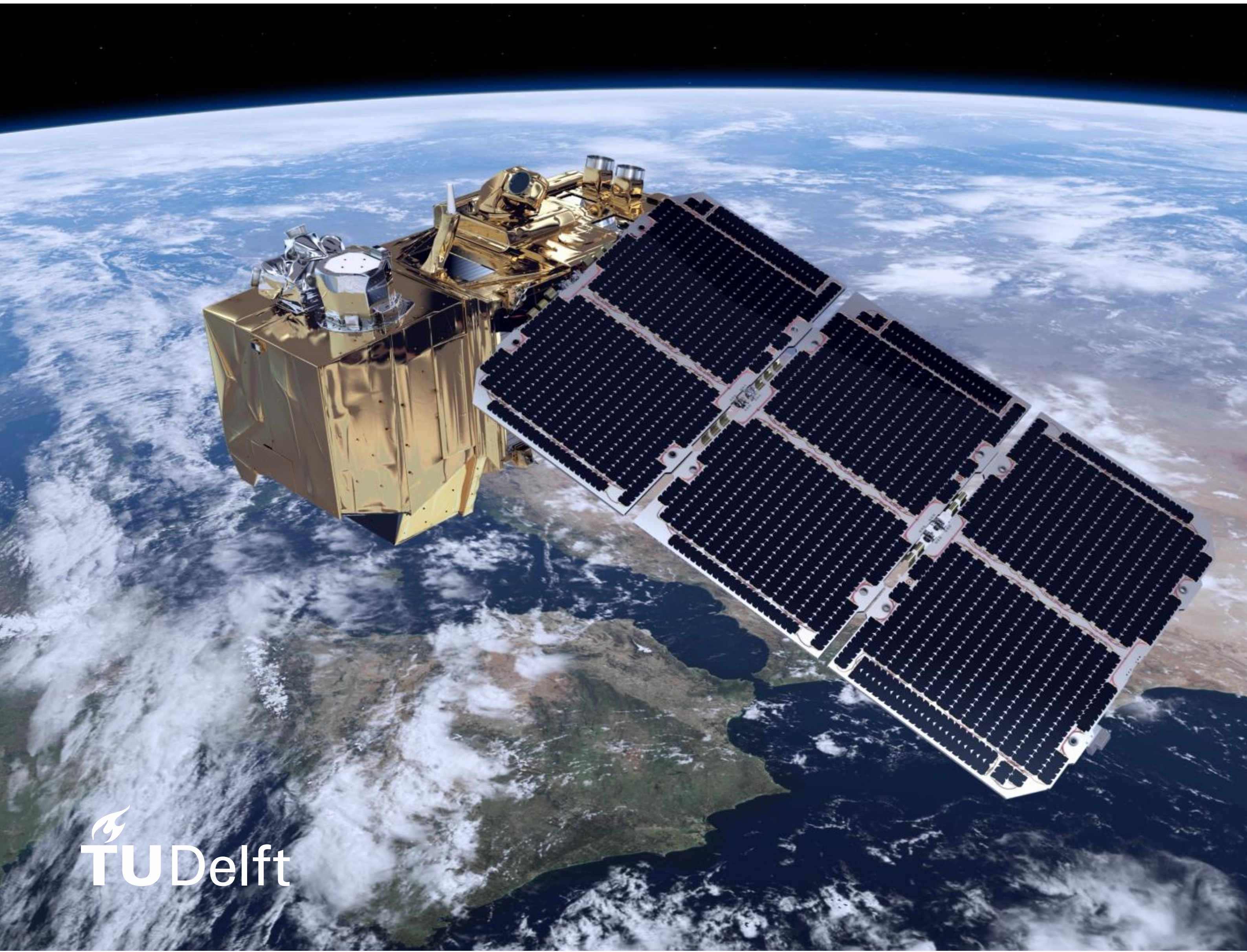
Viable Service Design Method for Earth Observation Applications

Developing a method for the design of viable services for applications using on big and open earth observation data as a resource

Stephan Kool



TU Delft

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Viable Service Design Method for Earth Observation Applications

Developing a method for the design of viable services for earth observation applications based on big and open earth observation data

By

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Terminology

Table 1: Terminology used in this document

Term	Description
Big data	Data is considered to be big data when it satisfies the criteria of volume, velocity and variety and may have latent value or issues with veracity (Rodríguez-Mazahua et al., 2016), see also section: 2.4 Big data.
Business Model	A business model is a representation of the concepts relevant to the provision of value to the customer and the retention of value by the provider (Bouwman & Fielt, 2008; Chesbrough & Rosenbloom, 2002). A plan on how to technically realise a service together with a business model that results in acceptable provision and retention of value is a viable service (Bouwman & Fielt, 2008).
Clipping	Clipping is the process of excluding non-relevant geographical locations of a set of earth observation data to obtain a smaller, more focused set. This is common practice in order to reduce the amount of data and computation time since a typical image set can span several hundreds of square kilometres, whilst only a part of this surface is needed for analysis (information obtained through case interviews).
Earth observation data	Earth observation data are data about the atmosphere and surface of the earth and is generally used to refer to satellite images of the earth (Koubarakis et al., 2016; Sutherland, Cameron, & Crawley, 2012; Wulder & Coops, 2014)
Feasible service	A service is feasible whenever it is technically and practically possible to perform the service (Chesbrough & Rosenbloom, 2002).
Open data	Open data is data that is both freely accessible and freely usable (Berners-Lee, 2009; Bonazzi & Liu, 2015; Janssen, Charalabidis, & Zuiderwijk, 2012).
Service	A service is the generally intangible result of a series of processes which apply specialized knowledge aimed at providing a form of benefit to someone who also participated in the processes but receives no ownership of anything physical and consumes the benefit the instant it is created (Bouwman & Fielt, 2008; Edvardsson & Olsson, 1996; Fitzsimmons, Fitzsimmons, & Bordoloi, 2008; Shostack, 1982; Vargo & Lusch, 2004; Williams, Chatterjee, & Rossi, 2008)
Viable service	A service is viable when all stakeholders involved in the network of service provision, including the client and user, have sufficient incentives to continue the service provision (Sharma & Gutiérrez, 2010). We will consider service feasibility a prerequisite for service viability (Chesbrough & Rosenbloom, 2002).

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After a long period of finding the right focus of research, as well as a lot of hard work only to reach a dead end and throwing parts away, the puzzle finally fits together and held up to scrutiny.

