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Approach for creating useful, gamified and social map applications utilising privacy-preserving crowdsourcing

BY Mikko Rönneberg



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Approach for creating useful, gamified and social map applications utilising privacy-preserving crowdsourcing

Mikko Rönneberg

A doctoral dissertation completed for the degree of Doctor of Science (Technology) to be defended, with the permission of the Aalto University School of Engineering, at a public examination held at the lecture hall M1 on 29 April 2022 at 12.

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Aalto University publication series

DOCTORAL THESES 53/2022

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FGI Publications No 166

ISBN 978-952-64-0767-8 (printed)

ISBN 978-952-64-0768-5 (pdf)

ISSN 1799-4934 (printed)

ISSN 1799-4942 (pdf)

<http://urn.fi/URN:ISBN:978-952-64-0768-5>

ISBN 798-951-48-0277-5 (printed)

ISBN 798-951-48-0278-2 (pdf)

ISSN 2342-7345 (printed)

ISSN 2342-7353 (pdf)

Images: (c) Hanna-Marika Halkosaari (cover image)

Unigrafia Oy

Helsinki 2022

Finland



Printed matter
4041-0619

Author

Mikko Rönneberg

Name of the doctoral thesis

Approach for creating useful, gamified and social map applications utilising privacy-preserving crowdsourcing

Publisher School of Engineering

Unit Department of Built Environment

Series Aalto University publication series DOCTORAL THESES 53/2022

Field of research Geoinformatics

Manuscript submitted 13 December 2021

Date of the defence 29 April 2022

Permission for public defence granted (date) 2 February 2022

Language English

☐ **Monograph**

☒ **Article thesis**

☐ **Essay thesis**

Abstract

The production and use of geographic information have become easier and more social. The interactivity of maps has fundamentally changed, not only because the touch-based interfaces are easier to use, but also because maps offer possibilities to interact with others. Map applications allow citizens to contribute but also share content to others. This contribution and sharing done by regular people is referred to as crowdsourcing. Map applications that utilise crowdsourcing face specific issues regarding the creation process, the usefulness and the crowdsourcing. These issues, however, have not been studied comprehensively and lack real world examples. This dissertation is the initial step to fill this gap by studying map applications that utilise crowdsourcing. These map applications are described using the design science research approach. Three issues relevant for the map application studied are: 1) the creation process, 2) utility requirements and usability heuristics, and 3) crowdsourcing approach. These issues are studied by using the design science research approach to produce theoretical and empirical knowledge of three map applications utilising crowdsourcing. The aim is to use this knowledge to form a design science research based approach suitable for creating map applications utilising crowdsourcing.

The results regarding the creation process indicate that following a specific approach will help in creating crowdsourced map applications. This dissertation provides a customised design science research approach for creating crowdsourced map applications. Furthermore, prescriptive knowledge that provides real world examples crowdsourced map applications is provided. The results concerning the usefulness of map applications utilising crowdsourcing indicate that there are specific utility and usability requirements to be accounted for. This dissertation provides key utility requirements and usability heuristics for crowdsourced map applications. In general, a map interface for exploring and sharing content is needed. The map interface should be simple, citizens should be supported and interaction should be intuitive. The results concerning the crowdsourcing approach of map applications indicate that there is a need for specifying how citizens are involved in the process. This dissertation provides key requirements of the crowdsourcing approach of these types of map applications. The community driven crowdsourcing approach should be supported by official content and an engagement approach based on gamified and social elements to motivate content sharing. Privacy of citizens should be preserved by applying the privacy by design approach throughout the creation process.

Privacy-preserving map applications utilising community-driven crowdsourcing, in which citizens can be engaged with gamification and social elements to explore and share content can be created by following the design science research based approach presented in this dissertation.

Keywords map application, usability, utility, crowdsourcing, gamification, social, privacy

ISBN (printed) 978-952-64-0767-8

ISBN (pdf) 978-952-64-0768-5

ISSN (printed) 1799-4934

ISSN (pdf) 1799-4942

Location of publisher Helsinki

Location of printing Helsinki **Year** 2022

Pages 191

urn <http://urn.fi/URN:ISBN:978-952-64-0768-5>

Tekijä

Mikko Rönneberg

Väitöskirjan nimi

Lähestymistapa hyödyllisten yhteisöllisten ja pelillistettyjen karttasovellusten luontiin yksityisyyden säilyttävää joukkoistamista hyödyntäen

Julkaisija Insinööritieteiden korkeakoulu**Yksikkö** Rakennetun ympäristön laitos**Sarja** Aalto University publication series DOCTORAL THESES 53/2022**Tutkimusala** Geoinformatiikka**Käsikirjoituksen pvm** 13.12.2021**Väitöspäivä** 29.04.2022**Väittelyluvan myöntämispäivä** 02.02.2022**Kieli** Englanti☐ **Monografia**☒ **Artikkeliväitöskirja**☐ **Esseeväitöskirja****Tiivistelmä**

Geospatiaalisen eli paikkaan liittyvän tiedon tuotanto ja käyttö on helpottunut ja muuttunut yhä yhteisöllisemmäksi. Myös karttojen vuorovaikutteisuus on perustavanlaatuisesti muuttunut. Karttapohjaiset käyttöliittymät ovat yhä helppokäyttöisempiä ja niillä kansalaiset voivat tuottaa, mutta myös jakaa tietoa toisilleen. Tätä tavallisten kansalaisten tekemää tiedon tuottamista ja jakamista kutsutaan joukkoistamiseksi. Karttasovelluksiin, jotka hyödyntävät joukkoistettua tiedonkeruuta liittyy kuitenkin erityisiä haasteita niiden luomisen, hyödyllisyyden sekä joukkoistamisen osalta. Näitä haasteita ei ole vielä samanaikaisesti tutkittu kattavasti eikä näistä karttasovelluksista ole tarjolla tarpeeksi käytännön esimerkkejä ja tietoa. Tämä väitöskirja on ensimmäinen askel näiden haasteiden ratkaisemiseen, sillä tässä väitöskirjassa tutkitaan joukkoistamista hyödyntäviä karttasovelluksia. Väitöskirjassa perehdytään kolmeen karttasovellusten haasteeseen: 1) luomisprosessin lähestymistapaan, 2) toiminnallisiin vaatimuksiin sekä käytettävyyden ohjeisiin ja 3) joukkoistamisen lähestymistapaan. Näitä haasteita tutkitaan käyttäen kehitystutkimusta, jolla tuotetaan tietoa kolmesta karttasovelluksesta jotka hyödyntävät joukkoistamista. Tavoitteena on muokata kehitystutkimukseen perustuvaa lähestymistapaa, jotta se soveltuisi joukkoistamista hyödyntävien karttasovellusten luomiseen.

Luontiprosessin osalta tulokset osoittavat, että tieteellisen lähestymistavan seuraaminen helpottaa joukkoistettujen karttasovelluksien luomisessa. Väitöskirja ehdottaa muokattua kehitystutkimukseen perustuvaa lähestymistapaa joukkoistettujen karttasovellusten luomiseen. Lisäksi väitöskirja tarjoaa tietoja joukkoistetuista karttasovelluksista käytännön esimerkein. Hyödyllisyyden osalta tulokset osoittavat, että joukkoistetuilla karttasovelluksilla on erityisiä toiminnallisia ja käytettävyyden vaatimuksia. Väitöskirja kokoaa keskeisiä toiminnallisia vaatimuksia sekä käytettävyyden ohjeita. Vaatimuksiin kuuluu helppokäyttöinen kansalaista tukeva karttakäyttöliittymä sisältöjen tutkimiseen sekä jakamiseen. Joukkoistamisen osalta tulokset osoittavat, että on tarve määritellä kuinka kansalaisen osallistuvat prosessiin. Tämä väitöskirja ehdottaa keskeisiä vaatimuksia lähestymistavalle joukkoistamiseen. Yhteisölähtöiseen joukkoistamiseen perustuvaa lähestymistapaa tulisi tukea karttasovelluksen sisällöillä, esimerkiksi kiinnostavalla taustakartalla. Lisäksi pelillisyyden ja yhteisöllisyyden avulla kansalaisia voidaan sitouttaa sisältöjen jakamiseen. Kansalaisten yksityisyys tulisi turvata seuraamalla sisäänrakennetun tietosuojan lähestymistapaa läpi koko karttasovelluksen luomisprosessin ajan.

Tässä väitöskirjassa esitettyä kehitystutkimukseen perustuvaa lähestymistapaa seuraamalla voidaan luoda yksityisyyden suojaavia ja yhteisölähtöistä joukkoistamista hyödyntäviä karttasovelluksia, joissa kansalaiset sitoutetaan pelillisyyden ja yhteisöllisyyden keinoin tutkimaan ja jakamaan sisältöjä.

Avainsanat karttasovellus, käytettävyyden, toiminnallisuus, joukkoistaminen, pelillistäminen yhteisöllisyys, yksityisyys**ISBN (painettu)** 978-952-64-0767-8**ISBN (pdf)** 978-952-64-0768-5**ISSN (painettu)** 1799-4934**ISSN (pdf)** 1799-4942**Julkaisupaikka** Helsinki**Painopaikka** Helsinki**Vuosi** 2022**Sivumäärä** 191**urn** <http://urn.fi/URN:ISBN:978-952-64-0768-5>

Acknowledgements

This dissertation has been quite a long journey that started roughly ten years ago when I took part in the effort to create the first of the three cornerstones of this study. Little did I know that creating map applications would be such a significant part of my research path, but this has not been a lonesome road. Being part of a team and a community is the strength of research.

First, I want to express my gratitude to my supervising professor Kirsi Virran-
taus who not only taught me geoinformatics through all my studies, but also guided me through this dissertation process. Kirsi has offered her invaluable help, seemingly effortlessly, whenever I have needed it. This help was a great asset, and I am truly thankful that she took me under her supervision. I am especially grateful for the academic discussions she inspired and her continued encouragement. The instructors of this dissertation Prof. Juha Oksanen and Dr. Pyry Kettunen both gave valuable support during this dissertation, but also during our long working history. Both have been a pleasure to work with at the Finnish Geospatial Research Institute FGI for all these years. The Geoinformatics and Cartography Department has seen many changes, but it is a great place to study the everevolving field of science we are interested in. Juha as the Head of the department has given me inspiration, encouragement, and guidance during this dissertation process. The same can be said about Pyry, with whom I have been working closely since the first time I set foot in the FGI. Both Juha and Pyry have tirelessly and patiently enabled this dissertation work through the ups and downs of the process.

I want to thank Prof. Tapani Sarjakoski and Prof. Tiina Sarjakoski for their guidance, especially in the early years of my research endeavours at the FGI. They provided the foundation for me to become a researcher by trusting me with a chance to do my Master's thesis and to become part of many interesting projects over the years. They lead the research projects in which the research presented in this dissertation was conducted. I also want to thank Tapani for acting as the instructor in the beginning of this dissertation. I want to thank Prof. Jarkko Koskinen as the Deputy Director General of the FGI for the continued effort to make it a great place to do research. I would also like to thank the FGI, National Land Survey of Finland, Aalto University and their School of Engineering as organizations for making this work possible.

The research in this dissertation has been carried out in three projects that offered something new for people to get their hands on. I want to thank my fel-

low researchers of both the MenoMaps projects “Multi-Publishing in Supporting Leisure Outdoor Activities” (MenoMaps) and “Map Services for Outdoor Leisure Activities Developing a Multi-Touch Map Application for a Large Screen in a Nature Centre Supported by Social Networks” (MenoMaps II) funded by the Finnish Funding Agency for Technology and Innovation. Namely, Ms. Hanna-Marika Halkosaari, for her expertise in design which gave a human-centred perspective for our research group and my research for the years to follow. I want to thank the fellow researchers of the MyGeoTrust project provided by Tekes, the Finnish Funding Agency for Innovation through a strategic research grant. Namely the researchers from the Department of Navigation who were involved in the MyGeoTrust project, for their expertise in privacy and great co-operation. I want to thank the fellow researchers of KMTK Kansa (National Topographic Database NTDB subproject Citizen) project by the National Land Survey of Finland (NLS). Namely, Dr. Mari Laakso, for her expertise in crowdsourcing, which further instilled the perspective of the citizens for our research group and my research. All the projects were filled with interesting academic debates and rewarding field work with citizens.

I am thankful to Dr. Ana-Maria Olteanu-Raimond and Dr. Jamal Jokal Arsanjani for pre-examining the manuscript of the thesis and for their valuable comments.

I would like to thank my friends, relatives, and family for their support. Thank you to all my teammates in Koalat Helsinki for the weekly discussions and matches. I want to thank Elina's parents and my own parents for taking such good care of our boys. Finally, I want to thank my lifelong companion and wife Elina and my two sons Johannes and Elias. I couldn't have done this without you.

I dedicate this dissertation to my parents Katri and Kari, who have encouraged and supported me all my life.

Helsinki, March 2022

Mikko Rönneberg

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List of Abbreviations

API	application programming interface
CGI	contributed geographic information
DSR	design science research
GI	geographic information
GIS	geographic information system
GPX	GPS Exchange Format
HCD	human centered design
HCI	human computer interaction
NMA	national mapping agency
POI	point(s) of interest
PPGIS	public participatory GIS
VGI	volunteered geographic information

List of Publications

This doctoral dissertation consists of a summary and of the following publications which are referred to in the text by their numerals

Publication I: Rönneberg, M., Sarjakoski, T. and L. T. Sarjakoski, 2014. Developing a multi-touch map application for a large screen in a nature centre. *Nordic Journal of Surveying and Real Estate Research*, 10(1): 47–62.

Publication II: Rönneberg M., Halkosaari H.-M., Sarjakoski T. and L. T. Sarjakoski, 2013, Hands-on Maps: a Multi-touch Map Application in a Public Space, *Kartographische Nachrichten*, (4/2013): 210–215.

Publication III: Halkosaari, H.-M., Rönneberg, M., Laakso, M., Kettunen, P., Oksanen, J. and T. Sarjakoski, 2016. Concept Design of #hylo – Geosocial Network for Sharing Hyperlocal Information on a Map. In: Gartner G and H Huang (eds.) *Progress in Location-Based Services 2016, Lecture Notes in Geoinformation and Cartography*. Springer, Cham, Switzerland, 309–327. DOI: 10.1007/978-3-319-47289-8.

Publication IV: Rönneberg, M., Halkosaari, H.-M., Laakso, M., Hietanen, E., Vallet, J., Kettunen, P. and T. Sarjakoski, 2016. #hylo – Privacy Preserving Geosocial Network for Sharing Hyperlocal Information on a Map. In Sarjakoski, T., Santos, M. Y. and L. T. Sarjakoski, (eds.), *Geospatial Data in a Changing World, the short papers and poster papers of the 19th AGILE Conference on Geographic Information Science*, June 14-17, 2016, Helsinki, Finland. ISBN: 978-3-319-33782-1. *Proceedings 2016. The 19th AGILE International Conference on Geographic Information Science. Geospatial Data in a Changing World*.

Publication V: Rönneberg, M., Laakso, M., and T. Sarjakoski, 2018. Map Gretel – Social Map Service Supporting a National Mapping Agency in Data Collection. *Journal of Geographical Systems*, 1-17.
<https://doi.org/10.1007/s10109-018-0288-z>

Author's Contribution

Publication I: Developing a multi-touch map application for a large screen in a nature centre

The present author carried out the design, development, demonstration, evaluation, and analysis of the artifact in the study in cooperation with the co-authors. He designed the artifact concept, user interface, utility, and architecture in cooperation with the co-authors. He implemented the user interface, utility, and architecture of the artifact. He demonstrated and evaluated the artifact in cooperation with the co-authors. He analysed the results of the evaluation. He prepared the publication as the first author while collaborating with the co-authors. The last author acted as supervisor for the design, development, evaluation, and analysis of the study, as well as for the preparation of the publication.

Publication II: Hands-on Maps: a Multi-touch Map Application in a Public Space

The present author carried out the design and analysis of the artifact in the study in cooperation with the co-authors. He designed the artifact concept, user interface, utility, and architecture in cooperation with the co-authors. He analysed the results of the evaluation. He prepared the publication as the first author while collaborating with the co-authors. The last author acted as supervisors for the design, development, evaluation, and analysis of the study, as well as for the preparation of the publication.

Publication III: Concept Design of #hylo – Geosocial Network for Sharing Hyperlocal Information on a Map

The present author carried out the design, development, demonstration, evaluation, and analysis of the study in cooperation with the first author and the co-authors. He designed the artifact concept, user interface, utility, and architecture in cooperation with the first author and the co-authors. He implemented the user interface and utility of the artifact. The architecture of the artifact was implemented in cooperation with the first author and the co-authors. He demonstrated and evaluated the artifact in cooperation with the first author and the co-authors. He analysed the results of the evaluation. He collaborated with the co-authors while the first author prepared the publication. The last author acted as supervisor for the design, development, evaluation, and analysis of the study, as well as for the preparation of the publication.

Publication IV: #hylo – Privacy Preserving Geosocial Network for Sharing Hyperlocal Information on a Map

The present author carried out the design, development, demonstration, evaluation, and analysis of the study in cooperation with the co-authors. He designed the artifact concept, user interface, utility, and architecture in cooperation with the co-authors. He implemented the user interface and utility of the artifact. The architecture of the artifact was implemented in cooperation with the co-authors. He demonstrated and evaluated the artifact in cooperation with the co-authors. He analysed the results of the evaluation. He prepared the publication as the first author while collaborating with the co-authors. The last author acted as supervisor for the design, development, evaluation, and analysis of the study, as well as for the preparation of the publication.

Publication V: Map Gretel – Social Map Service Supporting a National Mapping Agency in Data Collection

The present author carried out the design, development, evaluation, and analysis of the study in cooperation with the co-authors. He designed the artifact concept, user interface, utility, and architecture in cooperation with the co-authors. He implemented the user interface and utility of the artifact. The architecture of the artifact was implemented in cooperation with the co-authors. He demonstrated and evaluated the artifact in cooperation with the co-authors. He analysed the results of the evaluation. He prepared the publication as the first author while collaborating with the second author. The third author acted as supervisor for the design, development, demonstration, evaluation, and analysis of the study, as well as for the preparation of the publication.

1. Introduction

The production and use of geographic information have become more social. The ubiquitous nature of mobile devices and the plethora of map-based applications have made maps commonplace. The map itself has also become more interactive, because the interface that the map is embedded in has become an integral part of the whole. The interactivity of the map has also fundamentally changed, not only because touch-based interfaces are easier to use, but also because of the new possibilities of interacting with others. Maps are no longer used only to explore their contents anymore. Some maps also allow citizens to contribute and share place-based content. One form of this content is volunteered geographic information (VGI) (Goodchild 2007). The activity of allowing or even relying on citizens to create content is called crowdsourcing (See 2016). Crowdsourcing can be used to produce VGI, in which the voluntary nature of crowdsourcing allows for more complex goals to be achieved by the crowd (Morschheuser et al. 2017a, Gómez-Barrón et al. 2016). New forms of interaction have spun communities around maps, such as the OpenStreetMap community and the National Map Corps of the US Geological Survey (USGS) (McCartney et al. 2015). One benefit of this type of crowdsourcing is that citizens can share their contributions with each other. Undoubtedly, these VGI initiatives are beneficial to society, with OpenStreetMap being a very tangible example of this. Games have also adopted maps and crowdsourcing as an integral part of the experience, as in the popular Pokémon GO and Ingress Prime. For the purposes of this study, these map applications utilising crowdsourcing intended for citizens are referred to as *crowdsourced map-based artifacts*. The term artifact is used in design science research (DSR), related constructive research, to refer to a creation that solves a problem (Vaishnavi et al. 2004, Johannesson 2014, Dresch et al. 2015, van der Merve 2020). For these types of map-based artifacts the problem they solve can be anything from helping citizens share local knowledge about a nearby park to providing a global up-to-date background map for citizens. However, many issues with these types of map-based artifacts remain. Knowledge of complex issues involving the creation process, usefulness, and crowdsourcing is still lacking for these types of map-based artifact.

First, knowledge is needed on how approaches and frameworks are applied during the creation process of such map-based artifacts. A scientific creation approach providing both a practical solution to the problem, in the form of an artifact, and prescriptive knowledge, in the form of blueprints and guidelines

(Johannesson 2014, Dresch et al. 2015, Baskerville et al. 2018), would be beneficial. The design science research approach strives to create both an artifact and prescriptive knowledge (Vaishnavi et al. 2004, Johannesson 2014, Dresch et al. 2015, van der Merve 2020), but applying DSR is not straightforward for map-based artifacts. Second, general utility requirements and usability heuristics would be a good starting place for the creation of crowdsourced map-based artifacts. These still unresolved issues include the choice of platform for the artifact, the utility needed by the map interface (Roth 2013), the utility-usability trade-offs to be made (Roth, 2015), and the usability heuristics to be used (Kuparinen et al. 2016). Third, complex issues regarding the content creation in a map-based artifact, such as the crowdsourcing approach (Gómez-Barrón et al. 2016), the handling of participation inequality (Haklay 2016), the engagement approach (Gómez-Barrón et al. 2019), the gamification approach (Martella et al. 2019), the social approach (Kietzmann et al. 2011), and the privacy-preserving approach (Pratesi et al. 2018) should be addressed. Overall, though many established frameworks, approaches, and techniques exist, knowledge of applying them in combination for crowdsourced map-based artifacts remains lacking (Unrau & Kray 2019, Morschheuser et al. 2017a, Roth et al. 2017).

This dissertation therefore aims to fill the gap in creating useful, engaging, gamified, and social map-based artifacts with privacy-preserving crowdsourced content intended for all citizens to use. Examples of such map-based artifacts with crowdsourced content are available, such as WikiMapia, Waze, and Community Maps (Gómez-Barrón et al. 2019), as well as FirstLife (Boella 2019), but there is no clear generalised path in literature to creating them. There are numerous considerations regarding the process of creation, usefulness, and crowdsourced content creation approach of map-based artifacts. As these artifacts are directed at ordinary citizens, the complexity should be at a level that citizens can quickly grasp and even more importantly, made sufficiently engaging for citizens to enjoy using.

1.1 Motivation for the study

The motivation of this study is to aid designers and creators in making engaging and enjoyable crowdsourced map-based artifacts while encouraging them to share the knowledge gathered during the creation process. During the period that the research presented in this study has been conducted, knowledge about creating map-based artifacts has accumulated. This knowledge is presented from three mutually supporting perspectives. First, the creation process is something that every map-based artifact must undergo to exist. For a complex yet rewarding task of creating something new, something resembling a step-by-step guide should prove useful. Even if the process is not followed closely all the way through, it may prove valuable in some phases of the creation process. The creation process should give answers to the “How?” part of the questions regarding map-based artifacts. Second, usefulness, or more precisely utility and usability, is essential when creating anything new for citizens in general. An ex-

amination of what goes into a crowdsourced map-based artifact should therefore point the fellow creator in the right direction. The usefulness should give answers to the “What?” part of the questions regarding map-based artifacts. Third, since the idea is to involve citizens in the content creation of the map-based artifact, it is central that the community of the map-based artifact has means and motivation to contribute. The approach to crowdsourcing should give answers to the “Who?” part of the questions regarding map-based artifacts.

The artifacts presented in this study are from three research projects with their own motivations: MenoMaps, MyGeoTrust and KMTK Kansa. Each project aimed to create a useful map-based artifact for citizens and all three used crowdsourcing to provide content to citizens.

The motivation for the “Multi-Publishing in Supporting Leisure Outdoor Activities” (MenoMaps) and “Map Services for Outdoor Leisure Activities Developing a Multi-Touch Map Application for a Large Screen in a Nature Centre Supported by Social Networks” (MenoMaps II) projects was to provide better map-based services to support outdoor leisure activities, such as hiking. In the MenoMaps projects, citizens can access the same geospatial information from different devices and media types at different phases of their outdoor experience. The interest was to study how large multi-touch screens with a map could be used in public spaces. The MenoMaps project aimed to change the practice of how maps were experienced in public spaces by creating map-based artifacts that are used on a large touch-based screen to accommodate all kinds of users.

The vision of the MyGeoTrust project was to create an alternative location platform for mobile users, that allowed users to enjoy the benefits of location technologies without sacrificing their privacy (Guinness et al. 2015). In the project, artifacts were developed to demonstrate a new privacy-preserving way of applying crowdsourcing. One of the developed artifacts was the hyperlocal news and social media platform, which allows users to find local news, information, and community members, based on common geospatial parameters. The MyGeoTrust project aimed to change the practice in mobile location technologies by creating a crowdsourced map-based artifact that demonstrated how to preserve the privacy of citizens.

In the KMTK Kansa project by the National Land Survey of Finland (NLS), the national mapping agency (NMA) of Finland, a map-based artifact was created for collecting VGI to supplement the data acquired for the national topographic database (NTDB). The goal was to study whether it was possible to increase the quality (i.e., the completeness: missing features; and the accuracy: feature location errors) of the NTDB data via crowdsourced information. By offering more advanced map-editing tools and adding social features, the goal was to have more complete, accessible, and useful data. Citizens were incentivized to create new map features that were currently lacking the feature catalogue to reveal the novel data needs of citizens. With this new artifact, the NLS sought more refined ways of employing VGI to achieve better-quality map data with fewer resources, while developing the relationship between the NMA and citizens. The KMTK

Kansa project aimed to change the practice of crowdsourcing in a national mapping agency by creating a map-based artifact that allowed citizens to contribute to the national topographic database.

