would like to see new footpaths and pavements on the isles (Hart et al., 1968). The interface using the algorithm has the potential to improve support for participants by removing the need for detailed digitising and for making judgements about what might be a realistic route. In Gottwald et al.'s (2016) research into the usability of PPGIS among older adults, the drawing of a digital line proved to be such a major challenge that the tool was removed completely. The use of an informed interface removes this barrier, enabling participants to just select a start and end location should they wish, with the resultant route still being feasible. Additionally, by masking specific areas in the base-map, the routes are ensured to be physically feasible (avoiding water, steep slopes and other impassable obstacles). Elevation was selected for the underlying dataset as people tend to follow the easiest and most comfortable route when walking, avoiding sharp changes in elevation (Ciolek, 1978).

The use of simple digitised lines in PPGIS can also present challenges to the researcher with regard to aggregating and making sense of the data collected. One example derives from the challenges caused by the varied levels of generalisation that users might employ in

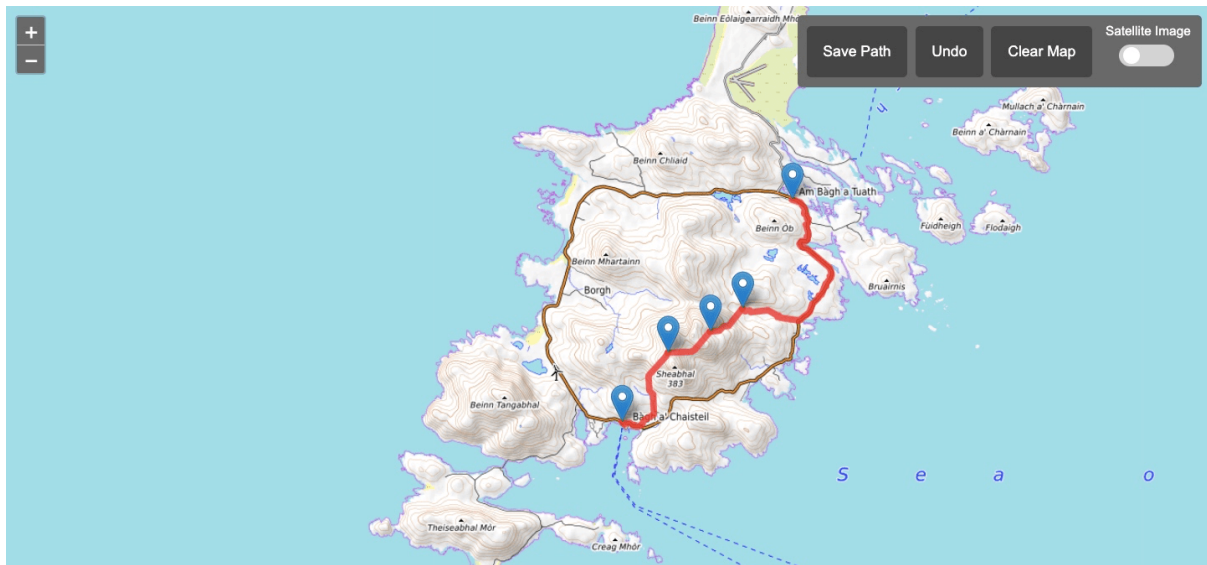
representing their route choices. For example if multiple participants are trying to plot the same route between two points, it is unlikely they will draw exactly the same route, even if they intended to do so. One participant might just draw a straight line segment between the two locations, whereas another might draw a far more detailed path. There is then no way of knowing whether they both meant the same route and just had different time available to complete the survey, had different levels of skill, or drew the routes exactly as desired (both being intentionally different). This challenge arises from varying levels of generalisation both between lines that have been digitised by different users, and between multiple lines that have been digitised by the same user (Figure 18).



**Figure 18** An illustration of a single line digitised with varying levels of generalisation

The A\* algorithm is a widely used, heuristic-based method of finding the most efficient route across a network. Here, it is used to address the challenges found in line-based PPGIS by rejecting the traditional line digitisation model in which user-generated nodes are joined with

straight edges. Instead it adopts one in which each node is joined to the next with a least-cost path, using an underlying elevation surface (Figure 19). The use of a routing algorithm means that the level of generalisation is standardised (to the spatial resolution of the DEM) across all users and routes. This standardised level of generalisation means that similar inputs will follow the same route, avoiding the need for path bundling, which can draw results away from their intended location (McGee & Dingliana, 2012). This also facilitates analysis using supervaluation, akin to the concept of ‘desire lines’ used by landscape architects, whereby paths are routed based on the lines on the ground caused by the greatest number of people walking there (Bates, 2017). Accordingly, the resulting paths avoid issues around comparability and representation, whilst permitting the user to maintain full control over the final route. As the interface standardises the level of generalisation in the resulting paths, it takes the onus for digitising quality away from the participant’s individual mapping effort or skill and places it instead on the spatial resolution of the dataset. This enables collective knowledge to be presented in a clear and uniform manner to decision-makers. In this instance, the Ordnance Survey Terrain 5 DEM (2019) was resampled to a spatial resolution of 35m and converted into JSON using raster2js (Huck, 2019). This resampling allowed an acceptable compromise between granularity and processing speed, with a near-instantaneous calculation time for each user click.



**Figure 19** Screenshot of the A\* interface connecting multiple nodes (blue markers) with least-cost paths (red lines) based on elevation

As the algorithm highlights (in real-time) the least-cost path between locations, the user can edit the route by adding a greater or fewer number of nodes, in order to maintain full control over the final path. Accordingly, the influence of the algorithm on the resulting route is therefore inversely proportional to the level of detail described by the participant. Once a path has been drawn and saved on the map, it remains at a lower opacity so that the participant can view all of their submissions simultaneously. The use of the A\* interface allows the participant to more effectively represent their ideas, whilst the standardisation of generalisation in the resulting routes makes processing easier for the researcher and the answer to the question being asked more meaningful and readily answered by the participant.

### 5.2.3 Data collection

Each of the informed interfaces were tested through both face-to-face workshops with residents of the isles, and remote usability testing with the general public. The details of which are presented below.

#### 5.2.3.1 Face-to-face workshops

In response to the challenges around transport and energy infrastructure highlighted in the Local Energy Plan, two distinct questions were developed:

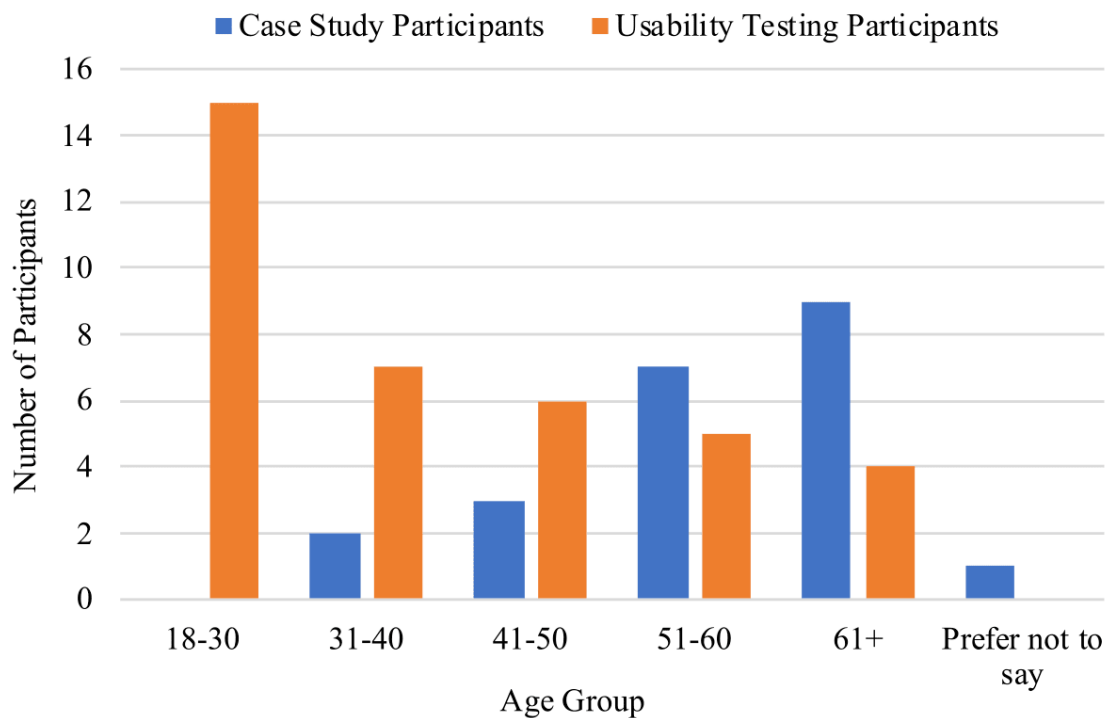
1. From which locations would you not wish to be able to see a wind turbine on the isles of Barra and Vatersay?
2. Where would you like new footpaths or pavements to be developed on the isles of Barra and Vatersay?

Responses to these questions were collected at three facilitated workshops across the three main settlements on the isles in November 2019 with a researcher in attendance. Workshops were advertised to residents on a local social media group, in the local paper and with posters at the venues used. A total of 22 participants (c.2.3% of the eligible population on the isles) attended the local, in-person workshops, contributing 107 footpaths and 18 viewsheds. Over half of the participants identified as female (59%), and 73% of the participants were over 51 years of age. Participants were not compensated for their time or incentivised to participate. During these workshops, participants were asked the two spatial questions using the two interfaces and standard demographic data were also collected (including gender and age). Alongside the mapping element of the workshop, participants were required to add free text

to explain their contribution and provide feedback on the interface, thus enabling qualitative and quantitative responses to be captured and analysed simultaneously. A workshop diary was kept to record additional data, however all of the quotes used in this paper are taken directly from the online participant comments.

#### *5.2.3.2 Usability Testing*

Two further interfaces using simple points and lines were developed to be used as a comparison to the informed interfaces, with all four hosted alongside two usability questionnaires. The new site and data collection format was beta tested on a group of 9 expert GIS users to ensure the interfaces and instructions were understandable and to locate any bugs, prior to the formal focus groups. Five focus groups were conducted in January 2021 via cloud-based video conferencing. A total of 37 participants attended the online focus groups, of which 51% identified as male, with 25% over the age of 51 years (Figure 20). Overall, 41% of focus group participants had some experience of public consultation and 78% were very familiar or experts with using a computer. Although a large number of participants had achieved an undergraduate degree or higher (81%) the largest proportion of participants did not consider themselves familiar with mapping (57%).



**Figure 20** Age category for all participants who took part in the November 2019 workshops and January 2021 usability testing

The focus groups began with a short presentation outlining the research before participants were asked to complete the comparative map survey and subsequent questionnaires, in which the viewshed and A\* routing interfaces would be directly compared to simple point and line-based interfaces respectively. For this study, the questions were re-framed to reflect the fact that participants did not live on the isles:

- A. Design a new footpath route between Castlebay (green marker) and the airport (purple marker).
- B. Imagine you live in one of the hamlets on Barra and enjoy the picturesque views from the inland areas of the isles, from where would you NOT like to see a wind turbine?

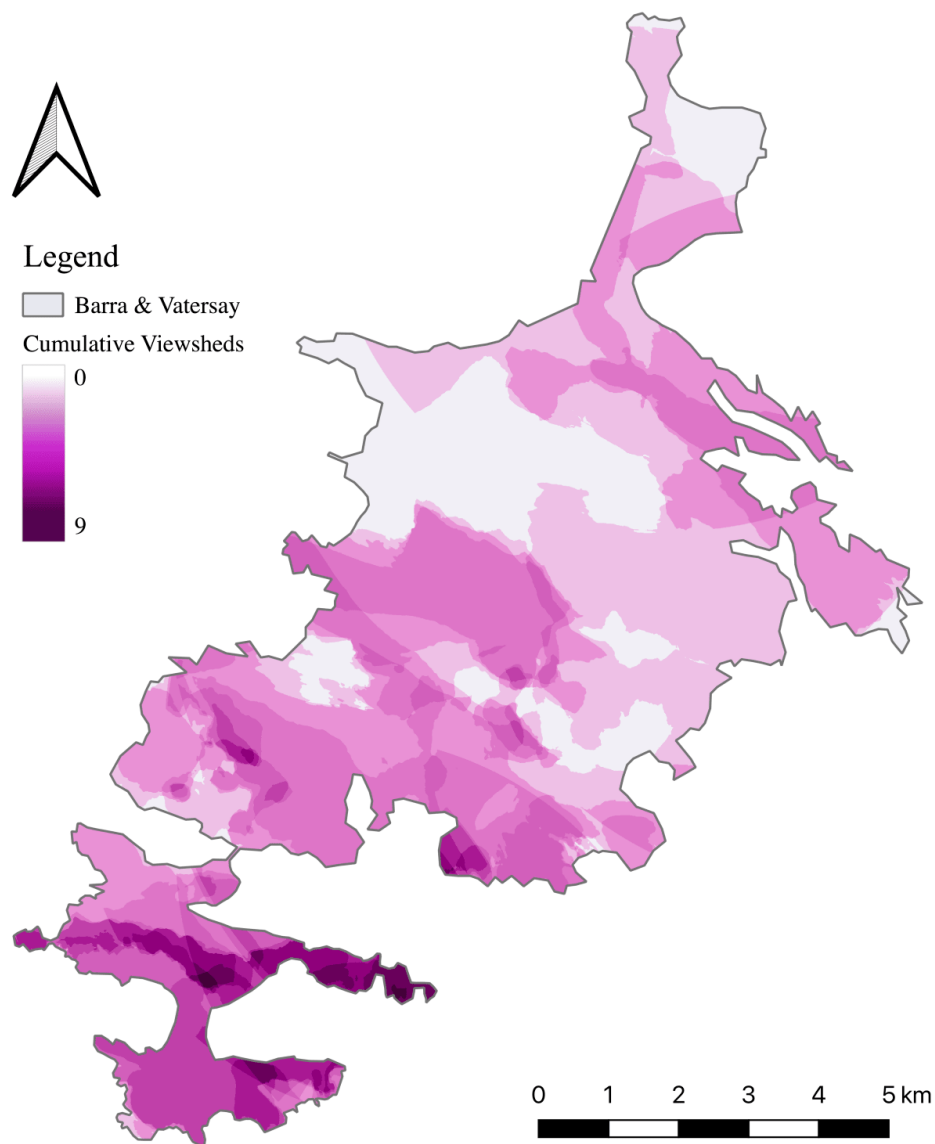
The order in which questions A and B were presented to each user were randomised, as was the order in which each interface for the relevant question was presented in order to control for fatigue bias. Each question (A or B) was accompanied by an instructions page, the two interfaces, and a questionnaire in order to gather feedback on their comparative qualities. Once again, participants were offered no incentive of compensation for taking part in the focus group. Standard demographic data were collected, with additional information collected on experience levels, i.e. education level obtained, computer experience, mapping experience and any past experience of participating in public consultations. The questionnaires set out a series of Likert scale questions asking participants to select which interface they preferred across twenty questions regarding mapping, effectiveness and representation, or whether they found them both the same (based on Ballatore et al., 2019). These were followed by four free text questions designed to collect more detailed feedback on the informed interface specifically. Whilst the spatial and textual data from the face-to-face workshops were both analysed, only the questionnaire responses were analysed from the usability study. This is because the mapping tasks in the usability study were hypothetical in nature and designed purely to ensure participants gave sufficient time to exploring the interfaces before assessing their usability in the questionnaires.

### **5.3 Results**

This section presents the results from the case study workshop with local residents and from the separate usability study focus groups. The results regarding the viewshed interface are analysed first, followed by the results from the A\* interface.

### 5.3.1 Viewshed Results: Case Study

The data collected using the viewshed interface are presented in Figure 21, with the darker areas indicating where a greater number of viewsheds are overlaid. The darker areas indicate where most participants would prefer not to see a turbine from the perspective of minimising visual intrusion at key points of interest.



**Figure 21** Cumulative viewshed formed from the 18 data sets collected from the residents of Barra and Vatersay

It is clear from Figure 21 that there was a strong preference for avoiding areas towards the south of the isles, predominantly on Vatersay and the more residential areas located towards the south of Barra. It is notable that locations in which a viewshed is absent (the grey areas in Figure 21) do not necessarily indicate areas where residents would explicitly *like* to see a turbine, but instead show locations from where residents are more ambivalent about turbines being visible. This knowledge can then enable decision-makers to identify areas that should cause least conflict in the planning process.