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I dedicate this thesis to my father, whose death I am still mourning. The accomplishment of graduation is also in part thanks to the hard work of my parents. An empty seat at my defence reminds me that I will not be able to share this accomplishment with my father.

Yours sincerely,

Stephan Kool

Delft, December 29th, 2017

Executive Summary

The publicly funded ESA Copernicus and NASA Landsat earth observation programs are publishing their data as open data in the promise of 30 billion euro of financial benefit for the EU as well as 50.000 new jobs, both by 2023. The move by these two space agencies fits in a larger pattern of 'new space', in which the launch and exploitation of satellites are moved from national agencies to private commercial stakeholders. The data offered by ESA and NASA are published as open data intended for reuse with the objective to create viable value-adding earth observation services, i.e. services which use big and open earth observation as a resource for analytics and provide incentives for all participants, including the client and user, to continue the service provision. Furthermore, the earth observation data are big data, as it satisfies the criteria of high volume, variety and velocity increasing the effort required for handling the data. Even though the market for value-adding earth observation services is growing and has the potential to become the most important market in the whole earth observation value chain from rocket to service, the initial promises of the release of the data are not going to be accomplished at the current pace.

Within searched academic literature and during conversations with practitioners, the lack of a structured approach to creating these viable value-adding services has been observed. Furthermore, the research articles on this topic are very much technology-oriented, with only very few articles invoking the interests of stakeholders to make a service design viable. And none of these followed a method for creating the service. This thesis addresses the lack of such a method for the creation of viable services using big and open earth observation data as a resource. Specifically, four knowledge gaps are identified: The first and second knowledge gaps concerned the lack of viable services which used a structured method for their design in the academic literature of respectively the narrow focus area of big and open earth observation data as well as in the larger area of earth observations which includes the previous narrow focus area. The third knowledge gap concerns the lack of factors of big and open earth observation data which influence the viability of a service design within the searched academic literature and the fourth concerns the actual lack of a structured method to guide the design of viable services which use big and open earth observation data as a resource. Together, these knowledge gaps lead to the formulation of the following research objective: "to design a method targeted at service providers for the creation of viable services which use big and open earth observation data as a resource." The artefact which is developed is a method which guides a service designer through the process of creating a viable service. Following the method results in creating a service design which is both feasible, i.e. technologically possible, and viable, i.e. provides sufficient incentives for all stakeholders involved to carry on its provision. The approach for structuring the creation of the method is the design science research approach for information systems. The demarcation of the problem is the first activity within this approach, and it uses a structured literature review as well unstructured explorative interviews. This is followed by a literature review on influencing factors, using only a structured literature review as a research method. The requirements gathering activity employs a case study method, in which participant-observations and interviews are used for information gathering within three cases. Then, creative methods are used in the design activity to create the artefact. For the following demonstration of the artefact, a case study is again used. Finally, for the evaluation of the artefact a survey based on the combined UTAUT-ECT theory and observations are used to evaluate whether the artefact attains its objectives, and improvements are suggested based on the evaluation and the demonstration. During this research, the author was a research intern at CGI Netherlands in the Space, Defence and Intelligence department, which allowed for rich observations and access to cases.

The result is the SIMEO-STOF method consisting of five phases. It combines the Service Innovation Method for Earth Observation (SIMEO) with the STOF model tailored for the earth observation domain. The first phase guides a designer through the process of finding together with a client a new service idea based on the current capabilities of earth observation analytics and the business processes of the client. Linking the earth observation capabilities to the limitations of current earth observation data supply allows for the rapid exclusion of unfeasible or unviable ideas. Any ideas that pass this initial set of limitations can proceed to the second phase. In this service domain, essential aspects of the value proposition are defined. This is followed by the technology phase, where principles of security and big data computing are set as well as a first architecture of the IT systems. Then, acquisition of external resources and inter-organizational relations are discussed in the organizational phase. Finally, the amount and form of value retained by the service provider are discussed in the financial phase. As a demonstration, the artefact is applied to the case of a crude and refined oil transhipment provider in the harbour of Rotterdam. The result of the application is a service design which is most likely to be viable, considering some issues still need resolving. Whilst not being definitively viable, the identification of issues which require resolution to achieve viability is an outcome which gets as close as possible to a viable design.

The artefact is evaluated for internal and external validity, respectively whether it fulfils the quality requirements and whether it fulfils its objective. Both were included in a survey held amongst employees of a service providing company interested in the use of the SIMEO-STOF method. Whilst the limited number of responses did not allow for any statistical analysis, the descriptive statistics and observations allowed for the concussion of a generally positive evaluation. Measured by the attitude towards using the SIMEO-STOF method, the method fulfils its objective of facilitating the creation of viable services which use big and open earth observation data as a resource. Whilst there is a mixed response to the quality requirements, observations indicate that part of these can be explained by different levels of expectation. Some participants thought of a future use for the artefact and judged the quality requirement based on this instead of the actual objective.

In terms of academic contributions, this research contributes to all four identified knowledge gaps. Foremost, it provides a viable service design method in form of the SIMEO-STOF method. This extends the service design literature to the application domain of earth observations, which has not previously been viewed from this perspective. Furthermore, factors of big and open earth observation data that contribute to the understanding of its effects on viable service design have been identified, in direct response to a further knowledge gap. Ultimately, the result of the SIMEO-STOF method demonstration is a viable service design created with a structured method, which is a contribution to the first and second knowledge gaps. In terms of societal contributions, the SIEMO-STOF method may accelerate growth in the ‘value-added EO services’ market, not only allowing service providers to more efficiently and effectively design viable service and create value, it may also lead to increased market growth on the suppliers side and an argument for open data publishers for the value of their activities. Though the use of the SIMEO-STOF method, EO service providers may be able to achieve the expected breakthrough of EO services within the broader society, which is one of the objectives of the ESA open data portal.

One of the principal limitations of this research comes from the choice of case study as the main research method, which limits the generality of the results. This is valid for the environment form which requirements are gathered, the type of data used and the design perspective of a service provider which is taken. The author suggests further research to include cases which cover aspects previously not included, for example, a business to consumer service, non-satellite earth observation data, and the inclusion of cases from different service providers. Another important limitation concerns the novel application of the UTAUT-ECT theory in a novel wats, including to an information system which is not a practical implementation of a technology but a method. Combined with the reduced number of respondents in the survey, the UTAUT-ECT-model adapted from theory for this research could not be tested statistically. Future research could focus on repeating the novel application of the theory with sufficient respondents to allow for validation of its application.