Common denominators for all three projects were that crowdsourced map-based artifacts were designed and developed from the ground up. They all had the goal of changing the real-world current practice of how things were done, focusing on the citizens not only as users, but also content creators. In summary, all three projects aimed to find ways of creating new crowdsourced map-based artifacts that changed how maps were previously experienced. The approach in each was to find ways of creating intuitive map-based applications and for citizens to be involved in the content creation through crowdsourcing.

1.2 Core concepts

This dissertation is built on core concepts that are briefly introduced below. Some concepts are covered further in the later chapters of this study.

Design science research (DSR) is a research strategy (van der Merve. 2020), a methodological approach (Dresch et al. 2015), and a problem-solving paradigm (vom Brocke et al. 2020) seeking to enhance knowledge via the creation of innovative constructions. DSR also simultaneously creates a prescriptive scientific contribution (Dresch et al. 2015) or design knowledge of how things can and should be designed to achieve a desired set of goals (van der Merve 2020). DSR is usually presented as a conceptual framework that includes several steps, from defining the problem to designing, implementing, demonstrating, and evaluating an artifact. The innovative constructs in DSR are called artifacts that are to solve problems in the real-world.

An *artifact* in the context of this study is a creation that solves a problem (Dresch et al. 2015). Artifacts can be instantiations, models, methods, or design theories (Gregor et al. 2013, van der Merve 2020). The term artifact is central to DSR, and it is used in this dissertation to simplify referencing, grouping and comparison of the creations presented. The term map-based artifact in the context of this dissertation refers to terms such as map application, geospatial software, and map service. When referring to artifacts, the term content is the information that is presented via the artifact.

Reference and crowdsourced content are the information presented via the artifact. Reference content is created by the entity in control of the artifact, while crowdsourced content is created by citizens. For example, the background map provided by the artifact is considered reference content while, a comment by a citizen on a point of interest is considered crowdsourced content. Content is used along with the artifact as a general term. When applicable, a more specific term is used, such as map feature.

The usefulness of an artifact is defined as the sum of its usability and utility (Nielsen 1994). Utility is a quantity attribute that expresses whether an artifact provides the functionality the user needs. Usability, on the other hand, is a quality attribute that expresses the ease of using the artifact utility. In more detail,

usability is defined by five quality components: learnability; efficiency; memorability; errors; and satisfaction (Nielsen 1994). The evaluation of the usefulness of an artifact is a part of the design science research approach.

Interactive maps are defined as web maps, map-based applications, and other GIS or visualisation tools that use digital map as the manipulable interface for geographic information (Roth 2015).

Cartographic interaction primitives are a taxonomy for map-based visualisation (Roth 2013). The two main categories are work operators and enabling operators. Work operators include operators for manipulating the layout (re-express, arrange, and sequence respectively), design (resymbolize, overlay, and reproject) and viewpoint (pan and zoom) of the map in addition to operators for examining (filter, search, retrieve and calculate) the features of the map. The enabling operators are import, export, save, edit, and annotate. The use of this taxonomy helps in comparing the utility of the map-based artifacts.

Citizens are considered to be the regular people and used as a general term throughout this dissertation. The term is used in citizen science in which people are seen as actors and as a source of data (Foody et al. 2017). To avoid confusion, a more precise expression is used, such as a participant of the evaluation of an artifact. The legal connotation of the term citizen is not relevant for this study.

Crowdsourcing is an online distributed problem-solving approach that transforms problems and tasks into solutions by harnessing the potential of large groups of citizens via the Web rather than traditional employees or suppliers (Morschheuser et al. 2017a). The approach to participation in crowdsourcing can be either more crowd-based or community-driven (Gómez-Barrón et al. 2016). Crowdsourcing is a process-based term (See 2016) that creates crowdsourced content.

The crowd-based approach to participation in crowdsourcing is characterised by Gómez-Barrón et al. as having a large number of passive contributors, with low interaction between contributors and simple tasks. The approach is mainly contributory, meaning mostly autonomous activity and tasks done independently (Gómez-Barrón et al. 2016).

A community-driven approach to participation in crowdsourcing is characterised by Gómez-Barrón et al. 2016 as having engaged active or proactive contributors with high interaction between contributors and complex tasks. The approach is either collaborative, meaning communication and relationships between the contributors, or participatory, meaning contributors are offered the opportunity to be involved in the process and can define necessary outcomes (Gómez-Barrón et al. 2016).

Volunteered geographic information (VGI), coined by Goodchild (2007), is crowdsourced information with clarity about purposes and abilities to control collection and reuse. VGI refers to geographic information collected with the knowledge and explicit consent of a person. VGI is crowdsourced content (See 2016).

Contributed geographic information (CGI) refers to geographic information that has been collected without the immediate knowledge and explicit decision

of a person using mobile technology that records location (See 2016, Bilogrevic 2018). CGI is crowdsourced content (See 2016).

A *geosocial network* is a social network in which geographic services and capabilities are used to enable additional social dynamics (Tiwari et al. 2011). Geosocial networks are a web-based or mobile-based artifact that allow citizens to create a profile containing some of their geolocated data, connect with other citizens of the artifact to share their geolocated data, and interact with the content provided by other citizens (Gambs et al. 2011). Geosocial networks use the utility of social media.

Hyperlocal information is information that is limited and relevant only to a small region (Xia et al. 2014) and is relevant to small communities or neighbourhoods (Glaser 2010). Hyperlocal information includes news or other content concerning a small geographically defined community (Radcliffe 2012).

The utility of social media can be used to create, modify, share, and discuss content (Kietzmann et al. 2011). Utility of social media includes seven functional building blocks: identity; conversations; sharing; presence; relationships; reputation; and groups. These building blocks can be used to assess how different levels of social media utility can be configured (Kietzmann et al. 2011). Practical implementations of the utility of social media are user profiles, groups, rating, and commenting that can be used by the citizens to share content. As it is referred to in this study, social utility can be used in tandem with gamification utility to enhance motivation and retention (Martella et al. 2019).

Gamification is the use of game design elements in non-game contexts (Sebastian et al. 2011). The utility of gamification can be used to motivate citizens in generating and sharing content (Olteanu-Raimond et al. 2017b). Typical utility of gamification includes points, badges, and leaderboards (Sailer et al. 2017). For example, a citizen can gain points by making annotations on a map.

A *citizen layer* is utility for map-based artifacts intended for storing and presenting the content citizens create (Khan & Johnson 2020). The citizen layer is often presented on top of the existing reference content or reference layer. The citizen layer can be visible to all citizens, or it can be visible just for the registered members of the community. For example, the citizen layer can be visible on top of a background map, and citizens can add points of interest-type content to the map for everyone to see.

Privacy by design is a paradigm that can be used to develop technological frameworks for countering the threat of privacy violation, without obstructing the knowledge discovery opportunities of the collected data (Pratesi et al. 2018). The idea of privacy by design is to take privacy into account from the outset of the artifact creation to create privacy-aware artifacts. The privacy by design approach rests on seven principles described by Cavoukian (2019). Crowdsourcing produces content that is created by the citizen and is often if not always related to a location. Presenting crowdsourced information on a map has obvious privacy issues.

1.3 Scope

This dissertation deals with forming an approach for creating useful, gamified, and social map applications utilising citizen privacy-preserving crowdsourcing. Crowdsourced map-based artifacts are designed to be useful for everyone and therefore have specific requirements regarding their creation approach, usefulness, and the approach to crowdsourcing (Figure 1). These are the focus areas of this dissertation.

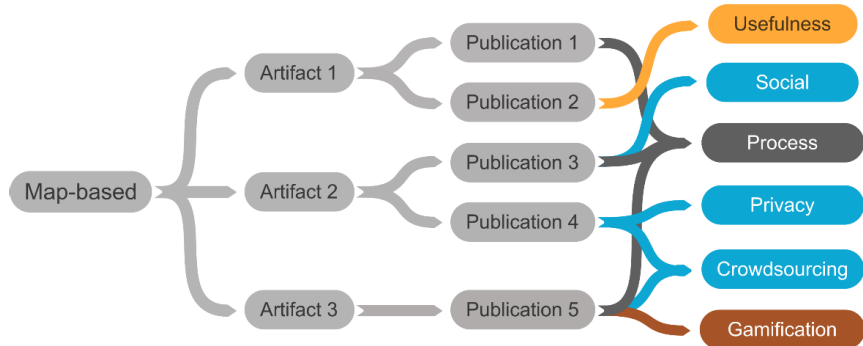


Figure 1. The artifacts' relationship with each publication and their scope.

1.3.1 Approaches for creating map-based artifacts

Numerous approaches are used for creating map-based artifacts, and the focus in this study is on scientific approaches. The scientific approaches share the logic that design, and development decisions are made based on scientific knowledge. Obviously, there are some caveats to this as: for example, the visual appearance of the user interface of an artifact in some respects is purely a subjective decision. The scientific approaches that fit the needs of map-based artifact creation in this study are action research, case study, and design science research (Williamson et al. 2017). However, there are other scientific approaches such as survey and constructivist grounded theory, but they lack the practical elements required for creating map-based artifacts (Johannesson 2014). Therefore, these approaches will not be explored in this study. The more practical software development methodologies such as agile, DevOps, and waterfall (Jabbari et al. 2016), are beyond the scope of this study, because they often focus only on the design and development part of the creation process.

However, these other scientific approaches and the empirical methodologies mentioned can be applied during the creation process of map-based artifacts. For example, it may be beneficial to apply the agile development process during the development phase of the creation process, while a survey approach may be applied during the evaluation phase of the creation process (Johannesson 2014). In addition to the more general creation approaches, a user-centered design process (Roth 2015) can be used to iteratively refine a map-based artifact. Furthermore, in participatory action design research methodology a user-centered design approach through participatory design cycles can be used to iteratively enhance the artifact (Boella 2019). The approach shares many phases with

DSR and was used to create an artifact that combined volunteered geographic information with social networking functionalities (Boella 2019) – yet another example of how approaches can be applied in combination.

Case studies, action research, and design science research (DSR) are used in crowdsourced disaster management (Horita et al. 2013) for example. Action research (McNiff 2013) and case study (Johannesson 2014) are similar approaches to DSR, but the research objectives of both are focused on exploration, description, or explanation (Dresch et al. 2015) rather than creating something new to solve problems. Action research aims to solve or explain problems of a given system by generating empirical and theoretical knowledge (Dresch et al. 2015), or to produce useful knowledge by addressing practical problems in real-world settings (Johannesson 2014). Case studies aim to assist in the understanding of complex social phenomena (Dresch et al. 2015) or investigate in depth a phenomenon with a well-defined boundary (Johannesson 2014). Meanwhile, DSR aims to develop artifacts that enable satisfactory solutions to practical problems. When the aim of the study is to design and develop artifacts and prescriptive solutions in a real environment, DSR is an appropriate research method (Dresch et al. 2015). The difference in the approaches stems from DSR being founded on design science while action research and case study are linked to the natural and social sciences (Dresch et al. 2015). The benefit of DSR is that traditional sciences have limitations when analysing artificial systems (Dresch et al. 2015). DSR creates knowledge of how things should be, instead of how things are or how they behave, as is the case with both case studies and action research (Dresch et al. 2015). However, other approaches such as action research and case study can be applied during many phases of DSR (Johannesson 2014). As an established approach dating back to the early 90's (Baskerville et al. 2018), DSR is therefore a suitable general approach for creating crowdsourced map-based artifacts that aim to solve a real-world problem.

1.3.2 Usefulness in map-based artifacts

The creation of map-based artifacts relies on the principles of Human Computer Interaction (HCI) and software engineering (Marquez 2021), because there are no standardised heuristics for map-based artifact specific usability evaluation (Resch & Zimmer 2013); nor are there generic solutions to GI-specific usability problems (Henzen, 2018). However, there are heuristics for specific types of map-based artifacts such as mobile (Nivala 2007, Kuparinen et al. 2016, Ricker & Roth 2018) and web maps (Hennig et al. 2016, Abraham 2021). This study focuses on the usefulness of crowdsourced map-based artifacts. Usefulness is understood as the sum of utility and usability (Nielsen 1994). Utility expresses whether the map-based artifact provides the functionality the citizen needs. Usability expresses how easy the utility of the map-based artifact is to use. The ISO standard definition of usability is “the extent to which a system, product or service can be used by specific users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO 9241-11). Usefulness is studied in this study from the perspective of utility and usability. For utility, the choice of platform and a taxonomy of cartographic interaction are

covered, while for usability, the evaluation of usability, usability-utility trade-off, and usability heuristics are addressed.

This thesis focuses on utility that is required by crowdsourced map-based artifacts. Utility such as a citizen layer and content sharing are therefore explored further than less prevalent requirements. The utility of artifacts will be limited to general descriptions and application areas of the utility instead of more technical descriptions. This is mainly because the technical implementations will vary significantly from one map-based artifact to another. The choice of platforms is a relevant issue when creating map-based artifacts. The focus in this study is on platforms that offer utility that is needed in crowdsourced map-based artifacts. Hardware platforms are covered from the perspective of mobile or non-mobile, where the main distinctions are screen size and the possibility to present the location of the citizen in the content. A taxonomy of cartographic interaction primitives for map-based visualizations (Roth 2013) is beneficial for referencing and comparing the utility of crowdsourced map-based artifacts. Especially in the design and development phases of the creation process a common way to refer to utility is helpful. This taxonomy is therefore used throughout this study.

The focus on usability in this study is intuitive map user interfaces. Most citizens are expected to learn to use the map-based artifact relatively quickly by relying on prior basic knowledge. Citizens should not be expected to have advanced knowledge of using map interfaces. The requirements of crowdsourced map-based artifacts therefore differ from expert systems, in which the expert can be assumed at least to have knowledge of their field, even if the form of interaction or elements in the user interface are unfamiliar. Methods for evaluating user interfaces are covered to support the creation process (Unrau & Kray 2019), such as the user-centered design process (Roth 2015). The concept of utility-usability trade-off, meaning the level of complexity of the interface, is especially important in crowdsourced map-based artifacts. Finally, usability heuristics can be used to avoid common pitfalls when creating map-based artifacts. Usability heuristics are covered for the common map platforms such as mobile maps, web maps and large public map installations. Usability evaluation is an important part of the creation process and provides methods for improving the design of map-based artifacts.

1.3.3 Crowdsourcing in map-based artifacts

Map-based artifacts are characterised by the content they provide. Traditionally, the source of the content is official – for example, a national mapping agency. The focus in this study is on a content creation approach in which citizens are involved. There are numerous approaches such as crowdsourcing (Morschheuser et al. 2017a) and public participatory mapping (Tulloch 2008) for creating content by involving citizens in the process. To properly align this dissertation an examination of community-driven crowdsourcing, volunteered geographic information, geosocial networks, and citizens engagement is presented.

The focus in this study is on community-driven crowdsourcing. In community-driven crowdsourcing citizens are engaged, active or proactive contributors with high interaction between other contributors, and they can complete complex tasks (Gómez-Barrón et al. 2016). More specifically, the focus is on artifacts in which part of the content is both explored and created by the community. These types of artifacts can have a completely crowdsourced content creation process (Peltonen et al. 2008) or only have part of their content created by citizens (Ballatore et al. 2019).

Volunteered geographic information is focused on for the following reasons. First, the aims of the map-based artifacts presented in this study were to encourage citizens to explore nature, enable citizens to control their privacy while sharing content, and give citizens means to ameliorate maps. These are in line with crowdsourcing that creates VGI. Second, VGI is inherently voluntary by nature, which is the starting point for the interaction with citizens for the artifacts of this study. Third, due to the voluntary and transparent nature, VGI also includes an inherent level of privacy (Bilogrevic 2018). When citizens voluntarily share content, they also give their consent (Bilogrevic 2018). Finally, crowdsourcing approaches that create VGI can also create communities, an obvious example is the OpenStreetMap community with its considerable potential (Arsanjani & Fonte 2016). An understanding of VGI in the context of crowdsourced map-based artifacts is relevant.

Similar to VGI, geosocial networks (Gambs et al. 2011) offer a perspective for understanding communities that contribute content to map-based artifacts. A geosocial network is a social network in which geographic services and capabilities are used to enable additional social dynamics (Tiwari et al. 2011). These additional social dynamics allow citizens to create a profile containing some of their geolocated data, connect with other citizens of the artifact to share their geolocated data, and interact with the content provided by other citizens (Gambs et al. 2011). Geosocial networks are typically web-based or mobile-based artifacts, because these platforms allow sharing the geospatial data of citizens. Some of the content created in geosocial networks can be hyperlocal. Hyperlocal information is limited and relevant only to a small region, e.g., a street corner or a certain venue (Xia et al. 2014). It is also relevant to small communities or neighbourhoods (Glaser 2010), because hyperlocal information includes news or other content concerning “a town, village, single postcode or other small, geographically defined community” (Radcliffe 2012). The concept of hyperlocal information can help artifact creators think in the right scale of things when considering their community.

Motivation in general is a topic to focus on in this dissertation due the voluntary involvement of communities and citizens. Motivating citizen is a significant challenge, but when done successfully it holds great potential to engage citizens in content creation. The focus of this study is on community engagement (Gómez-Barrón et al. 2019), gamification (Martella et al. 2019), and social utility (Kietzmann et al. 2011). The community engagement framework consists of core drivers, participant types and an engagement process (Gómez-Barrón et al. 2019). Citizens can be motivated to contribute by applying this framework for

map-based artifacts, creating engagement techniques that fit the participant types, and following the engagement process (Gómez-Barrón et al. 2019). Gamification is the use of game design elements in non-game contexts (Detering et al. 2011) or the application of lessons from the gaming domain to change behaviours in non-game situations (Robson et al. 2015). Gamification has been identified as motivating participation (Olteanu-Raimond et al. 2017b) by adding an element of fun (Fritz et al. 2017) to artifacts. It can also be used to cover repetitive tasks (Zichermann & Cunningham, 2011) that would otherwise be tedious for citizens.

A conceptual framework for the gamification of geographic artifacts provides a model for transforming a map-based artifact into a gamified map-based artifact (Martella et al. 2019). The geographic data tasks have been classified as gathering, validation, fixing, and integration. The task of gathering geospatial data can be transformed into a challenge, for example. Challenges are a gamification mechanism to motivate the participants to contribute (Martella et al. 2019). Social utility can be used to create, modify, share, and discuss content (Kietzmann et al. 2011). Kietzmann et al. present a framework of social utility with seven functional building blocks: identity; conversations; sharing; presence; relationships; reputation; and groups. These building blocks can be used to assess how different levels of social utility can be configured (Kietzmann et al. 2011). Gamification and social media frameworks can be used to motivate citizens to join and contribute to map-based artifacts, and the frameworks can be applied separately or in combination, based on the artifact requirements.

1.3.4 Privacy in crowdsourced map-based artifacts

As the main goal of motivation is to get citizens to contribute, privacy is an important aspect to consider from the outset of the creation process of map-based artifacts (Mooney et al. 2017). In Europe crowdsourced data collection is regulated by the General Data Protection Regulation (EU) 2016/679 (GDPR) which is a regulation on data protection and privacy in EU law. The GDPR incorporates the privacy by design approach, which takes privacy into account throughout an artifacts' creation process. The focus in this thesis is on mobile privacy, because desktop and installation artifacts pose less of a threat to the privacy of citizens because of their lack of accurate locating capabilities. This is not to say that privacy issues do not exist in desktop and installation artifacts, but there are substantially fewer than with mobile device which have greater sensing capabilities. In mobile location privacy, the focus is mainly on crowdsourcing that produces VGI. VGI is seen as a more privacy-preserving way of collecting data from citizens due to its voluntary nature (Bilogrevic 2018). It may seem easy for a VGI artifact creator to think of the mobile device wielding community as a treasure trove of content.

However, the guiding principle of privacy protection, according to Mooney et al. (2017), is to collect as little private data as possible. Instead of thinking that the more content is shared the better the artifact, the content should be examined from the perspective of the contributing citizen. Mooney et al. (2017) state that the contributor should not be identifiable through their contributions in a

VGI artifact. More specifically, the contributor should be identifiable within the VGI artifact, but their contribution should not be linkable to the actual persons' personal and private data and information. Other more indirect sources can also be used to identify citizens as subjects, such as photographs (Mooney et al. 2017).

This can happen intentionally or by accident. For example, automatic face recognition is an effective tool (Jenkins et al. 2008, Best-Rowden 2017) for identifying citizens and associating them with other data. Tools for automatically anonymising faces from images are already in use, and these can be used to filter image content, but the filtering method applied to the images needs to be carefully selected, as many anonymising attempts can be reversed (Ruchaud et al. 2016). Location privacy in this dissertation is addressed when the privacy by design approach (Cavoukian 2019) is covered. Adequate methods for creating privacy-preserving map-based artifacts are available (Bilogrevic 2018), and they will be covered in the following sections of this study.

1.4 Limitations of the research

This dissertation deals with an approach for creating useful, gamified, and social map applications utilising citizen privacy-preserving crowdsourcing. The main focus is on the creation process, requirements, and crowdsourcing of map-based artifacts. As such, there are three main limitations to the scope.

First, other scientific and empirical approaches such as case study method and agile development are not detailed because the focus is on DSR, even though these approaches can be used as part of the DSR process. Furthermore, there are many other approaches that are not covered. DSR as an approach is only described in detail when it is relevant for this study. Even though DSR has creative elements in the design and development phases, creativity itself is not in the scope of this dissertation.

Second, usefulness in map-based artifacts is limited to aspects of map-based artifacts utilising crowdsourcing. The utility requirements of map-based artifacts are not presented at a great level of detail, because these implementations undoubtedly vary from one artifact to another. Also, sustainability and the lifecycle of the artifacts are not covered for the same reason. The specifics of usability evaluation are beyond the scope of this study, because the focus is instead on applicable usability heuristics. Cognitive processes are not covered in this dissertation. Map design and aesthetics are also out of scope for this dissertation as the focus is more technical.

Third, the focus in this study is on crowdsourcing as an approach and the VGI the crowdsourcing process produces. As such, detailed descriptions of other approaches for involving citizens in data collection are beyond of the scope of this dissertation. While the quality of data is an important aspect of VGI (Fonte et al. 2015, 2017) and in geospatial data in general, this dissertation focuses on data quality such as positional accuracy, thematic accuracy, completeness, and temporal quality (Fonte et al. 2017) from the citizen perspective. The goals of

crowdsourced map-based artifacts may not always include collecting high-quality geospatial data. The goal may be something other than refining the geospatial data into official map content. The focus in privacy preservation is also on crowdsourcing. Privacy preservation is covered for map-based artifacts by presenting the privacy by design approach, and by presenting methods and techniques for preserving the privacy of citizens. The ethics in privacy are out of scope for this dissertation.

1.5 Objectives and research questions

The objective of this study is to form a novel approach for creating crowdsourced map-based artifacts based on the theoretical and empirical knowledge offered by the artifacts presented this study. Due to the complexity of creating map-based artifacts intended for citizens, this aim is divided into three key areas: first, to offer a general approach to follow during the creating process of crowdsourced map-based artifacts; second, to provide key utility requirements and usability heuristics for crowdsourced map-based artifacts; third, to provide a crowdsourcing approach for fostering crowdsourced creation of content in map-based artifacts. To create this approach, three research questions are answered in this study. Research question 1 concerns the creation, 2 concerns the utility and usability, and 3 concerns the crowdsourced content creation in map-based artifacts.

1. How can the design science research approach be applied to the creation process of crowdsourced map-based artifacts?

Creating crowdsourced map-based artifacts intended for citizens is not a simple task. It is therefore beneficial for the creator to follow an established framework or approach. Basing the creation process on the application of scientific knowledge in practice is a sound course of action. Because design science research is an established approach, it is a suitable way to create artifacts in general. A straightforward application of DSR to the creation process of map-based artifacts can be done simply by following the phases from problem awareness to conclusion. However, significant considerations come into play when map-based artifacts are intended for all citizens and rely on crowdsourced content. The DSR approach therefore needs to be adapted. The adapted approach can help the creator respond to the needs of citizens when creating new map-based artifacts.

2. What are the key utility requirements and usability heuristics for crowdsourced map-based artifacts?

Crowdsourced map-based artifacts intended for citizens should be useful. Utility, the functionality the citizen can use, and usability, how easy it is to use the functionality, are therefore central to the artifact. Utility requirements and usability heuristics are needed to create similar new artifacts. First, the choice of hardware and software platform

restricts many aspects of the utility and usability of a map-based artifact. For example, map-based artifacts on non-mobile platforms need a way to collect crowdsourced content. Second, the cartographic interaction techniques selected form the basis of what the artifact can be used for. Third, usability evaluation is needed to assess if the utility of the artifact is usable. Fourth, the balance in the utility-usability trade-off determines whether the artifact is useful and requires choices to be in its design. Finally, by following general and specific usability heuristics many pitfalls of creation can be avoided. Requirements for utility and usability heuristics are therefore needed to identify the key building blocks that make the crowdsourced map-based artifact.