Due to the small size of the isles and known limitations of the current energy infrastructure, local residents have a relatively high level of knowledge of local electrical systems. This knowledge resulted in some participants adding further details on why certain areas were unsuitable, as opposed to reasons purely related to visibility as indicated in the qualitative feedback:

*“Not got the infrastructure for a turbine on Vatersay.” [Female, 51-60]*

The viewshed interface was designed to identify where participants would *not* wish to see a turbine, based on the dominant public view given in the literature (i.e. that wind turbine visibility is undesirable, e.g. Wróżyński et al., 2016). However, the prevailing view on the isles appeared to be that the benefits of wind energy outweigh any perceived negative visual impact. Residents were therefore overwhelmingly in favour of having turbines regardless of location, and accordingly, many participants submitted no viewsheds whatsoever.

Whilst a number of participants did not contribute viewshed data, they still tested the interface and provided feedback. Participants found the tool easy to use, providing feedback such as:

*“Very easy to use if you follow instructions.” [Female, 31-40]*

Participants also commented on specific benefits of the informed interface. One participant, for example, initially selected a high peak as a location from which they would not wish to see a turbine, however upon seeing that this would mean a significant area of the island would also be blocked out, changed their mind:

*“I wouldn’t actually mind being able to see the turbine if it meant we could make more energy on the island, I didn’t expect it to be seen for so far though”. [Male, 61+]*

This example demonstrates how the informed interface can give participants a better understanding of the decisions that they are making. By being able to see the immediate impact of their choice and having the capacity to reassess based on the information provided by the viewshed, the participant has been able to present a more balanced and informed opinion. Additionally, it reduces the spatial accuracy problem associated with point-based PPGIS, as the viewshed represents the combined visual impact on the area rather than simply the pin-point location of the wind turbine.

### **5.3.2 Viewshed Results: Usability Testing**

The results of the comparative usability test between the viewshed and point interfaces are presented in Figure 22. For the majority of questions relating to the functionality of the underlying web map, the two interfaces were found to be *“both the same”*, as would be

expected (as both were based on the same ‘Leaflet’ web map). However, 97% of participants found the informed (viewshed) interface better for decision making. The informed interface helped 84% of participants decide turbine locations and 92% agreed that it helped them understand more about locating a wind turbine more generally.

QUESTION	More so the viewshed tool	A little more the viewshed tool	They were both the same	A little more the points tool	More so the points tool	N/A
It is easy to zoom in and out on the map	0	0	32	2	1	2
It is easy to move to a new location on the map	2	0	28	5	1	1
I can add new features to the map easily	4	3	19	5	6	0
When I add something to the map, it takes effect immediately	0	0	25	6	6	0
Mistakes can be easily undone	0	0	28	6	2	1
I feel confident using the mapping tool	5	4	18	7	3	0
The mapping tool enables me to effectively achieve the set tasks	10	14	11	0	2	0
The mapping tool is reliable	4	3	23	4	2	1
It is easy to remember how to perform tasks	2	1	30	3	1	0
I feel confident exploring the mapping tool by trial and error	5	4	26	0	2	0
It is easy to understand what I have added to the map	7	4	14	5	7	0
It was easy to get my views across by using the mapping tool	14	6	13	2	2	0
The mapping tool helped me decide my answer to the question	26	5	5	0	1	0
I think this mapping tool is useful for informing decisions about locating a turbine	30	6	0	0	1	0
I understand more about locating a wind turbine from using this mapping tool	27	7	1	0	1	1

**Figure 22** Participant responses to each question from part 1 of the usability testing questionnaire regarding the two wind turbine locating interfaces, with bright blue squares indicating the most popular answers and red indicating the least

The free text questions gave participants the opportunity to add reasons for their answers, such as:

*“Viewshed gives you a much better idea than guesswork about what is visible from where.*

*Points give basically no info except remembering where I clicked.” [Male, 18-30]*

*“I think the Viewshed tool made it easier to inform my mapping decisions as it allows me to see the context in which I was making a decision.” [Male, 18-30]*

Despite the positive reactions to the informed viewshed interface, some participants reported finding it more complicated:

*“[The viewshed tool was] More complicated for the initial user but probably easier for a planner. And easier to show a group the collective implications of a turbine location, not just individual points.” [Female, 18-30]*

In contrast to the informed viewshed interface, participants reported finding the point-based tool ineffective by comparison. For example, two participants, neither of whom had any mapping experience, stated:

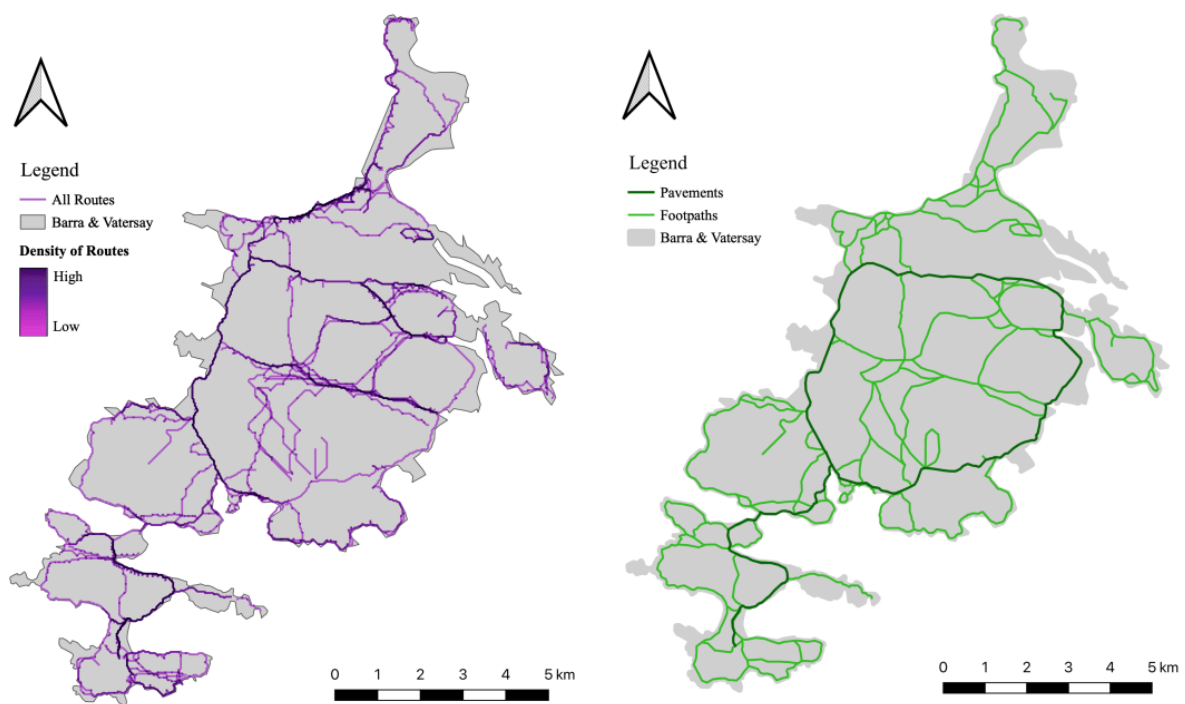
*“The points tool was rather hard to use as I felt like I could just put points anywhere and everywhere without really understanding where they were going.” [Male, 51-60]*

*“[The viewshed tool was] Easy to use. Good way to gather local opinions and work out any utterly unacceptable locations.” [Female, 51-60]*

There were no discernible differences in how participants found the usability of the informed interface based on their age, gender, mapping experience or computer experience.

### 5.3.3 A\*Results: Case Study

Figure 23 presents the complete ‘raw’ dataset produced using the A\* interface alongside the processed data demonstrating the potential network of footpaths and pavements. In Figure 23A the darker lines indicate where a greater number of participants desired the same paths to be located. These include areas that might be expected, such as the three main settlements, but also the centre of Barra and a particularly picturesque beach along the North coast.



**Figure 23** The 107 potential footpaths (totalling 541 km) designed by residents of the isles of Barra and Vatersay, showing: (A) the raw resulting paths; and (B) the processed data set of potential footpath and pavement networks

Again, qualitative feedback was obtained from the interface in addition to the routes themselves, with each new path requiring some comment or explanation in order to be saved to the database. The responses predominantly fell into two categories. Firstly, routes that

participants wished to be made more accessible for their scenic value through the use of footpaths; and secondly an increase in pavements along the road for the purpose of safety and accessibility, for example:

*“This is a traditional walk where people would cross the cliff from Claid to Aoligarra passing Dun Chliff and if so wish can carry on across Traigh Eais to Dun Scurrical.” [Male, 61+]*

*“[Current road infrastructure is] busy, narrow, large vehicles, unsafe for anyone walking.”  
[Female, 51-60]*

Whilst Figure 23A shows the initial output for the decision-maker, it is clear the interface also met the requirements of the participants in answering the question, as they validated the claim that the interface was both usable and useful in the qualitative feedback, adding comments including:

*“Like that it finds you the easiest route, very neat.” [Female, 61+]*

Based upon the raw geometric dataset and qualitative data provided by the online comments, the second map (Figure 23B) was produced illustrating a proposed path network, in which duplicates have been removed, loops have been closed, and classifications have been added to distinguish proposed pavements (i.e. concrete, raised and alongside a road) and footpaths. This proposed network comprises an increase of approximately 400% to the current network length, comprising the addition of 192km of new footpaths and 43km of new pavements, which cover approximately 40% of roads on the isles (including all primary roads).

The abundance of responses from even a small number of participants suggests that the interface was easy to use and effective for the task in hand, enabling those with no experience of route-planning to collectively create a new network of footpaths and pavements. For the decision-maker there are clear, realistic routes presented by residents from which new plans can be drawn without complications around generalisation, casting any doubt as to the reliability of the data.

#### **5.3.4 A\* Results: Usability Testing**

As with the turbine example, participants largely preferred the informed (A\*) interface for footpath routing (Figure 24; bright blue). However, in this case there was some variation in the extent of that preference, i.e. spread over a range of adjacent categories (light blue). Although not found as straightforward to use as the viewshed interface, most participants felt the A\* interface enabled them to achieve the set task effectively.

QUESTION	More so the A* tool	A little more the A* tool	They were both the same	A little more the lines tool	More so the lines tool	N/A
It is easy to zoom in and out on the map	0	0	35	0	0	2
It is easy to move to a new location on the map	0	5	30	1	0	1
I can add new features to the map easily	6	5	16	9	0	1
When I add something to the map, it takes effect immediately	1	4	28	4	0	0
Mistakes can be easily undone	0	0	32	4	1	0
I feel confident using the mapping tool	3	8	14	10	2	0
The mapping tool enables me to effectively achieve the set tasks	9	12	9	5	2	0
The mapping tool is reliable	6	7	20	2	2	0
It is easy to remember how to perform tasks	1	0	34	1	0	1
I feel confident exploring the mapping tool by trial and error	4	2	29	1	0	1
It is easy to understand what I have added to the map	8	8	18	1	2	0
It was easy to get my views across by using the mapping tool	9	10	8	8	1	1
The mapping tool helped me decide my answer to the question	14	13	8	1	0	1
I think this mapping tool is useful for informing decisions about footpath routing	19	11	5	1	0	1
I understand more about footpath routing from using this mapping tool	13	13	9	1	0	1

**Figure 24** Participant responses to each question from part 1 of the usability testing questionnaire regarding the two footpath routing interfaces, with bright blue squares indicating the most popular answers and red indicating the least

There is a clear preference towards the informed interface when it comes to questions regarding decision-making with 81% identifying it as the most useful. For example 73% of participants found it helped them decide footpath routes; and 70% found they learned more

about footpath routing from the A\* than the line-based interface. Participants who preferred the informed (A\*) interface commented:

*“I found the A\* tool much easier as it allows you to see which route would be the least difficult and gives you a better sense of the way the land lies.” [Female, 18-30]*

*“A\* made life a lot easier rather than clicking loads of little lines” [Male, 51-60]*

Whilst over half of participants found the A\* interface made their mapping decisions easier, this was not unanimous. Some preferred having control over the route taken instead of being drawn towards the easiest route based on elevation. Although feedback was more mixed, interface preference did not seem to be explained by age or experience. For example both of the below quotes are from two different 18-30 year old digital mapping experts:

*“Made it more complicated. When I was trying to draw a path to follow contours round hills the A\* tool kept making me 'walk' slightly down then uphill again. This made my path look frustratingly inefficient.” [Female, 18-30]*

*“Definitely a positive to inform mapping decisions, it allows the user to see the wider context of where they are placing their footpaths, and it's quicker to map rather than mapping lots of individual points.” [Male, 18-30]*

Suggestions for developing the tool further included making the route draggable, giving the user a preview of the route to their mouse location before they click, and allowing the user to influence the underlying algorithm by adjusting a setting to make routes either ‘faster’ or ‘easier’, for example. It would appear that many of the difficulties found with using the informed A\* interface came from the latter suggestion, in that participants did not feel that elevation was the most appropriate factor:

*“Maybe add more control to the least cost bit, so it could be based on speed or distance not just the lay of the land” [Female, 51-60]*

*“Being able to drag the path to change slightly the path without changing the waypoints.”*  
*[Male, 31-40]*

Based on both the results from the multiple choice and free text questions, the informed interface has again proved more effective in supporting the decision-making process than the more conventional (lines) interface.

## **5.4 Discussion**

This research has highlighted how the use of informed interfaces can produce more realistic and usable datasets in GIS-based spatial analysis, planning, knowledge production and decision-making. The analysis of the two case studies in the Outer Hebrides, UK, combined with the results from the usability study, indicate that the use of informed interfaces can benefit both the researcher and the participants. Our viewshed-based interface was shown to be more effective for guiding participants’ decisions about where turbine views would not be desirable compared to an equivalent point-based interface. In turn, onward users of the dataset could be confident about obtaining a more considered, robust and fit-for-purpose dataset, i.e. to meet public consultation goals. Similarly, our A\* informed routing interface was generally preferred over digitising paths with simple lines. By using least-cost paths between nodes as opposed to straight line segments, the skill-based barriers found by Gottwald et al., (2016) are reduced, placing the onus for data quality on the algorithm and background dataset rather than the assumed ability of the participant.

The uncritical use of spatial primitives has been widely criticised in the literature (Brown & Kyttä, 2018; Robinson et al., 2017; Huck et al., 2014 & Goodchild, 2011). Both of our ‘informed interfaces’ were therefore developed to support participants in answering the two specific questions posed, instead of allowing *‘the Hammer of Participatory GIS’* to dictate the questions being asked (Huck et al., 2018). The informed interfaces empowered participants to feel more confident in the datasets they produced and their usefulness in the decision-making process. This distinction between the usefulness of informed interfaces compared to interfaces using spatial primitives became particularly apparent in the direct comparison in the usability studies. In asking appropriate questions coupled with the support of an informed interface, participants can be reasonably expected to answer complex spatial questions without prior technical knowledge on the subject. Such technical developments may provide an important link in the ‘Chain of Trust’ (Dwyer & Bidwell, 2019) through facilitating more meaningful community engagement processes and therefore helping to overcome some of the barriers suggested by Firestone et al. (2020).

Whilst still deemed most useful in the decision-making process, some participants did find the informed interfaces more complicated to use during the usability testing. This contrasted with the in-person workshops (which had the benefit of a researcher being present), during which no participants reported this same issue. Whilst the difference in age demographic of those who attended the in-person workshop and online focus group should be noted (with participants on the isles being notably older than those who attended online), there were no apparent connections between the degree to which participants found the interfaces more complicated and their demographic or mapping experience. This suggests the use of a more informed interface does not require additional training or effort from those who participate

given a base-level of computer literacy. Indeed, much of the feedback for the A\* interface, in fact, suggested that increasing the complexity would improve the interface. For example by displaying a 'preview' of the route as the participant moves the cursor around the map, removing the need to edit and redraw points; or by increasing the number of variables which control the underlying algorithm such as distance or speed so that participants can select their priority, giving further feedback to the decision-maker. As such, the balance between an interface being more complicated and more useful is difficult to define and will vary between participants and situations, so it is important for the wider social context of the research to be considered when designing the most suitable interface.