The objective of this research is the design of a method targeted at service providers for the creation of viable services which use big and open earth observation data as a resource. Considering the successful demonstration, and the generally positive evaluation of the SIMEO-STOF method, the author considers this objective to be attained.

Keywords: big data; open data; earth observation; big and open earth observation data; viable service; viable service design; service-dominant perspective.

1 Introduction and Problem Definition

1.1 Introduction

We live in an age where more and more devices are collecting data every day about our surroundings and about our activities. We are continuously able to measure our locations, the temperature around us, noise levels, traffic and the composition of the Earth's atmosphere as well as taking pictures of the Earth from space. As technology advances and space travel is commercialized, the threshold to launch a satellite is drastically reduced, granting access to launch microsatellites into space to many more stakeholders, which in turn allows the collection of more data about the earth (Hayward, 2017). The publicly funded ESA Copernicus and NASA Landsat earth observation programs are publishing their data as open data (Wulder & Coops, 2014) in the promise of 30 billion euros of financial benefit for the EU as well as 50.000 new jobs, both by 2023 (ESA, 2015). The creation of innovative services, a breakthrough in the use of satellites by the general public and the increased tax returns, as a result, are explicit goals of the NASA Landsat and ESA Copernicus projects (ESA, 2015; Sawyer, 2012; Sutherland et al., 2012; Wulder & Coops, 2014). Service providers are continuing to create "value-adding EO services" (Denis et al., 2017, p. 429), i.e. services that use Earth observation data as a resource for the benefit of another stakeholder, in what has the potential to become the most important market in the Earth observation value chain (Denis et al., 2017). Yet it is unlikely the goals of value creation will be fulfilled in the current state of affairs, according to a recent study commissioned by the European Commission (PWC, 2016).

The availability of big and open Earth observation data, especially satellite imagery and geo-coded sentinel data, has allowed for the development of data analysis tools that take advantage of it. The examples of such feasibility studies are numerous, from measuring the snow coverage on a frozen lake (Kadlec, Miller, & Ames, 2016), to measuring the type and density of vegetation on an agricultural field (Karmas, Tzotsos, & Karantzalos, 2016) to measuring the amount of algae in a water surface (Karmas et al., 2016). Even more potentially valuable applications arise when combining Earth observation data with other data, such as meteorological ground stations, weather balloons, ocean buoys (Tsinganos, Gerasopoulos, Keramitsoglou, Pirrone, & Team, 2017) or even data collected by unmanned aircraft, through social media (Denis et al., 2017; Mathieu et al., 2017) or by internet of things (IoT) devices (Bach et al., 2010) (See also Appendix A: Table of Earth observation applications in literature). However, the number of viable commercial services based on these Earth observation applications that use the big and open Earth observation data is limited as of yet.

Open data, such as the Copernicus and Landsat data, are data published under a licence which allows reuse without restrictions (Jaakkola, Mäkinen, & Eteläaho, 2014; Janssen et al., 2012). It has gained attention in the public sector, where the data gathering is already funded through public means and the release of this information is expected to provide further public benefits, such as increased transparency, more participation in government and the creation of new and innovative commercial services (Attard, Orlandi, & Auer, 2016a, 2016c; Janssen et al., 2012). However, making use of the potential benefits of open data requires more than just publishing the data. Usage requires understanding the potential and risks, as well as the specialist technical and statistical skills to handle the data (Janssen et al., 2012). The lack of evidence of value creation in open data poses a threat to open data initiatives like the Copernicus and Landsat programs. It could lead to cutting public funding without which these initiatives would not exist and the uncertainty of the continuity of the open data initiatives reduces the likelihood of companies willing to create services based on the data, which in turn reduces the value creation (Jetzek, 2017; Zuiderwijk & Cligge, 2016). Adding to the complexity of the usage is that the open earth observation data from the Copernicus and Landsat programs also qualify as big data. Big data is data which satisfies at least the three criteria of high volume, high variety and high velocity (Gartner, 2013; IBM, 2008; Sagiroglu & Sinanc, 2013). Big data requires, similarly to open data, the technical and statistical knowledge as well as financial and specialized computational resources like high-capacity cloud infrastructure and software (Rodríguez-Mazahua et al., 2016). Evidence of commercial value creation with open data is mostly anecdotal (Foulonneau, Martin, & Turki, 2014; Susha, Zuiderwijk, Janssen, & Grönlund, 2015), as is the creation of value with big data (Gupta & George, 2016; Ohlhorst, 2013).

From a service-dominant logic perspective, economic value is created through the exchange of services between stakeholders (Vargo & Lusch, 2004). In order for such an exchange to be successful, it needs to be practically possible, i.e. "feasible", and all stakeholders involved need to have sufficient incentives to provide or continue the exchange, making the service viable (Bouwman & Fielt, 2008; Chesbrough & Rosenbloom, 2002; Sharma & Gutiérrez, 2010). When considering the feasibility and viability of a service, it is important to consider the context a service operates in. This is because only application of the service offering (e.g. 'drill a hole') within a context (e.g. 'in this wall') provides value for the customer, and thus the incentives for service provision (El Sawy & Pereira, 2013). The characteristics of the context of the service, i.e. the application domain, shape the design choices of service viability and feasibility (De Reuver, Bouwman, & De Koning, 2008). In other words, a technology which has been developed still needs a business model to unlock the latent value of the technology by applying it to a context with its own logic of value creation (Chesbrough & Rosenbloom, 2002). Viable and feasible service design is thus both technical architecture design as well as a business model design (Bouwman & Fielt, 2008; Chesbrough & Rosenbloom, 2002). As detailed in the next section, a method guiding service designers through the process of creating a feasible and viable service for earth observation applications considering the characteristics of big and open earth observation data has not been encountered in searches as of yet.

In summary, earth observation data are opened to the public in the pursuit of new, innovative services. These services should result in a breakthrough in the use of satellite data by the general public as well as causing economic growth. Within academic literature, the technology of what is possible with these big and open earth observation data is constantly demonstrated, yet as of now, viable services based on these technologies are the exception and no method for their design has been found.

1.2 Problem Demarcation

The problem demarcation section further encloses the problem by precisely defining the issue at hand. This results in a set of explicit knowledge gaps which are positioned in order to achieve a problem statement. The main research method is a structured literature review, which is explained in the first subsection together with the used keywords for this search. The literature review focusses on the application domain of earth observation, and within this domain, a search for viable services is performed. The results of the search are presented in the second subsection. In addition to the structured literature review, explorative interviews have been conducted at CGI, a service consulting, integration and provision company which has the objective to offer services based in big and open earth observation data. Finally, based on the results of the search and the trends and issues proposed in the introduction, the knowledge gaps are formulated in the last subsection (1.2.5) which will be used in section 1.3 to define the problem and objective of this research.