3. What are the key requirements for the crowdsourced content creation in map-based artifacts?

To find key requirements for the crowdsourced content creation in map-based artifacts, three aspects need considering. First, the crowdsourcing technique for collecting and sharing the actual content needs to be chosen. Second, defining how citizens are introduced and kept interested in using the artifact, should be chosen. This engagement approach requires citizens to be motivated in contributing. Furthermore, suitable approaches to motivation should be identified. Finally, as crowdsourcing relies on contributions of citizens, how the privacy of citizens is preserved should be determined. The key requirements for the crowdsourced approach for supporting content creation in map base artifacts would be beneficial when creating map-based artifacts.

1.6 Structure of this dissertation

This dissertation consists of a summary and five appended papers. Chapter 2 reviews the related research that explains the dissertations' theoretical foundations while presenting the previous work undertaken to respond to the research questions. Chapter 3 introduces the research methods of the appended papers. Chapter 3 presents the methods of each artifact structured in three sections: research strategy; data collection; and data analysis methods following the DSR approach. This allows for a better comparison of the methods used to create the artifacts studied. Chapter 4 presents results that attempt to answer the research questions by following the DSR approach structure. First, the phases of problem identification, design and development, artifact demonstration, and artifact evaluation are presented, followed by a comparison of the artifacts from a scientific and empirical perspective. Second, key requirements for map-based artifacts are presented. Third, the crowdsourcing approach is depicted. Finally, the results are summarised. Chapter 5 discusses the results' implications. Chapter 6 summarises and concludes this dissertation.

2. Related work and theoretical foundations

In this chapter, the earlier research related to this study's research questions is presented as this dissertation's theoretical foundations. Four aspects of creating crowdsourced map-based artifacts are covered: the application of design science research in the creation process; utility and usability; community as the source of content; and privacy. Design science research offers a framework for designing, developing, demonstrating, and evaluating artifacts. To apply DSR to creating map-based artifacts with community-driven content, it is necessary to understand the inner workings of DSR. In addition, DSR is used to structure and present part of the methods and results in this study, because it is suitable for presenting artifacts at a comparable level of detail. All the artifacts in this study are based on different kinds of map interfaces, and their usefulness has been evaluated in the appended publications. An examination of the usable utility in map applications is therefore a key part of any artifact creation process. All the artifacts contain or even rely on content created by citizens. This citizen created content is addressed in this study from the perspective of content creating methods and privacy. Privacy issues arise whenever content is created by citizens and are therefore relevant for this study.

2.1 Application of the design science research approach

This subchapter covers the application of design science research in the creation process of map-based artifacts. First, the design science research approach is explained followed by the phases it contains. The phases are covered from the perspective of map-based artifacts.

2.1.1 The design science research approach

Design science research has been studied for more than a decade (Vaishnavi et al. 2004, Peffers et al. 2007) and is now accepted as an approach in top information systems publication outlets (van der Merwe et al. 2020). DSR is a methodological approach concerned with devising artifacts that serve human purposes (Dresch et al. 2015). DSR is a form of scientific knowledge production that involves the development of innovative constructions intended to solve problems faced in the real-world, and simultaneously makes a kind of prescriptive scientific contribution (Dresch et al. 2015). This knowledge can be, for example prescriptive, consisting of blueprints for developing artefacts and guidelines

and procedures that help creators solve problems systematically (Johannesson 2014, Baskerville et al. 2018). For example, the guideline to develop map-based artifacts iteratively is prescriptive knowledge. In DSR, the goal is to study the design, creation, or construction of something that does not yet exist, or to conduct research that focuses on problem solving (Dresch et al. 2015). Both apply when something new is created to solve a problem. This new thing is called an artifact. For example, an artifact can be a map-based mobile application that a citizen uses to gain and share content.

Design science research is the study of artifacts, and an artifact is theoretically defined as a man-made interface between the inner environment and the outer environment of a given system (Simon 1996). The inner environment would be the map-based artifact and the outer environment the users and the space in which the artifact interacts in, for example a city district. Another definition of the term artifact is that it is a human-made object for addressing a practical problem (Johannesson et al. 2015), such as a navigation application that helps the user find their way to a destination. Artifacts are a solution to a real-world problem, while the research into the artifact in question offers a blueprint for solving a similar real-world problem. It is therefore important outcome of DSR that the artifact solves a real-world problem (Dresch et al. 2015), but it is equally important that the gained knowledge is available for others to build upon. With DSR offering a solution to a real-world problem and a blueprint for replicating the solution, the solution can be altered or elaborated by others. Thus, creating another navigation application does not start from scratch, but instead can be refined using existing artifacts and blueprints as a basis for the creation.

Numerous DSR frameworks are presented in literature (Baskerville et al. 2018, Dresch et al. 2015, Johannesson et al. 2014, Hevner & Chatterjee 2010, and Peffers et al. 2007), and they all divide the process into similar phases (Figures 2, 3 and 4). While there are differences in terminology, they all repeat the same pattern found also in project management models (Thiry 2002). First, the problem is identified and understood. Second, requirements to solve the problem are defined. Third, the artefact is designed and developed. Fourth, the artefact is demonstrated to solve the problem. Fifth, the artefact is evaluated. Finally, the whole process is communicated. A more detailed framework by Dresch et al. list the phases as: the identification of the problem; problem awareness; a systematic literature review; identification of the artifacts and configuration of the classes of problems; the proposal of artifacts that solve a specific problem; the design of the selected artifact; the development of the artifact; the evaluation of the artifact; the clarification of learning achieved; conclusions; generalization for a class of problems; and finally, the communication of the results. The application of the framework is iterative in the phases from the identification of the problem to the conclusions. There are usually multiple iterations that span across different phases – for example, during the development, technical limitations can arise that affect the design, or a real-world evaluation reveals that the requirements need adjusting. To better understand the process of DSR, the phases need to be explained further with examples in the context of map-based artifacts.

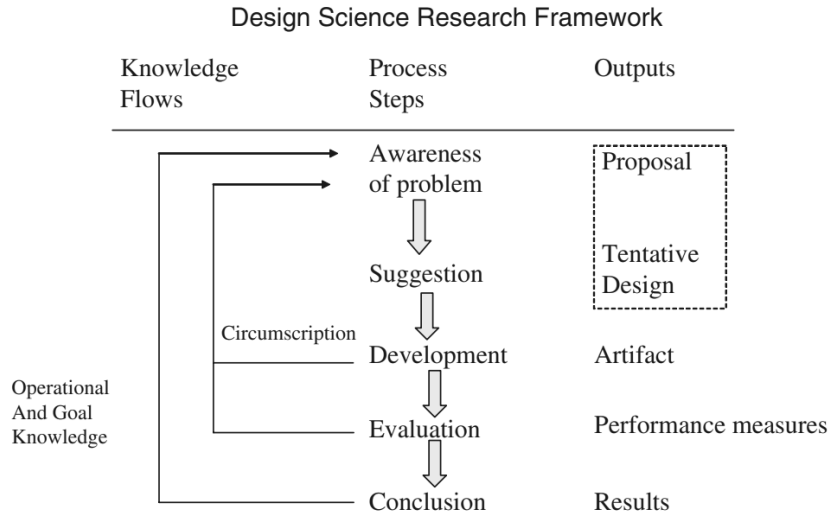


Figure 2. Design science research approach by Hevner & Chatterjee 2010, p. 27, Fig 3.2.

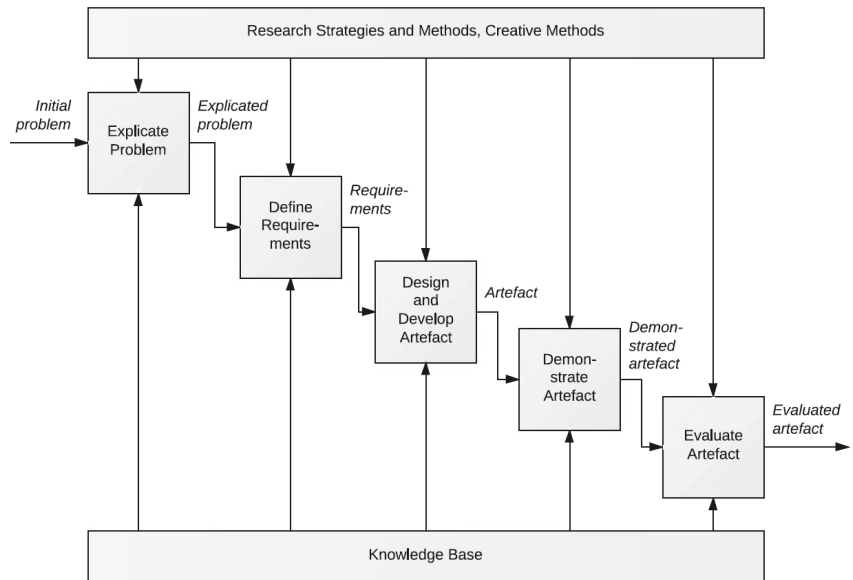


Figure 3. Design science research approach by Johannesson 2014, p. 82, Fig 4.4.

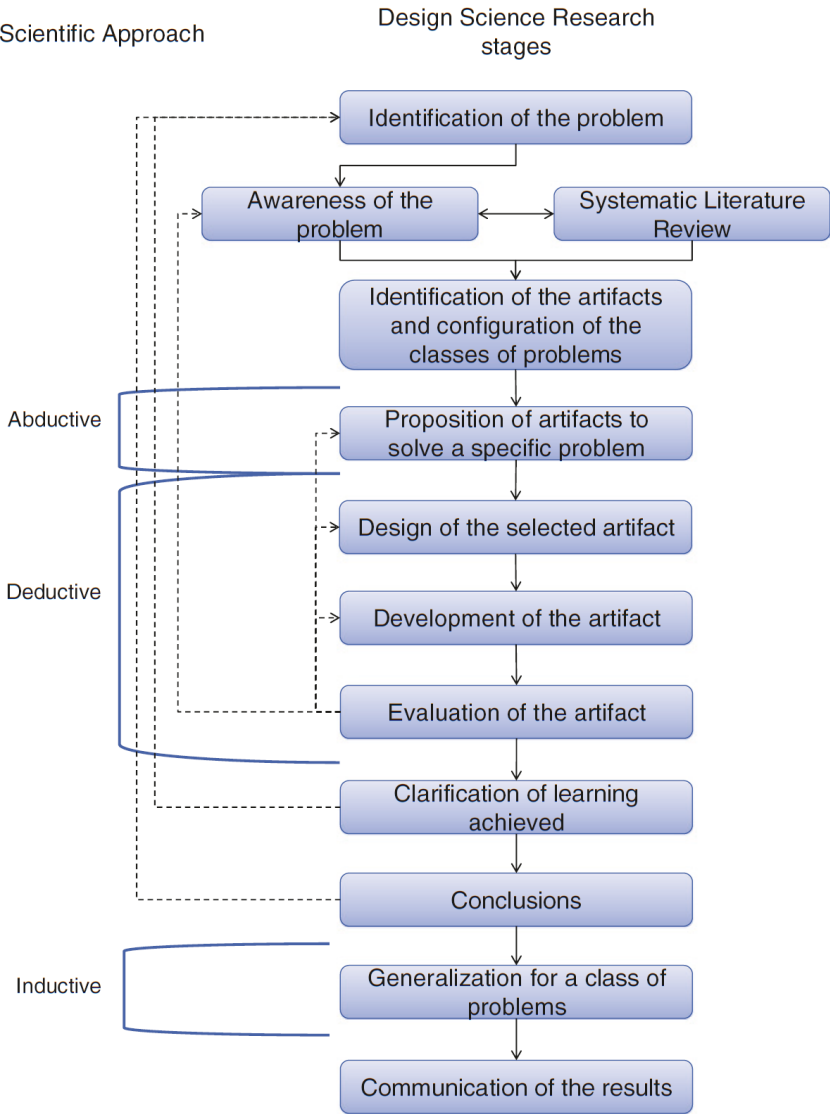


Figure 4. Design science research approach by Dresch et al., 2015, pp. 119, Fig 6.1.

Each phase of DSR can be carried out using one or several research strategies, data collection methods, and data analysis methods. Research strategies, overall plans for conducting research, include: experiments; surveys; case studies; ethnography; grounded theory; action research; phenomenology; simulation; modelling; and mathematical and logical proof (Johannesson 2014, Dresch et al. 2015). For collecting data, the methods are: questionnaires; interviews; focus groups; direct observations; documents or documentary; and bibliographic review (Johannesson 2014, Dresch et al. 2015). Data analysis can be separated into quantitative data analysis such as descriptive statistics, and multivariate or inferential statistics, and qualitative data analysis such as content analysis,

grounded theory, and discourse analysis (Johannesson 2014, Dresch et al. 2015).

2.1.2 Problem identification and requirement definition

In the identification of the problem phase, the task is to identify the real-world problem to be solved by the artifact (Dresch et al. 2015) or investigate and analyse the practical problem (Johannesson 2014), while also justifying the artifact's value (vom Brocke 2020). However, there are occasions when the research is driven by curiosity in creating radical innovations. In these cases, rather than a specific problem, it is possible no specific problem is explicitly addressed (Johannesson 2014). The problem can also be identified using survey, case study, and action research (Johannesson 2014). After the relevant problem has been identified, the problem needs to be deeply understood using methods such as systemic thinking, the theory of constraints thinking process (Dresch et al. 2015) and root cause analysis (Johannesson 2014) which can be applied in multiple ways (Fagerhaug & Andersen 2006). These will reveal the root causes of the problem and facilitate the problem solving, while yielding the requirements the artifact must fulfil to solve the problem. A systematic literature review performed at this point is necessary to gain an adequate awareness of the problem (Johannesson 2014, Dresch et al. 2015, van der Merwe 2020). The literature review may even reveal that solutions to solve parts of the problem already exist. In this phase, it is often beneficial to contact experts who can shed light on the context of the problem.

In the identification of the artifacts and configuration of the classes of problems phase, artifacts that have already been used to solve similar problems are identified and structured (Dresch et al. 2015). An example of this phase in the context of map-based artifacts would include the identification of artifacts, best practices, and lessons learned that have been used to solve a class of problems such as motivating citizens to contribute or citizen privacy. However, these solutions and heuristics are for generic problems, and they may not be the optimal solution for the specific problem studied. In proposing artifacts that solve a specific problem phase, the artifact must be adapted to the reality of the study (Dresch et al. 2015). For example, motivating citizens to contribute can have artifacts that employ multiple gamification techniques, but some of these techniques may be unsuitable, because privacy sets limits to the creation of the artifact. It may therefore be necessary to adapt the artifact in question to meet the specifics of the situation. This phase's objective is to find solutions that work in practice; hence, the phase is creative in nature, but benefits from following systematic approaches such as root cause analysis and literature review.

The requirement definitions in this phase can also be conducted using surveys. If the artifact is complex or innovative, case study and action research should be used, as they allow practitioners to participate and learn the more difficult aspects of the artifact in an iterative process (Johannesson 2014). For example, in a map-based artifact, the use of augmented reality elements (Fogliaroni 2019) is likely to be unfamiliar to many citizens for the time being.

2.1.3 Design and development

In the design phase, the artifact is designed based on the requirements found in the previous phases. The functionality and structure or architecture of the artifact is designed (Johannesson 2014, vom Brocke 2020). The internal characteristics of how the artifact works, and the external context in which the artifact will operate, are defined (Dresch et al. 2015). Johannesson 2014 has depicted four subphases for the design and development phase: imagine and brainstorm; assess and select; sketch and build; justify and reflect. In practice, these subphases are carried out at the same time, iteratively jumping from one phase to another and back.

The imagine and brainstorm subphase consists of getting new ideas or elaborating existing ones. These can be used later to inform the design of the artefact. In the assess and select subphase, the ideas are assessed so that designers may select one or more of them. The selected ideas are used as the basis of the design and built on. Methods to be used in this phase of the process include interviews, observation studies, and other data collection methods, because these can be very effective in producing ideas for design solutions (Johannesson 2014). In crowdsourced map-based artifacts these phases involve diagrams such as how the client-server interactions are handled in the architecture, and what utility is available in the map interface.

In the third subphase, sketch and build, the artefact is constructed based on the design formed in the previous phases. This can start with a sketching phase in which the sketch of an artefact gives an overview of both core utility and general structure (Johannesson 2014). Several methods can be used in this phase, such as use case diagrams, use case descriptions, user stories and storyboarding (Johannesson 2014). Mock-ups and prototypes can be created before the finalised version of the artifact. They reveal design challenges for developing the final artefact and are used to obtain feedback from stakeholders (Johannesson 2014). The actual implementation should follow some established software development methodologies such as agile, DevOps, or waterfall (Jabbari et al. 2016). Both agile and DevOps have stakeholder involvement as part of their development process (Fowler & Highsmith 2001, Jabbari et al. 2016). As for more detailed development methods, pair design, in which designers take turns in making design decisions that the other one evaluates, and walkthrough, in which a designer explains part of the artifact utility to the development group or stakeholders to allow feedback, are effective methods for the development phase (Johannesson 2014).

In the final subphase, justify and reflect, the designers discuss and argue for the design decisions that have been made (Johannesson 2014). This phase should include the documentation of the design rationales, which are a list of decisions and reasoning for these decisions that were made during design and development (Johannesson 2014). This phase produces the artifact itself, which solves the problem but also offers knowledge about the artifact such as the design rationales, concerning how similar artifacts can be created (Dresch et al. 2015). The artifact itself is useful in solving the problem, but it is also important

to learn from the creation of the artifact. The sketch and build phase of the development process of a map-based artifact for citizens can reveal that applying a certain utility yields unexpected results, for example. Overusing the reward gamification technique may motivate the most active citizens to contribute more, while discouraging more casual citizens to contribute less (Fritz 2017). This emphasises the importance of an iterative creation process that is not merely limited to design and development but includes other phases (Johannesson 2014).

2.1.4 Demonstration and evaluation

In this phase, the artifact is demonstrated and evaluated in the real-world. These can often be done simultaneously, as parts of the real-world demonstration can act as part of the evaluation process. For example, the artifact can be observed during a demonstration. Methods and techniques for evaluating artifacts are plentiful (Johannesson 2014, Dresch et al. 2015). For the artifact to be valid, it must be assessed against criteria of value or utility (Dresch et al. 2015). Simply put, the question concerns whether the artifact solves the defined problem. Specific methods for evaluating artifacts created following DSR are (Dresch et al. 2015): observational (case study, field study); analytical (static, dynamic and architecture analysis, optimisation); experimental (controlled experiment, simulation); testing (functional and structural test); descriptive (informed argument, scenarios) (Hevner et al. 2004); and focus groups (Bruseberg & McDonagh-Philp 2002). Johannesson (2014) categorises evaluation methods according to naturalistic (real-world setting) and artificial (laboratory setting), but also to *ex ante* (no artifact or limited utility artifact) and *ex post* (ready artifact). The real world setting with a limited utility artifact includes evaluation methods such as action research, focus groups, and interviews. A real-world setting with an artifact made ready includes evaluation methods such as action research, case studies, ethnography, phenomenology, surveys, focus groups, and observation. To evaluate the interface of a map-based artifact methods such as heuristic evaluation, conformity assessment, cognitive walkthroughs, scenario-based design, participant observation, surveys, interviews, focus groups, card sorting, think aloud and interaction studies can be used (Roth 2015). As crowdsourced map-based artifacts are socio-technical, they benefit from conducting the evaluation in a real-world setting (Johannesson 2014). Both the mock-up and the finalised versions of the artifacts should undergo evaluation in a real-world setting (Johannesson 2014).

Observational evaluation includes methods and techniques such as observing the created map-based artifact being used by citizens in the real-world situation. Analytical evaluation includes methods (Dresch et al. 2015) such as studying the map-based artifact performance during its use. Experimental evaluation can include a simulation in which the artifact is used with artificial data (Dresch et al. 2015) such as populating a map-based artifact database with geospatial data. Testing as an evaluation method is based on methods such as functional tests where the artifact interface is implemented to discover potential failures (Dresch et al. 2015). A functional test of a map-based artifact can be e.g., a stress

test including heavy network use of the artifact backend, typical in spatial analysis. A descriptive evaluation includes methods such as a literature review of existing arguments or scenario construction that can be used to demonstrate the utility of the artifact in various contexts (Dresch et al. 2015). An example of this would be to present an existing concept of car navigation in another context such as pedestrian navigation. Focus groups as an evaluation method bring the artifact to the real users. In the case of crowdsourced map-based artifacts, the most obvious methods to use are those that include an element in which the citizens are involved. This is especially important with a novel map-based artifact design or with a map-based artifact that has an unconventional interface. It is therefore natural to use case studies and field studies which are observational evaluation methods. Focus groups are also suitable and can be combined with many of the evaluation methods previously mentioned. An analysis of the usage data such as the number of times a functionality is used during a functional test can reveal performance and user interface issues, for example. Privacy needs to be considered when handling usage data, especially if it contains the location data of citizens. Instead of applying individual methods when evaluating citizen maps, a mixed method approach of combining evaluation methods can offer a broader view of the artifact in question (Johannesson 2014, Rzeszewski & Kotus 2019). For example, an exploratory focus group can be presented with the new functionality of a map-based artifact (functional test), observed using the new functionality, given a questionnaire, and interviewed. An understanding of how the new utility is used, how it performs, and what improvements can be gained is thus possible. The chosen methods need to suit the research questions and be feasible considering the resources of the research project and ethical for the citizens providing the data to be studied (Johannesson 2014).

2.1.5 Conclusion and communication

In the conclusion phase, the factors that have positively contributed to the research success along with the elements that have failed are explicitly identified (Dresch et al. 2015). A way to determine positive and negative factors is to evaluate the artifact by including only a subset of utility and comparing the results. If artifact A1 has gamified utility applied while artifact A2 does not, comparing the results achieved with both will reveal the effect of the gamified utility. The results can be formalised in the conclusion phase by generalising the solution of a specific problem to a generalised problem (Dresch et al. 2015). The generalisation allows the artifact and the generated knowledge to be applied in similar situations. For example, if the research has found that a certain gamification utility can be used to make repetitive tasks less tedious, this knowledge can be applied in other artifacts created later. This knowledge is shared in the communication of the results phase from a scientific and empirical perspective. Methods for communicating about the artifact include methods such as a literature review (Dresch 2015), Ishikawa (fishbone) diagrams, documenting design rationales, and a design science canvas (Johannesson 2014). These diagrams, figures, and documents can be used in publications about the artifact.

2.2 Usefulness in crowdsourced map-based artifacts

The literature covered in this subchapter is related to usefulness of crowdsourced map-based artifacts. The perspectives are platform choice, cartographic interactions, usability evaluation, the utility-usability trade-off, and usability heuristics. First, the choice of platform for map-based artifacts is presented from the cross platform and mobile platform point of view. Second, the key cartographic interactions in crowdsourced map-based artifacts are explained. Third, the usability evaluation methods and results of map-based artifacts are presented. Fourth, the utility-usability trade-off is adapted for crowdsourced map-based artifacts. Finally, usability heuristics for map-based artifacts are presented.

Utility and usability define the usefulness of an artifact (Nielsen 1994). Usability is defined by five quality components: learnability; efficiency; memorability; errors; and satisfaction (Nielsen 1994). First, learnability expresses how easy it is for users to accomplish basic tasks the first time they encounter the artifact. Second, efficiency then builds on top of learnability by showing how quickly users can perform tasks once they have learned them. Third, when users return to the artifact after a period of not using it, memorability measures how easily the users can re-establish proficiency. Fourth, the errors of the artifact express how many errors users make, how severe the errors are, and how easily users can recover from the errors. Finally, satisfaction describes how pleasant the artifact is to use. A lack of either utility or usability will lead to the artifact becoming useless, because without utility there is no user experience, and without usability, the utility cannot be used. For example, a vehicle navigator with high utility but with low usability can require additional time for the user to get to their destination but will eventually get them there. A vehicle navigator with low utility but high usability can lack a street address search but be otherwise easy to use.

2.2.1 Choosing a platform

The hardware and software platform of a map-based artifact is relevant in the context of usefulness, because the chosen platform dictates what utility is available to a degree. The platform choice is therefore made early in the creation process. From a hardware perspective the platform of a map-based artifact can be anything from a mobile device to a large installation with multiple displays. In the case of map-based artifacts, the initial choice of platform is related to the utility and usability of the artifact. Questions such as is the current location of the citizen necessary for the artifact to function and whether screen size is important should be asked in the first steps of the artifact's creation.

A mobile platform is often chosen for map-based artifacts that rely on crowdsourcing, because it allows the citizen to locate themselves and share their location. With mobile-based artifacts the question often is between a native or a browser-based approach. A native mobile-based artifact offers direct access to the device memory and components, improving processing and interaction performance, and offer extended offline capabilities (Ricker & Roth 2018). Native

mobile-based artifacts can save the state of the artifact when performing other actions such as in the Android activity lifecycle model (Zein & Grundy 2017). However, native mobile-based artifacts are operating system dependent. This increases development costs if multiple operating systems are to be developed, and if not, the choice of the operating system limits the potential number of citizens that can use the artifact. However, there are ways of creating cross-platform mobile-based artifacts. Currently, the five major approaches to the cross-platform creation of artifacts, presented by Felipe & Lucrédio (2019), are as follows. First, the web approach, in which the artifact is a browser-based artifact. Second, a hybrid approach, in which the artifact is browser-based, and the artifact is used by an embedded browser in a native application. Third, the interpreted approach, in which an interpreter is used to transform the artifact code into native actions during runtime. Fourth, the generative approach, in which the artifact code is converted into a native project. Fifth, the model driven approach, in which modelling languages, models, meta-models, and model transformations are used to generate native projects from the artifact code.