The engagement process is also important. Although instructions provided were similar in content and a facilitator was present, online focus group participants seemed reluctant to ask questions or seek assistance, preferring to leave any feedback about the tools in the online questionnaire. Conversely during the in-person workshops there was much greater interaction both between participants, and participants and the facilitator. This created an atmosphere of trust in which participants were more comfortable asking questions and seeking assistance to use or better understand the tool. This is despite the participants being predominantly older adults, which has presented challenges in similar PPGIS research (e.g. Gottwald et al., 2016).

The results from the in-person workshop data collection also demonstrate the types of additional insight that can be revealed by using informed interfaces, such as the thought process of participants changing their minds based on the immediate feedback from the viewshed interface. Equally, participants trusted the A\* algorithm to take them along the easiest route. The algorithm was particularly beneficial for non-residents unfamiliar with the

local terrain, but it helped to improve the data provided by all participants (whether local or not). The datasets obtained from the use of informed interfaces are intrinsically richer, as participants are presented with feedback on their decision in real-time, and then given the option to adjust or accept it accordingly.

The results from both informed interfaces demonstrated in this paper are overwhelmingly positive with regard to supporting participants in providing their answers and in turn giving the researcher more confidence in their validity of the resulting dataset without adding bias from intermediary steps in analysis. Despite this, there are certain limitations to the approach, such as the additional skill or funding required to design and develop the appropriate tools, as well as supporting participants in their use of the resulting interfaces. However, the two examples demonstrated in this paper give an indication of the potential of informed interfaces for empowering and engaging participants in consultative exercises. The interfaces provide a foundation for use in other visual impact or routing decisions, but are not limited to these areas.

## **5.5 Conclusion**

This research sought to assess how PPGIS interfaces might be designed in a way that better supports the researcher (in the question they are asking) as well as the participant (in the answers they are giving). Through using conventional GIS tools as spatial units in two purpose-built web-based interfaces we demonstrate how participants can better answer the questions being asked and consequently produce richer, more veracious datasets. Although our examples are most directly relevant to visual impact and routing exercises, the

fundamental principles apply more widely. For example, other applications in the wind industry could consider the integration of other conventional GIS tools into interfaces for PPGIS, for example as proxies for ‘ice throw’ or ‘shadow flicker’, whilst other forms of industrial development might include pollution plume dispersal or noise propagation. The advantages of informed interfaces have been evidenced by both rigorous usability testing as well as being demonstrated through a successful, in-person case study in the Outer Hebrides, UK. During each data collection stage, participants found the informed interfaces beneficial in their decision-making process, and enabled the production of datasets that were straight-forward to interpret for the researcher. The use of informed interfaces facilitated the collection of additional insights into local opinion that would not have been possible with more traditional interfaces. Additionally, participants were given an increased understanding of the question at hand with no additional effort or skill required.

We suggest that informed interfaces provide the foundation for a step change in the development of PPGIS, moving away from the traditional approaches that are known to be inadequate but remain largely unaddressed (Radil & Anderson, 2019; Brown & Kytä, 2018; Huck et al., 2014). Informed interfaces hold the potential to improve and diversify spatial data representation, and therefore decision-makers’ understanding of participants’ views. Informed interfaces can also simultaneously increase the ability of participants to express their opinions, thus encouraging further participation and enhancing trust in participatory processes. Accordingly, the continued development of informed interfaces can both increase democratisation in the decision-making process and also progress the field of PPGIS by improving the potential veracity of the data collected. This research has demonstrated the

potential in moving beyond the status quo, providing an indication of just what might be achieved by abandoning the '*Hammer of Participatory GIS*' once and for all.

## 6.

### **Paper2GIS: improving accessibility without limiting analytical potential in Participatory Mapping**

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Paper2GIS makes use of Mapnik (<https://github.com/mapnik>) and the following Open Source Python Libraries: Pillow (<https://github.com/python-pillow/Pillow>), PyZbar (<https://github.com/NaturalHistoryMuseum/pyzbar/>), Rasterio (<https://github.com/rasterio/rasterio>), Shapely (<https://github.com/shapely/shapely>), Numpy (<https://github.com/numpy/numpy>) and OpenCV (<https://github.com/opencv/opencv-python>).



## **Abstract**

Participatory Mapping encompasses a broad spectrum of methods, each with advantages and limitations that can influence the degree to which the target audience is able to participate and the veracity of the data collected. Whilst being an efficient means to gather spatial data, the accessibility of online methods is limited by digital divides. Conversely, whilst non-digital approaches are more accessible to participants, data collected in this way are typically more challenging to analyse and often necessitate researcher interpretation, limiting their use in decision-making. We therefore present ‘Paper2GIS’, a novel sketch mapping tool that automatically extracts mark-up drawn onto paper maps and stores it in a geospatial database. The approach embodied in our tool simultaneously limits the technical burden placed on the participant and generates data comparable to that of a digital system without the subjectivity of manual digitisation. This improves accessibility, whilst simultaneously facilitating spatial analyses that are usually not possible with paper-based mapping exercises. A case study is presented to address two energy planning questions of the residents in the Outer Hebrides, UK. The results demonstrate that accessibility can be improved without impacting the potential for spatial analysis, widening participation to further democratise decision-making.

*Keywords:* ppgis, participatory mapping, digital divides, sketch mapping

## 6.1 Introduction

Participatory Mapping is used as a blanket term to cover a range of participatory methods of gathering spatial data (Brown and Kyttä, 2018). It has become a well-established subfield of geography, intended to enhance engagement from historically marginalised groups (Elwood, 2006). The inclusion of different parties (and consequently different views and experiences) is widely accepted as being beneficial to the decision-making process, allowing for a more comprehensive understanding of the way citizens interact with space (Huck et al., 2016; Carver et al., 2009; Anderson et al., 2009; Evans & Waters, 2007). Participatory Mapping can be used to collect and combine spatial thoughts and ideas from a range of stakeholders to facilitate engagement in policy, decision-making and community level planning (Czepkiewicz et al., 2018; Anderson et al., 2009). It comprises a number of different methodological approaches, including Public Participatory GIS (PPGIS; e.g. Brown, 2012) and sketch mapping (e.g. Boschmann & Cubbon, 2014), each of which have their own advantages and drawbacks.

The greatest challenges in the successful application of Participatory Mapping are how to achieve the effective representation of the geographic entities about which views are sought, and how to ensure maximum accessibility for the widest possible range of participants (Huck et al., 2017). Indeed, some methods can result in the exclusion of those people they originally set out to empower and therefore fail to effectively represent opinion (Radil & Anderson, 2019). Conversely, whilst the use of more accessible, paper-based methods can enable wider participation, they then create difficulties in conducting onward analyses, for instance due to the unstructured nature of the data that are produced (Curtis et al., 2014). This research therefore introduces and demonstrates a novel method of Participatory Mapping to explore

whether accessibility for participants can be maximised *whilst* maintaining the capacity for a range of spatial analyses.

### **6.1.1 Digital Divides**

Early forms of Participatory Mapping centred around the use of computing applications and digital visualisations of geospatial data to open up the field of public participation, however this was often at the expense of wider social and cultural contexts (Dunn, 2007; Elwood, 2006; Sieber, 2006). Subsequently, following the development of Web 2.0, the field of Participatory Mapping grew rapidly, facilitating discussions, encouraging feedback and supporting the decision-making process (Fagerholm et al., 2021; Green, 2010; Dunn, 2007). Despite web-based approaches meaning that participants can theoretically provide information rapidly, without confrontation and whenever they may choose, it is not always feasible (or desirable) to apply highly technical solutions to elicit responses to spatial questions (Huck et al., 2014). Although there are a number of advantages of using digital approaches for increasing user participation, such as the removal of temporal and geographical limits for participants; their use can also pose challenges. For instance, using digital technologies can exclude those without the skills, inclination, or access to the necessary devices, or the high-speed internet often required to utilise them (Gottwald et al., 2016). In some countries the diffusion of the Internet has reached up to 95%, but as of April 2020 approximately 40% of the global population is still offline, and as such would be excluded from the decision-making process if public participation were only conducted in this way (Statista, 2020; van Deursen & van Dijk, 2019).

Inequalities in access to digital technologies exist across a broad range of macro and micro-level domains and have previously been referred to as the ‘digital divide’ (Robinson et al., 2015). There is some dispute however over the singularity of the term and the dichotomous image it presents, implying a distinct boundary between the ‘haves’ and ‘have-nots’, which in reality is considerably more nuanced (van Dijk, 2020). Instead, it is now considered more appropriate to refer to ‘digital divides’, accounting for the multifaceted and complex reasons behind such inequalities in participation. The issues surrounding digital divides do not necessarily concern digital technology specifically, but rather are inherently connected to socially constructed barriers to access (van Dijk, 2020). Digital divides not only reflect social inequalities but can also amplify them, particularly where consultations on public policy and related decisions rely solely on digital methods (Warf, 2019). This can lead to inequalities between those who can and cannot participate, in turn resulting in the views of those who have the skills, or means to participate being over-represented (Riddlesden and Singleton, 2014; Dunn, 2007). Uneven access to the internet and computer materials can occur due to ethnicity (Abreu 2015), gender (Mariscal et al., 2019), education (Crocker & Mazer, 2019), disability (Duplaga & Szulc, 2019), location (e.g. remote rural areas compared to inner cities; Ye & Yang, 2020), and age (Robinson et al., 2015).

Older people are often over-represented in Participatory Mapping studies, yet are also likely to experience accessibility issues with computing equipment (Brown, 2017; Haworth et al., 2016; White & Selwyn, 2013). Physical challenges such as visual impairments or reduced fine motor skills, as well as more psychological barriers such as technological self-efficacy can make the use of digital technologies more challenging for some older adults (Gottwald et al., 2016; Vrenko & Petrovič, 2015; Carpenter & Buday, 2007; Nielsen, 2013). Although it is

not older adults alone that face these challenges - nor all older adults - increasing accessibility to meet these needs can improve the user experience for the wider public as a whole, for example through non-digital methods (Gottwald et al., 2016; Meng & Malczewski, 2010). The inclusion of multiple viewpoints across society is central to the benefits and aims of Participatory Mapping, making it important that an appropriate level of accessibility is maintained for the given situation (Radil & Jiao, 2016). The challenge, however, is in preventing this from being at the expense of other benefits found with digital methods of Participatory Mapping (i.e. efficiency), or introducing new issues (i.e. the subjectivity of researchers).

### **6.1.2 Representations in Participatory Mapping**

It is undoubtedly a great technical challenge to translate something as emotive and subjective as public opinion into a tangible form (Godwin and Stasko, 2017). Formally, and adopting the terminology of Couclelis (1996); this challenge is how to create digital objects (the GIS representation of a thing) that are capable of adequately representing real-world entities (the thing itself). This is achieved through a combination of an interface (through which the object is created) and a data model (through which the object is stored); with the former providing the focus for this research. Interfaces for Participatory Mapping may be considered to fall into one of two categories. Notative interfaces (based on a scheme of notation), comprise a formalised and pre-agreed mode of communication (e.g. “draw an X where...”), and ensure a consistent scheme of representation between participants. On the other hand, indicative interfaces (based on a scheme of indication), comprise the informal capture and communication of ‘free-hand’ gestures (e.g. “mark the map to show where...”), resulting in high levels of variation between the modes of representation used by individual contributors

(after Ingold, 2007). When considering notation, Vygotsky (1978) comments that a child who is learning to write cannot truly be said to be writing until they are also capable of reading, as otherwise they are simply reproducing letters without meaningful communication. In this way, notative interfaces in Participatory Mapping (e.g. points, lines and polygons upon which digital map interfaces typically depend), must be both adequately understood by the participant and well suited to the nature of the entity that they are intended to represent, in order to convey a meaningful understanding of the knowledge and views. Indicative interfaces on the other hand are not reliant upon restrictions, however the high levels of variability between individual contributions precludes all but visual comparison.

Digital approaches such as PPGIS typically use complex technology and a strict notation to collect and compile spatial data from a broad range of stakeholders to represent individual interests and priorities on a digital base map (Anderson et al., 2009). The issue of representation is commonly identified in criticisms of the inaccessibility of PPGIS to non-experts (e.g. Godwin and Stasko, 2017; Gottwald et al., 2016; Evans & Waters, 2007). It has been argued by one author that using point-based notation in particular is a highly effective means of collecting spatial data with PPGIS, yielding high response rates and reducing levels of bias due to the simplicity of the object (Brown, 2012). However, point-based data collection methods alone have been criticised for over simplifying the nuanced human experience, restricting complex information to spatially primitive notation and not effectively representing the fundamental characteristics of the entity (Denwood et al., 2020; Huck et al., 2014; Evans & Waters, 2007).

Attempts to address this issue in the literature include the use of alternative interfaces or more complex spatial units for the collection of participatory spatial data. Denwood et al. (2020), for example, use a web-based PPGIS but incorporate complex spatial units to provide participants with contextual information in real-time as they input suggestions on the location of a new wind turbine and transport network. Similarly, Huck et al. (2014) created a web-based tool to enable participants to indicate vague areas regarding the positioning of a wind farm, without having to impose ‘artificial boundaries’ (after Montello et al, 2003) onto uncertain areas (a similar approach was also taken by Evans & Waters, 2007). Whilst increasing the level of autonomy on the part of the participant and improving the way in which perceptions and ideas are represented as objects, these approaches still require computer technologies and high-speed internet access so in themselves do little to address the digital divides which exclude some from participating.

One solution to this intransient problem may be provided through paper-based methods. ‘Sketch mapping’, for example, is a more accessible method, used to balance the freedom of indication whilst maintaining spatial context through the provision of a paper base map or satellite image (Boschmann & Cubbon, 2014). Sketch maps have been used to collect experiential and locational data across a broad range of research areas, such as cycling safety; where children take part in physical activity, and the delineation of neighbourhood boundaries (Marquart et al., 2020; Wridt, 2010; and Curtis et al., 2014 respectively). For these purposes, data are often collected at workshops or in small groups to engage with community members and develop dialogue alongside the maps (Wridt, 2010; Weiner & Harris, 2003). In taking this approach, the use of sketch maps can aid conversation by acting as a visual supplement to qualitative interviews, providing familiarity and comfort for

participants in what can sometimes be an intimidating setting, a key challenge in encouraging participants to share information with the researchers (Marquart et al., 2020; Yabiku et al., 2017; Boschmann & Cubbon, 2014).

However, whilst the use of sketch maps can improve accessibility, the lack of control over the way in which the maps are marked-up can create difficulties in the resultant spatial analysis. Without a clear scheme of notation, the translation from entity to object can be unclear (Klonner et al., 2018). For example, in Huck et al's (2017) study, local residents in rural India were asked to indicate what they considered as 'valuable' landscape areas. As the participants were given total freedom to mark-up a paper map of the region, the results included wide variations, from the relatively precise (e.g. arrows, crosses and marked routes) to the extremely vague (e.g. a pair of brackets used to indicate a region on the map). Whilst the variety of approaches is certainly interesting for visual analysis, such a range of representations could not be objectively analysed as would be typical with a PPGIS. Similarly, Broelemann et al. (2016) found difficulty with the variation in representation of hand-drawn features, with the mixed representations resulting in their automated digitisation software misclassifying a number of features. Other studies also found the data from sketch maps challenging to digitise and analyse effectively when no consistent approaches were used to mark-up the map (Prener, 2020; Pánek et al., 2020). Further, attempts to manually digitise data collected on paper maps can lead to the introduction of subjective interpretation in the resulting dataset due to both the positionality and level of understanding of the researcher (Brown and Kyttä, 2018). Whilst flexibility in representation of the entity with sketch mapping gives participants the opportunity to freely illustrate their views and suggestions on the base map, placing more restrictions with a clear scheme of notation (such

as only permitting lines or points to be added to denote certain features or locations), could lead to more comparable and homogenous results (Klonner et al., 2018).

### **6.1.3 Research Aim**

The aim of this research is therefore to demonstrate how a novel method of notative sketch mapping might improve accessibility whilst maintaining the capacity for spatial analysis, using a comparative case study in the Outer Hebrides, UK. The proposed system provides a highly accessible ‘pen and paper’ based method for the participant (ensuring it is widely accessible), whilst utilising automatic digitisation coupled with a strict notation to remove reliance on the researcher to interpret mark-up. This limits the impact of subjective interpretation that can be found in the processing of digitising sketch mapping data, whilst maintaining the efficiency and analytic potential of PPGIS data. In doing so, the benefits of each method are preserved and the challenges minimised, improving the veracity and credibility of the resulting dataset so that it might be more acceptable to policy and decision makers and therefore ensure that local views are effectively represented in the decision-making process (Boschmann & Cubbon, 2014).