1.2.1 Structured literature review approach

The structured literature review is a methodological search of the scientific literature in order to gain an understanding of the topic and its current state of research (Hart, 1998). The approach for reviewing literature in this thesis is based on Hart (1998) and Machi and McEvoy (2009) and by performing the literature review in a structured manner, the presence, and especially the absence of topics within research fields can be identified in a consistent manner.

Hart (1998) is the more dated approach when it comes to tools and search approaches, being written before the internet and digital search systems were popular in science. However, it does provide a strong background and explains why a literature review is important in the research as a whole. Machi and McEvoy (2009) provide a step by step approach which uses more modern and digital search tools. Their approach uses 6 steps: topic selection, literature search, argument development, literature survey, literature critique and writing the review (Machi & McEvoy, 2009, p. 5). The search process of the review is depicted in Figure 1 and takes as input keywords and search engine settings and will be entered in specified search engines. When the keywords produce a set of articles which is reasonable in size (i.e. less than 100 articles), the titles are scanned for relevancy. When the titles appear not well-related to the research topic, keywords or search settings can be adjusted. When the titles do appear to be relevant, the abstracts of the articles are read. When the abstract also appears relevant, the article citation is saved to the reference software and the full article is downloaded and read. The relevance of both title and abstract is judged on whether the article contains elements that could contribute to the answering of the research question. Once a full reading of the article took place, a backward and forward search is performed. The backward search serves the purpose of finding original sources and ideas, whilst the forward search could provide further developments of the concepts discussed in the literature (Hart, 1998). The titles of these articles in this search are again scanned and relevant abstracts read, resulting in looping the previously described process. The process stops once the researcher has sufficient material to answer the research question.

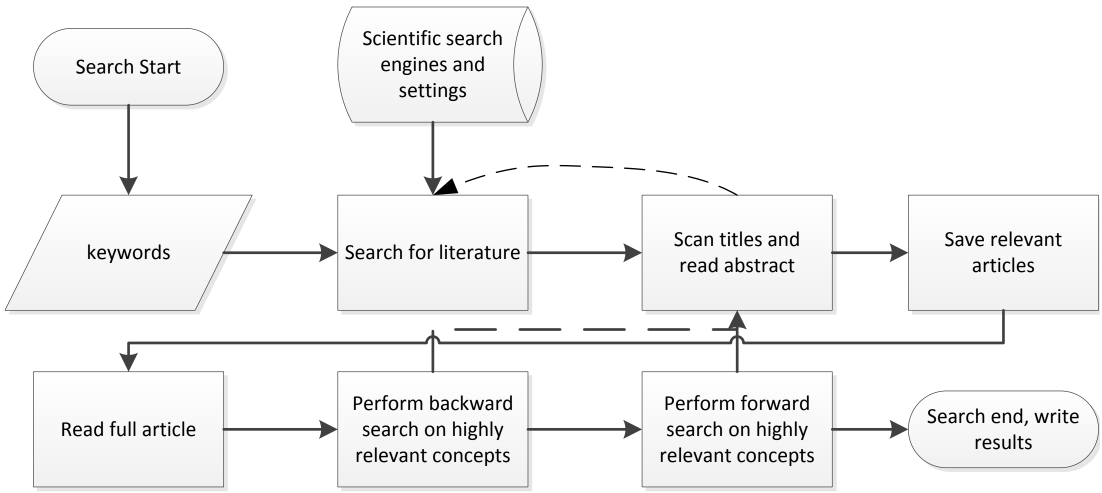
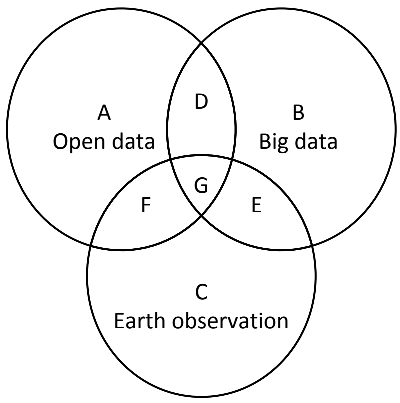


Figure 1: Literature review search process based on Hart (1998); Machi and McEvoy (2009)

1.2.2 Focus of the literature search

The focus of this research is on viable services based on earth observation applications which use big and open earth observation data. The Venn-diagram in Figure 2 illustrates the different areas of research of open data, big data and earth observation. The research area of earth observation is a broad domain entailing geo-data collection and processing, as well as developing tools for its analysis. Examples of academic journals within this area are the Journal of Applied Earth Observation and Geoinformation[1], the IEEE Geoscience and Remote Sensing Magazine[2] and the ISPRS International Journal of Geo-Information[3]. These applications of earth observation frequently use earth observation data that are both big data and open data, which in themselves are significant areas of research. The research field of open data looks at the effects of opening data (Janssen et al., 2012), the governance of open data structures (Janssen, Estevez, & Janowski, 2014) as well as how to create policies to open up data (Zuiderwijk & Janssen, 2014). Big data looks at the generally technical challenges that arise when handling large amounts of data. This can be in terms of improving algorithms for data analysis, improving storage methods or taking a holistic approach to making service architectures more suitable for big data processing (Sagiroglu & Sinanc, 2013; Thomas & Leiponen, 2016). In Figure 2, the research domain of open data is assigned to area A, big data to area B and earth observation to area C. The focus of this thesis is on viable services within area "G" of Figure 2, where open data, big data and earth observation overlap.