All approaches come with benefits and disadvantages compared to native mobile-based artifacts, and it is the artifact creator's responsibility to choose the most suitable option. The main advantages and disadvantages of the approaches can be revealed by examining the web approach. The web approach blurs the lines of hardware platforms, because web-based artifacts can be used on any device with a suitable web browser. Browser-based artifacts can also be adapted to most hardware and operating system platforms with less effort. For example, an artifact based on a desktop browser can be made responsive to work on mobile platforms. Web maps have potential for greater access and distribution but suffer from the limitations of the web browsers with slower processing and interaction speeds (Ricker & Roth 2018), problems accessing native APIs, and compatibility issues (Felipe & Lucrédio 2019). Since web-based map artifacts often rely on a network connection to transfer data from and to the citizen's device, offline capabilities are at least a consideration. Previously, the offline capabilities of the web approach were limited compared to the native approach, but they have improved in this respect (Park et al. 2016). However, there are constraints for mobile-based artifacts that are unlikely to change in the near future. The main constraints of mobile map-based artifacts are available screen size, inaccuracy of touch input, the mobility of device and network bandwidth (Ricker & Roth 2018).

An artifact can also be created to function on multiple platforms with differing utility. The utility required to complete the workflow of the artifact can also be spread across multiple platforms. For example, an artifact can have a mobile and an installation user interface in which the touch screen can be controlled with a mobile device (Schmidt 2012). For example, in map-based artifacts this could mean that the positioning utility is on the mobile platform of the artifact while the utility to display results of a complex visualisation is on a large screen installation. This splitting of the utility plays to the strengths of each platform to form synergies. It is noteworthy that the approaches presented here are subject to change due to evolution of the field (Felipe & Lucrédio 2019).

2.2.2 Cartographic interaction

Roth (2013) categorises cartographic interactions, a taxonomy of interaction primitives for map-based visualizations, into two categories of enabling operators and work operators. Work operators include: re-express; arrange; sequence; re-symbolize; overlay; reproject; pan; zoom; filter; search; retrieve; and calculate. Enabling operators include: import; export; save; edit; and annotate. This categorisation of utility in map-based artifacts can be used in many phases of the creation process of map-based artifacts such as in the identification of similar artifacts to obtain an understanding of what utility an artifact has. In map-based artifacts, the most used work operators are pan, zoom, and search. These are used for exploring the map content. A re-express operator is used to change the background map. Retrieve, filter, search, and annotate are the common enabling operators, and are used for exploring and creating content in the artifact. Retrieve enables content on the map to be loaded and presented based on the request of the citizen – for example, if the citizen wants to see what others have shared. Searching for content on the map is a typical task in many map-based artifacts. Some map-based artifacts offer a text-based search to access content (OpenStreetMap), while others may make the entire point of the artifact a more exploratory experience (Pokémon GO). In the latter case, the requirement for finding content is still present, but finding the content without text-based input is part of the artifact experience. The filter work operator can be used along with the retrieve or search operator to specify a specific location or a parameter to limit the results, for example. The search and filter are also recognised by Boella 2019 as an important element in their map-based artifact. Meanwhile annotation allows citizens to share content on the map – for example, marking points of interest. The use of only a few operators tends to make for a more simplistic artifact, which is usually one of the design goals of crowdsourced map-based artifacts. The complexity of the map-based artifact increases with the number of map operators used (Rzeszewski & Kotus 2019).

2.2.3 Usability evaluation methods and results

Human centered design (HCD, ISO CD 9241-220:2015) strives for human-centred quality, which consists of usability, accessibility, the user experience, and risk reduction (Bevan, et al. 2015). Evaluation of usefulness, or more often simply usability, in map-based artifacts has previously focused on the artifact's demonstration phase (Nivala 2007). This is natural, because it is easier for the artifact creator to establish a test with a functional artifact, instead of introducing citizens to the process in the design phase. More than a decade ago, utilising the human centered design approach systematically in the entire lifecycle of a map-based service was rare (Nivala 2007). The HCD approach has since received more attention (e.g., Delikostidis 2011, Haklay 2010, Ooms 2012, Schoebesberger 2012) in the field of geoinformatics and location-based services. More recently, GIS evaluation studies have been systematically reviewed by Unrau and Kray (2019). The systematic literature review reported a lack of user guidance (Unrau & Kray 2019, Abraham 2021) and low efficiency in using geospatial

tools (Unrau & Kray 2019). This means the citizens using the map-based artifacts were not guided in using the artifact's utility and were unable to efficiently use it. Furthermore, standardised guidelines for cartographic elements and UI design are lacking, as are warning errors and the visibility of map status (Abraham 2021). The evaluation methods have stayed relatively the same: lab-based studies are still most common, while inspections and field-based studies are relatively rare, and the participants do not represent the actual target users (Unrau & Kray 2019). The recommendation to develop tailored heuristics and usability guidelines for map-based artifacts (Unrau & Kray 2019) suggests there are still many studies to be made in the usability of map-based artifacts.

Methods for evaluating user interfaces can be found in the user-centered design process (Roth 2015) and from the extensive literature review by Unrau & Kray (2019). The evaluation methods in the user-centered design process have been presented from the evaluator's perspective and have been organised into three categories of expert-based, theory-based, and user-based methods (Roth 2015). For The literature review, the methods have been categorised to quantitative and qualitative (Unray & Kray 2019). Expert-based methods such as heuristic evaluation are suitable when input is needed quickly, but unsuitable when consultants are unavailable (Roth 2015). Other expert-based methods listed are conformity assessment and cognitive walkthroughs. Theory-based methods such as scenario-based design are suitable when the interface needs to adapt to different users or objectives but is unsuitable when the scenario is over-simplistic (Roth 2015). Other theory-based methods are secondary sources and automated evaluation. User-based methods such as think aloud are suitable when the interface is flexible, allowing multiple ways to complete the same objective, but are unsuitable when each task requires a long time to complete. Other user-based methods are participant observation, surveys, interviews, focus groups, card sorting, and interaction studies. More than one usability evaluation method is often applied in the same study, such as the think aloud method and questionnaire (Flink 2011). Additional quantitative usability evaluation methods include subjective ratings, interaction logging, and eye tracking, while qualitative methods include videotaping, and user and expert comments (Unray & Kray 2019).

2.2.4 The utility-usability trade-off

The road to successful cartographic interaction is finding a sweet spot between user motivation and interface complexity (Roth 2013). When citizens are involved, the complexity of the interface cannot be overextended, because only very few users are experts. Even if citizens have prior experience of map-based artifacts, such as Google Maps or Bing Maps, they may have used them simply to explore the map and not to create geospatial content (Rzeszewski & Kotus 2019). Designing map-based artifacts for the public brings a wide range of citizens from children to the elderly, and from the more traditionally experienced to the technologically savvy, to be considered. When citizens in general are the users of the map interface, complexity becomes one of the main issues on which the designer of the map-based artifact must focus on (Rzeszewski & Kotus

2019). For example, if the interface is simplistic to the extent that it lacks the utility most citizens need, it ceases to be useful. In this case the utility threshold is set to be very narrow (Roth 2015). The same is true for overcomplex interfaces, because citizens may lack the skills and knowledge, but perhaps most importantly, the time or motivation, to learn to use the interface. In this case, the utility threshold is very wide, and even the sheer amount of utility is therefore a usability issue, not to mention each utility's individual usability issues. The problem with usability issues is that they can lead to lower participation rates (Rzeszewski & Kotus 2019).

The map-based artifact design should lie somewhere between the usability and utility extremes. This balancing act is named the usability-utility trade-off (Roth 2015). For the user interface to be successful, the complexity of the interface should be adjusted according to the user. Enabling operators to edit the map for example, may be unfamiliar with citizens. Including such utility to map-based artifacts increase the map interface's the cognitive complexity (Rzeszewski & Kotus 2019). The creator of the artifact therefore needs to consider the usability-utility trade-off from the user's perspective. In map-based artifacts intended for citizens, usability is often more important than utility.

To design a successful map interface, Roth (2015) suggests applying an iterative process, in which three components are defined for the artifact: user; utility; and usability. First, the user requirements are determined; second, the utility threshold is set according to the user requirements; third, the usability is improved in the constraints of the utility threshold; and finally, the artifact is evaluated with the users. This process can be repeated to enhance all three components (Roth 2015). This closely resembles the DSR approach phases, from the problem awareness step to the artifact evaluation.

2.2.5 Usability heuristics

Usability heuristics for user interface design (Nielsen 1994) can be applied as general rules of thumb for map-based artifacts. However, there are specifics in map-based artifacts that need attention. Kuparinen et al. (2016) have developed heuristics for mobile map-based artifacts that can also be adapted to work with larger screens and other input methods. These heuristics are built on the general heuristics presented by Nielsen (1994). Kuparinen et al. propose the following twelve heuristics for mobile map-based artifacts, Table 1.

Table 1. General heuristics for mobile map-based artifacts (Kuparinen et al. 2016).

1. Match the map and the physical surroundings	7. Use understandable terminology consistently
2. Keep the map visible when needed	8. Prevent errors and recover from them
3. Keep the important utility easily accessible	9. Recognise errors and inform of them clearly
4. Offer shortcuts for locations	10. Provide flexibility, adaptability, and scalability
5. Allow multitasking and interruptions	11. Follow balanced and simplistic visual design
6. Prefer commonly used design solutions	12. Offer help

More specific heuristics for mobile map-based artifacts are presented by Ricker & Roth (2018) (Figure 5). The heuristics are categorised as map composition and layout (e.g., maximize the map view), scale and generalisation (e.g., generalise the background map), projection (e.g., show the position of the citizen on

the map), symbolisation (e.g., use self-explanatory icons for points of interest), typography (e.g., increase the text size and tracking), map elements (e.g., hide supplementary info by default), and interaction (e.g., support tap and hold for advanced options). However, mobile map-based artifacts have restrictions regarding limited screen size, touch input, and network bandwidth. The limit of screen size can be mitigated by maximising the map view, generalising the background map and using self-explanatory icons for both the user interface elements and for the POIs. Touch input should support gestures for pan, zoom, and rotate, and have on screen buttons for one handed use, and the user interface should consist of widgets that support touch input. As mobile devices are inherently mobile, the user's location should be updated, and the map should be reoriented and centered to the user location. Network bandwidth limits can be mitigated by using vector tiles, progressive loading, and caching.

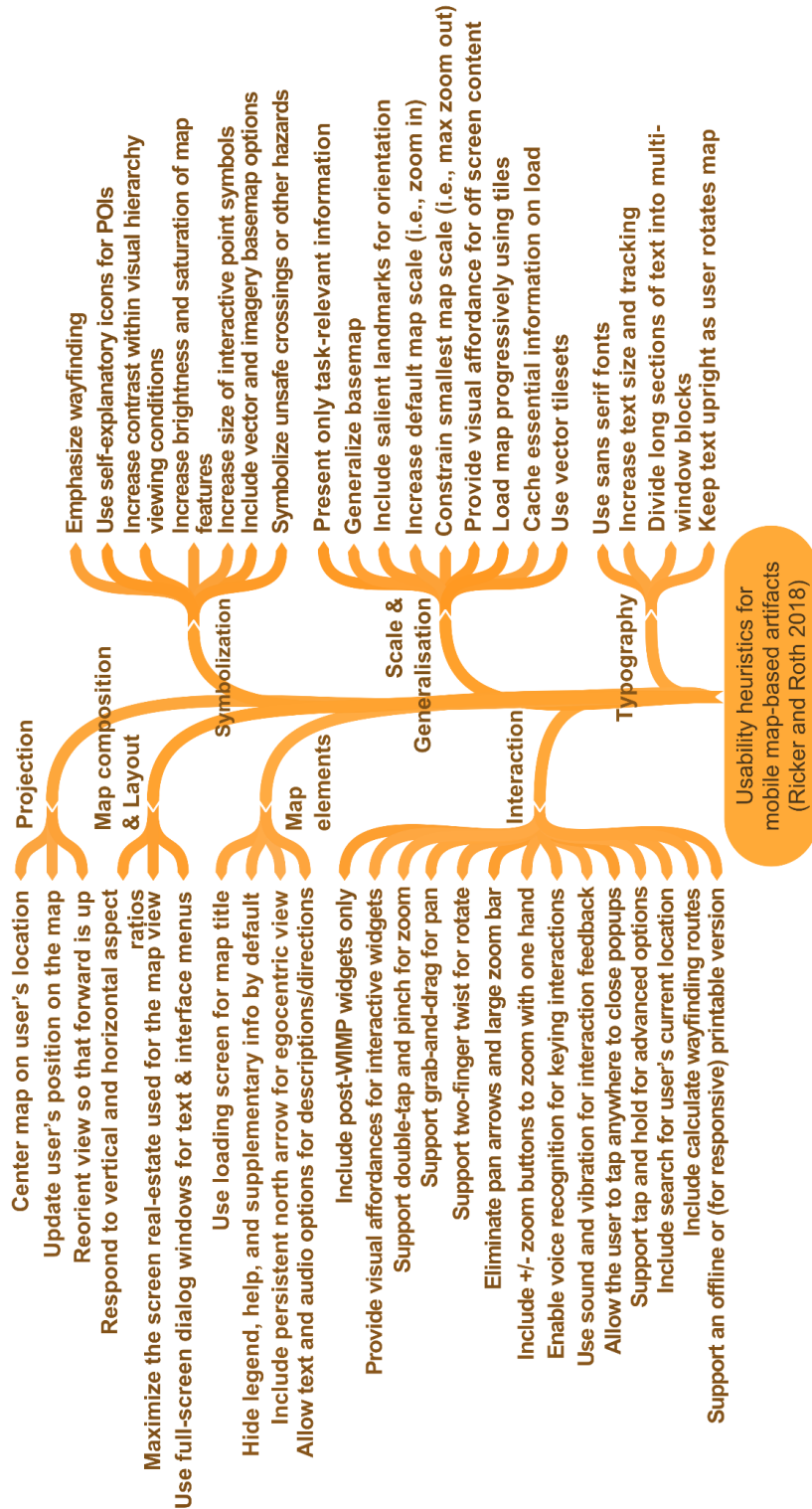


Figure 5. Categorized usability heuristics for mobile map-based artifacts (Ricker & Roth 2018).

Heuristics for web map-based artifacts have a long history (Komarkova et al. 2007). A more recent study suggests heuristics for web maps (Hennig et al. 2016). First, citizens should be able to choose the platform on which they use the artifact on. Second, the user interface design should be simple, consistent, clear, and predictable. Third, commonly used symbology should be used. Fourth, citizens should not be overwhelmed with utility. Fifth, only important utility is visible. Sixth, utility should be depicted in an easily understandable way. Finally, help and support should be available for citizens when they use map-based artifacts. However, tutorials involving reading are sometimes ignored by citizens (Hennig et al. 2016).

2.3 Citizens as the source of content for map-based artifacts

This subchapter explores the use of citizens as the source of content for map-based artifacts. First, the concept of the community-driven approach to crowdsourcing is explained and further detailed, using artifacts as an example. Second, approaches for involving citizens as content creators are defined and compared with volunteered geographic information. Third, the geosocial network approach and the concept of hyperlocal information is presented as an alternative perspective for involving citizens in mapping. Finally, community engagement, gamification, and the utility used in social media are covered to better understand the motivation aspect of citizen contribution.

2.3.1 Community-driven approach to crowdsourcing

Advances in location-aware mobile devices and web technologies have enabled citizens to easily acquire, use, and share geographic information (Foody et al. 2017). Numerous approaches are available with differing goals and focus areas. The activity in which citizens contribute content is called in literature: participatory mapping (Bryan 2015); public participatory GIS (PPGIS, Brown 2012); crowdsourcing (Morschheuser et al. 2017a) with a focus on crowd based or community-driven participation (Gómez-Barrón et al. 2016); volunteered geographic information (VGI, Goodchild 2007); user generated spatial content, neo-geographies and the pervasive media (See et al. 2016); geosocial networks (Park et al. 2014); contributed geographic information (CGI, Bilogrevic 2018). As is evident, the terminology can be confusing, and each approach overlaps (Norris 2017).

There are notable differences in each approach, but in general, all describe the citizen as an actor and a source of data (Foody et al. 2017). However, some are better suited for the purposes of this study, in which where the map-based artifacts are intended for citizens. The crowdsourced participation approach can be more crowd-based or more community-driven (Gómez-Barrón et al. 2016). These approaches are on the opposing ends in many aspects. The crowd-based participation approach relies on passive contributors, as opposed to the community-driven approach in which the contributors are active. In map-based artifacts, the comparison between the Google Maps Traffic Layer (Petrovska 2015) and OpenStreetMap would fit nicely between the crowd-based and community-

driven approaches. The Google Maps Traffic Layer is based on crowd-based participation where the contributors are passive (Petrovska 2015), whereas in OpenStreetMap, contributions are done intentionally.

Crowdsourcing relies on reference content. For example, OpenStreetMap used Yahoo aerial images as a reference (Haklay 2008), while many artefacts use OpenStreetMap as their background map (Juhász 2020, Martella et al. 2019, Boella 2019). Examples of applying the sharing of crowdsourced content will further explain the matter. An example of a community-driven approach to creating content outside map-based artifacts is the CityWall (Peltonen et al. 2008), where citizens can explore images shared in Flickr (an image-sharing platform) by other citizens with a specific hashtag on a large touch-based display in public space. The display is acting as the citizen layer in the artifact and is in fact the only content available. This artifact is intentionally designed to rely solely on the constant feed of images shared by citizens. As the artifact is an installation situated outside on a busy street, it is available to be explored by anyone passing by. It is easy to imagine that CityWall could present the shared content on a map placing the images on the map according to geotags instead of just showing them as a feed of images. Given this, a background map would be needed, but the other content would be fully crowdsourced. The multitouch nature of the CityWall artifact, allowing multiple simultaneous users, is probably why Peltonen et al. observed that the artifact supported teamwork, and users could learn to use the artifact from other users. Another effect of such artifacts is the “honey pot” effect (Marshall et al. 2011, Peltonen et al. 2008 and Jacucci et al. 2010), in which seeing other people use the artifact attracts more people. The honey pot effect, teamwork, and learning from others can be extended to purely digital artifacts such as map-based artifacts, in which the actions and content shared by others motivates others to participate.

Wikimapia is another example where part of the content is shared among citizens (Ballatore et al. 2019). The goal of Wikimapia is to describe the whole world by compiling as much useful information about all geographical objects as possible. Wikimapia is a map-based artifact for collecting information about places. Wikimapia uses a complex system to manage and encourage citizens with experience points, awards, and privileges by using a gamification approach. In Wikimapia citizens share content on a map for others by drawing rectangles on a satellite background and adding descriptions of places, such as cities, parks, and notable buildings (Ballatore et al. 2019). The content that is shared in Wikimapia is the contributions of citizens that are drawn on the background map. Finally, the Tigatrapp artifact is an example of sharing crowdsourced content. The Tigatrapp artifact is used for studying, tracking, and monitoring the expansion of the disease-spreading tiger mosquito (Gómez-Barrón et al. 2016). The Tigatrapp crowdsourced content is shared on a citizen layer on top of the background map by citizens. In these artifacts, some of the content is created and used by the community. Map-based artifacts that allow citizens to share content to others can be thought of as a feedback loop, in which the content shared by citizens is used by citizens.

2.3.2 Volunteered geographic information

VGI is part of the transformation of how geographic content is used today (Sui 2012) and plays a special role among the approaches due to its voluntary nature. To further understand how to choose the content contribution approach for a map-based artifact with content created by citizens, a comparison made by Bilogrevic (2018) between official data, VGI and CGI, can help. The data collection methods can be compared according to data: quality; coverage; temporal quality; transparency; privacy control; and user benefit. The strength of official data lies in quality and user benefit, but it comes with the cost of temporal quality, coverage, and control. High-quality data requires resources and country-wide, let alone global data, may prove too expensive to produce and update. The main difference between VGI and CGI is the approach in which data are collected. The strength of CGI is in coverage and temporal quality, but it lacks privacy control and transparency. The strengths of VGI are transparency, privacy control, and user benefit, but it has issues with data quality and coverage. VGI is voluntary and active; CGI is passive and can even be involuntary. In the context of crowdsourced content, VGI stands out as a more citizen-friendly way of collecting data than CGI. In CGI, citizens may not even be aware of them being the source of data if an “opt-in” approach is not utilised. VGI is collected with the explicit decision of the citizens and is therefore by definition always “opt-in”. Transparency is another strength of VGI, as the purposes and abilities of controlling data collection and data reuse are clear for the citizen (Bilogrevic 2018).

Another beneficial comparison can be made between VGI and public participatory GIS (PPGIS). PPGIS is a “field within geographic information science that focuses on ways the public uses various forms of geospatial technologies to participate in public processes, such as mapping and decision making” (Tulloch 2008). The main difference between the two is that in PPGIS the process in which the spatial data is collected is purposive and agency-driven, while in VGI the spatial data collection is initiated by the citizen and is voluntary in nature (Brown 2012). The process emphasis of PPGIS is on enhancing the public involvement to inform land-use planning and management, while in VGI the emphasis is on expanding spatial information using citizens as sensors (Brown & Kytta 2014). However, the differences between PPGIS and VGI are still minor (Norris 2017), but enough to warrant a more detailed description of VGI instead of PPGIS.

As an approach to crowdsourcing, VGI has the potential to complement and even rival traditional mapping sources in terms of both data quality and richness (See et al. 2017), but due to VGI data quality challenges, the workflow and protocols for data collection processes must be developed (Minghini et al. 2017). VGI suffers from numerous challenges, such as, data quality, contributor motivation, legal issues (Olteanu-Raimond et al. 2017a), data ownership (Foody et al. 2017), but also from less conspicuous challenges such as participation inequality (Haklay 2016), in which most of the contributions are done by a small group of volunteers and semantic challenges (Ballatore 2016) such as simple definition conflicts. Bilogrevic (2018) lists issues for VGI as follows. A drawback of VGI is that data origins and collection methods are less well known, while the

trustworthiness of data does not always reach the standards of official and CGI gathered data. In VGI data, temporal quality depends on volunteers, not periodic surveys, as with official data, or continuous data collection, as with CGI. VGI also has limited coverage, because the location of the volunteers plays a significant role in where the data accumulates (Bilogrevic 2018). These limitations can be mitigated with another community-based mapping endeavour called mapping parties, which are targeted at a small number of citizens, and are events that are limited in both space and time (Brovelli et al. 2016, Fritz 2017). Mapping parties can be used to cover a specific data need while increasing participation (Perkins & Dodge 2008), which in the context of citizen maps could be a mapping of an area that is otherwise not visited by many – an industrial area, for example. There are other major considerations in the use of VGI such as privacy and ethical issues (Foody et al. 2017). Privacy is examined further in this study.

Despite the challenges in VGI, long-term initiatives have been successful, and examples of these are OpenStreetMap and the National Map Corps of the USGS. Swisstopo in Switzerland (Federal Office of Topography swisstopo 2018) and Kadaster in the Netherlands (Verbeter de kaart 2018) have active citizen feedback services. In these two services, citizen contributions and their status in the update process are visible to everyone on the map as a citizen layer, separating it from the services' official content. Similarly, in OpenStreetMap the contributions are visible to all. Pokémon GO has a system in which the players can assign points of interest to the citizen layer for other players to interact with. Content in these artifacts can be shared with others. However, VGI is not the only way examine citizens as a source of content.

2.3.3 Geosocial networks and content moderation

Another way of examining the citizens as a source of content for map-based artifacts is geosocial networks (Espinoza et al. 2001, Gupta et al. 2007, Park et al. 2014, Pat et al. 2015). A geosocial network is a social network in which geographic services and capabilities are used to enable additional social dynamics (Tiwari et al. 2011). Geosocial network artifacts are web-based or mobile-based services that allow citizens to create a profile containing their geolocated and descriptive data, connect with other citizens of the artifact to share their geolocated data, and interact with the content provided by other citizens (Gambs et al. 2011). Martella et al. (2019) list social utility in the context of gamification as avatars, rating, voting, and special roles, for example. The content shared by citizens in a geosocial network artifact can be presented on a citizen layer as available for others (Khan & Johnson 2020, Boella 2019). By commenting on, replying to, or rating content created by others, the citizen adds a social aspect to geospatial data. To better understand the utility of social media that is available, a framework of social utility can be used (Kietzmann et al. 2011). In this framework, the utility is presented by seven functional building blocks: identity; conversations; sharing; presence; relationships; reputation; and groups. These building blocks can be used to assess how different levels of social utility can be configured. For example, the identity block represents the extent citizens reveal

themselves in using the artifact, and utility is therefore needed for self-promotion, but also for privacy control. In a map base artifact for citizens, this could mean that the user profile shows the tasks the citizens has completed, but these tasks can be made public or private.