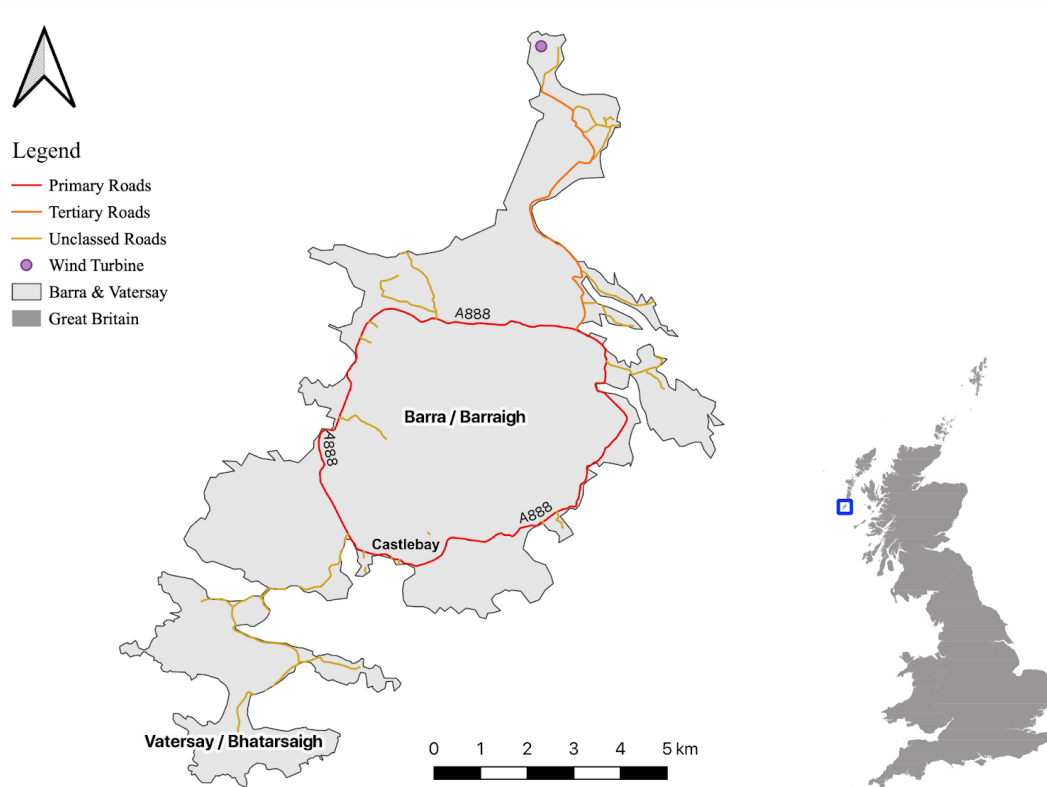
## **6.2 Methods**

The system is demonstrated through two examples: the first relates to the visual impact of new wind turbines and the second to the design of a new footpath network, using the isles of Barra and Vatersay, Outer Hebrides, UK as a case study. This section elaborates further on the specific case study, introduces the paper-based system used to collect and compile the

participatory data, how this was implemented remotely, and how it will be assessed through visual comparison to the same questions being asked with a facilitated PPGIS.

### **6.2.1 Case study**

The isles of Barra and Vatersay (Figure 25) cover a total area of approximately 70km<sup>2</sup> and host a population of approximately 1,300 (CNE Siar, 2011). Barra and Vatersay (two separate islands that are joined by a causeway) consist of machair (low-lying grassy plains), hills and lochs, with the majority of the population residing in small hamlets and crofts along the coast, leaving the centre of the isles uninhabited. Residents have recently produced a Local Energy Plan to enable the assessment of existing and future energy needs, therefore opening up opportunities to obtain views on challenges already identified as important by those that live there (Local Energy Scotland, 2018). The Local Energy Plan specifically identifies the production of electricity and active transport infrastructure as two key areas of concern. This is largely due to the remote location of the isles as can be seen in Figure 25, which makes importing fuels of any kind challenging and expensive.

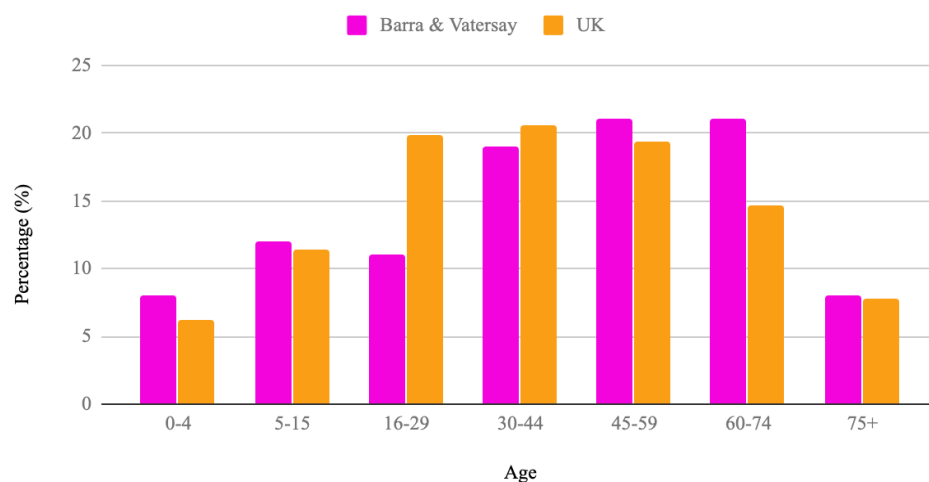


**Figure 25** The isles of Barra and Vatersay, Outer Hebrides

The current energy provision infrastructure on the isles is very restricted, comprising a single mains connection to the grid and requiring oil to be shipped in from mainland Scotland. Just one single track primary road (A888) circumnavigates the island of Barra which, coupled with a very limited number of footpaths and pavements, means that the transport systems on the isles are inadequate. Consequently, this has meant that the isles experience high levels of fuel poverty and forced an over-reliance on motorised transport for travelling short distances (Local Energy Scotland, 2018). The addition of further local renewable energy sources coupled with a network of new footpaths (to open up opportunities for movement across the isles) and pavements (along roadsides for the purposes of safety) could alleviate some of the pressure on the current system by addressing the issues raised by residents. Whilst it is clear

there is demand for an increased renewable energy supply and development of the current active transport infrastructure, the almost complete absence of any existing industrial landscapes on the isles means that any new developments will have a high impact. This, coupled with an economic reliance on tourism brought about by the prevalence of natural beauty on the isles, means that community input is vital to ensure that the most suitable solutions can be identified.

In addition to the pre-existing interest in energy challenges, the age demographic of the isles is that of an older population in comparison to the rest of the UK (Figure 26). Discussion with officials on the isles indicated that the population has since aged further than is represented in the last census, which was carried out almost a decade ago, due to young families moving away from the isles for job opportunities on the mainland. This therefore increases the potential impact that a non-digital Participatory Mapping interface may have on participation in accommodating the needs of older residents.



**Figure 26** Demographic comparison between % age on the isles of Barra and Vatersay and the UK based on the 2011 Census (data source: Gov.uk, 2011; Local Energy Scotland, 2018)

This location provides a good opportunity to explore the use of non-digital Participatory Mapping interfaces, hosting an older population that could not only benefit from a paper-based method, but is already engaged in the energy challenges facing the isles.

### **6.2.2 Data collection**

Residents of the isles were asked for their views on two key questions raised by the Local Energy Plan (Local Energy Scotland, 2018):

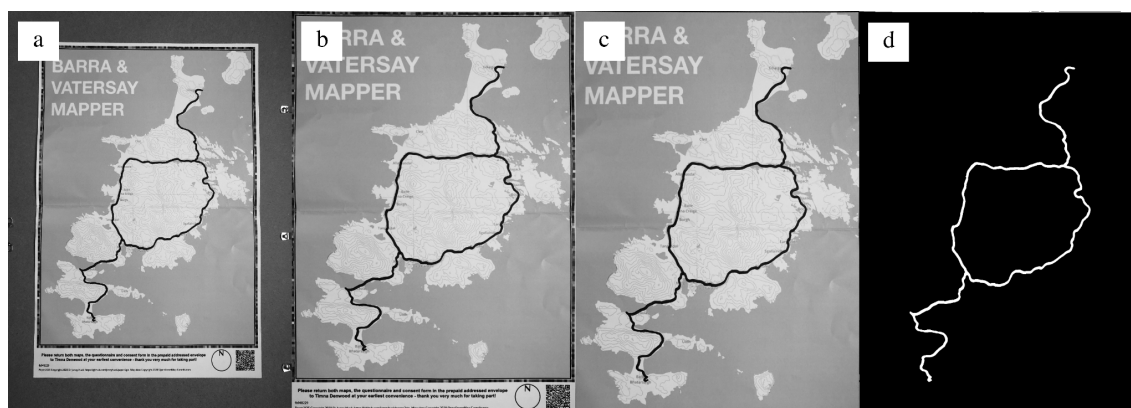
- (1) From which locations would you not wish to be able to see a wind turbine from on the isles of Barra and Vatersay?
- (2) Where would you like new footpaths and pavements to be developed on the isles of Barra and Vatersay?

These two spatial energy-planning questions were asked of participants using Paper2GIS, a Participatory Mapping software developed by this research group (<https://github.com/jonnyhuck/Paper2GIS>). Paper2GIS is used to produce the base map (upon which participants will draw), which includes a QR code containing georeferencing information for the map (bounds and projection information) and a border of random noise Figure 27; and then automatically extract the markup from the map and export to a GIS. The design of the base map uses the Mapnik renderer (<https://mapnik.org>), and so is completely customisable using any GIS data source and XML or CSS style sheets.



**Figure 27** A3 paper map of the isles of Barra and Watersay used for Paper2GIS data collection

Markup extraction is achieved using computer vision (CV) technologies in order to allow georeferenced markup to be extracted, cleaned, georeferenced and stored as a GIS dataset using only a photograph of the marked up map (target image, Figure 28a) and a 'clean' digital version of the map (reference image). Specifically, the paper containing the map is identified in the target image using the SIFT algorithm (Lowe, 2004) to detect easily recognisable points in both images, and a FLANN-based matcher is then used to identify matching points of points between the two images, which are evaluated and filtered using Lowe Distance (Lowe, 2004) to ensure that spurious matches are rejected. Based upon the relative locations of these matches, image homography calculations (see Malis et al. 2007) are then used to construct a transformation matrix, which may be used to warp the target image in order to correct any perspective distortion caused by differences in the relative planes of the camera and the paper. This results in the extraction and transformation of the paper from the target image (Figure 28b), which is then cropped to extract the map from the page (Figure 28c). The extracted map from both the target and reference images are then thresholded (converted to binary image) and 'differenced' in order to extract the markup. The resulting markup which is then 'cleaned' using image 'opening', whereby features in the image are first eroded (making them smaller, which removes noise) and then dilated (which returns the remaining features to their original size). Finally, the markup data is georeferenced using the data extracted from the QR code and exported either as a GeoTiff (GIS raster data format; Figure 28d) or ShapeFile (GIS vector data format) for analysis.



**Figure 28** The input and automated extraction of Paper2GIS

Although non-digital methods of Participatory Mapping tend to be conducted in a facilitated setting, with adequate instructions they can also be conducted remotely. Therefore, during the COVID-19 restrictions, data collection was conducted via postal delivery. A supply of the required mapping materials along with instructions were sent by post to 525 households to complete and return. The materials consisted of two A3 paper maps, an instruction sheet, a consent form and a feedback questionnaire. The cartographic design used for the basemap included the main roads, water bodies, and main settlements so that participants could locate the areas they wished to mark-up with ease (Figure 27). Contours were also added so that participants could account for topography when designing the routes for footpaths and pavements. Following both questions, participants were then asked to provide supplementary information using a questionnaire, which allowed contextual data to be collected about the participants, their decisions, and their views on the usability of the non-digital data collection method. Participants were recruited through advertisements on local social media, posters on the isles and in the local newsletter. Participants were neither compensated for their time nor incentivised to participate.

Explicit instructions on notation were given to ensure that the dataset could be analysed without the need for subjective interpretation on the part of the researcher (Klonner et al., 2018). Participants were asked to shade any areas on the map from which they would not wish to be able to see a wind turbine. A similar notative approach has previously been used by Curtis et al. (2014), who asked participants to draw crosses on the map as a notation to represent areas of perceived fear. However, Curtis et al., (2014) identified post-hoc that the varied sizes of resulting crosses still raised questions of representation and interpretation: for example, was the participant referring to the pinpoint location at the centre of the cross, or the whole area that it covered? In order to avoid this issue of uncertainty, shading was selected to allow the participants to clearly and simply show the area they were referring to without the requirement for any further interpretation. This standardised notation enables the shaded areas to be automatically digitised as polygons from each paper map using Paper2GIS and then analysed using viewsheds from the shaded locations. Additionally, by asking participants from where they would rather not be able to see a turbine, participants are being asked something they can reasonably be expected to answer as residents of the isles (Denwood et al., 2020). This contrasts with more traditional approaches to PPGIS surveys, which have asked participants to select already designated areas they deem appropriate for development (e.g. Mekonnen & Gorsevski, 2015), which is a more complex and ambiguous question to which a member of the general public could not reasonably be expected to answer.

Participants were then instructed to use a second, identical paper map to draw their desired network of paths on the isles. Drawing lines in digital map interfaces has previously proved

difficult in participatory research with non-expert GIS users. Gottwald et al. (2016), for example, removed a line-based tool from their research altogether as it created too many challenges in both representation and accessibility when participants struggled with the high level of technological skill required. Whilst Denwood et al. (2020) sought to address the issue of representation in lines and improve usability through the addition of an underlying routing algorithm, the use of paper-based systems are still more accessible. Marquart et al. (2020) and Yeboah & Alvanides (2015) found that the use of paper-based methods gave participants more confidence in their route-based contributions, without the need for technical knowledge or specific skills.

### **6.2.3 Comparison to PPGIS**

In order to demonstrate the potential of Paper2GIS as a more accessible interface whilst maintaining the capacity for spatial analysis, the same two questions have also been asked of 22 residents on the isles using a PPGIS (available at <https://github.com/jonnyhuck/ppgis-interfaces>; Denwood et al., 2020). The PPGIS data was collected through facilitated, face-to-face workshops on the isles with a researcher present to provide one-to-one support and instruction throughout. The PPGIS systems make use of underlying algorithms to support the participant in their decision-making by illustrating the implications of their choice in real-time. This was done by firstly calculating viewsheds to delineate areas from which a wind turbine would be visible; and secondly using least-cost-paths between nodes rather than straight ‘point-to-point’ lines to ensure that realistic footpath routes were drawn. Each could be edited before being saved to the database, allowing the participant to edit their input accordingly and maintain full control over the output (Denwood et al., 2020).

As both surveys (the PPGIS and Paper2GIS) were conducted independently of one another with relatively small numbers of participants, the results should not be expected to be identical. Nor should one method be considered the benchmark from which the other is assessed, as each has its own advantages and drawbacks as well as being produced by different (yet potentially overlapping) samples of the population. Nevertheless, a simple visual comparison is useful for understanding that similar information can be collected using both methods.