A: Open data
B: Big data
C: Earth observation
D: Big open data
E: Big earth observation data
F: Open earth observation data
G: Big open earth observation data

Figure 2: Venn-diagram of research areas

[1] See: https://www.journals.elsevier.com/international-journal-of-applied-earth-observation-and-geoinformation ISSN: 0303-2434
[2] See http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=6245518 ISSN: 1939-1404
[3] See http://www.mdpi.com/journal/ijgi ISSN: 2220-9964

Using the structured literature review method defined previously, the search engines of Scopus and WorldCat are used to search the overlapping area "G" of Figure 2 using the search terms of open data, big data and earth observation. This area contains only six articles (see the first search in Table 2), in which the author wishes to search for viable services and "value adding EO services" (Denis et al., 2017, p. 429), i.e. services that use earth observation data as a resource to provide benefit to another stakeholder. As this search result of six is too small, the application domain of earth observation is also searched, specifically including terms to look for viable services. All searches for the area "C" of Figure 2 use "earth observation" to demarcate the application domain, which according to the Scopus search engine encompasses about 9562 articles. This is combined with the keywords "viable service" and "commercial service" to search for services from an economic perspective instead of a technical perspective which also uses the word service e.g. a web service, meaning a machine-to-machine communication over a network (Alonso, Casati, Kuno, & Machiraju, 2004). To find more services that use earth observation data as a resource, the whole earth observation application domain is also searched for "economic value" and "commercial value", as this is what should be the outcome of a viable service. The last search includes the term "business model" because these unlock the latent value of a technology (Chesbrough & Rosenbloom, 2002). Table 2 below provides an overview of these searches, the used keywords and their syntax, the number of search results that the search term provides and the number of results that are considered relevant for value-adding EO services. Articles that were selected were considered to be relevant based on the relevancy criteria of accuracy (i.e. is the information free from errors), authority (i.e. are the authors and the publishers credible and trusted), objectivity (i.e. is the source factual and methodological), currency (i.e. whether the information is up to date), and coverage (how comprehensive and encompassing is the information) (Metzger, 2007).

Table 2: Overview of searches and results

#	Literature search	Used search term with keywords and syntax	# search results	# results selected
1	Big and open earth observation data	"big data" AND "open data" AND "earth observation"	6	4
2	Earth observation viable services	"earth observation" AND "viable service"	1	1
3	Earth observation commercial services	"earth observation" AND "commercial service"	16	5
4	Earth observation economic value	"earth observation" AND "economic value"	12	6
5	Earth observation commercial value	"earth observation" AND "commercial value"	1	0
6	Earth observation business model	"earth observation" AND "business model"	13	7

The next subsection presents the search results by summarizing the main contents of the articles which have been selected.

1.2.3 Search results

This subsection presents the contents of the articles identified in the search which are selected as relevant. This will be done for each of the search terms, after which the main findings are summarized. These are then used for the identification of knowledge gaps in the last subsection 1.2.4.

In the first search for the big and open earth observation data resulted in 6 articles. Because of the small size, the whole set can be searched manually for viable services with earth observation. The first article is right on topic, concerning the tracking of ships in the Mediterranean by processing over 11000 radar images from the ESA Copernicus project over the past two years (Santamaria et al., 2017). The authors of the article demonstrate the feasibility of a service, based on both the technical capability of tracking specific ships as well as how to process the big and open earth observation data. What is lacking is the viability of the service, as the authors make no mention of stakeholders that would benefit from the service, not the costs that are incurred by a service providing stakeholder. The other articles in this search do not provide a service design but stress the challenges of big and open earth observation data. The importance of standardization of earth observation data format so when it is published as open data and linked data, it can be easily processed by computers (Zotti & La Mantia, 2014). The call for such ontology, i.e. standardization of formats and meanings in a dataset, is repeated in Waterfall et al. (2016). Alternatively, Mazzetti et al. (2016) Propose a broker in the middle performing integration and computation of big earth observation data available from open sources. Instructions to this broker should be provided in a business process model notation (BPMN) language derived format.

The second search is aimed at viable earth observation services and returned only one result describes the commercialization of a precision farming service, integrating satellite earth observation data with local ground sensors to advice farmers on whether to apply site-specific activities with little operating effort (Bach et al., 2010). This is a example of a service which is including parts of viability, where the feasibility of the technology has been demonstrated previously and the service is created to contain usage incentives for the farmer, as well as whether the service provides sufficient value to the farmer for his or her willingness to pay a service provider sufficiently to maintain such a precise farming service. However, the extent of these incentives is not discussed within the article.

In the third search, another article has been identified which describes the use of earth observation applications in the agricultural sector (Denis & Lefevre, 2008). This article describes how earth observations assist farmers, the end users of the service, in not only optimising their processes but also limiting their environmental impact. The reduction in pesticide, water and fertilizer use is not only attractive to the farmers but also to the regional government which has the objective to reduce the environmental impact of its agriculture, creating sufficient incentives for the provision of the service. A different article mentions the inability to create a viable service model for meteorological earth observation data, continuing the data provision as a public good by national governments (Pelton, Madry, & Camacho-Lara, 2013), although this is not elaborated upon. What does become clear is that earth observation programs have the clear intention of creating value through services and both big earth observation data as well as open earth observation data. Further articles detailing the improvements to new satellites or satellite programs, the objective of improved commercial usage and increased profitability of services based on the data provided by the satellites is continuously mentioned (McGuire, Parashar, Mahmood, & Brule, 2001; Morena, James, & Beck, 2004; Pirondini, López, González, & González, 2014). The rest of the articles from the third search are almost exclusively focused on the earth observation satellites themselves and are out of scope. A first topic is the advancement of law in space considering the further commercialization of satellites (Morelli, 2006; Stelmakh-Drescher & Kosenkov, 2016). A second topic concerns the improvement of data connections using lasers between satellites and ground stations for better data transfer aiming at improving commercial data services (Böhmer et al., 2012; Motzigemba, 2013; Van Duijn, 2016). Further topics include the suggested improvement in data management of satellite EO data, especially when the data is sold to clients (Wolfmüller et al., 2009), the improvement of the agility of a satellite (Yoon, Choi, Chung, & Bang, 2012), and design guidelines for CubeSat's, which is a type of micro-satellite popular amongst commercial users for their relatively positive cost-benefit relation (Jacobs & Selva, 2015; Sandau & Briess, 2010)

In the fourth search on economic value and earth observation, the most notable result is a feasible service design for the assessment of damages after a flooding by combining land use (i.e. industrial, agricultural, etc.) data with the satellite images flooded areas (Bach, Appel, Fellah, & De Fraipont, 2005). This is a feasible service design as it demonstrates the technical application and names the stakeholders, specifically insurance companies, which are interested but fails to provide a plan on how to provide the service and a plan on how incentives for continued service delivery are created. A number of articles describe the idea of information as a commodity as initially coined by Arrow (1962) to assess the value of the information itself (Bounfour & Lambin, 1999), the value of the information within decision modelling (Pearlman, Bernknopf, Stewart, & Pearlman, 2014) and the marginal value of information quality improvement (Bouma, Kuik, & Dekker, 2011). The method of assessment for the value of earth observation information is also discussed, noting that methods are often non-comparable or based on ex-ante assessments (Häggquist & Söderholm, 2015), as is for example performed in (Pasher, Smith, Forbes, & Duffe, 2014) on the value of earth observation data on wildlife ecosystem monitoring and maintaining. However, these articles concern the resource of earth observation data itself and do not focus on the services which use earth observation data as a resource.