In geosocial networks, the contributions of citizens are often related to a very specific place, such as a comment on the state of a playground. Such content is referred to as hyperlocal information and is a concept used in geosocial networks. Hyperlocal information is limited and relevant only to a small region, e.g., a street corner or a certain venue (Xia et al. 2014). Hyperlocal information is relevant to small communities or neighbourhoods (Glaser 2010), because hyperlocal information includes news or other content concerning a town, village, single postcode, or other small geographically defined community (Radcliffe 2012). Hyperlocal information therefore has connotations of being more relevant to the citizens who are closer to it. Citizens have a need to belong to online communities and interact with one another (Matikainen 2015), which is what geosocial networks aim to provide. Motivators unique for local knowledge sharing have been identified to be ownership of local knowledge and a sense of community (Park et al. 2014). Citizens benefit from knowing what is in their local area, and more importantly, who their neighbours are. Due to the focus on the citizen and their immediate surroundings, geosocial networks and hyperlocal information can be a valuable perspective for creators, who design their artifact around the sharing of content. Hyperlocal information as much as crowdsourced content in general is subject to overcrowding when presented on a citizen layer in a map-based artifact. As the completeness of the content varies greatly, some places can become filled with map markers. However, using methods such as symbolization, selection, refinement, displacement, aggregation, typification, spatial distortion, and animation avoid this issue (Korpi & Ahonen 2013).

Content moderation is done in social artifacts to improve the quality of the content created by the citizens (Jhaver 2019). There are three main ways to moderate content: manual; automated; and distributed. Manual moderation usually consists of a small group of employees who set the rules while a larger group of freelancers enforces the set rules (Jhaver 2019). Meanwhile, automated moderation can use a filter to remove undesirable content, for example (Jhaver 2019). A map-based artifact can be set to filter all content with a phone number, for example. Social utility can be used to moderate content (Jhaver 2019). This distributed content moderation relies on citizens flagging content that they assess contravenes community rules (Jhaver 2019). Rating can also be used to moderate content by aggregating the ratings of citizens (Jhaver 2019). Content with low ratings can be automatically hidden once it reaches a certain threshold. However, moderation does not have to be limited to hiding or removing content. For example, highly rated content can be elevated in the artifact by giving it more visibility in the user interface. Content moderation in map-based artifacts can be done using one or more of these main ways. A hybrid approach to moderation may be more laborious to design, but the benefits are noteworthy.

Distributed moderation can enable civil participation on online forums, for example (Lampe et al. 2014).

2.3.4 Engaging citizens to contribute

Regardless of the perspective, community-driven crowdsourcing or geosocial network, map-based artifacts require content. Motivation plays a major role in how well an artifact can generate content. Typically, a significant part of the crowdsourced content of a map-based artifact is created by a small number of contributors. This participation inequality (Haklay 2016) has consequences that need to be considered early in the creation of a map-based artifact. Nielsen's (2006) 90:9:1 rule describes that in most online communities, 90% of users are "lurkers", who never contribute, 9% of users contribute a little, and 1% of users account for almost all the action. Among other issues, this presents significant privacy concerns, especially if the map-based artifact uses the user's location as an input, because active users can begin to create patterns such as travel from home to work. However, the effects of participation inequality can be mitigated with the use of special events, such as mapping parties and gamification (Gómez-Barrón et al. 2019). For a more complete view of motivating contributions in crowdsourced map-based artifacts, an engagement approach is required. This approach consists of a community engagement framework, and a framework for transforming a crowdsourcing artifact into a gamified crowdsourcing artifact. Both apply gamification to motivate citizens.

Gamification is defined as the use of game design elements in non-game contexts (Detering et al. 2011) or the application of lessons from the gaming domain to change behaviours in non-game situations (Robson et al. 2015). Gamification has been identified to motivate participation (Olteanu-Raimond et al. 2017b) by adding an element of fun (Fritz et al. 2017) to artifacts. For example, gamification can be used to ease repetitive tasks (Zichermann & Cunningham 2011) that would otherwise be tedious for citizens. Typical utility of gamification includes points, badges, leaderboards, and performance graphs (Sailer et al. 2017). There are however numerous other gamification techniques available such as badges and narrative context (Banuri 2017), bonus, levels, awards, and achievement (Martella et al. 2019) that can all be used in various combinations (Morschheuser et al. 2017b). For example, points and a leaderboard are a typical combination, in which points are given to citizens for making contributions and the leaderboard is sorted according to the number of points. To allow comparisons this type of leaderboard requires a citizen profile, which is why the utility of gamification can be combined with the utility of social media for even more synergies (Martella et al. 2019). However, the effects are greatly dependent on the context in which the gamification is being implemented, as well as on the users using it (Hamari et al. 2014). Gamification can be part of a larger more structured engagement approach.

Whenever the content of a map-based artifact relies on the community, the motivation of community members to contribute is essential for the health of the artifact. An approach for engagement is therefore needed. Community engagement tools can be used for motivating contributing. An example of such a

tool is a framework for motivating contributions to VGI systems (Gómez-Barrón et al. 2019). The framework consists of core drivers, participant types, and an engagement process. First, the core drivers rely on supporting conditions that can be designed into an artifact. For example, the core driver of mastering challenges, in which the participant is learning, developing, and mastering skills and abilities to gain a sense of progress and accomplishment, can be supported with a ranking system of participants or competition in the artifact. A ranking system is a typical example of introducing gamification into a VGI artifact. Second, Gómez-Barrón et al. have created eight participant types of VGI, based on the core drivers motivating each. This new classification will allow an artifact to be designed for a specific community or take into account multiple types of participants, for example. The core drivers and participant types explain why participants are motivated to create content. Finally, Gómez-Barrón et al. present an engagement process for VGI systems. The process consists of three phases: enrol; grow; and retain. In the enrol phase, awareness of the artifact is created while providing the participants with the means to easily reach the set tangible goal. In the growth phase, contributions are facilitated, and behaviour is sustained. Participation inequality is reduced by lowering the barrier for participation with simpler tasks and ensuring that the participants continue to contribute. This is done by providing participants who complete tasks with immediate feedback. Therefore, artifacts should have updated leaderboards, for example. The behaviour is sustained by a well-designed feedback and reward system based on meeting the needs of citizens and addressing their core drivers. In the retain phase, participants should be made aware of their investment in the artifact and its network effects. Participants should also be re-engaged when they stop participating. This framework can be applied for map-based artifacts by creating engagement techniques that fit the participant types and by following the engagement process to motivate citizens to contribute. The application of an engagement approach can create effective feedback loops (Gómez-Barrón et al. 2019).

A conceptual framework for the gamification of geographic artifacts provides a model that shows how to transform a VGI-based artifact into a gamified VGI artifact (Martella et al. 2019). In the framework, geographic data tasks have been classified as gathering, validation, fixing, and integration. For example, the task of gathering geospatial data is transformed into a challenge, which is a gamification technique for motivating the participants (Martella et al. 2019). A specific participant type can be motivated by specific gamification techniques such as providing the achiever type with a leaderboard for completing challenges to compare their results to others, thus creating competition (Martella et al. 2019). Compared to mapping parties that fulfil a specific need, gamification is more suitable for collecting large amounts of data over a long period (Brovelli et al. 2016). Social utility, mentioned earlier, can be used in combination with gamification methods to create synergies. Following the previous example, the tasks in the user profile can be converted into badges that can be shared through social media and made public or private in the profile. Gamification for motivating citizens in crowdsourced map-based artifacts is a sound approach. However,

Morschheuser et al. (2017b) lists why gamification is difficult to design into an artifact. First, games are complex and multifaceted, and therefore difficult to comprehensively transfer to other environments. Second, gamification involves an understanding of motivational psychology. Finally, the goal of gamification is to affect behaviour, which adds yet another layer of complexity. To tackle this challenge, Morschheuser presents a comprehensive overview of gamification guidelines and provides insights into the overall nature of the gamification development and design (Morschheuser et al. 2017b). The application of the gamification approach therefore requires careful consideration.

2.4 Privacy in map-based artifacts with crowdsourced content

This subchapter covers privacy in map-based artifacts by presenting the privacy by design approach, as well as methods and techniques for preserving the privacy of citizens.

2.4.1 Privacy by design

Privacy is a considerable research challenge in map-based artifacts (Mooney et al. 2017). It is understandable that privacy is something most citizens want (Al-ayes et al. 2014), because location traces can be used to discern a citizen's home and workplace, political affiliations, activities, interests, and social networks, for example (Bilogrevic 2018). However, many solutions and legislation are available to protect citizens. The General Data Protection Regulation (EU) 2016/679 (GDPR) is a regulation on data protection and privacy in EU law. The GDPR incorporates the privacy by design approach, which takes privacy into account throughout an artifact's creation process. Privacy by design is a paradigm that can be used to develop technological frameworks for countering the threats of privacy violation, without obstructing the knowledge discovery opportunities of the collected data (Pratesi et al. 2018).

The idea of Privacy by design is to take privacy protection into account from the outset of the artifact creation. The privacy by design approach relies on seven principles described by Cavoukian (2019). First, privacy should be proactive and preventive, meaning that a creator of a map-based artifact should proactively prevent data breaches by assessing risks, for example. Second, privacy should be the default setting and should require no action from the citizen to be applied fully. In a map-based artifact intended for sharing content with other citizens, the privacy settings should be set to ask for consent to allow content sharing. Third, privacy should be embedded into the design, where the privacy aspects are considered from the beginning of the creation process. In map base artifacts that often rely on citizen location, privacy-preserving methods such as aggregation should be part of the core design (Gürses 2011). Fourth, privacy should support or even elevate utility by documenting the interests and objectives of actors around the artifact. In map-based artifacts, both the citizens and the entity providing the artifact should benefit from the application of privacy. For example, aggregating the content provided by the citizens in a manner that preserves privacy does not automatically reduce the quality of the content. On

the contrary, the aggregated content can be more valuable if analysed properly (Pratesi et al. 2018). Fifth, end-to-end security that means taking care of data security from the beginning to the end of the content lifecycle. Map-based artifacts should therefore have a plan on how to manage the lifecycle of the geospatial content. This presents challenges, especially when the content of a single citizen is aggregated with others (Xu 2017). Sixth, privacy should be visible and transparent to establish trust. For example, this entails letting the citizen know why and how their content is used. If a citizen shares their location information, they should be aware of how it is being used. Finally, privacy should be respected, meaning that whenever the content of a citizen is used, the citizen should give consent. Similarly, a citizen should have access to their own content. For example, in map-based artifacts this means asking for permission to use the citizens location and providing them with the means to obtain their content.

As has been shown, the privacy by design approach is especially important when creating map-based artifacts for citizens, because the artifact design often relies on VGI created by citizens. However, from a privacy perspective, the benefits of VGI are clear (Bilogrevic 2018). First, VGI offers transparent data collection practices, processing, and limits. Second, VGI offers privacy control for the user, because they can decide the extent to which they wish to contribute. Third, VGI can be as beneficial for the participant as official geospatial data (Bilogrevic 2018).

2.4.2 Methods for preserving citizen privacy

Bilogrevic 2018 has divided contributing to geospatial crowdsourcing into tasking and reporting phases. In the tasking phase, the tasks can be published in either push or pull mode. In push mode, contributors share their location with the artifact and receive tasks that are nearby. Push mode therefore allows the control of tasking on a highly granular scale but requires the contributor to share their location. For example, the contributor can be assigned the closest and most interesting task, based on their location and their profile information. In pull mode, the tasks are published by the artifact for all participants, and they can choose a task without revealing their location. However, in pull mode, the granular control of tasking is lost. In the reporting phase, contributors obviously need to reveal their location to the artifact for the contribution to be tied into a specific location.

Bilogrevic (2018) presents methods for increasing privacy both in tasking and reporting phases. Pseudonyms can be used to unlink the contribution from the contributor. Contribution mixing between contributors can further fade the spatial patterns formed when e.g., a contributor does most of their contributing in the same area. Spatial cloaking of contributions can be used to reduce the location accuracy of contributions to hide e.g., the home of a contributor. Perturbation of contributions adds random noise to the location of contributors. Aggregation of contributions generally makes the data less spatially accurate and hides individual contributors while maintaining the value of the contributions (Bilogrevic 2018). Some of these methods may not be applicable as e.g., spatial

cloaking may significantly reduce the value of the data. However, even complicated tasks can still be achieved while following the privacy by design paradigm such as identifying previously unknown groups of people and their meeting places without invading privacy (Gupta et al. 2007). Privacy by design can complicate the designs of artifacts, but it is possible to reach a good trade-off between data privacy and the good quality of data (Pratesi et al. 2018).

3. Materials and methods

The choice of artifacts for this dissertation was made based on the similar goal of each artifact to change the current practice. All three artifacts were also aimed for regular citizens and the citizens were designed to be part of the content creation. This dissertation's research strategy was to follow the design science research approach to categorise and compare the three artifacts presented in the appended papers. Papers I and II describe the TouchMaps artifact, Paper III and IV describe the #hylo artifact, and Paper IV describes the Map Gretel artifact. As the DSR objectives are to design and recommend, each artifact description inherently comes with recommendations for how to proceed when creating similar artifacts. The data collection methods for each artifact are presented in Table 2. The research questions (RQ), research strategy, research methods used, and scopes of each appended paper is presented in Table 3.

The literature reviews were undertaken mostly before the design phases, and they helped choose effective solutions when available. Functional tests were undertaken throughout the development process of the artifacts and provided much-needed information about potential failures in design and development. A focus group in the initial phase of the #hylo artifacts provided direction for the design of the artifacts. The artifacts were designed to change how maps are used by citizens and therefore to change the current practice. The design process required a varying degree of active participation from practitioners to further develop the artifacts. An iterative development process, in which utility is added, and then tested or evaluated with fellow designers or citizens, was therefore chosen. This was done to take feedback from the fellow designers or citizens into account when further designing and developing the artifacts. Pair design and walkthrough were used as the development methods, because they fitted the designer group well. The artifacts were demonstrated in practice with real users and in a real situation for the evaluation results to be valid.

Part of the research strategy was to use multiple data collection methods in the evaluation phase. This mixed method approach provided a view of the artifacts from different perspectives. Both qualitative and quantitative data from the artifact's use was gathered with the data collection methods. Questionnaires after the personal experience of using the artifacts provided valuable quantitative and qualitative information about the use of the artifacts. Interviews after the personal experience of using the artifacts provided valuable qualitative information about the artifacts. Observation during the use of the two artifacts provided valuable qualitative information about the artifacts, while documents

collected from the use of the artifacts offered valuable quantitative information about the use of artifacts.

Table 2. The data collection methods were chosen to complement and confirm one another in evaluating the artifacts in this study

Methods	TouchMaps	#hylo	Map Gretel
Literature review	✓	✓	✓
Scenario building		✓	
Functional test	✓	✓	✓
Focus group		✓	
Case study	✓	✓	✓
Observation	✓	✓	
Questionnaire	✓	✓	✓
Interview	✓	✓	✓

Table 3. The research questions (RQ), research strategy, research methods used, and scopes of each appended paper.

Paper	RQ	Artifact	Key methods	Scope
I: Developing a multi-touch map application for a large screen in a nature centre	2	TouchMaps	Literature review functional test	The study describes the development of a map-based artifact used on a large multi-touch screen in a public space.
II: Hands-on Maps: a Multi-touch Map Application in a Public Space	1	TouchMaps	demonstration observation interview questionnaire	The study presents a usability evaluation of a map-based artifact used on a large multi-touch screen in a public space.
III: Concept Design of #hylo – Geosocial Network for Sharing Hyperlocal Information on a Map	1 2 3	#hylo	Literature review scenario building focus group demonstration observation questionnaire interview	The study describes the creation process of a map-based artifact for sharing hyperlocal information on a map.
IV: #hylo – Privacy-preserving Geosocial Network for Sharing Hyperlocal Information on a Map	1 2 3	#hylo	Literature review functional test	The study describes the creation process of a privacy-preserving map-based artifact for sharing hyperlocal information on a map.
V: Map Gretel – Social Map Service Supporting a National Mapping Agency in Data Collection	1 2 3	Map Gretel	Literature review functional test demonstration questionnaire interview	The study presents the creation process of a map-based artifact for supporting a national mapping agency in data collection.

A more detailed description of the research strategy and data collection methods used is presented for each artifact. The methods of each artifact are presented, considering research strategy, data collection methods, and data analysis.

3.1 Materials and methods for the TouchMaps artifact

Paper I answered RQ2 by designing and developing an artifact for changing how maps are experienced in public spaces. In this study, the literature review was followed by a detailed description of the artifact creation process and the functional test of the developed artifact. These were compiled into creation considerations for developing map-based multi-touch user interfaces. The literature review focused on multi-touch and multi-touch map artifacts and presented similar artifacts in order to find heuristics and guidelines to follow. The focus was on the design of the user interface and the cartographic interaction of the artifacts. In the creation process part of this study, the user interface elements were described in detail, and the experiences gained during the creation process of the artifact were presented. The considerations of the creation process, which stemmed from the previous parts of the study, were categorised according to interaction, map browsing, and users. Paper II answered RQ1 by evaluating the artifact designed and developed in Paper I. This study is based on an evaluation of the artifact presented in Paper I. A literature review of multi-touch displays in public spaces was followed by a detailed description of the user interface of the created artifact. The artifact was demonstrated to citizens in a real environment. The evaluation of the artifact consisted of observation, interviews, and a questionnaire. The findings of the evaluation were summarised.

3.1.1 Research strategy for TouchMaps

Given that public spaces are open to citizens, an interactive large touch-based screen was chosen as the foundation for the artifact design to accommodate all kinds of users. Social utility was included in the design to motivate citizens in sharing content. A citizen layer was included in the design to allow citizens to share content. The design was first functionally tested by creating an artifact on a large rigid platform in a laboratory setting to determine how the designed utility could be applied. Usability was also taken into consideration in the functional tests. The artifact was then demonstrated on a more mobile platform that could be transported to public spaces. Both the functional tests and the demonstration gave valuable feedback for refining the design and artifact.

3.1.2 Data collection and analysis methods for TouchMaps

The artifact was evaluated for one week in a public exhibition for leisure cyclists in the centre of Helsinki in 2012. During the week, users were observed for how they experienced and interacted with the artifact. The observation method was naturalistic. Observation focused on the first contact users had with the artifact, how many used the artifact simultaneously, what gestures were used, how easy it was for the users to grasp how to use the artifact and what the users had difficulties with. After the participants had used the artifact, they were asked to fill out a short questionnaire. The questionnaire included background questions and how familiar the users were with touch-based devices. The questionnaire mainly focused on usability issues such as how easy the artifact overall was to

use, and how easy specific utility of the artifact was to use. The questionnaire also asked about how interesting the participants considered the content of the artifact. Short informal interviews were randomly conducted after a participant had used the artifact to collect feedback and form a general understanding of how users approached and used the application. The data collected from the questionnaire, the observation, and the interview were analysed and formed into three general findings. The results of the questionnaire were also numerically analysed. After a further analysis of the whole data, a list of considerations for developing map-based touch user interfaces was produced.

3.2 Materials and methods of the #hylo artifact

Paper III answered RQ1, RQ2 and RQ3 by designing, developing and evaluating an artifact for changing how citizens shared hyperlocal information about their surroundings on a map. This study consisted of a literature review, building a scenario, a focus group, a demonstration, observation, a questionnaire, and interviews. The literature review focused on previously created geosocial artifacts. The human-centered design approach was used in the artifact's creation process. Paper IV answered the RQ1, RQ2 and RQ3 by describing the design and development of a privacy-preserving geosocial network for sharing hyperlocal information on a map. This study consisted of a literature review and a functional test. The literature review focused on privacy from the citizen's perspective. The study described in detail how the privacy by design approach was designed and implemented in the artifact. A functional test of the privacy utility of the artifact was presented.

3.2.1 Research strategy for #hylo

Decisions regarding the early design of the artifact were made in a workshop by collaboratively reviewing three design concepts. A mobile platform was chosen to reach as many citizens as possible and enable them to use the artifact and allow content to be tied to real-world locations via mobile positioning. The artifact was integrated into a privacy-preserving location platform to allow users to manage their location and content privacy. Methods of social media and gamification were included in the design to motivate citizens to share content. A citizen layer was included in the design to allow hyperlocal data to be shared. The design was demonstrated first for two focus groups and then demonstrated online, made available for all citizens to use. Both types of demonstration gave valuable feedback for refining the design during development.

3.2.2 Data collection and analysis methods for #hylo

A scenario was made to help focus the artifact concept creation. Three artifact concepts were presented to a focus group, which reviewed them collaboratively. The best concept was chosen and further developed in the focus group. To evaluate the concept chosen in the workshop, a focus group of eight participants tested a mock-up version of the artifact while filling out a questionnaire. The

design of the artifact was altered based on the results gained from the first focus group. To evaluate if the artifact was suitable for one of the target audiences, a small focus group of teenagers was given a task to simulate the use of the artifact on a paper map. The teachers of the teenagers in the focus group were also interviewed. The focus group observations and the teacher interviews were used to plan a demonstration in a school setting. The artifact was demonstrated with 86 teenagers in five different schools. The demonstration consisted of an introduction to the artifact, and a task where participants used the artifact. The use of the artifact was observed during the demonstration while documenting the content shared by the participants. A questionnaire was filled out by the participants after the demonstration. The evaluation including questionnaires, documenting and observation was analysed. The results of the questionnaire were numerically analysed.

3.3 Materials and methods for the Map Gretel artifact

Paper V answered RQ1, RQ2 and RQ3 by designing, developing, and evaluating an artifact for changing how a national mapping agency collected data from citizens. Followed by a literature review focusing on applying volunteered geographic information in national mapping agencies, a functional test of the created artifact was performed. The artifact was then available to citizens during which the artifact was evaluated using questionnaires and interviews.

3.3.1 Research strategy for Map Gretel

VGI methods and web mapping were chosen as the foundation for the artifact design to accommodate all kinds of users. Social and gamification utility were included in the design to motivate citizens in data collection. A citizen layer was included in the design to allow collected data to be shared. The design was demonstrated first in a laboratory setting and then made available online for all citizens. Both types of demonstrations gave valuable feedback to refining the design during development.

3.3.2 Data collection and analysis methods for Map Gretel

The artifact was evaluated during a six-month pilot period by questionnaires and documenting the use of the artifact. One of the questionnaires was aimed at the citizens using the artifact while another was aimed at the NMA employees working with the artifact. The number of registrations, shared content, content modifications, and feedback given via the artifact was documented. The evaluation, including questionnaire and documenting, as well as the demonstration, was analysed. The results of the questionnaire were numerically analysed.

4. Results

The results related to RQ1 concerning the creation of crowdsourced map-based artifacts are presented in Chapters 4.1 by presenting a general adapted DSR approach, and in Chapters 4.2, 4.3 and 4.4 by presenting each artifact in the appended papers. A summary of the artifacts from both a scientific and empirical perspective is presented in Chapter 4.5 to allow a comparison of the artifacts. The results related to RQ2 concerning the utility and usability of crowdsourced map-based artifacts is presented in Chapter 4.6. Chapter 4.7 presents the results related to RQ3 concerning key requirements of privacy-preserving crowdsourced content creation in map-based artifacts. Summary of the results is presented in Chapter 4.8.

4.1 Adapted general design science research approach

The DSR approach has been used to categorise the three artifacts presented in appended papers to present the artifacts at a comparable level of detail. The following phases of DSR have been adapted from the literature: problem identification; requirement definition; artifact design; artifact development; artifact demonstration; artifact evaluation; conclusion; and communication (Figure 6). This DSR approach was chosen as the method for presenting the result. It is worth noting that this DSR approach was not used for creating the artifacts presented in this dissertation. However, the creation process of each used some of the same methods and generally followed the order of this DSR approach.

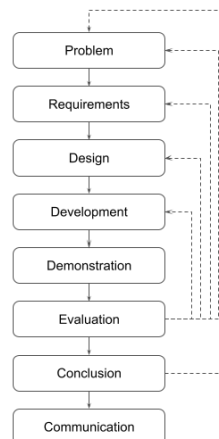


Figure 6. Design science research approach with an emphasis on phase iteration. Adapted from Peffers et al. 2007, Johannesson et al. 2014, Dresch et al. 2015, Baskerville et al. 2018.

4.2 Creation process of the TouchMaps artifact

For this artifact, the overall theme is to provide citizens with better map-based services to support outdoor leisure activities. Maps have always been an important aspect of planning outdoor leisure activities such as hiking in ensuring that you are on the right trail. Public spaces such as visitor centres of national parks, have often been furnished with large wall maps and interactive displays. As a result, TouchMaps a map-based artifact used for exploration on a large touch screen in a public space was created (Figure 7).



Figure 7. The intuitive touch-based user interface and the large high-resolution screen allows multiple users to simultaneously interact with the content of TouchMaps. The user on the left is browsing pictures from a point of interest, while the user on the right is zooming into the map.