### **6.3 Results**

Overall feedback on the methods of data collection suggests that participants not only understood how to complete the survey, but also felt that collecting data through a paper-based method can enable citizens to be included who may not otherwise be able to when the only option is a digital alternative. Feedback regarding the Paper2GIS survey (which was conducted remotely without additional assistance) included the following comments from participants:

*‘Suitable since it is accessible by all who wish to participate whether they have internet access or not and whether mobile or not’ [Female, 61+]*

*‘It appears to be a good method as the data would be provided by various contributors with different ideas’ [Male, 61+]*

Whereas feedback for the PPGIS which was collected during the face-to-face workshops highlighted the issues found amongst older participants with digital interfaces as identified in the literature (e.g. Gottwald et al., 2016) and the importance of having a researcher on hand to assist:

*‘Should have brought my glasses, could do with a bigger screen’ [Male, 61+]*

*‘Good to have help on hand’ [Female, 61+]*

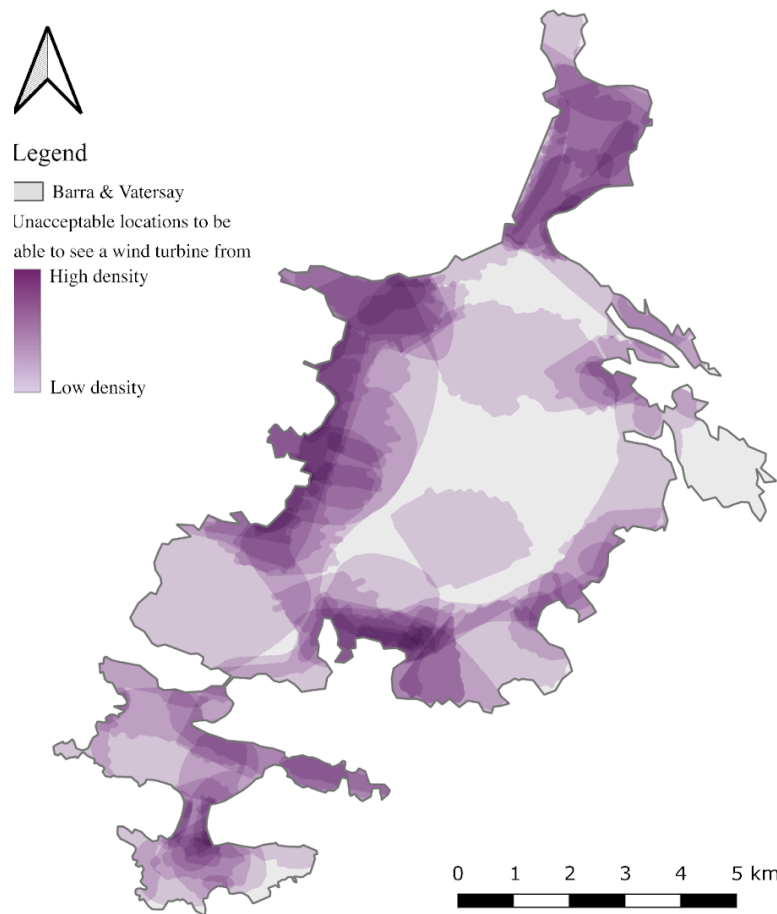
### **6.3.1 Participants**

Between November 2020 and March 2021, 35 households returned the Paper2GIS survey (c.7% of the targeted households). Of these, 23 maps were returned indicating locations from which participants would not wish a wind turbine to be visible. This includes 4 participants who did not wish to see a wind turbine anywhere on the isles, and 7 would be happy to see a turbine anywhere on the isles (and therefore marked no locations on the map). All 35 participants wished to see new footpaths and returned maps indicating where they would prefer them to be routed. Of the 35 households, 91% (n = 32) provided the requested demographic information, indicating that 56% (n = 18) of those who responded identified as male with the remaining 44% (n = 14) identifying as female. Whilst all age groups from 18 years upwards are represented in the respondents, 53% (n = 17) were over 61 years of age.

### **6.3.2 Unacceptable locations for a new wind turbine**

Figure 29 shows the raw dataset (extracted using Paper2GIS) of all areas shaded by residents to delineate areas deemed undesirable from which to be able to see a wind turbine (examples

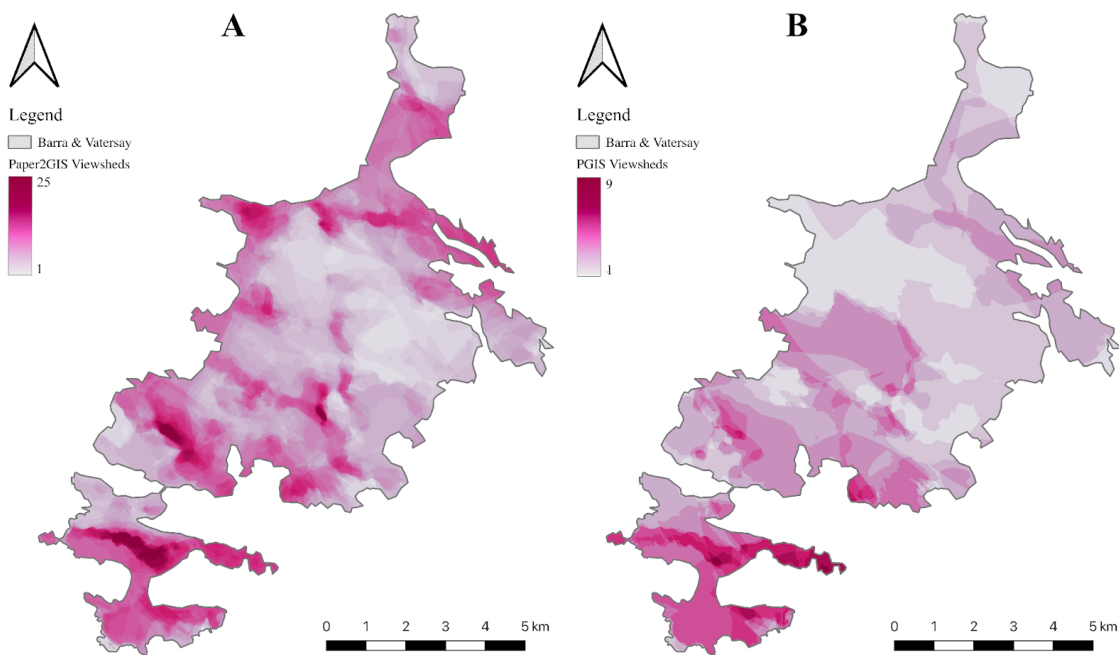
of the original participants' responses are available in Appendix 8). The darker areas (where multiple shaded areas are overlaid) indicate the most undesirable locations.



**Figure 29** Map indicating locations from where participants would not wish to be able to see a new wind turbine, with darker areas denoting higher levels of agreement

The shaded areas indicated in Figure 29 have been converted to viewsheds to enable the visibility of wind turbines in those locations to be analysed by filling each polygon with regular points at 100m intervals, from each of which a viewshed was calculated. The results of this process are displayed in Figure 30A. The PPGIS was used to ask the same question of an independent sample, with participants being required to click on a location from which a

viewshed would automatically be calculated in real time. The same parameters were used in both cases: 50m target height (the height of the turbine), 5km radius (the extent of the viewshed from the turbine location) and 1.6m observer height (the height of an average person's eye level).



**Figure 30** Comparison between viewsheds calculated from the Paper2GIS (A) and PPGIS (B) datasets produced by independent samples of the population

Figure 30 presents the composite viewshed produced with the dataset from the Paper2GIS results (A), and the PPGIS results (B), in which darker areas indicate where multiple viewsheds are overlaid. In this way, the resulting datasets can be considered as an inverse suitability surface, with the darkest colours showing the areas in which a turbine would impact upon the greatest number of the identified locations from which participants would

not wish to see a wind turbine. Whilst the magnitude of viewsheds is greater in the Paper2GIS dataset due to the difference in methodology (polygons filled with points, as opposed to single points to represent identified locations) the broad pattern identified in both datasets is clearly very similar, with the same parts of the island identified as the most unacceptable in both datasets. Such regions include the hills running from East to West across Vatersay (the Southern isle), the area surrounding the largest settlement (Castlebay, see Figure 25), particularly picturesque peaks and coastlines around the isles, and the area surrounding the airport (located at the North of the main isle). Participant feedback from the Paper2GIS questionnaire explaining why they did not want to be able to see a wind turbine from certain areas suggested that the primary motivation was in order to maintain the natural beauty of the isles and avoid residential areas:

*'It would spoil the scenery of the area and be harmful to livestock in the area.'* [Male,

61+]

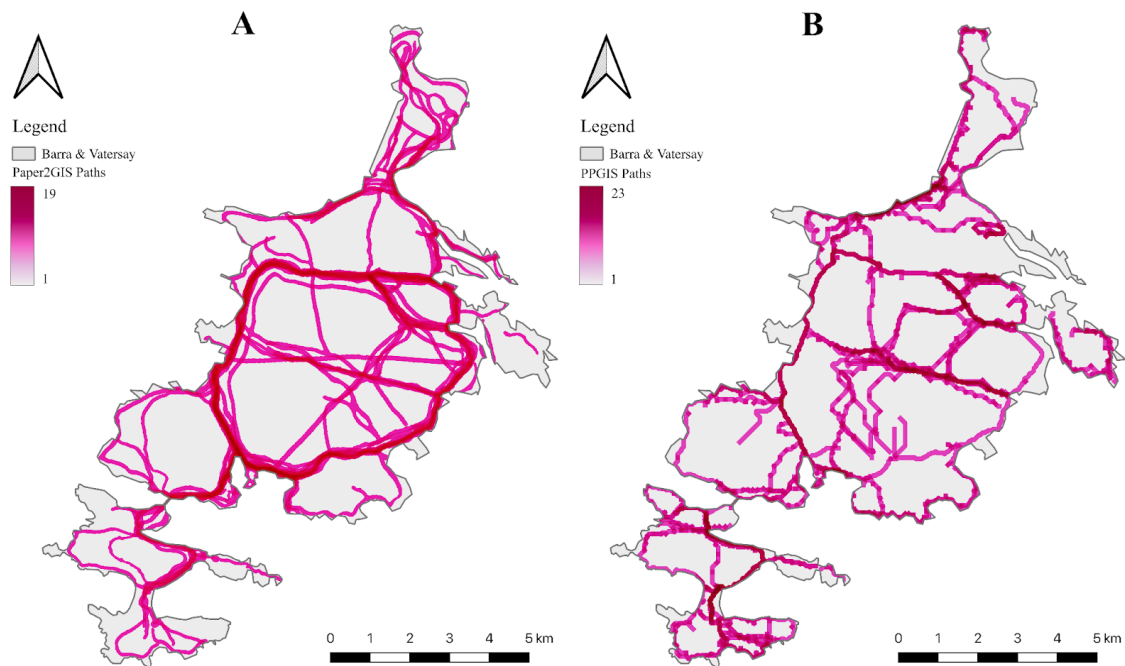
*'Avoiding main areas that are linked to tourist attractions and the views connected.'*

[Female, 51-60]

### **6.3.3 Desired locations for a new network of paths**

The network of paths proposed by participants using Paper2GIS are presented in Figure 31A, where darker areas indicate multiple participants proposing the same routes (examples of the original participants' responses are available in Appendix 9). For example, there is a clear desire from over half of the participants ( $n = 19$ ) for a path alongside the main road which circumnavigates Barra (Figure 25) to be developed. The comparative dataset is shown in Figure 31B, which was produced by users clicking a series of points onto the digital map,

which were joined together in real time using least-cost paths (as opposed to straight lines) in order to give more realistic results.



**Figure 31** Comparison between the raw network of paths produced from two independent samples, firstly through a Paper2GIS (A) and secondly through PPGIS (B)

The results produced through both methods are again broadly similar, giving further confidence that the two datasets are of comparable quality. For example, routes along the coast, as well as through the main valleys running east-west and north-south through the island interior were popular in both datasets. Participant feedback from the Paper2GIS questionnaire suggested a path along the road would be beneficial for safety reasons, whilst the more scenic routes would re-establish and encourage the use of historic walking routes or provide easier access to particular beauty spots:

*'Largely to increase/improve safety and accessibility to existing walks, to increase connectivity of existing path networks, and promote walking for health benefits.'*

*[Female, 18-30]*

*'A footpath would be safer alongside the road from Castlebay to Vatersay Causeway as it is very narrow in places.'* *[Male, 61+]*

## **6.4 Discussion**

With the growing popularity of Participatory Mapping as a means to improve democracy in the decision-making process, ensuring that methods are accessible to as many diverse members of society as possible is key. The location of the research, the nature of the question being asked and the characteristics of the target population should all be considered when selecting the most appropriate method for any given situation (Denwood et al., 2022).

It is often reported that older people are more likely than those in other age groups to contribute to Participatory Mapping surveys, so the benefits of providing more accessible approaches such as Paper2GIS can be realised in many different contexts, not just those focused on older populations (Haworth et al., 2016). Issues of self-efficacy, visual impairments and reduced mobility (found to limit participation in digital methods of Participatory Mapping) are minimised by using a paper-based method, as is evident in much of the supporting literature (Gottwald et al., 2016; Vrenko & Petrovič, 2015; Nielsen, 2013).

As the population of the isles is generally older than the UK population as a whole, it is likely to benefit from increased accessibility provided by non-digital methods of data collection (Gottwald et al., 2016; White & Selwyn, 2013). The similarity in both datasets demonstrates that notative sketch mapping provides a viable alternative or complementary approach to PPGIS for the collection of participatory data, increasing accessibility for those who are unable or unwilling to use digital methods. That a comparable dataset was achieved using Paper2GIS without any facilitation or additional assistance from the researchers suggests that the method and accompanying instructions were easy to understand, and that participants were comfortable using the familiar tools of pen and paper.

Participatory data collected using conventional paper map approaches require digitisation prior to analysis, but the methods to do so are often slow and subject to the interpretation of the researcher (Ramirez-Gomez et al., 2015). The advantage of automated digitisation in Paper2GIS is not only one of time efficiency, enabling accessible participatory research to be carried out at scale and speed; but also an improvement in the replicability of the research by removing the need for manual classification and intermediate interpretations. This also minimises the influence of positionality on the part of the researcher, an ongoing challenge in participatory research (Brown & Kytä, 2018). Due to the prescribed notation, data are comparable to that of a digital equivalent and therefore suitable for a range of spatial analyses rather than only suited to visual analysis.

It is important to recognise that neither dataset (Paper2GIS nor PPGIS) should be considered a benchmark against which the other can be measured, as each approach has its own advantages and drawbacks and there were several differences between the two methods of

collection. For example, the fact that one was facilitated, and one remote, along with differences in the characteristics of the participants, the base map, and the instructions will all have influenced the resulting datasets (Curtis et al., 2014). Whilst non-digital methods are more accessible, there are a number of limitations associated with their use in comparison with digital approaches. For example, in using paper maps many of the advantages of digital approaches are lost, such as the ability to zoom in on specific features, switch between map and satellite imagery, and edit data after it has been added to the map. The physical size of the paper base maps in particular can influence the resulting dataset by restricting either the areas covered or the level of detail possible in responses (Yabiku et al., 2017). Whilst increasing the physical size of the maps can improve this situation, by enabling larger geographic areas to be covered at a larger scale (as used by Haworth et al., 2016, Yabiku et al., 2017 and Usher et al. 2020), there is still a trade-off between maintaining accessibility through the simplicity of the system and the advantages of more complex digital systems. However, the similarity between the two datasets in this instance demonstrate that the size and scale of the maps were adequate for the questions being asked, and did not result in any reduction in the quality of data. A further potential limitation could occur in the participants not following or understanding the specific instructions, and, for example, adding alternative mark-up to the maps. This could introduce issues with interpretation of more ambiguous notation (i.e. crosses, circles or brackets), as was encountered by Curtis et al., (2014) and Huck et al., (2017). However, despite the data being collected remotely, no instances of this occurred in this research, with every participant following the set instructions correctly.

Whilst there will always be trade-offs when selecting the most appropriate method, the use of a paper-based approach (coupled with automated digitisation and a prescribed notation),

enables the collection of data suitable for spatial analysis whilst simultaneously improving accessibility for the participant. This is vital both for enabling accessible, remote participation and including those for whom participation would be prevented or impacted by digital divides. Although the research presented has focussed on improving accessibility to support an older population in a UK context, Paper2GIS has also been used in other technological contexts where a digital counterpart would not be possible or appropriate. One recent example conducted by this research group is the rapid and wide scale collection of participatory data on COVID-19 transmission in informal settlements in three cities in Kenya. These areas exhibit extremely low levels of access to computers, mobile devices and electricity; and low levels of literacy. Paper2GIS was used to help navigate these challenges in order to support participation from those who would otherwise currently be excluded from the decision-making process. The automated digitisation also facilitated a rapid response, without the inevitable delay that would have been caused by the manual digitisation of >1,200 responses. Another example where Paper2GIS has been successfully used to overcome a different accessibility issue is in the already discussed example in rural India (Huck et al., 2017), which once again demonstrated the benefits of the use of such a technique in a region with no Internet, mobile data or computer access. These examples not only demonstrate the successful deployment of Paper2GIS in a range of contexts but also the potential for future research.