The fifth search for commercial value in earth observation only resulted in an ESA study with the architecture for a collaborative environment between EO data users (Beco et al., 2006). The focus is a platform for improved infrastructure for collaboration and knowledge sharing, both for scientists as well as commercial parties providing "commercial value-added products" (p. 1). The focus is again on earth observation data as a resource or product itself, not on the service using this as a resource.

In the last search on business models within the domain of earth observation, the results mainly concerned the business models for new forms of satellites or satellite components. Specifically, the business model of small, cubic satellites for earth observation is covered (Dyczynski & Kuiper, 2013), as well as agile satellites (Mombazet & Hernandez, 2011). There is also a set of policy proposals for European governments, Germany in particular, to advance the environment in which new technology and initiatives concerning private spaceflight can develop (Frischauf et al., 2016). Other results included the business model of a component of an earth observation satellite, specifically the laser technology allowing for improved satellite communications (Aoyanagi, Kato, Yasunaka, Uematsu, & Satori, 2008; Satori et al., 2008). The first article to mention services which adds value to earth observation data proposes a portal in which earth observation data is offered as data sets with other data sources such as local sensor data already integrated (Sekiguchi, 2009). The final selected article provides an overview of the whole service value chain of earth observation data, from instrument development, launch and the value adding service for clients. It also asks where in this chain the profits will be made (Denis et al., 2017). This is done by drawing an analogy to the gold rush in the United States, where supplying gold miners turned out to be more profitable than gold mining itself. It specifically states that the promised huge growth in the earth observation and geoformation services will depend, amongst others, on the "actual development of the EO services" (Denis et al., 2017, p. 431).

In conclusion, the earth observation domain frequently names the ample opportunities for commercial value creation through services that provide added value, but rarely specifies such services. Only three articles mention a service based on earth observation, of one both feasible and viable and the other two only feasible (Bach et al., 2010; Denis &

Lefevre, 2008; Santamaria et al., 2017), and a third article the failure to build a commercial model based on data (Pelton et al., 2013). Big and open earth observation data imposes challenges to the technical aspects of the service design, yet whether these data affect the viability has not been indicated in the articles. Denis et al. (2017) analysed the earth observation services as a market which is beginning to develop. They identified as a key issue of the market the development of value-adding earth observation services. These are the most important contributions on added value services within the academic literature on earth observation as most articles focus on technical innovations for satellites, the environment in which EO data is published or the value of the earth observation as a product itself. The next section will piece together the results into knowledge gaps.

1.2.4 Explorative interviews

This subsection presents the results of the explorative interviews which have been conducted amongst employees of the service providing company CGI to better scope the problem statement. These interviews are non-structured and were held with four employees with the job titles "Data analyst and Solutions Architect", "Systems Architect", "Opportunity Leader and Manager", and "Director Consulting Services". Whilst the interviewees had different perspectives and expectations on how their company could provide the service and what the challenge would be, all agreed that the first step would be the creation of services that would create value for both their company and the clients. However, how this should be done was not yet known to them. They did not know of any guiding method within the domain. Their expertise mainly consisted of technical integration and feasibility and their work mainly focused on the development of so-called 'demonstrators', with which they could show potentially interested stakeholders what a service could look like.

This is similar to the perspective within the academic earth observation literature, whereas the technical feasibility of a potential service is described in detail, yet how to achieve the viability of the service remains unclear. The structured approach to the service design is lacking, whilst the desire to transform these technical applications into viable services is strong. Furthermore, the perceived potential value of the earth observation services is considered very high by the people involved.

1.2.5 Identified knowledge gaps

This final subsection of the problem demarcation defines the knowledge gaps for this research by combining the information previously presented in the introduction, in the search results on viable earth observation services, and the information obtained through the explorative interviews.

The first search in the previous section on the focus area of open data, big data and earth observations found that the focus area has a low number of articles, indicating that it is an area which can benefit from further research. Within the articles found, only one described the feasibility of a service using big and open earth observation data as a resource (Santamaria et al., 2017). The viability of this service is not discussed, resulting in the first knowledge gap:

Knowledge gap 1: Within the searched focus area of big and open earth observation data, no viable service using a structured method for its design has been found.

In the widening of the search to the whole domain of earth observations, but specifically searching for viable services led to the identification of a few service designs which discuss stakeholder perspectives and incentives on the service, moving towards viability (Bach et al., 2005; Bach et al., 2010; Denis & Lefevre, 2008). These earth observation applications also use data from publicly available sources and can be considered big data. However, none of the identified services uses a method to achieve viability, which results in different aspects being included when stakeholder interests are discussed within the articles. This results in the formulation of the second knowledge gap:

Knowledge gap 2: Within the searched application domain of earth observations, no method for the design of viable services for applications using big and open earth observation data as a resource is found.

The characteristics of big and open earth observation data on the technical feasibility of the earth observation applications are discussed in detail in e.g. Santamaria et al. (2017), Zotti and La Mantia (2014) and Waterfall et al. (2016). What is absent from the literature are the influences of these characteristics on the viability of the designs. For instance, the requirements for computation and storage are named as technical challenges in e.g. Santamaria et al. (2017). However, the distribution of the burden for e.g. the required computation and storage are not mentioned in any of the articles, which would be part of the viability of the service. The same is true for the characteristics of open data. This leads to the formulation of the third knowledge gap:

Knowledge gap 3: The factors of big and open earth observation data that influence the viability of service designs are not identified within the searched literature

A few viable services have been identified, yet the focus seems to be on feasibility within the identified articles. Whilst this could be because of the focus of the earth observation communities and journals, limiting design of services to feasibility hampers the actual creation of value with the earth observation data (Chesbrough & Rosenbloom, 2002; Vargo & Lusch, 2004). Denis et al. (2017) stress the importance of the end user services in the whole earth observation value chain, stating that developments in this area would largely impact the profitability of the other segments of the EO market. A structured method to help service designers create viable services will allow services to be created more easily, allowing for more value to be created with the services (De Vos & Haaker, 2008). Such a method is currently absent in the searched literature, as it is neither encountered nor do the previously identified viable services have a method on which the viability of the design is based.

Knowledge gap 4: A structured method to guide the design of a viable service for earth observation applications using big and open earth observation data is absent in the searched literature and absent to the knowledge of the interviewees.