4.2.1 Problem and requirements

The problem elicited for this artifact is how a large touch-based map display could be used in a public space to encourage exploration. To further outline the problem, requirements for the artifact have been elicited – Table 4. The artifact should be in a public space and thus be accessible for citizens. Citizens are interested in high-quality map content that hikers can use to explore the surrounding area to find new places to visit, for example. There are two main use cases for the artifact: passive and active users. Passive users tend to view the artifact from further away and thus need to be able to see the content. Active users on the other hand are close to the screen. For both use cases, a large high-resolution display is needed. Simultaneous use is expected which further emphasises the need for large displays. The artifact is supposed to be useful (both usable and utilisable) for everyone, including children and the elderly, interested in exploring maps. To summarize, the users need an artifact with a large

high-resolution display accompanied by an intuitive map user interface to high-quality map content available in a public space.

Table 4. The key requirements, requirement types and rationales of the TouchMaps artifact.

Requirement	Type	Rationale
Situated in a public space	Environmental	Citizens need access to artifact
High-quality map content	Environmental	Citizens are interested in the content
Large high-resolution UI	Environmental	Content details visible from up close and further away; simultaneous use
Touch-based map UI	Functional	Effective way to convey map content
Intuitive UI	Usability	UI used by citizens
Citizen layer	Functional	Enable citizens to comment features

4.2.2 Design and Development of artifact

To satisfy the requirements, the following design choices were made when designing and developing the artifact. The artifact is designed to be used in a public space on a large high-resolution touch-based display installation (Figure 7). The high-quality map content includes a topographic, relief, forest, winter, and orthophoto map roughly covering the area of Nuuksio National Park in Espoo, Southern Finland (Oksanen et al., 2011). The five different map themes are each divided into eight generalised raster scale levels, the highest level being in 2-metre resolution. Points of interest and hiking routes including descriptions and pictures are also part of the artifact content. This content can be commented on and liked using Facebook, on a mobile phone for example. The artifact was used on a MultiTouch Cell Advanced (MT467) 46-inch Full HD resolution LCD display manufactured by MultiTouch Ltd (MultiTouch 2012). The display's touch technology is based on infrared cameras and allows for unlimited touch points with low latency. Low latency is a key requirement of touch-based interfaces and provides the feeling of instant feedback. The designed touch-based UI supports multiple touchpoints and thus allows for multiple users to use different UI elements simultaneously. The simplistic UI has an interactive element for automatically centring the map view on places of interest by pressing the place name. This navigation menu element acts as a rudimentary yet intuitive place search which replaces the need for a text-based search and supports the more exploratory nature of the artifact. The background map can be changed by pressing the desired map from the background map element. Elements for browsing POIs, routes and picture galleries are available on the map at their locations on the citizen layer. The artifact user interface is designed to be intuitive and can be used without any prior knowledge or training. To achieve this, the most basic map manipulation had multiple gestures for performing the same task. Map panning can be done with one finger, multiple fingers, one hand, or both hands. Map zooming can be done with a two-finger pinch, a one-hand multiple finger pinch, or moving both hands together or apart (two-hand pinch).

4.2.3 Artifact demonstration

The artifact was demonstrated in two different environments. The first demonstration, “Cyclist installation”, was organised for one week in a public exhibition for leisure cyclists in the centre of Helsinki in 2012 (Figure 8). The second demonstration, “Nature Centre installation”, has been on-going since 2013 in a public exhibition for the visitors of the Finnish Nature Centre Haltia near the city of Helsinki. The “Cyclist installation” had one screen, and the Nature Centre installation had two screens next to each other.



Figure 8. The artifact was demonstrated and evaluated in a public exhibition aimed at leisure cyclists.

4.2.4 Evaluation of artifact

The evaluation during the “Cyclist installation” focused on the usability of the artifact. During the one-week exhibition the citizens were passively observed to use tapping as their first touch gesture in using the artifact. However, many citizens needed encouragement to touch the interface from the facilitators. It was also observed that the “honey pot” effect of seeing other people use the artifact attracted more people. Citizens were observed to quickly grasp the idea of the user interface. After the citizens had used the artifact, they could answer a questionnaire – Table 5. The 56 participants were more familiar with small touch displays such as mobile or tablet devices. On a scale of 1 (I have never used one) to 5 (I use one every day), the average score was 3.5. For large touch displays, the average score was 2.3. When asked how easy it was to move the map, on a scale of 1 (very difficult) to 5 (very easy), the average score was 3.9. Zooming the map with a pinch gesture, either with fingers, the whole hand, or both hands, was also easy as the average score was 4.0. Changing the background map was

considered the easiest with the average score of 4.3. Photos and written descriptions of the points of interest presented on the map received an average score of 3.9 on a scale of 1 (not at all interesting) to 5 (very interesting).

Table 5. The average score of common tasks on a scale of 1 (very difficult) to 5 (very easy) in the questionnaire of the artifact.

Task	Gestures available	Score
Pan the map	one-finger swipe, multi-finger swipe, one-hand swipe, two-hand swipe	3.9
Zoom the map	two-finger pinch, multi-finger pinch, one-hand pinch, two-hand pinch	4.0
Change the map	one-finger button press, multi-finger button press	4.3

Overall, it was found that most users considered the multi-touch user interface of the artifact to be a useful way to explore interactive maps. The artifact demonstrated how to create a simple multi-touch user interface used with intuitive, continuous, and simultaneous gestures for map browsing, and how to take different kinds of users and their needs to interact with each other into account.

4.3 Creation process of the #hylo artifact

For this artifact the idea was to help citizens share their hyper-local knowledge. Personal geospatial knowledge is rarely shared, although it would be interesting and useful to others. As a result, #hylo a privacy-preserving geosocial network artifact for sharing hyperlocal information on a map was created (Figure 9).

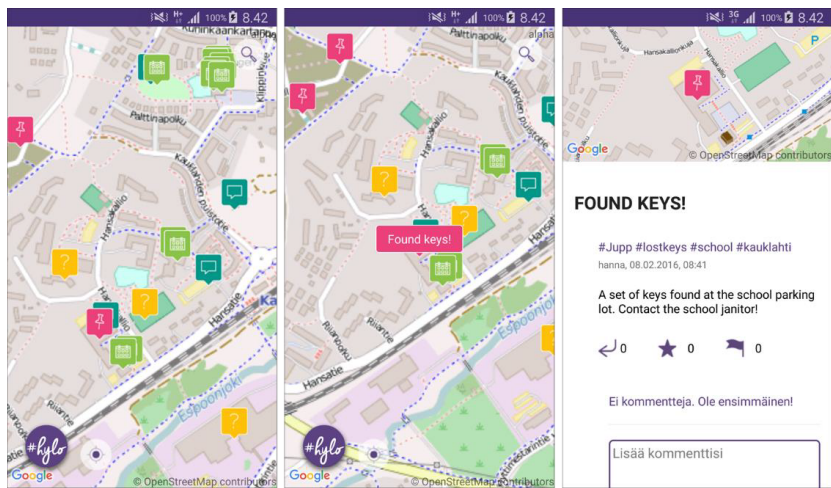


Figure 9. Users share hyperlocal information on a citizen layer in the #hylo geosocial network. A class, title, description, descriptive hashtags and place names can be added. Rating, flagging and commenting is available in the feature view.

4.3.1 Problem and requirements

The problem elicited for this artifact is how to encourage citizens to share hyper local knowledge using a geosocial network while preserving their privacy. To further outline the problem requirements for the artifact have been elicited – Table 6.

Table 6. The key requirements, requirement types and rationales of the #hylo artifact.

Requirement	Type	Rationale
Encourage sharing of hyperlocal information	Functional	Increase people’s awareness of and personal attachment of people to their local surroundings
Preserve privacy of citizens	Functional	Hyperlocal information contains elements that are private
Mobile map UI	Usability, Functional	Content is presented in relation to user location and interests
High temporal and spatial quality background map	Environmental	Hyperlocal information needs a high-quality reference map.
Citizen layer	Functional	Enables citizens to share hyperlocal information
Social and gamification utility	Functional	Engagement and sense of community

The artifact is required to encourage sharing of hyperlocal knowledge to increase people’s awareness of and personal attachment to their local surroundings. Increased awareness and personal attachment are expected to increase social participation, motivating further sharing of hyperlocal knowledge. This content-sharing cycle requires citizens to be able to share content to others. For

citizens to be able to share their hyper-local knowledge, a citizen layer is required. As the content is presented in relation to the user's location and interests, a mobile map user interface is required. To engage citizens and create a sense of community, social utility is required. As the shared hyperlocal information contains private elements, it is required to preserve the privacy of the citizens.

4.3.2 Design and Development of artifact

The #hylo artifact was developed first as an interactive web-based mock-up, then as a web map application and, finally as a native Android application (Figure 10). The artifact supports standard map manipulation, in which panning is done with a one-finger drag gesture and zooming with a pinch gesture. OpenStreetMap is used as the background map. The main elements of the map interface are main menu, user's current location, annotation and search. Annotation in the #hylo artifact is done by sharing hyperlocal information called "geonotes". Citizens can add geonotes anywhere on the background map by pressing the plus symbol on the map view (Figure 10). The annotated content is on a citizen layer and is publicly visible by default. A heatmap visualisation of aggregated anonymous user location tracks is also available for the citizens on the citizen layer. With #hylo citizens can share their favourite picnic spot, ask a question about a dog park, or create an event for others to see, for example. A category, title, description, descriptive hashtags, and place names can be added to the annotated geonotes, so they are easier to find by others. The geonotes shown on the map are filtered by default according to the interests and places defined by the citizen in their profile. A citizen therefore sees geonotes on subjects and from places they have specified in their profile. Citizens can easily search nearby geonotes if they tap and hold anywhere on the map to perform a proximity-based search of geonotes. Nearest geonotes in the area originating from the pressed location are revealed. Another similar proximity search is done when the citizen requests to see their location on the map by pressing the current location button (Figure 10).

Geonotes are clustered, while still showing their categories, when needed to avoid overcrowding. Citizens can also switch between the map and a list by either opening all the visible geonotes on the map in a list or by showing the geonotes in the list on the map. A map is shown as a reference when viewing a geonote. A search bar is available, and the search can include hashtags and place names to further filter the results. All geonotes can be rated with a star, flagged as inappropriate, and commented on by citizens in the annotation view while the annotation is presented on a map (Figure 9). The rating and flagging enable distributed content moderation. Profiles and annotation are enhanced with gamified profile avatars that are designed to promote interesting content. Citizens who share interesting geonotes acquire new predefined avatars according to a levelling system. A quality content provider will therefore be more distinguishable by others. The gamification utility of the artifact was not implemented, demonstrated, nor evaluated.

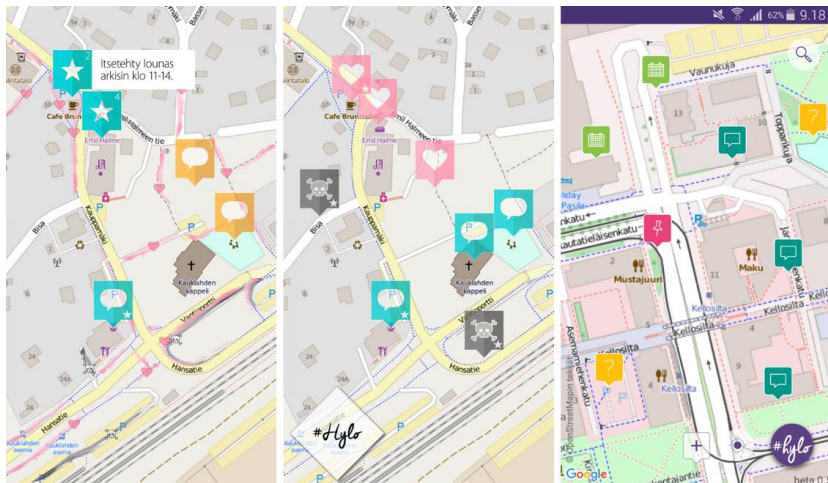


Figure 10. A mock-up, a web map prototype, and the finalised Android application of the #hylo artifact.

A location platform based on privacy by design called MyGeoTrust was used to preserve the privacy of citizens. The platform stores citizen profiles, the content shared by the community via the artifact, and the location tracks of the citizens. Privacy modes set by the citizen can be used to limit outside access to the content of the citizen, offering citizens complete control of their data. For example, citizen profiles are considered personal content while, geonotes shared on the citizen layer are considered public, given the citizen has consented to publishing the geonote. Technically, the interactions of the #hylo artifact and the MyGeoTrust artifact were the following (Figure 11). The MGT stack handles the location data and provides the location information, user authentication, and authorization for the #hylo app. The MGT stack sends the location information of the citizen to the MGT server according to the privacy mode selected by the citizen. On the server side, the #hylo server stores and transfers all the public data used in the #hylo app, such as the geonotes. Personal data from the #hylo app, such as the interests of the citizen in their profile, are passed on to the MGT server via the MGT API. Personal data requests are also done through the API.

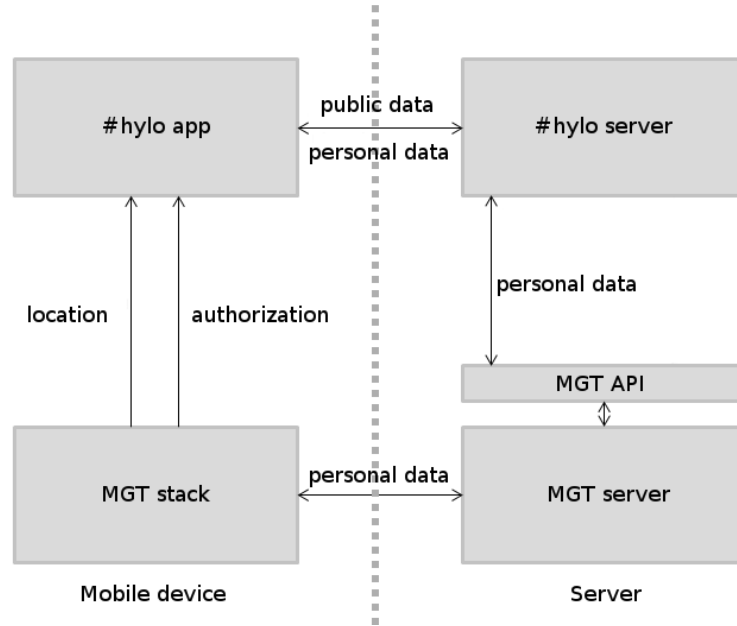


Figure 11. The #hylo artifact (#hylo app and #hylo server) and the MyGeoTrust artifact (MGT stack and MGT server) interactions.

4.3.3 Artifact demonstration

#hylo was demonstrated as a tool for students to use when completing a school assignment. To create suitable tasks for the students, a brainstorming workshop was conducted with five 13-years-old students, and two of their teachers. Based on brainstorming with the teenagers and interviews with the teachers, tasks such as “Look for signs of spring and mark them on the map”, were created. During the demonstration the shared content of the participants was documented. #hylo was demonstrated in five different schools with a total of 86 teenagers, aged between 13 and 14.

4.3.4 Evaluation of artifact

The evaluation of #hylo was conducted using #hylo mobile application during the demonstrations at the five schools. After a short introduction to #hylo, the students were given one and a half hours to complete a few tasks using #hylo. After completing the tasks near the school area, the students answered a questionnaire. In general, the students thought the assignment was fun. For exploring the content of #hylo, 49 out of 76 students (64%) preferred the map over the feed. Finding content shared by other students was considered easy: on a scale of 1 to 5 (1=very difficult, 5=very easy), the average was 3.6. When asked if the content shared by others was considered interesting, the average was 3.1. Thirty-four out of 83 (41%) answered they would go to a new place if the content was interesting to them and near to them, 37% said maybe, and 22% would not go. The majority (50 out of 81) could also use #hylo for something else other than school assignments.

Overall, the artifact promoted interest in visiting new areas in the demonstration. The evaluation showed that the artifact content was interesting, and the participants found #hylo useful. The artifact also demonstrated how to preserve user’s location privacy in a geosocial network.

4.4 Creation process of the Map Gretel artifact

For this artifact, the overall theme is that the success of different VGI activities together combined with increasing technological advances, have prompted national mapping agencies to consider the possibilities of using crowdsourced geographic information in topographic data collection. As a result, Map Gretel a social map service that supports a national mapping agency in data collection was created (Figure 12).

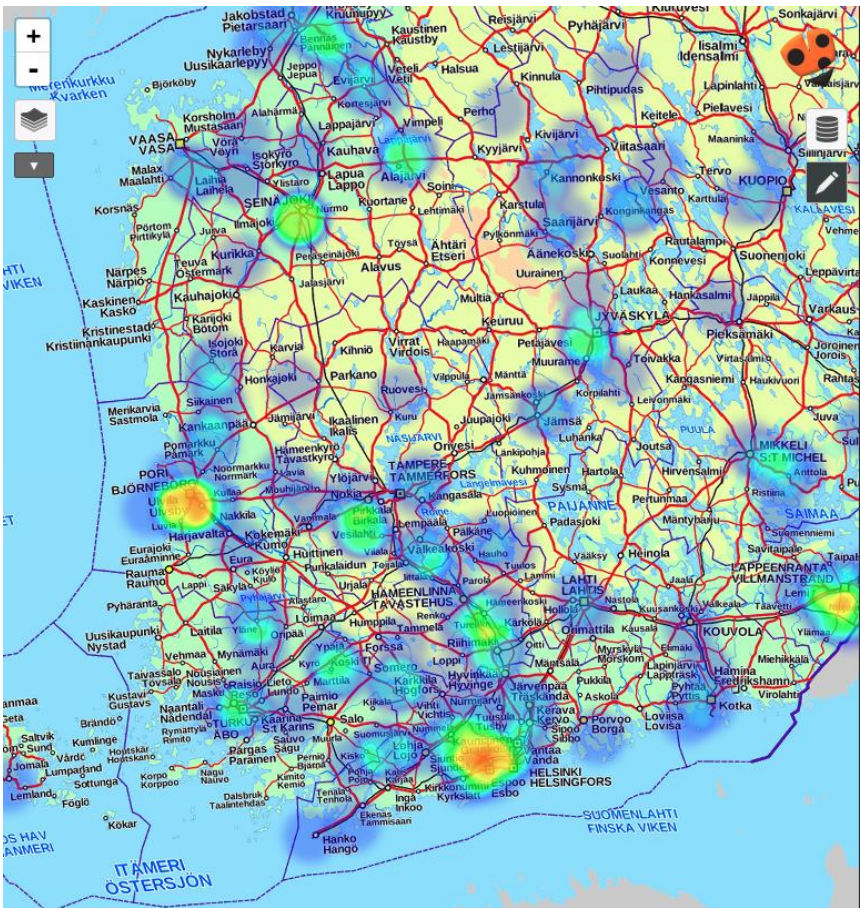


Figure 12. Map Gretel web map interface with a heatmap visualisation of crowdsourced content.

4.4.1 Problem and requirements

The problem elicited for this artifact is how an NMA can find more refined ways of employing VGI to achieve better-quality map data with fewer resources while

developing the relationship between the NMA and citizens. To further outline the problem, requirements for the artifact have been elicited – Table 7. The artifact is required to involve citizens in geospatial data collection to improve map data quality, decrease the need for resources required by the map data collection and develop the relationship between the NMA and citizens. The NMA topographic map as the background map is needed for referencing the crowdsourced content contributed by the citizens. For the citizens to be able to share and edit their features, a citizen layer is required to separate the background map and the crowdsourced content. The adaptation cost of the artifact needs to be low to capture a wider mapper audience. This requires a simpler than usual web map user interface, because the user base includes novice mappers. For mappers with more experience, advanced mapping tools are needed as they will provide more complete, accessible, and useful data. For the mappers to be more engaged and feel a sense of community, the use of social and gamification methods is needed. To summarise, the NMA needs a low barrier of entry and simple web map-based service for citizens to share geospatial data on a citizen layer.

Table 7. The key requirements, requirement types and rationales of the Map Gretel artifact.

Requirement	Type	Rationale
Citizens involved in geospatial data collection	Functional	Improve quality of map data; decrease resources needed for data collection; develop relationship between NMA and citizens
A background map with the NMA NTDB content	Environmental	A reference for the crowdsourced content contributed by the citizens is required.
Citizen layer	Functional	Enable citizens to share their features and edit features of others
Low adaptation cost	Functional, usability	Lower barrier of entry captures a wider mapper audience
Simple web map UI	Usability	User base also includes novice mappers
Advanced mapping tools	Functional	Need for more complete, accessible and useful data

4.4.2 Design and Development of artifact

To satisfy the requirements, the following design choices were made when designing and developing the artifact. The artifact was designed as a web map application to involve citizens in data collection. The adaptation cost was kept low by allowing anyone to register as a mapper with just an email address. The artifact has two modes: exploration and editing. The exploration mode is simpler (Figure 12), while the edit mode is more complex (Figure 13). A citizen layer was developed to allow the mappers to share features, edit their own features, and edit features shared by others (Figure 13). The citizen layer is on top of the topographic map that shows the current state of the NTDB. The user interface was kept as simple as possible to take novice mappers into account (Figure 13). When in edit mode, the user interface has an element for saving the changes made. More advanced mapping tools such as the ability for users to import their

GPX tracks were introduced to enable more complete, accessible, and useful data. A feature type could be chosen from thirty or more. The feature type list guides the citizens to contribute the kind of data in which the NMA is interested. The operational workflow of artifact consists of two phases: contributing and processing. There are therefore two types of actors in the artifact: mappers and operators. A mapper can assume the role of either creator or editor. Mappers can create or edit features shared by other mappers. Features shared by the mappers are stored on the citizen layer, from where an operator can process them. If accepted by the operator, the features shared by a mapper are transferred to the NTDB. Once the features are processed, they become part of the background map under the citizen layer (Figure 14).

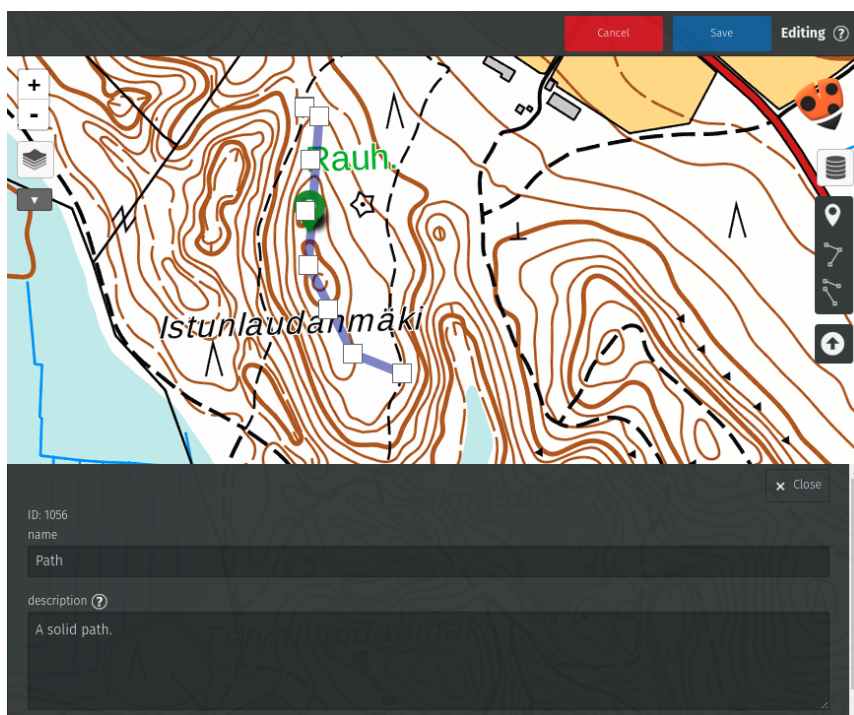


Figure 13. Citizens can share and edit features on a common citizen layer visible for all users of the Map Gretel artifact. Crowdsourcing is used to ameliorate the NMA topographic map. In edit mode, the user interface has an element to save changes, which is not present in the exploration mode.

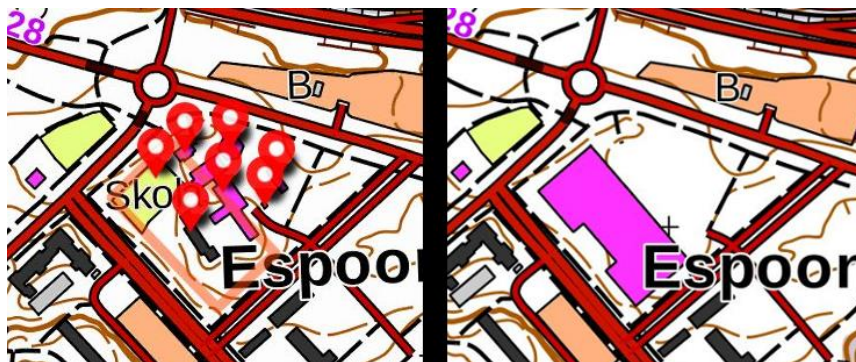


Figure 14. A before and after illustration of user contributions (on the left) of buildings that no longer exist and a vector feature of a new building. An operator processed and transferred the contributions to the national topographic database (NTDB) (on the right).

Social and gamification elements such as feature rating, feature commenting, comment rating, user profile, and user ranking, were designed to enhance the engagement of users and create a sense of community. The ranking of mappers is based on the number of contributed features, the number of highly rated comments, and comment upvotes by the citizens. The social and gamification utility of the artifact was not implemented, demonstrated, or evaluated.