This paper has demonstrated how a notative sketch mapping system can utilise technology to reduce the technical burden placed on the participant and therefore increase accessibility whilst still producing data suitable for spatial analysis. It is self-evident and well understood in the literature that pen and paper is more accessible than digital technology, enabling data to

be collected in locations that do not have access to or use of high-speed internet or computer technologies. In turn, this widens the potential for participation, leading to more datasets that are more representative of the stakeholders involved and better-informed decision making.

## 7.

# CONCLUSION

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### 7.1 Introduction

Over the last 35 years, significant technological advances have taken place in a range of technologies and systems that can be used in support of Participatory Mapping activities; and there has also been a significant increase in the popularity of these methods both in research and in practice. Despite this, in many ways the field has stagnated, with a notable lack of innovation and development. There has been a clear over-reliance on familiar tools and methodologies, which has resulted in a plethora of unrealised potential, limiting the impact of Participatory Mapping upon decision-making.

The overarching aim of this thesis was not only to establish the current state of the field of Participatory Mapping, but to begin to make steps towards addressing some of the fundamental issues that have contributed to this stagnation. This has been achieved through a systematic review which established the *status quo* of the field, and a real-world case study which demonstrated steps that can be made to minimise the challenges of both accessibility and representation. This final chapter begins by summarising the three empirical Chapters (4, 5 and 6) to demonstrate how they each answer a specific research question (set out in Section 1.5) and have contributed to the field, before presenting the limitations of the research and potential directions for future work.

## **7.2 Research Questions**

The literature review presented in Chapter 2 revealed significant gaps in knowledge regarding how to address the challenges of representation and accessibility in Participatory Mapping. The three research questions set out below were hence developed and answered within this thesis to achieve the overarching aim. Practical solutions have been presented to demonstrate each intellectual argument, using a real-world case study and a framework with which future work can be enhanced. Participatory Mapping has also been considered in the context of wider Open Science agendas.

### **7.2.1 Who is it that participates in Participatory Mapping research and how?**

Participatory Mapping is a broad field, used across an array of disciplines connecting participants to researchers and decision-makers, each of whom have different requirements and motivations. Chapter 4 followed the PRISMA Protocol to consolidate current practices in Participatory Mapping, identifying who participates, how this information is collected and compiled, and demonstrating how this might be used to advance the field through the formation of an Open Science framework. This is the first comprehensive, systematic review of *how* Participatory Mapping is conducted in academic articles and who it is that takes part, allowing insights into the field as a whole, for example confirming that discrete points are the dominant mode of spatial representations. The PRISMA Protocol enforced an objective and transparent analysis of the articles, preventing bias in the selection process which could impact the outcomes. This study comprised an unprecedented exploration of the field of Participatory Mapping, leading to the production of a set of recommendations outlining the necessary details to be gathered and reported to support an Open Science approach.

The framework for an Open Science approach to Participatory Mapping is intended to encourage more transparent reporting and research, encouraging replicability and accountability. Understanding the finer details of who it is that participates and how, enables important lessons to be learned for future work, however the key finding revealed by the systematic review was in fact that at present there is highly inconsistent reporting on such details. The systematic review presented in Chapter 4 revealed that participant demographics, the use of incentives and even the specific details on the questions being asked are often not reported in the literature. These are fundamental basics in scientific reporting that should be provided regardless of method selected and to not include them in published outputs brings the credibility and veracity of the research into question.

Chapter 4 also identified that the field of Participatory Mapping is disparate and disconnected, with confusion over the terminology used to define methods, no ‘home’ journal and little transparency regarding methodological details. High-level definitions of key methods were therefore established at the outset of the review to unify methods in a usable way, finessing the breakdown of Participatory Mapping into: PGIS (digital with spatial context), sketch mapping (non-digital with spatial context) and mental mapping (non-digital without spatial context). Learning from the analysis of such a body of previous research could lead to more transparent and replicable research across the field, adding to the veracity and credibility of participatory data provided by the public.

### **7.2.2 How can PPGIS better support the researcher in the question they are asking, and the participant in the answers they are providing to better represent spatial information?**

It is widely agreed that the use of local knowledge adds value to the decision-making process, and PPGIS are often deployed for this purpose (Carver et al., 2009; Anderson et al., 2009; Evans & Waters, 2007). However, the PPGIS literature exhibits a persistent over-reliance upon specific spatial primitives that are often selected for their familiarity to the researcher and ease of analysis, rather than their suitability for representing the nuanced and complex information that participants wish to impart (as demonstrated in Chapter 4). Chapter 5 explored how PPGIS interfaces might be designed in a way that better supports both the researcher (in the question that they are asking) and the participant (in the answers that they are providing). Relying on pre-existing, familiar methods and forms of spatial representation can impact both the effectiveness of the resultant decision-making and the value in obtaining public opinion. Whilst potentially simplifying analysis for the researcher, for the participant, it can limit their ability to elucidate their spatial thoughts and feelings; and for the decision-maker, it can serve to influence the definition of the question being asked in the first place (Huck et al., 2019).

To this end, Chapter 5 introduces the concept of ‘informed interfaces’ which use alternative spatial units to give participants greater context and control over their input. The possibilities that arise from the use of two alternative spatial units were examined using a case study on the Isles of Barra and Vatersay, Outer Hebrides, UK. In the first example, viewsheds were used (rather than simple points) to enable participants to make informed decisions about desired locations for a new wind turbine. The second used least cost paths (rather than simple

lines) to allow users to suggest realistic routes to contribute to the design of a path network in a way that reflects the terrain and obstacles. To assess whether the informed interfaces supported participants in answering the questions, a remote usability study was also conducted with non-residents. Both interfaces were designed to empower participants to produce datasets that are better suited to the questions that they are being asked and the answers that they wish to give, and as a result provide richer datasets with the potential to improve outcomes for both participants and decision-makers. Participants favoured the informed interfaces in both studies, finding the additional information they were provided in real-time increased confidence and impacted the choices made. It is clear that a step change is required in the development of new forms of Participatory Mapping, moving away from repeatedly using the same spatial primitives to instead introducing more innovative methods, with a focus on what is most appropriate for the given situation instead of just the most familiar.

### **7.2.3 To what extent can the use of a non-digital interface improve accessibility for participants whilst still producing data that can be rigorously analysed in order to inform policy?**

Whilst the use of informed interfaces addresses issues around representation, it does not address the issue of accessibility. It is widely understood that some of the more technological methods for supporting community engagement can also prevent certain social groups from participating (Radil & Jiao, 2016; Gottwald et al., 2016; Deursen and van Dijk, 2011). Digital divides exist, often preventing citizens from fully engaging in what are now predominantly web-based approaches to Participatory Mapping (Gottwald et al., 2016). Digital divides can exist for a range of reasons, be it social, cultural or technical; and can create inequalities in

participatory data, limiting the degree to which certain groups are heard in the decision-making process (van Dijk, 2020). Chapter 6 demonstrated a novel sketch mapping tool, intended to enhance the accessibility of Participatory Mapping without restricting the potential analysis of the resulting dataset.

Paper-based mapping has long been used as the solution to issues around accessibility as it removes the need for digital skills, however, the lack of standardisation in data collection makes it difficult if not impossible to conduct quantitative spatial analysis of the type typically favoured by decision makers. Additionally, the need for manual interpretation by the researcher to digitise contributions is not only inefficient but also introduces bias. The method presented in Chapter 6 solves these issues. Here, the same two energy planning questions were asked of the residents of Barra and Vatersay as in Chapter 5. By collecting local views and ideas using a remote, auto-digitising, paper-based approach (*Paper2GIS*), it was possible to assess whether accessibility could be improved without introducing researcher subjectivity whilst also maintaining the capacity for analysis. It was revealed that, when used in conjunction with clear instructions on notation, a dataset can be produced through a paper-based method that is comparable to a digital equivalent (using the dataset from Chapter 5). The use of notative sketch mapping can improve accessibility for participants by reducing the technical skill required to participate without reducing the range of analytical options available to the researcher, permitting a wider proportion of society to be reached and improve democracy in decision-making.

### 7.3 Limitations

This thesis has contributed to the field through the theoretical arguments made within the three empirical chapters as well as the more tangible outputs of open source software and an Open Science framework for Participatory Mapping. The key contributions from the empirical chapters are two in-depth demonstrations of Participatory Mapping innovations; firstly the feasibility of using alternative spatial units through using viewsheds and least cost paths; and secondly through the application of a paper-based method that enables the collection and compilation of data that can be analysed in the same way as digitally collected data. An argument has been made for more creativity and innovation in the development of Participatory Mapping interfaces, as well as for more transparent and effective knowledge sharing; which will act to improve Participatory Mapping for participants, researchers and decision-makers. Nevertheless, the research presented in this thesis is not without limitations.

Whilst the systematic review (Chapter 4) aimed to be as wide reaching as possible to represent an effective cross section of the field of Participatory Mapping, the included articles were limited to those using a specific set of keywords, which could have omitted relevant research that uses different terminology. Additionally, only those written in the English language were included in the analysis, which could have resulted in the omission of a number of international contributions. Further, while great effort was made to accurately extract the data from each article, this was done manually and as such leaves space for human error.

Chapters 5 and 6 both used a case study approach to ensure that the questions being asked had real-life context and meaning for those participating. The limitation of this however, is that the research was therefore developed in the social and geographical context of the isles of Barra and Vatersay. Although most directly transferable to research of a similar scale in a Western context, the findings and theoretical arguments have wider relevance. Furthermore, the systems used are open source and can be adapted and applied to communities of a similar scale facing other energy challenges. The research for both Chapters 5 and 6 was also heavily impacted by the Covid-19 pandemic (see section 3.5). The pandemic limited the number of participants who were able to take part as several data collection trips to the isles had to be cancelled. Whilst sufficient adaptations were made to the research design to overcome this challenge, such as including a usability study in Chapter 5 and conducting the Participatory Mapping via post in Chapter 6, this nevertheless represents a significant divergence from the original plan.

## **7.4 Future Research**

As the case study used in this thesis was quite specific, there is great potential to test the systems elsewhere to assess whether they would be equally as effective in different geographical, cultural or social settings and at different scales. It would also be of value to conduct further research using Paper2GIS in a facilitated rather than remote setting to obtain more feedback from participants in real-time; as well as exploring how this system might be used alongside other data collection methods such as walking interviews, for example. In addition to this, usability testing of Paper2GIS could provide an insight into the impact of scale on the effectiveness of the tool in accurately representing the intentions of the participants. As the public is now much more technologically-literate than at the inception of

Participatory Mapping, and as participants found both informed interfaces easy to use, it would also be of interest to explore the use of other tools that are commonly found in desktop GIS in other decision-making contexts (e.g. pollution plumes or flood fill models). One route this could take is to consider practical approaches to address another challenge with Participatory Mapping, which is that of uncertainty. Whilst not within the scope of this thesis, it would be interesting to further explore the potential of tools such as Huck et al.'s (2014) spraycan to address issues around vagueness and fuzziness in the way people perceive and interact with the world around them. An exploration into the addition of measures to quantify the certainty or confidence that participants have in the data they are providing may also be a novel way of improving the veracity of the datasets produced.

Further, it would also be advantageous to explore the extent to which Participatory Mapping exercises are used to inform policy; whether the intentions set out at the offset are in fact realised and the extent to which the method of data collection used influences this (i.e. whether quantitative evaluation of contributions has a greater impact on decision-making than qualitative). Similarly, whilst the systematic review extracted a great breadth of data from a broad range of papers, it did not explore the *why*. Future research could therefore explore more directly why it is that Participatory Mapping research is conducted, and why it is that members of the general public do or do not participate.

## **7.5 Contribution to Knowledge**

Participatory Mapping has been used across a wide range of disciplines, exploring a fascinating array of topics over the last 35 years, however in contrast to wider technical

development, it has stagnated. The challenges of representation and accessibility have been widely explored in the literature, but largely remain merely acknowledged as opposed to addressed. In spite of their wide recognition, it is apparent that ease of use and familiarity win out over innovation.

Representation and accessibility represent the two most significant challenges in Participatory Mapping. This research has demonstrated through the use of alternative methods of Participatory Mapping that steps can be made to address both of these issues, and that more can be done than acknowledging that barriers to implementation exist. The issue of representation has been challenged and veracity added to the collected data by giving more control and context to the participant to enable informed decisions to be made, enabling them to elucidate their spatial thoughts and feelings in a more effective manner. The issue of accessibility has been challenged, demonstrating that reducing the technical requirement on the participant to improve accessibility does not have to mean reducing the analytical capacity of the resultant data - one of the fundamental challenges of more low-tech methods. This is not to say that the systems presented in this thesis are suitable for all situations, nor that the use of digital platforms or spatial primitives are never appropriate, but that much more can be done than has been to date in regard to innovation and creativity to obtain the best results from such a nuanced and insightful practice of data collection.

An unexpected outcome of conducting this research has been the discovery of the apparent lack of uniformity and transparency in reporting of Participatory Mapping research. The systematic review revealed that a significant proportion of Participatory Mapping research failed to report what would normally be considered basic but essential details, such as

participant demographics or the use of incentives to encourage participation. Not only will innovation and development in the field remain stunted without open and transparent knowledge sharing, but also the veracity in the practice and therefore onward use of the data obtained (Kedron et al., 2021). Taking an Open Science approach to Participatory Mapping (following the framework set out in Chapter 4) across all methods from hi-tech PGIS to mental mapping with paper and pencil would ensure more replicable, reproducible, and rigorous research, and therefore increase the potential for more meaningful contributions to decision making. There is a clear need and plentiful scope for the field of Participatory Mapping to adopt an Open Science approach, as has been successfully undertaken in other fields (Nüst & Pebesma, 2021). Such a move would be transformative for the field, enhancing the way in which research is conducted and communicated as well as improving trust and innovation. As the intention of Participatory Mapping is to improve democracy in decision-making, and provide an insight into the largely untapped knowledge-base that is the general public it is essential that steps be taken toward improving this. This research has illustrated this point by considering what *could* be done, rather than what is *usually* done; and has demonstrated that such approaches can overcome long-standing challenges to the benefit of those both who propose and those who partake in Participatory Mapping research.

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Wróżyński, R., Sojka, M., & Pyszny, K. (2016). The application of GIS and 3D graphic software to visual impact assessment of wind turbines. *Renewable Energy*, 96, 625-635.

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Yeboah, G., & Albanides, S. (2015). Route choice analysis of urban cycling behaviors using OpenStreetMap: Evidence from a British urban environment. In *OpenStreetMap in GIScience* (pp. 189-210). Springer, Cham.

Zolkafli, A., Brown, G., & Liu, Y. (2017). An Evaluation of Participatory GIS (PGIS) for Land Use Planning in Malaysia. *The Electronic Journal of Information Systems in Developing Countries*, 83(1), 1-23.

## APPENDIX 1

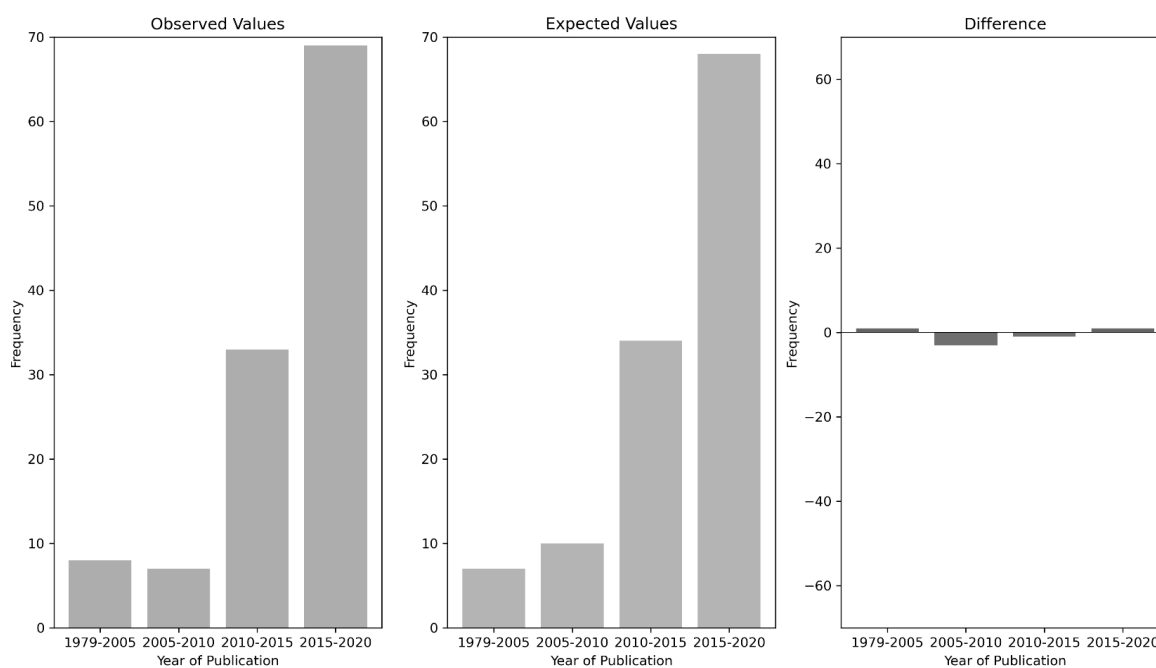
### Photographs of the isles of Barra and Vatersay to illustrate the landscape setting of the case study research



All photographs taken by Timna Denwood November 2019.