These four knowledge gaps form the basis for the research objective and questions, as well as the academic contributions which are discussed in the next section.

1.3 Research Objective and Approach

This section defines the research objective based on the previously formulated knowledge gaps and selects a suitable research approach for the structuring of this thesis. The previously identified research gaps indicate that viable service designs exist sporadically within the searched literature. However, none of these used a method to achieve this viability. Furthermore, the characteristics of big and open earth observation data and how these affect the feasibility of the proposed services are discussed, but not their influences on the viability of the service. No indication that any method exists for the design of viable services in the big and open earth observation domain has been found. This is a problem to service providers of "value-adding EO services" (Denis et al., 2017, p. 429), which could use such a method to design services which use big and open earth observation data as a resource more effectively and more efficiently, allowing for more value creation. The objective of this research is thus formulated as follows:

The objective of this research is to design a method targeted at service providers for the creation of viable services which use big and open earth observation data as a resource.

To attain this objective, a design approach is required to help structure and reduce the research into smaller components which can be solved individually. The two main approaches in design science are the design science research (DSR) approach (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) which has been applied and specified for the area of information systems (Hevner & Chatterjee, 2010) and the action design research (ADR) which is already specified for the application domain of information technology artefacts, focussing on the premise that such artefacts are shaped by the context they are operated in (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011). Whilst both approaches allow for problem-solving and evaluation, the focus of DSR is on the design and positioning of an artefact instead of the context of the artefact in ADR. ADR also requires a local, practical problem as a starting point for a problem definition and active participation by the researcher, whilst both of these are not required in DSR (Johannesson & Perjons, 2014).

Table 3: Comparing DSR and ADR approaches, adapted from Johannesson and Perjons (2014)

Design Science Research	Action Design Research
Problem solving and evaluation	Problem solving and evaluation
Addresses practical problems through the design of an artefact	Addresses problems through psychological, social and organizational change and requires no artefact
Requires no local practical problem as a starting point	Requires a local practical problem as a starting point
Does not require active participation by researcher	Requires active participation by researcher

This research will be structured using the design science research approach applied to information systems as described by Hevner, March, Park, and Ram (2004) based on the consideration that the objective of this research is the creation of an information systems artefact (Gregor & Hevner, 2013). This focus on the artefact is the decisive criterion for the choice of DSR, as this research is aimed at solving a problem, has a local and practical problem as a starting point as well as the possibility of active participation by the researcher. Further material in DSR will include the enriched descriptions and clarifications published in a follow-up article (Hevner & Chatterjee, 2010), the general publication of DSR (Peffers et al., 2007) and in the book on design science by Johannesson and Perjons (2014).

The design science approach is structured into a number of logically structured activities with well-defined input and output. Each of these activities correspond to one of five design phases: (1) the identification and explication of the problem, (2) the definition of objectives and requirements for an artefact, (3) the design and development of the artefact using the requirements, (4) the demonstration of the artefact and finally (5), the evaluation of the artefact. The result of the approach is an artefact which is designed for its specific environment (Johannesson & Perjons, 2014; Peffers et al., 2007). In the first phase of problem identification and explication, the problem is formulated precisely and its importance is justified using academic literature from the knowledge base. It describes a current problem and what gaps exist to achieve the desired state and the stakeholders which are involved and asks the question "What is the problem experienced by some stakeholders of a practice and why is it important?" (Johannesson & Perjons, 2014, p. 91). In the second phase, the environment is analysed and requirements for the artefact are formulated. This corresponds to the 'requirements' in the relevance cycle on the left side of Figure 3 below and the question "What artefact can be a solution for the explicated problem and which requirements for this artefact are important for the stakeholders?" (p. 103).

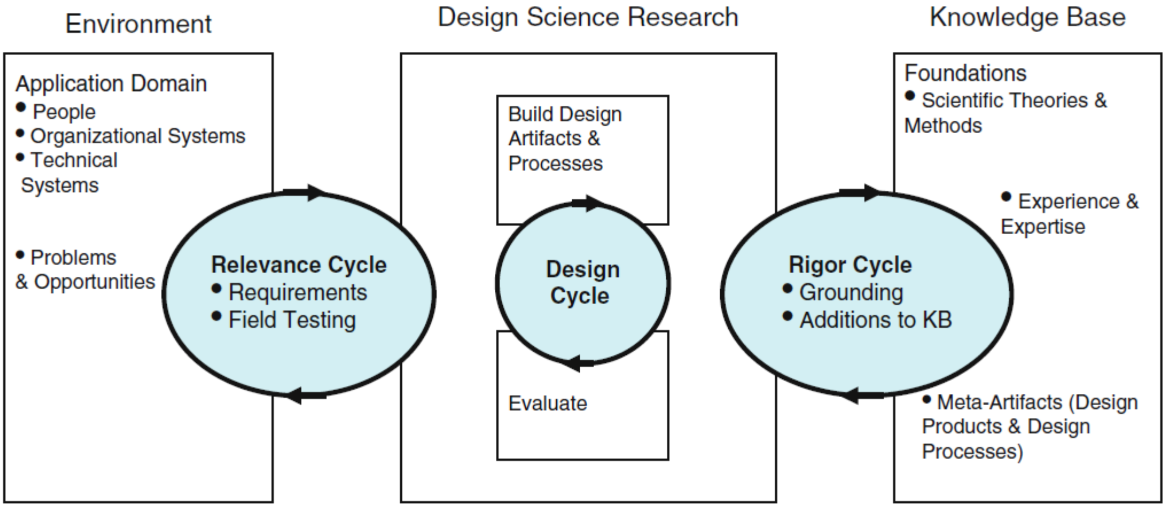


Figure 3: Design Science Research Cycles (Hevner & Chatterjee, 2010)

In the third phase, the artefact is designed based on the requirements from phase two, corresponding to the 'design cycle' in Figure 3. This phase does not contain a question but an instruction: "create an artefact that addresses the explicated problem and fulfils the defined requirements" (p. 117). The artefact is then demonstrated in the fourth phase to provide a proof of concept and show that the artefact can actually solve the problem. This corresponds to the 'field testing' in the relevance cycle of Figure 3 and follows the question "how can the developed artefact be used to address the explicated problem in one case" (p. 133). Finally, the artefact is evaluated to determine to what extent the defined problem has been solved. The question related to the evaluating activity is: "how well does the artefact solve the explicated problem and fulfil the defined requirements" (p. 137) (Johannesson & Perjons, 2014). These phases and questions are used in the next section to structure this research and thesis.