4.4.3 Artifact demonstration

The pilot for the social map service was launched on 23 March 2017 for the whole of Finland. During the launch the pilot was promoted by NLS on their website and on their Twitter and Facebook accounts. The pilot was also covered in a few newspapers at the time. The pilot was available online for six months.

4.4.4 Evaluation of artifact

In the six months of operation, the Map Gretel pilot had more than 363 registered users, who contributed more than 950 features to the citizen layer. In comparison, the NMA receives roughly 500 error or change reports about map data annually through their form-based feedback system. Map features were edited 2,086 times in the artifact. The features were processed by 15 NMA operators who participated in the pilot. Forty-eight percent of the processed features were accepted by the operators. During the pilot, mappers could give feedback, which consisted mainly of bug reports and suggestions regarding functionality. After the pilot ended mapper and operator surveys were conducted. The mapper survey had 78 participants. Participants were asked how often they had visited the artifact. Fifty-four of the 78 respondents answered, “a few times” and 12 answered “often” or just “once”. Roughly 70% (54) of mappers responded that they had added features. Twenty-five percent of users found the features contributed by others useful. Concerning new functionality, 68% of respondents wanted a mobile application for sharing features. The operator survey had 8 participants from the 15 operators. The operators estimated that 10% of the contributions by

mappers were of low quality. They considered more than 60% of the contributions usable or useful. Three out of eight considered the processing of features laborious.

Overall, it was found that the artifact benefitted both citizens and NMAs. The NMA considered the quality of the artifact content high enough for their purposes. By utilising crowdsourcing in the artifact, citizens obtained a means to contribute and be involved in ameliorating maps. The artifact demonstrated how to create a social map service for supporting an NMA in data collection.

4.5 Scientific and empirical summary of the presented artifacts

The artifacts have been summarized from two perspectives catering both to a scientific – Table 8, and an empirical audience – Table 9. The scientific perspective follows the DSR methodological framework by presenting the problem, requirement summary, crowdsourcing approach, supporting approaches, key design elements, key usability-utility trade-offs, demonstration, and main evaluation methods and results.

Table 8. Properties of the three map-based artifacts with crowdsourced content in this study from a scientific point of view.

Scientific summary	TouchMaps	#hylo	Map Gretel
Artifact type	Instantiation	Instantiation	Instantiation
Description	An intuitive touch-based map installation for exploration in a public space	A geosocial network for sharing hyperlocal information on a map	A social web map service supporting a national mapping agency in ameliorating the basemap
Problem	How can citizens be encouraged to explore via a map-based artifact?	How can citizens be encouraged to share hyperlocal knowledge via a map-based artifact?	How can citizens be encouraged to participate in supporting NMAs in data collection via a map-based artifact?
Requirement summary	An intuitive touch-based map interface for exploring high-quality maps and sharing content.	An intuitive privacy-preserving mobile map interface for exploring, sharing, rating and discussing content.	A simple web map interface for sharing and exploring content motivated by gamification.
Crowdsourcing approach	Community-driven, contributory	Community-driven, collaborative	Community-driven, participatory
Supporting approaches	Social	Gamification Social Privacy by design	Gamification Social
Key design elements	Touch-based map interface, citizen layer, social annotation	Mobile map interface, citizen layer, social annotation	Web map interface, citizen layer, social and gamified annotation
Key usability-utility trade-offs	Touch-based installation instead of desktop. Navigation menu instead of text search. Multiple gestures to pan and zoom the map instead of just one. Map rotation disabled.	UI elements symbolised instead of text. One-press proximity- and current location-based search for map features instead of just a text search. Map features also presented as a list that can be sorted and filtered.	Easy email registration. UI elements symbolised instead of text.
Demonstration	Part of a public exhibition for leisure cyclists for a week and part of a nature centre exhibition.	Geosocial network mobile application used as a tool for completing school assignments.	Six-month pilot for a social web map service for collecting data for an NMA.
Key evaluation results	Participants considered the artifact a useful way to explore the map content. The artifact demonstrated how to create a simple user interface with intuitive, continuous and simultaneous gestures for map browsing while taking different users into account.	The artifact promoted interest in participants in visiting new areas. The participants considered the content interesting and the artifact useful. The artifact demonstrated how to create a privacy-preserving geosocial network.	The artifact benefitted both citizens and the NMA. The content quality suited the NMA. The participants obtained means to contribute and be involved through the utilisation of VGI. The artifact demonstrated how to support an NMA in data collection.

Table 9. Properties of the three map-based artifacts with crowdsourced content presented in this study from an empirical perspective.

Empirical summary	TouchMaps	#hylo	Map Gretel
Description	A touch-based map installation for exploring multiple high-quality maps	A mobile map application for sharing and commenting on map features	A web map for sharing features on a shared map
Platform	A map application for large touch screen installations	An android map application for mobile devices	A web map application for desktop web browsers
Primary use	Exploration via maps	Exploring and sharing of hyperlocal knowledge on a map	Refinement of a NMA topographic basemap
Key utility	touch map interface citizen layer content views	mobile map interface citizen layer content views annotation tools user profile	web map interface citizen layer content views annotation tools user profile
Map specific utility	Explore Place menu Comment on and rate content	Explore Retrieve annotations based on position or input List annotations Share content Comment on, rate, and flag annotations	Explore Import content Export content Share content Edit content of others
Background map content	Multiple custom maps	OpenStreetMap background map	NMA topographic basemap
Work operators	arrange, overlay, pan, zoom, search, retrieve	arrange, overlay, pan, zoom, filter, search, retrieve, re-symbolise, calculate	arrange, overlay, pan, zoom, filter, search, retrieve, calculate
Enabling operators	annotate	annotate, save	annotate, import, export save, edit
Crowdsourced content	Comments and ratings on reference map features (point type).	Map features citizens annotate, rate, and comment on (point type).	Map features citizens annotate, edit, and comment on (point, line, and polygon type).
Crowdsourced content properties	creator, ratings, comments	creator, title, description, category, ratings, comments	title, description, category, style
Privacy solutions		Privacy preserved via a privacy by design location framework	Profile anonymity

4.6 Key utility requirements and usability heuristics of a crowdsourced map-based artifact

A comparison of the scientific and empirical summary reveals similarities in the artifacts despite their being created on different platforms – Tables 8 and 9. Based on the comparison, generalised design requirements for crowdsourced

map-based artifact are introduced. In this generalised design, the citizens are motivated to create content by the artifact's usefulness. The target audience for all of them are citizens. The utility-usability trade-off can therefore be seen in the map interfaces of the artifacts favouring usability. In a map-based artifact for citizens, the user interface needs to be more intuitive than to include advanced functionality. This design choice is made to lower the barrier of entry and allow all citizens to participate. The user interfaces of all the artifacts strive to be as simple and easy to use as possible. Each artifact has a map interface with a citizen layer, in which the crowdsourced content is presented on top of a background map. The full-screen map interfaces have only the necessary operators such as pan, zoom, and search for exploration. All artifacts allow users to annotate the map to a varying degree, and this is the basis for the crowdsourced content creation in each artifact. Social utility is present in all three artifacts, because annotations can be rated and commented on in each. This allows the citizens to take part in the creation of the artifact content. Gamification is used in two of the artifacts to further motivate the citizens to contribute. The privacy solutions were based on the artifact content creation approach.

4.6.1 Utility requirements of crowdsourced map-based artifacts

The main utility requirements of crowdsourced map-based artifacts are a map user interface with simple map operators, a reference and a citizen layer to hold content, and gamified enabling map operators. This utility can be presented as user interface elements (Figure 15). General elements include the map view that can be used for exploring and searching both the reference and crowdsourced content of the artifact. Regarding the content delivery technology of the artifact, vector tiles and geojson can be used to efficiently deliver both reference and crowdsourced content, for example. The reference content can be presented on a reference layer, which requires a background map and optionally annotations, as in the TouchMaps artifact. Crowdsourcing requires an element for sharing content and a citizen layer to present the content. The citizen layer is also needed to separate the crowdsourced content from the reference content. A profile for the citizens, rating and commenting are social elements that are needed to enable gamification and social interaction.

Gamification elements can include leaderboards and ranks that are based on the social ratings or the amount of shared content. In the presented artifacts, enabling operators included utility for sharing, editing, rating, and commenting features. The enabling operators can be enhanced with gamification and social utility to further motivate citizens to create content. An example of gamifying crowdsourced content creation is to assign points for citizens when they share content and present this data on a leaderboard. This means that the number of annotations a citizen has made is stored server-side and can be queried for the purposes of leaderboards, for example. Enabling operators can also be extended with social utility such as allowing annotations to be rated and commented on by other citizens. This means having a rating and comment element in each an-

notation view. Social utility, such as user profiles, can be used to add more engaging gamification utility to the artifact, such as avatars that are earned through contributions.

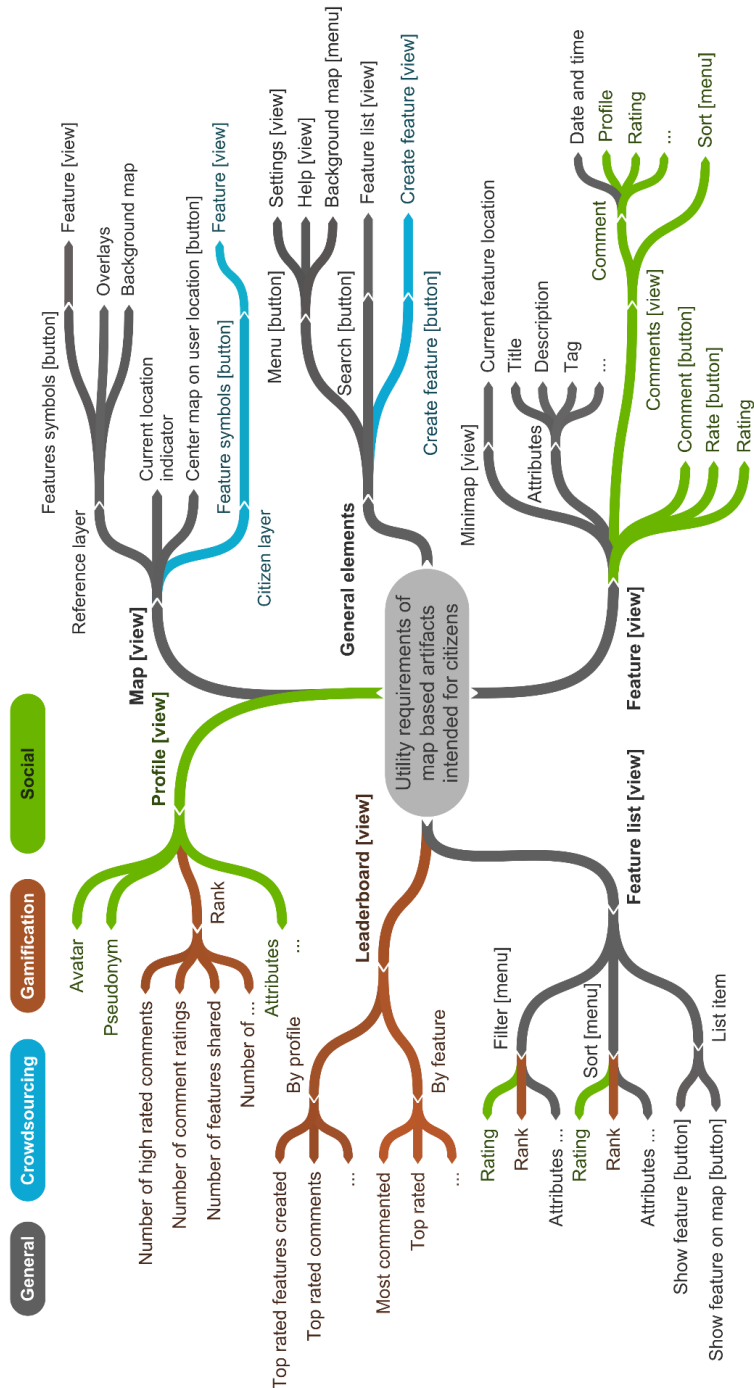


Figure 15. Utility requirements of crowdsourced map-based artifact with crowdsourced content categorised by the user interface elements: view, menu, and button. A map view, a feature view, a feature list view, and buttons are needed for general purposes. To enable crowdsourcing in the artifact, a button for sharing features and a citizen layer is required. To add gamification to the artifact, a leaderboard view is required for example. To make the artifact social, a profile view is required along with the ability for the citizens to comment on features and rate both features and comments.

4.6.2 Usability heuristics for crowdsourced map-based artifacts

The main usability requirements of crowdsourced map-based artifacts are an intuitive map interface and support for crowdsourced content creation (Figure 16). These usability heuristics for crowdsourced map-based artifact are based on the studies by Hennig (2016), Kuparinen et al. (2016) and the heuristics presented in the study of the TouchMaps artifact. These usability heuristics are categorised based on user, map, and interaction. An intuitive map interface makes the exploration of the content of the artifact easier for the citizens. An intuitive map interface for citizen maps is above all usable. The map is the primary way of conveying information, and as such, the user interface design should strive for minimal elements. For example, text in user interface elements can be replaced with symbols when feasible, as done in the TouchMaps, #hylo and Map Gretel artifacts (Figures 7, 10, 12, 13). The map itself should occupy most of the screen. This means only the most important map elements are visible. The important map elements such as main menu, centre map to current location of user, search, and create content, should be available when exploring the map and its content (Figure 10). This can mean hiding elements that are less used, for example, a search bar does not have to be fully visible all the time, if the button for it is available (Figure 10). Multiple ways of performing the same action, such as panning and zooming enhance many aspects of usability, as was found with the TouchMaps artifact.

The utility-usability trade-off of map-based artifacts with crowdsourced content should be set up to support citizens in content creation. An element for sharing content should therefore be visible on the map among the other central elements. The distinction between the reference content (e.g., background map) and the content created by citizens should be clear (Figure 13). Overcrowding is an issue when presenting the crowdsourced content which can be solved by clustering or a heatmap (Figure 12). The map inherently displays the location information in the location context, but other ways of presenting information should also be used. Lists can be used to filter and sort content. One important aspect of other ways of conveying information other than the map is to always have a link back to the map where the content is presented in the location context. For example, if a list of crowdsourced map content is sorted according to the highest-rated feature, it is natural that many will want to see where the feature is on the map in relation to other map features. The map context can also be presented at the same time as other content by adapting the user interface to show both, as done in the #hylo artifact (Figure 9).

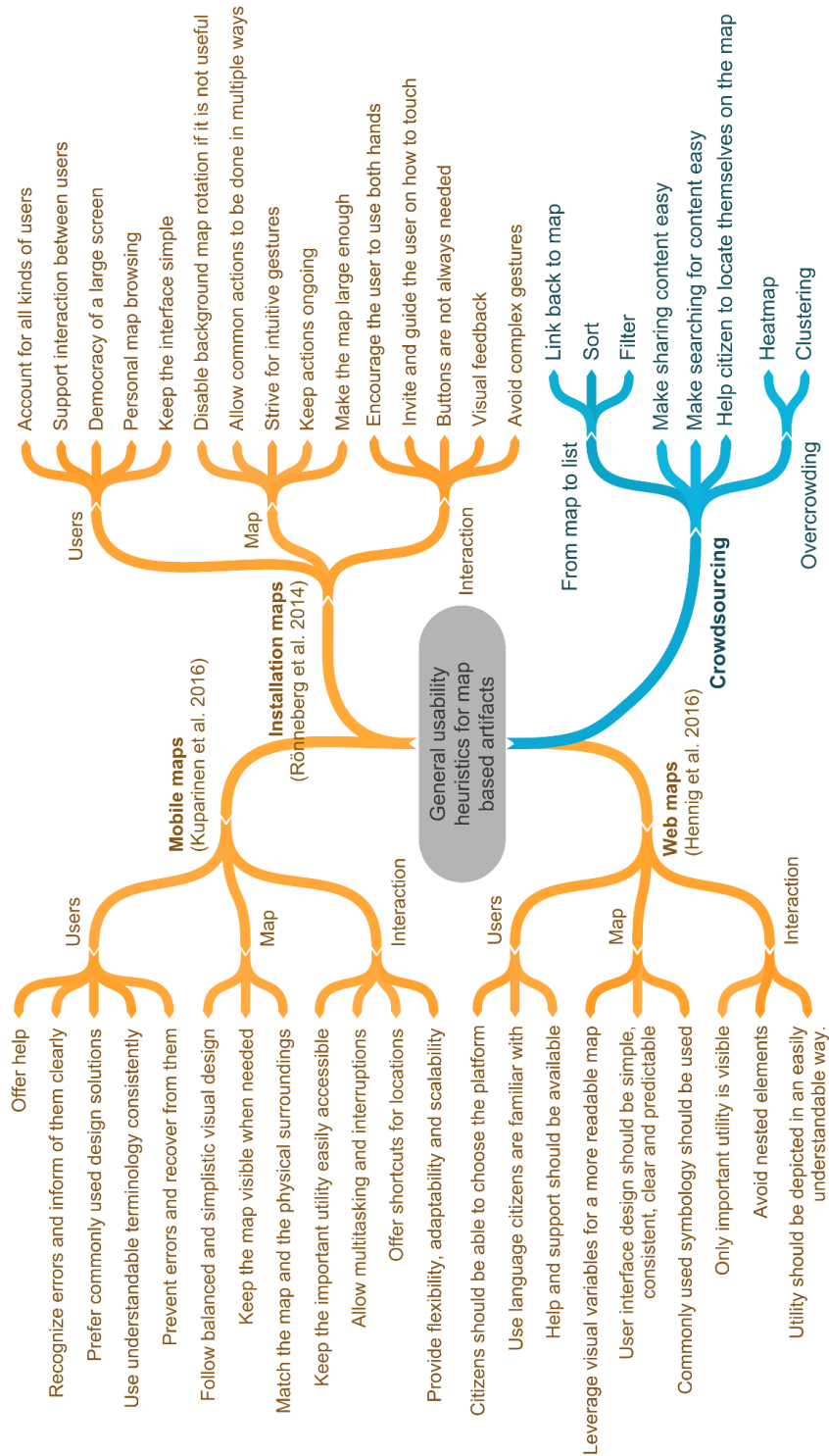


Figure 16. General usability heuristics of map-based artifacts by Hennig (2016), Kuparinen et al. (2016), and Rönneberg (2014).

4.7 The key requirements for creating crowdsourced content in a map-based artifact

The crowdsourcing approach presented here is based on the descriptions and comparison of the three artifacts presented earlier. The crowdsourcing approach for map-based artifacts relies on reference content to explore and use, community-driven crowdsourced content creation, citizen engagement using social and gamified elements, and the application of the privacy by design approach (Figure 17).

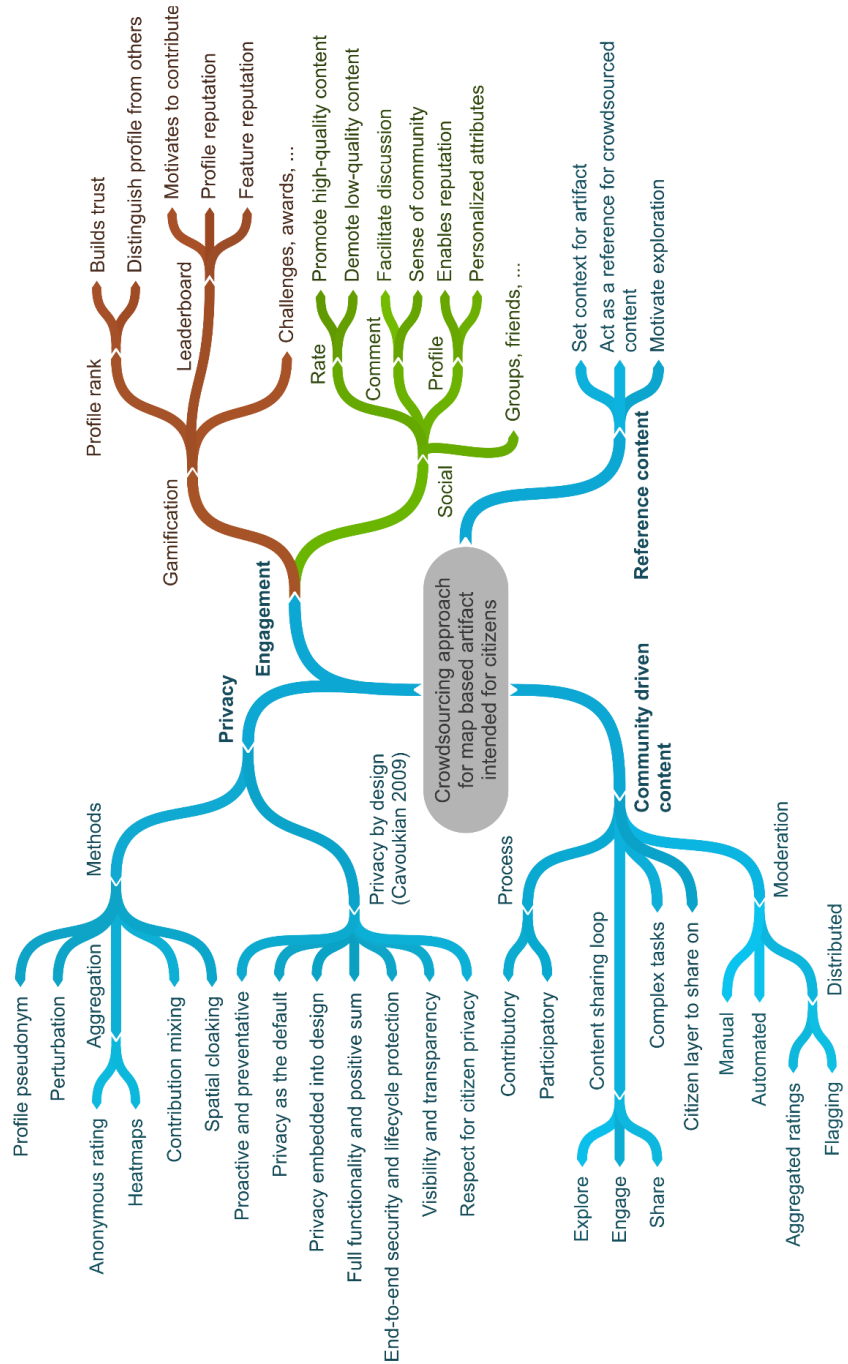


Figure 17. The approach for crowdsourcing in map-based artifacts is based on reference content, community-driven content creation, social and gamified engagement, and privacy by design.

4.7.1 Reference content to build on

The content that is created by the citizens via the crowdsourcing approach is built using the reference content. For the TouchMaps artifact focusing on exploration, the background maps offered citizens alternative map themes to explore, and the annotations presented points of interest to the citizens. For the #hylo artifact focusing on sharing hyperlocal knowledge, the OpenStreetMap background map offered the most up-to-date and small-scale information for citizens to share their hyperlocal content on. For the Map Gretel artifact focusing on ameliorating the NMA national topographic database, the national topographic map offered citizens a reference to share the crowdsourced content on. The reference content such as background maps and annotations set the artifact's context. The reference content should also motivate citizens by offering interesting and relevant high-quality content. In the case of the #hylo artifact, presenting the crowdsourced content on the background map was preferred to a simple list of the crowdsourced content.

4.7.2 Community-driven crowdsourced content creation

The crowdsourcing approach should be adapted according to the goals of the artifact and the needs of the citizen. The crowdsourcing approach for all three artifacts was voluntary in nature. For the TouchMaps artifact, the crowdsourcing only enabled citizens to rate and comment on existing points of interest on the map. As the focus of the artifact was on exploration, the crowdsourcing approach used was only contributory. For the #hylo and Map Gretel artifacts, the citizens were able to share their own geospatial content, which enabled more complex tasks for the citizens to perform. In the #hylo artifact, the approach was community-driven and collaborative, as citizens could annotate the map. In Map Gretel, the approach was also community-driven, but also participatory, as citizens could choose a category for their annotation from an extensive list not yet available in the reference content. The citizens could also edit the content created by others in addition to just sharing on the map and discussing it in comments.

The chosen community-driven crowdsourcing approach should offer citizens a means to share content with others. This will enable a content-sharing loop, in which citizens are motivated by the content of others to share their own content (Figure 18). This loop of sharing content was the base of the crowdsourcing approach in the #hylo artifact. When local knowledge is shared on the map by other citizens, the awareness and personal attachment of citizens to their local surroundings is increased. This then motivates the citizens to share their own local knowledge on a map continuing the loop. This content-sharing loop can be adapted to work on other crowdsourced map-based artifacts. The content citizens share should be presented on a citizen layer.

Manual, automatic, and distributed content moderation increase the quality of the content shared by citizens. Distributed content moderation can be based on citizens flagging content as inappropriate or rating content. Once the content reaches a threshold for either flags or rates, it can be hidden or removed. Highly

rated content can be distinguished in the artifact user interface by a star badge, for example. From the perspective of privacy, the approach should be based on the principles of privacy by design. The crowdsourcing should therefore be volunteer and transparent.