## APPENDIX 2

**The difference between the observed and expected frequency distributions of the ‘eligible’ set to ensure the stratified sample is representative of the ‘included’ set**



### APPENDIX 3

#### All 117 articles in the 'included' set analysed using the PRISMA Protocol

Author	Year	Journal	Title
Wise, N.	2014	Geographical Research	Layers of the landscape: Representations and perceptions of an ordinary (shared) sports landscape in a Haitian and Dominican community
White, R. J. Green, A. E.	2015	Work, Employment and Society	The importance of socio-spatial influences in shaping young people's employment aspirations: case study evidence from three British cities
Mansournia, S.	2020	Urban Studies	Understanding children's perceptions and activities in urban public spaces: The case study of Zrêbar Lake Waterfront in Kurdistan
Bishop, J.	1984	Places	Place debate: Milton Keynes. Passing in the night: public and professional views of Milton Keynes
Biolek, J.	2015	Human Geographies	Investigating suburban environment by means of mental maps: A case study of Olomouc hinterland
van Gent, W. P. C. Boterman, W. R. van Grondelle, M. W.	2016	Housing, Theory and Society	Surveying the Fault Lines in Social Tectonics; Neighbourhood Boundaries in a Socially-mixed Renewal Area
Ruin, I.	2007	Environmental Hazards	How to get there? Assessing motorists' flash flood risk perception on daily itineraries
Catney, G.	2019	Qualitative Research	Residents' perspectives on defining neighbourhood: mental mapping as a tool for participatory neighbourhood research
Soukup, M.	2018	Cesky Lid	Visual spatial representation of social and cultural phenomena and its effect on local education: The case of Papua New Guinea
Bereitschaft, B.	2018	Journal of Urbanism	Walk score versus residents' perceptions of walkability in omaha, ne

Osch, B.	2019	Miscellanea Geographica	City image based on mental maps-the case study of Szczecin (Poland)
Tsoukala, K.	2009	Semiotica	Spatial representation, activity, and meaning: Children's images of the contemporary city
Teh, L., Teh, L., Meitner, M.	2012	Human Ecology	Preferred resource spaces and fisher flexibility: Implications for spatial management of small-scale fisheries
McLees, L.	2013	Professional Geographer	A Postcolonial Approach to Urban Studies: Interviews, Mental Maps, and Photo Voices on the Urban Farms of Dar es Salaam, Tanzania
Visser, Kirsten Sichling, Florian Chaskin, Robert J.	2017	Journal of Youth Studies	Hot times, hot places. Youths' risk perceptions and risk management in Chicago and Rotterdam
Boyer, Anne Lise Comby, Emeline Flaminio, Silvia Le Lay, Yves François Cottet, Marylise	2019	Ambio	The social dimensions of a river's environmental quality assessment
Foshag, Kathrin Aeschbach, Nicole Höfle, Bernhard Winkler, Raino Siegmond, Alexander Aeschbach, Werner	2020	Sustainable Cities and Society	Viability of public spaces in cities under increasing heat: A transdisciplinary approach
Cox C., Morse W., Anderson C., Marzen L.	2015	Journal of the American Water Resources Association	Using Public Participation Geographic Information Systems to Identify Places of Watershed Service Provisioning†
Muller-Eie, D; Alvarez, AL	2020	JOURNAL OF URBAN DESIGN	An approach to perception mapping: using maps to investigate local user perceptions of urban quality in Hillevag, Norway
Craig Williams, Christine E Dunn	2003	Transactions in GIS	GIS in Participatory Research: Assessing the Impact of Landmines on Communities in North-west Cambodia

Kingston R., Carver S., Evans A., Turton I.	2000	Computers, Environment and Urban Systems	Web-based public participation geographical information systems: An aid to local environmental decision-making
Kujinga K., Chingarande S.D., Mugabe P.H., Nyelele C.	2012	Journal of Social Development in Africa	Interface Between Research, Development and Local Actors in Enhancing Sustainable Forest Resources Management: Lessons from Chimanimani District, Zimbabwe Krasposy
Migliaccio T., Raskauskas J., Schmidtlein M.	2017	Learning Environments Research	Mapping the landscapes of bullying Todd
Van Riper, CJ; Kyle, GT	2014	JOURNAL OF ENVIRONMENTAL MANAGEMENT	Capturing multiple values of ecosystem services shaped by environmental worldviews: A spatial analysis
Sun Y., Zhou H., Wall G., Wei Y.	2017	Journal of Sustainable Tourism	Cognition of disaster risk in a tourism community: an agricultural heritage system perspective
Maillet, D. G. C.	2016	Ocean & Coastal Management	The role of public participation GIS (PPGIS) and fishermen's perceptions of risk in marine debris mitigation in the Bay of Fundy, Canada
Kyttä, M.	2013	Landscape and Urban Planning	Towards contextually sensitive urban densification: Location-based softGIS knowledge revealing perceived residential environmental quality
Luz, A. C. Buijs, M. Aleixo, C. Metelo, I. Grilo, F. Branquinho, C. Santos-Reis, M. Pinho, P.	2019	Urban Forestry and Urban Greening	Should I stay or should I go? Modelling the fluxes of urban residents to visit green spaces
Chirowodza, A.	2009	Journal of Community Psychology	Using participatory methods and geographic information systems (GIS) to prepare for an HIV community-based trial in vulindlela, South Africa (project accept-HPTN 043)

Ives, C. D.	2018	Journal of Environmental Planning and Management	Spatial scale influences how people value and perceive green open space
Loerzel, J. L. Goedeke, T. L. Dillard, M. K. Brown, G.	2017	Marine Policy	SCUBA divers above the waterline: Using participatory mapping of coral reef conditions to inform reef management
Altmann, B. A. Jordan, G. Schlecht, E	2018	Sustainability (Switzerland)	Participatory mapping as an approach to identify grazing pressure in the Altay Mountains, Mongolia
Huck, J. J.	2019	Annals of the American Association of Geographers	Exploring Segregation and Sharing in Belfast: A PGIS Approach
Black, B. D.	2015	Environmental Biology of Fishes	Mapping of stakeholder activities and habitats to inform conservation planning for a national marine sanctuary
Aheto, D. W.	2016	Ocean and Coastal Management	Community-based mangrove forest management: Implications for local livelihoods and coastal resource conservation along the Volta estuary catchment area of Ghana
Laatikainen, T. Tenkanen, H. Kytä, M. Toivonen, T.	2015	Landscape and Urban Planning	Comparing conventional and PPGIS approaches in measuring equality of access to urban aquatic environments
Kivinen, S. Vartiainen, K. Kumpula, T.	2018	Land	People and post-mining environments: PPGIS mapping of landscape values, knowledge needs, and future perspectives in Northern Finland
Pedregal, B. Laconi, C. del Moral, L.	2020	Isprs International Journal of Geo-Information	Promoting environmental justice through integrated mapping approaches: The map of water conflicts in Andalusia (Spain)
Kienberger, S.	2014	Journal of Maps	Participatory mapping of flood hazard risk in Munamicua, District of Mozambique

Fagerholm, N. Eilola, S. Kisanga, D. Arki, V. Käyhkö, N.	2019	Landscape Ecology	Place-based landscape services and potential of participatory spatial planning in multifunctional rural landscapes in Southern highlands, Tanzania
Gorokhovich, Y. Leiserowitz, A. Dugan, D.	2014	Journal of Coastal Research	Integrating coastal vulnerability and community-based subsistence resource mapping in Northwest Alaska
Hasala, D. Supak, S. Rivers, L.	2020	Landscape and Urban Planning	Green infrastructure site selection in the Walnut Creek wetland community: A case study from southeast Raleigh, North Carolina
Cinderby, S.	2010	Area	How to reach the 'hard-to-reach': The development of Participatory Geographic Information Systems (P-GIS) for inclusive urban design in UK cities
Cervený, L. K. Biedenweg, K. McLain, R.	2017	Environmental Management	Mapping Meaningful Places on Washington's Olympic Peninsula: Toward a Deeper Understanding of Landscape Values
Wang, Y. Kotze, D. J. Vierikko, K. Niemelä, J.	2019	Urban Forestry and Urban Greening	What makes urban greenspace unique ,Äi Relationships between citizens,Äô perceptions on unique urban nature, biodiversity and environmental factors
Pietla, M.	2015	Journal of Outdoor Recreation and Tourism-Resear ch Planning and Management	Examining the relationship between recreation settings and experiences in Oulanka National Park - A spatial approach
Bitsura-Meszaros, K. Seekamp, E. Davenport, M. Smith, J. W.	2019	Sustainability (Switzerland)	A PGIS-based climate change risk assessment process for outdoor recreation and tourism dependent communities
Kyttä, M.	2014	Urban Design International	Perceived safety of the retrofit neighborhood: A location-based approach
Álvarez, P.	2015	Landscape Research	Regional Landscape Change in Fishing Communities of the Mexican North Pacific

Wolf, I. D. Wohlfart, T. Brown, G. Bartolomé Lasa, A.	2015	Tourism Management	The use of public participation GIS (PPGIS) for park visitor management: A case study of mountain biking
Vanolya, N. M.	2019	Applied Geography	Validation of spatial multicriteria decision analysis results using public participation GIS
Brown, G. Smith, C. Alessa, L. Kliskey, A.	2004	Applied Geography	A comparison of perceptions of biological value with scientific assessment of biological importance
Salonen, M.	2014	Applied Geography	Do suburban residents prefer the fastest or low-carbon travel modes? Combining public participation GIS and multimodal travel time analysis for daily mobility research
Brown, G.	2014	Landscape and Urban Planning	Using participatory GIS to measure physical activity and urban park benefits
Strickland-Munro, J.	2016	International Journal of Sustainable Development and Planning	Valuing the wild, remote and beautiful: Using public participation gis to inform tourism planning in the Kimberley, Western Australia
Canedoli, C.	2017	Sustainability (Switzerland)	Public participatory mapping of cultural ecosystem services: Citizen perception and park management in the Parco Nord of Milan (Italy)
Hassan, M. M.	2005	Health Policy	Arsenic poisoning in Bangladesh: Spatial mitigation planning with GIS and public participation
Wynecoop, M. D.	2019	Fire Ecology	Getting back to fire: exploring a multi-disciplinary approach to incorporating traditional knowledge into fuels treatments
Buendía, A. V. P. Albert, M. Y. P. Giné, D. S.	2019	Isprs International Journal of Geo-Information	PPGIS and public use in protected areas: A case study in the Ebro Delta Natural Park, Spain
Darvill, R. Lindo, Z.	2015	Ecosystem Services	Quantifying and mapping ecosystem service use across stakeholder groups:

			Implications for conservation with priorities for cultural values
Brown, G.	2018	Applied Geography	Identifying potential NIMBY and YIMBY effects in general land use planning and zoning
Brown, G.	2014	Journal of Environmental Planning and Management	Which 'public'? Sampling effects in public participation GIS (PPGIS) and volunteered geographic information (VGI) systems for public lands management
Murray, T.	2019	New Zealand Journal of Ecology	How do we go about restoring the wetlands of Ngati Maniapoto?
Pějínek, J.	2018	Quaestiones Geographicae	Participatory mapping in community participation - Case study of Jeseník, Czech Republic
Nyantakyi-Frimpong, H.	2019	Geoforum	Visualizing politics: A feminist political ecology and participatory GIS approach to understanding smallholder farming, climate change vulnerability, and seed bank failures in Northern Ghana
Sijtsma, Frans J. Mehnen, Nora Angelstam, Per Muñoz-Rojas, José	2019	Landscape Ecology	Multi-scale mapping of cultural ecosystem services in a socio-ecological landscape: A case study of the international Wadden Sea Region
Petrakis, Roy E. Norman, Laura M. Lysaght, Oliver Sherrouse, Benson C. Semmens, Darius Bagstad, Kenneth J. Pritzlaff, Richard	2020	Air, Soil and Water Research	Mapping Perceived Social Values to Support a Respondent-Defined Restoration Economy: Case Study in Southeastern Arizona, USA
Brown, G., Weber, D.	2011	Landscape and Urban Planning	Public Participation GIS: A new method for national park planning
Muñoz, Lorena Hausner, Vera Brown, Greg Runge, Claire Fauchald, Per	2019	Tourism Management	Identifying spatial overlap in the values of locals, domestic- and international tourists to protected areas

Jaligot, Rémi Kemajou, Armel Chenal, Jérôme	2018	Land Use Policy	Cultural ecosystem services provision in response to urbanization in Cameroon
Ricker, Britta A. Johnson, Peter A. Sieber, Renee E.	2013	Journal of Sustainable Tourism	Tourism and environmental change in Barbados: Gathering citizen perspectives with volunteered geographic information (VGI)
Sarky, Sarook Wright, Jim Edwards, Mary	2017	Journal of Environmental Planning and Management	Evaluating consistency of stakeholder input into participatory GIS-based multiple criteria evaluation: a case study of ecotourism development in Kurdistan
Raymond, Christopher M. Gottwald, Sarah Kuoppa, Jenni Kyttä, Marketta	2016	Landscape and Urban Planning	Integrating multiple elements of environmental justice into urban blue space planning using public participation geographic information systems
Kobryn, Halina T. Brown, Greg Munro, Jennifer Moore, Susan A.	2018	Ocean and Coastal Management	Cultural ecosystem values of the Kimberley coastline: An empirical analysis with implications for coastal and marine policy
Noble, M. M.	2019	Journal of Environmental Management	Understanding the spatial diversity of social uses, dynamics, and conflicts in marine spatial planning
Shrestha, S.	2016	Journal of Ethnobiology	Landscape Mapping: Gaining "sense of Place" for Conservation in the Manaslu Conservation Area, Nepal
Jankowski, P.	2016	Transactions in Gis	Geo-questionnaire: A Method and Tool for Public Preference Elicitation in Land Use Planning
Killeen, G. F.	2007	International Journal of Health Geographics	Participatory mapping of target areas to enable operational larval source management to suppress malaria vector mosquitoes in Dar es Salaam, Tanzania
Wartmann, F. M. Purves, R. S.	2017	Land	What's (not) on the map: Landscape features from participatory sketch mapping differ from local categories used in language
Norris, T. B.	2014	Applied Geography	Bridging the great divide: State, civil society, and 'participatory' conservation mapping in a resource extraction zone

Ferreira, Beatrice Padovani	2009	Neotropical Ichthyology	Fishers' resource mapping and goliath grouper <i>Epinephelus itajara</i> (Serranidae) conservation in Brazil
Aswani, S. Diedrich, A. Currier, K.	2015	Society and Natural Resources	Planning for the future: Mapping anticipated environmental and social impacts in a nascent tourism destination
Derkzen, M. L.	2017	Ecology and Society	Shifts in ecosystem services in deprived urban areas: Understanding people, responses and consequences for well-being
Eilola, S. Käyhkö, N. Fagerholm, N. Kombo, Y. H.	2014	Agroecology and Sustainable Food Systems	Linking Farmers' Knowledge, Farming Strategies, and Consequent Cultivation Patterns into the Identification of Healthy Agroecosystem Characteristics at Local Scales
Tschakert, P.	2016	Social Science and Medicine	Situated knowledge of pathogenic landscapes in Ghana: Understanding the emergence of Buruli ulcer through qualitative analysis
Wilson, K. Coen, S. E. Piaskoski, A. Gilliland, J. A.	2019	Canadian Geographer	Children's perspectives on neighbourhood barriers and enablers to active school travel: A participatory mapping study
Pérez-Darros, J. A.	2020	Biological Conservation	Rallying citizen knowledge to assess wildlife occurrence and habitat suitability in anthropogenic landscapes
Lopes, P. F. M. Rosa, E. M. Salyvonchik, S. Nora, V. Begossi, A.	2013	Marine Policy	Suggestions for fixing top-down coastal fisheries management through participatory approaches
Connors, E. E.	2016	Plos One	Quantitative, qualitative and geospatial methods to characterize HIV risk environments
Moomen, A. W.	2017	Resources Policy	Strategies for managing large-scale mining sector land use conflicts in the global south
Townley, G.	2009	Health and Place	Understanding the experience of place: Expanding methods to conceptualize and measure community integration of persons with serious mental illness