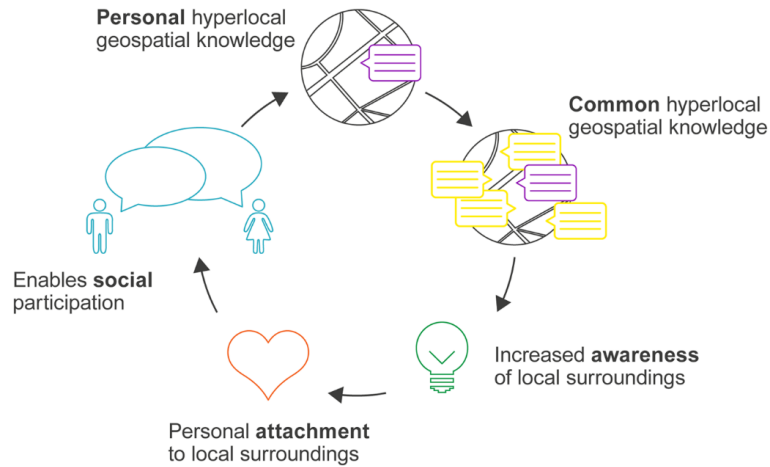


Figure 18. The crowdsourcing approach in the #hylo artefact was based on a content-sharing loop.

4.7.3 Engagement through social and gamification utility

Social utility and gamification can be used to further engage citizens to contribute. For the TouchMaps artifact, the social utility was implemented using Facebook ratings and commenting. This allowed the citizens to rate and comment on the reference annotations. For the #hylo artifact, annotations could be rated and commented on by citizens. This social utility was designed as the main way for citizens to interact. The avatars of the citizen profiles were gamified to promote interesting content. This was done by designing a levelling system for the profile avatars to promote quality content. A citizen who provided good content was more distinguishable via their avatar for other citizens. The levelling system was based on content ratings made by other citizens. For the Map Gretel artifact, the key aspects of social and gamification utility are citizen profiles, citizen rankings, feature rating, feature commenting, and feature confirming. The social utility of ratings and commenting were used as the basis of the gamification utility. This ranking system used annotation and annotation comment ratings to rank each profile. Applying social utility such as user profiles, rating, and comments, allows citizens to form and be a part of communities. The ratings and comments can also be used as the basis for gamification utility such as ranking and levelling. Content moderation can also be partly distributed. The ratings citizens assign to content created by others can also be used to support moderation. Content that has been flagged enough times or rated poorly can be automatically hidden for example.

4.7.4 Applying privacy by design to preserve privacy in crowdsourced map-based artifacts

As the citizens are also the content creators, the privacy by design approach should be followed as part of the artifact creation process. For the TouchMaps, artifact the content creation was handled through a Facebook account and therefore the privacy aspects followed the Facebook privacy settings of the citizen. For the #hylo artifact, a location platform based on the privacy by design approach called MyGeoTrust was used to preserve the privacy of citizens. Privacy modes could be used to limit outside access to the content of the citizen, offering citizens control of their content. The platform stored citizen profiles, the content they shared, and the location tracks. For the Map Gretel artifact, the content citizens shared was protected by profile anonymity. Annotations, feature ratings, and feature comments remained anonymous. The privacy by design approach has utility such as profile anonymity through pseudonyms, aggregation of content, and giving citizens control over their data, that are required when citizens use the enabling operators to create content. An example of giving citizens control of their data, is that the artifact can offer privacy controls for adjusting who has access to the content created by the citizens everyone, a select group, or just the content creator.

4.8 Result summary

In summary, when creating map-based artifacts with community-driven crowdsourced content for citizens, three main findings, regarding the creation process, the requirements of the map-based artifact and the crowdsourcing approach, emerge from the results of this thesis. First, the requirements and crowdsourcing approach are presented in Subsection 4.8.1 followed by the creation process in Subsection 4.8.2.

4.8.1 Key utility, usability, and crowdsourcing requirements for map-based artifacts

The results offer key requirements for utility and usability of crowdsourced map-based artifacts (Figure 19). The key utility of such map artifacts are **a background map** to explore and use as reference, **a citizen layer** to hold crowdsourced content, **simple map operators and gamified enabling operators** for exploring and creating crowdsourced content. As the target audience of the map-based artifacts are citizens in general, the usefulness of the artifact depends on how well the **utility-usability trade-off** has succeeded. The utility of the artifact should be therefore presented on **an intuitive map interface** with simple and usable utility for browsing the map.

The utility and usability are in place to support the **community-driven crowdsourcing** (Figure 19). Offering citizens the means to share content makes the map-based artifact more compelling and enables the **content sharing loop** for citizens to participate in. This community-driven crowdsourced content creation approach requires the citizens to be motivated, which can be realised through the **social and gamification utility**. As part of the artifact

content is created by the citizens, the **privacy by design approach** is to be followed during the entire creation process of the artifact.

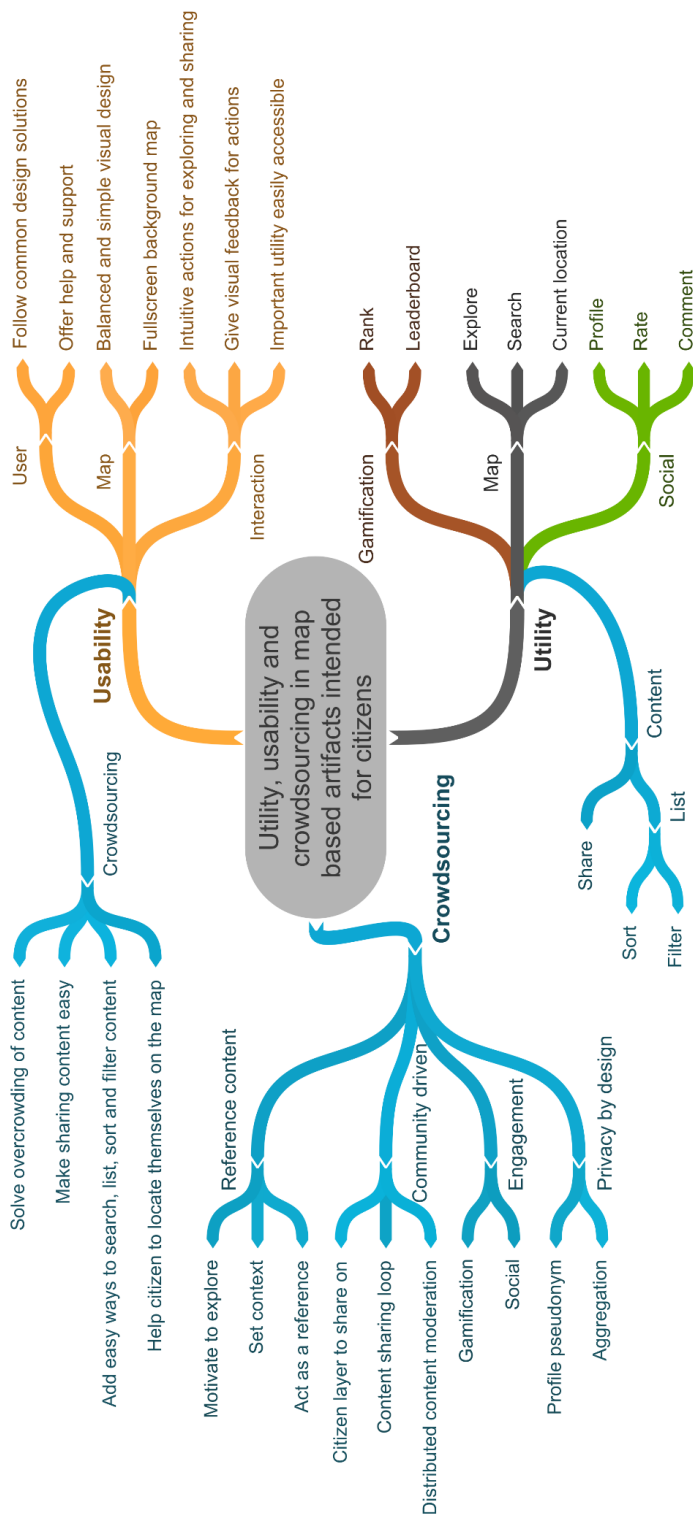


Figure 19. Utility requirements, usability heuristics, and crowdsourcing approach for map-based artifacts.

4.8.2 Customised design science research approach for crowdsourced map-based artifacts

The general DSR approach has been customised for the creation of crowdsourced map-based artifacts intended for citizens (Figure 20). This customised approach is iterative in the early phases from the problem phase to the development phase. For example, there can be unexpected difficulties developing a certain utility in the requirements, and they therefore need to be altered. In addition, the evaluation phase often produces results that need to be considered all the way through in the problem phase, which adds another iteration step to the process. Another form of iteration comes from the chosen methods used – for example, when a mock-up is used during the creation process. Using a mock-up can involve all the phases from problem to evaluation. Mock-ups can be used early to discover reactions of citizens to new concepts, as was done in the #hylo artifact with a group of students. The results from this focus group were used to further understand the problem, which led to the forming of new requirements and so on. As the creation process for crowdsourced map-based artifacts requires citizens to be involved early on, the process itself should be iterative.

In the problem phase, stakeholders and citizens should be involved early to understand the problem. A systematic literature review will form an adequate awareness of the problem, while root cause analysis will reveal the reasons why the problem exists. A study of similar artifacts and their properties will facilitate the definition of requirements. In the requirements phase, the central needs of the artifact such as an intuitive map interface, reference content, crowdsourcing, and engagement are further defined. The requirements stem from the problem phase, in which the needs of the citizens are studied.

In the design phase, choices are made based on the requirements. The platform or platforms are chosen for the artifact. Utility and the cartographic interaction primitives needed are included in the artifact design. The usability-utility trade-off is made for the designed utility. The usability heuristics to be followed are chosen. The content-sharing loop for motivating citizens to contribute and share is designed. The privacy by design approach is followed throughout the design process.

In the development phase, the design of the artifact is implemented. The development process should follow an established approach, such as agile or DevOps, and be iterative. Pair design and walkthroughs can be used to get rapid feedback both from fellow designers and from stakeholders and citizens. Mock-up and prototype versions of the artifact can be created before the finalised artifact. In addition to the finalised artifact, the mock-ups and prototypes can also be demonstrated and evaluated to acquire information more rapidly on the design choices, for example. Functional tests are a way to get feedback from stakeholders and citizens on some part of the artifact utility. Functional tests can be done for a mock-up and prototype or the finalised version of the artifact. The design rationales should be documented in this phase, because this will allow made design decisions to be used in later iteration cycles.

In the demonstration phase, the mock-up, prototype, or finalised artifact is given for citizens to use in a real-world situation. The demonstration is a good opportunity to evaluate the artifact. In the evaluation phase, the different versions of the artifact are evaluated. Naturalistic methods for evaluation should be favoured, because they are intended to involve stakeholders and citizens in the process. Methods such as action research, focus groups, and interviews are suitable for mock-ups and prototypes while action research, case studies, surveys, focus groups and observation are suitable for the finalised version of the artifact. A mixed method approach for evaluation is beneficial, because it allows the artifact to be analysed from multiple aspects. In the conclusion phase, knowledge acquired from the artifact creation process is documented, and the negative and positive outcomes of the evaluation are compared. The discovered heuristics are also documented. It is concluded whether the artifact solves the problem or not. Finally, the communication phase includes sharing the knowledge gathered in the previous phases.

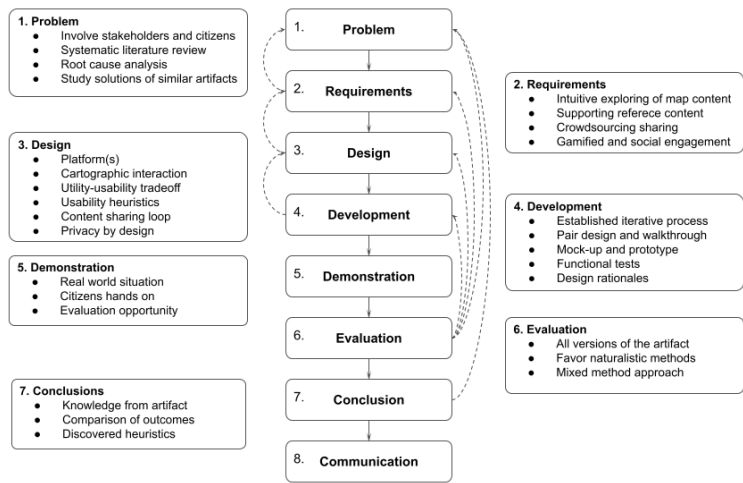


Figure 20. Design science research approach adapted for iteratively creating useful, gamified, and social map-based artifacts with privacy-preserving crowdsourced content intended for citizens.

5. Discussion

The aim of this dissertation was to identify how to create useful, gamified, and social map-based artifacts with privacy-preserving crowdsourced content intended for all citizens to use. The creation, evaluation, and comparison of these map-based artifacts produced findings that could be used to realise this aim. The results are discussed from the research question perspective regarding the creation process, usefulness, and crowdsourcing in map-based artifacts. The theoretical and empirical implications, as well as the research's reliability, validity and limitations are also considered. Finally, the future of this work is addressed.

5.1 Creating map-based artifacts for citizens using the design science research approach

The RQ1 of this dissertation was: *how can the design science research approach be applied to the creation process of crowdsourced map-based artifacts?* In answering RQ1, the creation process of three map-based artifacts for citizens was described using the design science research approach. The descriptions and comparisons of the artifacts reveal descriptive and prescriptive knowledge and general requirements for similar artifacts. This knowledge was used to supplement the DSR approach for map-based artifacts. When applying the DSR approach to crowdsourced map-based artifacts, the following should be considered. First, the problem identification phase helps the creator of the artifact to understand the problem to be solved (Johannesson 2014, Dresch 2015). Methods such as root cause analysis and a systematic literature review are useful (Johannesson 2014, Dresch et al. 2015) for gaining an understanding of the problem at hand. This helps the creator define the requirements of the artifact, which in turn facilitates the design and development phase. Second, the iterative nature of the DSR design process (Johannesson 2014) allows citizens to be involved early and improve the artifact after each phase. This is especially useful in the problem identification, development, and evaluation phase, because citizens are a great resource for the creator. Third, in the demonstration and evaluation phase, demonstrating the artifact in a real-world setting allows an evaluation to be performed with citizens (Johannesson 2014). The evaluations act as a basis for the creator to either continue the chosen design path or alter it, based on the evaluation results. This in turn makes design decisions easier to justify. In practice, the strengths of the DSR approach when creating map-based artifacts are the clearly defined phases that the creator can follow in the iterative

creation process. The creator of the artifact can rely on the approach, because it allows or even encourages “going back to the drawing board” to improve the design.

The main limitation of this dissertation is that the customised design science research approach for map-based artifacts has not been evaluated. However, demonstrations of the artifacts in real-world situations followed by evaluations with citizens were done for each artifact. This improves the validity and reliability of the results. The creation process of the artifacts did lack scientific rigour attached to some phases of DSR. A detailed problem definition by applying root cause analysis was not among the used methods, for example. The artifacts have been compared using the DSR approach as a tool to structure the descriptive and prescriptive knowledge they offer. However, this knowledge has limits because it has been gathered after the artifacts have been created. For example, the knowledge about an artifact problem definition is simply not available, if it has not been documented accordingly in that phase. Although the artifacts differ significantly regarding the interaction method used and content, the fact remains that map-based artifacts are not a homogenous group. Therefore, generalising the results from just three artifacts has limits. What may be a key requirement of one platform, may not be even feasible using another, for example. To gain a better understanding of the creation process, the presented DSR approach should be studied when applying it for multiple map-based artifacts.

5.2 Key usability requirements and usability heuristics of crowdsourced map-based artifacts

RQ2 of this dissertation was: *what are the key utility requirements and usability heuristics for crowdsourced map-based artifacts?* In answering RQ2, key requirements regarding utility and usability heuristics for map-based artifacts with crowdsourced content were examined. Based on these, the design of a crowdsourced map-based artifact was generalised. In short, these artifacts require an intuitive map interface that supports citizens in content creation. The utility-usability trade-off (Roth 2015) should be geared towards usability rather than utility. These map-based artifacts should therefore have simple utility that is useful for all citizens. To make the map interface intuitive, some elements of the utility need to be considered. Intuitive map interfaces should have simple user interface elements (Hennig et al. 2016) to avoid overwhelming the citizen with the artifact’s utility. However, community-driven crowdsourcing (Gómez-Barrón et al. 2016) requires utility for exploring and sharing content. This adds more complex utility such as content lists with sort and filter functionality, which may prove more difficult to make usable. Similarly, the sharing and retrieving of content requires utility. For example, a long press on the map can open sharing or create a proximity-based location search. The complexity of utility can be mitigated to an extent by gamification. If the utility of the artifact is presented in a game-like form, it can be more easily understood and used (Gómez-Barrón et al. 2019). The distinction between the reference content such as a background map and the citizen layer holding the crowdsourced content

should be clear. Citizens can thus rely on the reference content when sharing. The utility-usability trade-offs made in the three artifacts presented in this study should provide creators with practical examples such as replacing a text-based search with a navigation menu, presenting map features as a list that can be sorted and filtered, and replacing text UI elements with symbols.

All three of the artifacts presented in this study were evaluated and found to be useful by citizens. However, the evaluations did not cover all the requirements for all artifacts, as is intended in the DSR approach (Johannesson 2014). For the TouchMaps artifact, panning and zooming were evaluated, with promising results. The usability of #hylo and MapGretel artifacts were not evaluated on the same level of detail, because the focus in them was more on the creation of crowdsourced content. The utility and usability results presented in this study therefore rely on the existing literature (Hennig 2016, Kuparinen et al. 2016, Ricker & Roth 2018). To fully uncover the requirements of map-based artifacts for citizens, further studies are required, both with different platforms such as multiple mobile and desktop artifacts, and different designs such as comparing artifacts with and without gamification and social elements enabled.

5.3 Approach for crowdsourced content creation in map-based artifacts

The RQ3 of this dissertation was: *what are the key requirements for the crowdsourced content creation in map-based artifacts?* In answering RQ3, a crowdsourcing approach for content creation in map-based artifacts for citizens was presented to form part of a preliminary design of a general map-based artifact. The content should be built on background maps, the crowdsourcing method should be community-driven, engaging citizens should be based on gamified and social elements, and the creation process of the artifact should follow the privacy by design approach.

The need for a background map is the foundation that the community-driven crowdsourced content can be built on (Olteanu-Raimond 2017), because the citizens need context and a reliable reference to tie their contribution into. It is noteworthy here that OpenStreetMap is used as a background map in many map-based artifacts and is considered by many citizens as the official data. Although OSM is not official data, this mistaken impression is largely irrelevant for citizens. For places where OSM is of high quality, it may even exceed the quality and provide content that is unavailable in the official maps (Mooney & Minghini 2017). If citizens see individual trees marked on the reference layer (Ludwig & Zipf 2019), they are more inclined to share content at a similar level of detail. The information presented on the reference content therefore affects what is shared on the citizen layer. If the tree is not on the map, the citizen may not share about it.

The community-driven approach to crowdsourcing should be applied to compel citizens to contribute crowdsourced content. The crowd-based approach to crowdsourcing is more suitable for passive simple tasks of contributing, without interaction among citizens (Gómez-Barrón et al. 2019). However, the crowd-

based approach can be part of the crowdsourced approach along with the community-driven approach. The community-driven approach offers greater interaction among citizens and can be used to perform more complex tasks (Gómez-Barrón et al. 2016) such as having citizens share and edit map features, as was done in the #hylo artifact. The community-driven approach to crowdsourcing can be used as a foundation for engagement and motivation approaches.

An engagement approach can be applied to enrol, grow, and retain citizens (Gómez-Barrón et al. 2019) in map-based artifacts utilising crowdsourcing. Gamified and social elements can be included in the engagement approach to further motivate citizens. Gamification elements such as points and leaderboard (Martella et al. 2015) are relatively easy to implement, add relatively little complexity, yet can be effective (Martella et al. 2015, Sailer 2017, Olteanu-Raimond et al. 2017b). Social utility (Martella et al. 2019) can also be seen as similar to gamification, because it motivates citizens. The approval of other citizens – for example, gained from ratings or the relative number of comments, can be seen as a measure of how well a citizen is performing in the “social game” present in the map-based artifact. The addition of social utility therefore in a way adds a form of gamification to the artifact.

When a community-driven crowdsourcing approach is applied for map-based artifacts, preservation the citizens’ privacy should be accounted for. For example, the map-based artifact could allow citizens to share and comment on map features, while preserving their privacy through methods such as profile anonymity and aggregation. The application of privacy by design Cavoukian (2009) has many benefits such as citizens having control of the content they share and the artifact generating content that is beneficial for both the citizens and third parties.

5.4 Future work

The custom DSR approach presented in this study has not been applied to create a new artifact from the very beginning. Therefore, the custom DSR approach would benefit from applying it on a new artifact to further refine the approach and evaluate its usefulness. However, this work has begun during the end of this dissertation process. There is currently a project on-going in the National Land Survey of Finland where an artifact for crowdsourcing the refinement of cadastre border markers has been created using the custom DSR approach. This project presents an opportunity to continue the current research and refine the approach presented.

6. Conclusions

Map-based artifacts intended for citizens are now common days, but their creation process, usefulness, and crowdsourcing approach have not been studied systematically and extensively in combination. This dissertation presents a collection of studies dealing with creating crowdsourced map-based artifacts intended for citizens. The studies provided prescriptive knowledge that can be used to solve challenges that are relevant for creating crowdsourced map-based artifacts. The challenges are related to the creation process, usefulness, and crowdsourcing in map-based artifacts. Three main findings emerge as the conclusion of this research. First, the design science research approach can be adapted to support the creation process of crowdsourced map-based artifacts. Second, the crowdsourced map-based artifacts require specific utility requirements and usability heuristics to be useful. Third, a community-driven privacy-preserving crowdsourcing approach is required to enable an engaging content sharing loop to foster content creation. Combined these conclusions form a basis to create new crowdsourced map-based artifacts.

The creation process for crowdsourced map-based artifacts was adopted and customised from the general design science research approach. The scientific form associated with DSR constitutes a solid base to build on. From the early phases of the process, in which the problem and requirements are defined, scientific methods are used, such as a literature review and root cause analysis. However, the empirical aspects of the DSR approach, such as having a stronger emphasis on demonstrations in real situations with citizens involved, offer concrete ways to improve the design of the artifact. The iterative nature of the DSR approach is also a benefit that can assist in many phases of creation. Design decisions are easier to make when they are supported by scientific knowledge. The descriptive and prescriptive knowledge that forms along the developed artifact by following the DSR approach, can be reused later when creating new artifacts.

Usefulness is an important aspect of map-based artifacts utilising crowdsourcing. The utility requirements are a map interface for exploring and searching for content while showing the citizens current location. The citizen should be able to share content on the map and list, sort, and filter the content. Social elements such as a profile, rating, and commenting engage and enable gamified elements. Leaderboards, ranks, and other gamification elements can be based on both the sharing and social elements. A leaderboard for citizens with the most shared content can be supplemented with a leaderboard with most top-rated content

shared. For usability, the heuristics favour an intuitive map interface when citizens are involved. This means that the usability-utility trade-off is geared towards a simpler set of utility instead of complex functionality. An example of this, an intuitive map user interface the map should fill entire screen and only the most important utility should be visible in symbol form such as the elements for annotation and search. When applicable, an element should be available to centre the map to and show the citizen's current location. As crowdsourced content easily becomes overcrowded, available methods should be used to present the content more informatively such as using clustering and heatmaps.

The crowdsourcing approach for map-based artifacts relies on four pillars. First, reference content is required to build on. This means that the background map should be informative to support content creation by acting as a reference, while being interesting to motivate exploration. Second, crowdsourcing approach should be community-driven. Citizens are engaged actively with high interaction between citizens and can perform complex tasks. The community-driven crowdsourcing approach enables a content-sharing loop, in which citizens are motivated to share content by content created by others. As an example of the more complex tasks this approach enables, citizens can also improve the quality of the content by participating in distributed content moderation. Third, citizens can be further engaged by adding social and gamification elements to the artifact. Finally, to preserve the privacy of citizens, the privacy by design approach should be followed from the beginning of the creation process.

This dissertation has three general limitations related to the design science research approach, usefulness, and crowdsourcing. The main limitation of the customised DSR approach for map-based artifacts is that it has not been evaluated. Adapting the DSR approach to map-based artifacts is also not straightforward as it is by nature general and does not consider the issues related with map-based artifacts utilising crowdsourcing. However, the general DSR approach is sound according to the literature. This should also carry over to adaptations for more specific fields. The fact remains, that the customised DSR approach should be applied to creating new crowdsourced map-based artifacts and evaluated. The utility requirements and usability heuristic are also more general than specific and have only partly been evaluated in the presented artifacts. More specific heuristics will probably be available when such artifacts are studied further. As for the community-driven crowdsourcing approach, the main limitation is that it has only partly been implemented and evaluated. The crowdsourcing approach as a whole has not been therefore applied in map-based artifacts utilising crowdsourcing. However, crowdsourcing and its supporting social and gamification elements are based on the literature presented in this study. The community-driven crowdsourcing approach is just a remix of existing concepts. The application of the crowdsourcing approach requires further study, because the mixing of gamification and social elements can have unexpected results, for example. The custom DSR approach would also benefit from further study.

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