Brown, S. T.	2019	Sociological Review	Maps cannot tell the whole story: Interpreting the shiftscape with a mixed methods approach
Frangos, M.	2017	Design Journal	Infrastructuring Place. Citizen-led Placemaking and the Commons
Zaehring, J. G. Llopis, J. C. Latthachack, P. Thein, T. T. Heinimann, A.	2018	Journal of Land Use Science	A novel participatory and remote-sensing-based approach to mapping annual land use change on forest frontiers in Laos, Myanmar, and Madagascar
Cadag, J. R. D.	2012	Area	Integrating knowledge and actions in disaster risk reduction: The contribution of participatory mapping
Ventin, L. B.	2015	Marine Pollution Bulletin	Towards adaptive management of the natural capital: Disentangling trade-offs among marine activities and seagrass meadows
McEwen, L. Gorell Barnes, L. Phillips, K. Biggs, I.	2020	Transactions of the Institute of British Geographers	Reweaving urban water-community relations: Creative, participatory river ,Áúdaylighting,Áù and local hydrocitizenship
Rohrbach, B.	2018	Landscape and Urban Planning	Comparing multi-criteria evaluation and participatory mapping to projecting land use
Harman Parks, M.	2014	Geojournal	Gender and conservation agriculture: constraints and opportunities in the Philippines
Wario, H. T. Roba, H. G. Kaufmann, B.	2015	Environmental Management	Shaping the Herders,Áô ,ÁúMental Maps,Áù: Participatory Mapping with Pastoralists,Áô to Understand Their Grazing Area Differentiation and Characterization
Hodbod, J.	2019	Land	Integrating Participatory methods and remote sensing to enhance understanding of ecosystem service dynamics across scales
Battisti, L.	2019	Sustainability (Switzerland)	Management and perception of Metropolitan Natura 2000 Sites: A case study of La Mandria Park (Turin, Italy)

Hong, N. T.	2019	Human Ecology	Forest Ecosystem Services and Local Communities: Towards a Possible Solution to Reduce Forest Dependence in Bach Ma National Park, Vietnam
Rachlow, J. L.	2016	Ecology and Society	A social-ecological impact assessment for public lands management: application of a conceptual and methodological framework
Dallabetta, G.	2003	Sexually Transmitted Diseases	Participatory mapping of sex trade and enumeration of sex workers using capture-recapture methodology in Diego-Suarez, Madagascar
Hellier, Augustine Newton, Adrian C. Gaona, Susana Ochoa	1999	Biodiversity and Conservation	Use of indigenous knowledge for rapidly assessing trends in biodiversity: A case study from Chiapas, Mexico
Eide, Arne H. Dyrstad, Karin Munthali, Alister Van Rooy, Gert Braathen, Stine H. Halvorsen, Thomas Persendt, Frans Mvula, Peter Rød, Jan Ketil	2018	Bmc International Health and Human Rights	Combining survey data, GIS and qualitative interviews in the analysis of health service access for persons with disabilities
Méndez, V. E. Lok, R. Somarriba, E.	2001	Agroforestry Systems	Interdisciplinary analysis of homegardens in Nicaragua: Micro-zonation, plant use and socioeconomic importance
Saija, Laura Pappalardo, Giusy	2018	Journal of Planning Education and Research	An Argument for Action Research-Inspired Participatory Mapping
Gilmore, Michael P. Young, Jason C.	2012	Journal of Ethnobiology	The use of participatory mapping in ethnobiological research, biocultural conservation, and community empowerment: A case study from the peruvian amazon
Woodhouse, Emily Mills, Martin A. McGowan, Philip J.K.	2015	Human Ecology	Religious relationships with the environment in a Tibetan rural community: Interactions and contrasts with popular notions of indigenous environmentalism

Milner-Gulland, E. J.			
Malinga, R. H.	2018	Ecology and Society	On the other side of the ditch: Exploring contrasting ecosystem service coproduction between smallholder and commercial agriculture
Chowdhury, A. N.	2016	Indian Journal of Psychiatry	Stigma of tiger attack: Study of tiger-widows from Sundarban Delta, IndiaFNx01
Hohenthal, J.	2017	Professional Geographer	Mapping Meaning: Critical Cartographies for Participatory Water Management in Taita Hills, Kenya
Bogdan, Sorina Mihaela Stupariu, Ileana Andra-Topârceanu, Andreea Năstase, Irina Iulia	2019	Carpathian Journal of Earth and Environmental Sciences	Mapping social values for cultural ecosystem services in a mountain landscape in the Romanian Carpathians
Thoya, P.	2019	Fisheries Research	Effects of assets and weather on small-scale coastal fishers' access to space, catches and profits
Reilly, Kate Adamowski, Jan John, Kimberly	2018	Ecosystem Services	Participatory mapping of ecosystem services to understand stakeholders' perceptions of the future of the Mactaquac Dam, Canada

## APPENDIX 4

**All data extracted from the sample of 117 included articles using the PRISMA protocol**

How are different Participatory Mapping methods being used and reported?	What information is given on the data collected through Participatory Mapping?	How are participant demographics being recorded?	Who is conducting the research and where is it being published?
<i>Year of publication</i>	<i>Question being asked</i>	<i>Intended participants</i>	<i>Research establishment</i>
<i>Participatory Mapping method (as referred to in title, abstract or keywords)</i>	<i>Research domain</i>	<i>Targeted/public</i>	<i>Journal of publication</i>
<i>Participatory Mapping method (according to given definitions)</i>	<i>User interface</i>	<i>Gender demographic</i>	<i>Intended/actual policy influence</i>
<i>Facilitated/remote</i>	<i>Spatial representation used</i>	<i>Age demographic</i>	
<i>Data collection method (i.e. focus group, interview)</i>	<i>Justification of spatial representation used</i>		
<i>Incentivisation</i>			
<i>Number of participants</i>			

## APPENDIX 5

### Participant instructions and consent form for Paper2GIS data collection

#### Consent Form

If you are happy to participate in this Barra and Vatersay Participatory Mapping PhD Research Project please complete and sign the consent form below and return with the completed survey and maps in the prepaid envelope provided.

This consent form will be kept for the length of the research and then destroyed. It will not be published, distributed or used to identify individual contributions at any stage.

	Activities	Initials
1	I confirm that I have read the attached information sheet for the above study and have had the opportunity to consider the information, ask questions and had these answered satisfactorily.	
2	I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason and without detriment to myself. I understand that it will not be possible to remove my data from the project once it forms part of the data set as it is anonymous.  I agree to take part on this basis	
3	I agree that any data collected may be published in anonymous form in academic books, reports or journals.	
4	I understand that data collected during the study may be looked at by individuals from The University of Manchester or regulatory authorities, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my data.	
5	I agree to take part in this study	

#### Data Protection

The personal information we collect and use to conduct this research will be processed in accordance with data protection law as explained in the Participant Data Information Sheet and the Privacy Notice for Research Participants available at <http://documents.manchester.ac.uk/display.aspx?DocID=37095>

\_\_\_\_\_  
Name of Participant

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## APPENDIX 6

### Participant Information Sheet for Paper2GIS data collection

#### Participant Data Information Sheet

You are being invited to take part in a study to map potential new infrastructure on the isles of Barra and Vatersay as part of a PhD research project. As part of our ethical research obligation, it is important for you to understand why the research is being conducted and what it will involve before you take part. Please take time to read the following information carefully before deciding whether to take part. Please get in touch if there is anything that is not clear or if you would like more information.

#### About the research

*Who will conduct the research?*

Timna Denwood, School of Environment, Education and Development, University of Manchester

*What is the purpose of the research?*

The purpose of this research is to assess the usability of a paper-based map design tool by collecting data on where local residents would like new footpaths to be located and would prefer not to see a new wind turbine. Whilst my research focuses on the method, it is important that the research is applicable in the real world and of use to those participating. All participants must therefore be residents of the isles of Barra and Vatersay.

*Will the outcomes of the research be published?*

The results will be published in my PhD thesis and hopefully also in an academic journal. They will also be presented back to the isles when complete.

*Who has reviewed the research project?*

The project has been reviewed by The University of Manchester School of Environment, Education and Development Ethics Committee.

*Who is funding the research project?*

This research is funded by EPSRC (EP/L016141/1) through the Power Networks Centre for Doctoral Training.

## **My involvement**

*What would I be asked to do if I took part?*

You will take part in a paper-based mapping task, by drawing routes for new footpaths on a one map of the isles and marking out areas you would rather not see a wind turbine on a separate map. Precise instructions are provided on a separate page.

*Will I be compensated for taking part?*

There is no compensation available for taking part in this research.

*What happens if I do not want to take part or if I change my mind?*

It is up to you to decide whether or not to take part. However, it will not be possible to remove your data from the project once returned as it is anonymous so we will not be able to identify your specific data. This does not affect your data protection rights. If you decide not to take part you do not need to do anything further.

## **Data Protection and Confidentiality**

*What information will you collect about me?*

In order to participate in this research project we will not need to collect information that could identify you. We will just need to collect 'Age Bracket' and 'Gender'.

*Under what legal basis are you collecting this information?*

We are collecting and storing this information in accordance with data protection laws which protect your rights. These state that we must have a legal basis (specific reason) for collecting your data. For this study, the specific reason is that it is "a public interest task" and "a process necessary for research purposes".

*What are my rights in relation to the information you will collect about me?*

You have a number of rights under data protection law regarding your personal information. If you would like to know more about your different rights or the way we use your personal information to ensure we follow the law, please consult our privacy notice <http://documents.manchester.ac.uk/display.aspx?DocID=37095>.

*Will my participation in the study be confidential and my personal identifiable information be protected?*

In accordance with data protection law, The University of Manchester is the Data Controller for this project. This means that we are responsible for making sure your personal information is kept secure, confidential and used only in the way you have been told it will be used. All researchers are trained with this in mind, and your data will be looked after in the following way: All data is fully anonymous and will not be held for longer than 5 years, which is the standard retention period for anonymised data. Individual data will not be transferred to other organisations and will be stored on a secure server. Your consent forms will be kept for the duration of the research. Please also note that individuals from The University of Manchester or regulatory authorities may need to look at the data collected for this study to make sure the project is being carried out as planned. All individuals involved in auditing and monitoring the study will have a strict duty of confidentiality to you as a research participant.

## Complaints

If you have a complaint that you wish to direct to members of the research team, please contact:

**Dr Jonathan Huck, Department of Geography, The University of Manchester, Room 1.034 Arthur Lewis Building** Email: [jonathan.huck@manchester.ac.uk](mailto:jonathan.huck@manchester.ac.uk)

If you wish to make a formal complaint to someone independent of the research team or if you are not satisfied with the response you have gained from the researchers in the first instance then please contact **The Research Governance and Integrity Officer, Research Office, Christie Building, The University of Manchester, Oxford Road, Manchester, M13 9PL** Email: [research.complaints@manchester.ac.uk](mailto:research.complaints@manchester.ac.uk)

If you wish to contact the University about your data protection rights we will guide you through the process of exercising your rights at: **The Information Governance Office, Christie Building, The University of Manchester, Oxford Road, M13 9PL**

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Tel: 0303 123 1113

## Contact Details

If you have any queries about the study then please contact the researcher(s):

TIMNA DENWOOD: [timna.denwood@postgrad.manchester.ac.uk](mailto:timna.denwood@postgrad.manchester.ac.uk)

JONATHAN HUCK: [jonathan.huck@manchester.ac.uk](mailto:jonathan.huck@manchester.ac.uk)

## APPENDIX 7

### Participant questionnaire for Paper2GIS data collection

#### Participatory Mapping on the Isles of Barra and Vatersay

Hello, my name is Timna Denwood and I'm a PhD Student at the University of Manchester. I am interested in the development of the Isles of Barra and Vatersay, and have been working closely with Barra and Vatersay Community Ltd. for the past two years in order to collect information on public opinion relating to potential developments on the Isles. My research is all about ensuring that local opinions are better heard in decision-making. Last winter I was lucky enough to come to stay on the isles and meet a number of you at various mapping workshops across Barra and Vatersay, in which I gathered opinions using some online mapping tools. This second phase of the research will use a paper-based mapping system in order to gather more local views on the potential locations of footpaths and a wind turbine on the isles. The original plan was to return to the isles and run workshops again in April 2020, but I was prevented from doing this due to COVID-19. Therefore, we are posting out these maps to residents of Barra and Vatersay in the hope of gathering more information. Everything that you need to take part is inside this envelope. **Please take part in this survey, even if you attended the previous workshops.**

The aim of this research is to address two key issues highlighted by the 2018 Community Energy Plan. First, the lack of footpaths on the isles and consequent reliance on cars/concerns over road safety; and second, a need for more local, sustainable energy production on the isles. As such, there are two distinct questions we are trying to answer using local knowledge and opinions:

- 1. Where would you like to see new footpaths/pavements on the isles of Barra and Vatersay?**
- 2. From where would you NOT consider it acceptable to be able to see a wind turbine?**

By answering the first question, this research seeks to enable suggestions for new footpaths to be put forward to planners based on the views and experiences of those who would use them and know the isles well, rather than an outside agency. By answering the second, we can produce a map of areas that residents would find acceptable for a wind turbine to be positioned, based on local knowledge. Providing it's safe to do so, I will be returning to the isles to present the findings from both parts of this research next year.

Because this research is all about community participation in decision making, its value will be maximised by more people taking part, so if you could find five minutes to take part it would be greatly appreciated! For more detailed information on your involvement in this research, how your data will be used and further contact details, please see the participant data information sheet. If you are happy to take part, please sign the consent form and return with the questionnaire on the reverse of this page as well as the two completed maps in the

prepaid addressed envelope. Please feel free to get in touch if you have any questions or concerns by emailing: [timna.denwood@postgrad.manchester.ac.uk](mailto:timna.denwood@postgrad.manchester.ac.uk)

**In this envelope are two identical maps, please use one map to answer Question 1 and the other to answer Question 2.**

**Please use a clearly visible pen or pencil to draw on the maps**

## INSTRUCTIONS

1. On the first map **please draw lines to show the route of any footpaths or pavements you would like to see on the isles**. You may draw as many or as few paths as you wish, both going along roads (for pavements) or through more rural areas (for footpaths) – there is no wrong answer!
2. On the next map, **please shade/block out any areas from which you would NOT wish to be able to see a wind turbine**.
3. Once you are happy with both maps, **please fill out the brief questionnaire below** providing comments on your choices for Questions 1 & 2, age/gender information and feedback on the method. If you run out of room in the comment boxes, feel free to continue on another piece of paper and include it in your returned envelope.
4. Finally, place **both maps**, your **consent form** and this **questionnaire** into the prepaid envelope addressed to Timna Denwood and post it back at your earliest convenience.

## QUESTIONNAIRE

Please circle your age category...

**18-30**

**31-40**

**41-50**

**51-60**

**61+**

**Prefer not to say**

Please circle which gender you identify as...

**Female**

**Male**

**Other**

**Prefer not to say**

Please explain why you would like to see the paths you drew on the first map...

Please provide the reasons you would not like to see a wind turbine in the areas you blocked out on the second map...

Please provide as much feedback on this method of data collection as you can...

**Thank you very much for participating in this PhD research!**

## APPENDIX 8

**Examples of participant responses when asked to shade or block out areas they would not wish to see a wind turbine using Paper2GIS**



## APPENDIX 9

Examples of participant responses when asked where they would like to see new footpaths using Paper2GIS