1.4 Application of DSR and Formulation of Research Questions

This section is dedicated to the application of the design science research approach presented above to the research in this thesis. In doing so, the thesis is structured and research questions are formulated.

The first question on the problem of this research requires the addition of the problem owner, i.e. the stakeholder which perceives an undesirable state of affairs. In this research, this is the service provider wishing to create viable services which use big and open earth observation data as a resource. Applying this to the research question for the problem explication from Johannesson and Perjons (2014, p. 91) results in the following first research question:

1. What is the problem experienced by service providers which desire to create viable services which use big and open earth observation data as a resource and why is it important?

As you may have noted, this research question has already been addressed in this chapter. Using a structured literature review, knowledge gaps have been used to identify the lack of a method for viable service design which uses big and open earth observation data as a resource. This is a problem experienced by service providers of such a service, as their continued existence and growth is dependent on the viability of services on top of the feasibility of a service. The knowledge gaps furthermore exposed that the characteristics of big and open earth observation data and their effects on viable service design are not yet described, making it difficult to state what challenges are specific to this type of data when designing viable services. Thus, further research is needed into what current methods for viable service design exit and what factors of big and open earth observation data are influencing viable service design. This is still part of the grounding phase of the design science research approach and has the following question:

2. What are the factors of big and open earth observation data influencing the creation of viable services?

This research activity is an addition to the DSR approach and is aimed at obtaining more background into viable services and the factors of big and open earth observation data. Again, the research method of a structured literature review is used to search for viable services, but this is extended to open data and big data in relation to earth observation. The search results in two outcomes: a number of models which allow for the description of viable services and the factor of each of the three types of data that influence viable service design. This should provide the research with sufficient grounding to start collecting requirements. As it is already clear that the artefact to be developed is a method, the second phase of this research focusses on the gathering of requirements specifically for the method. The question for this second phase is formulated as follows:

3. What are the requirements for a method that creates viable services which use big and open earth observation data as a resource?

The objective of this third research question is to obtain the requirements which will allow for the design of a method. The access to several cases of the information technology consulting and integration company CGI allows for identifying functional requirements through case studies supported participant observation in addition to expert interviews. CGI is selected because it has the intention to become a service provider for added-value earth observation services, making it a stakeholder filling the role of problem owner. The grounding of the factors influencing viable service design and existing service design methods from the previous research question provides structure and guidance throughout the case study. Additionally, the grounding provides a set of quality requirements to check for the internal validity and environmental quality of the artefact. A full description of considered research strategies and the used approach for the requirements gathering is described in section 3.1 together with the criteria for the case selection. In total, three cases are selected, each providing additional requirements to the artefact which is designed in the next research activity, which is guided by the following research question:

4. What does the service design method for viable services which use big and open earth observation data as a resource that satisfies the requirements look like?

The research activity of this phase consists of the design of the artefact, and the chapter contains a description of how the design choices are made. The result is a method to design viable services, i.e. create a plan for a service which provides incentives to all stakeholders to continue the service delivery as well as a description of the feasibility of the service, i.e. the technical capability of providing the service. This method is then used in the next phase of the research: the demonstration of the artefact. This phase is guided by the research question:

5. How can the method be used to create a viable service design?

The objective of this activity is to use the artefact in a case to demonstrate its feasibility, effectively the first step towards the evaluation. The observations obtained from the demonstration are described and used in the in the actual evaluation chapter of the artefact, which is executed using the following question:

6. How well does the method design viable services which use big and open earth observation data as a resource, and how well does the method fulfil the defined quality requirements?

Essentially, this research question puts the focus of the evaluation on both the objective of the artefact as well as the internal structure of the artefact. This question is answered using the observations from the demonstration of the artefact and through a survey in which employees of CGI, the company which provided cases and fits the role of problem owner, rate the quality and indicate their future use intention after having received a presentation of the artefact.

Finally, the conclusions of this research together with its limitations are presented and future research is proposed in chapter 7. The conclusions chapter is a stand-alone chapter in which the research questions and their answers are reiterated and the answers that are given in the individual chapters are represented. Then, the scientific and societal contribution of this research is presented, by demonstrating how this research provides the knowledge to fill the identified knowledge gaps. Furthermore, the limitations of the artefact and its research are discussed as well as opportunities for future research.

To give a more structured overview of the research design, a research design overview diagram is created, as depicted in Figure 5. The figure is based on the IDEF0-format, meaning that every block represents an activity which is logically related to its previous and/or following activity. The number on the bottom right of an activity block is equivalent to its chapter number within this research. Every block contains an input from the left and an output at its right. The research method is depicted with the arrow from above and anything used from the knowledge base is depicted with an arrow from below. In addition to the whole overview, every following chapter has their own activity depicted in this format at the beginning of every chapter, like the Figure 4 below. Figure 4 depicts the first phase of the problem definition, which is the activity of this current section. The number 1 in the bottom right indicates that this is the first chapter. An initial problem, which has been identified through a structured literature review as a research method, has been structured and explicated using the design science research approach from the knowledge base. The explicated problem is the output of this activity, which is used as input for the next activity in chapter two, the literature review (see Figure 5)

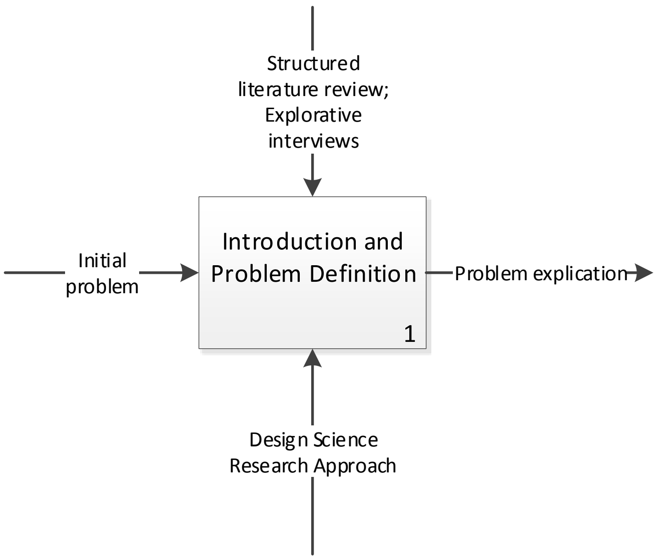


Figure 4: Research design for the current chapter of Introduction and Problem Definition

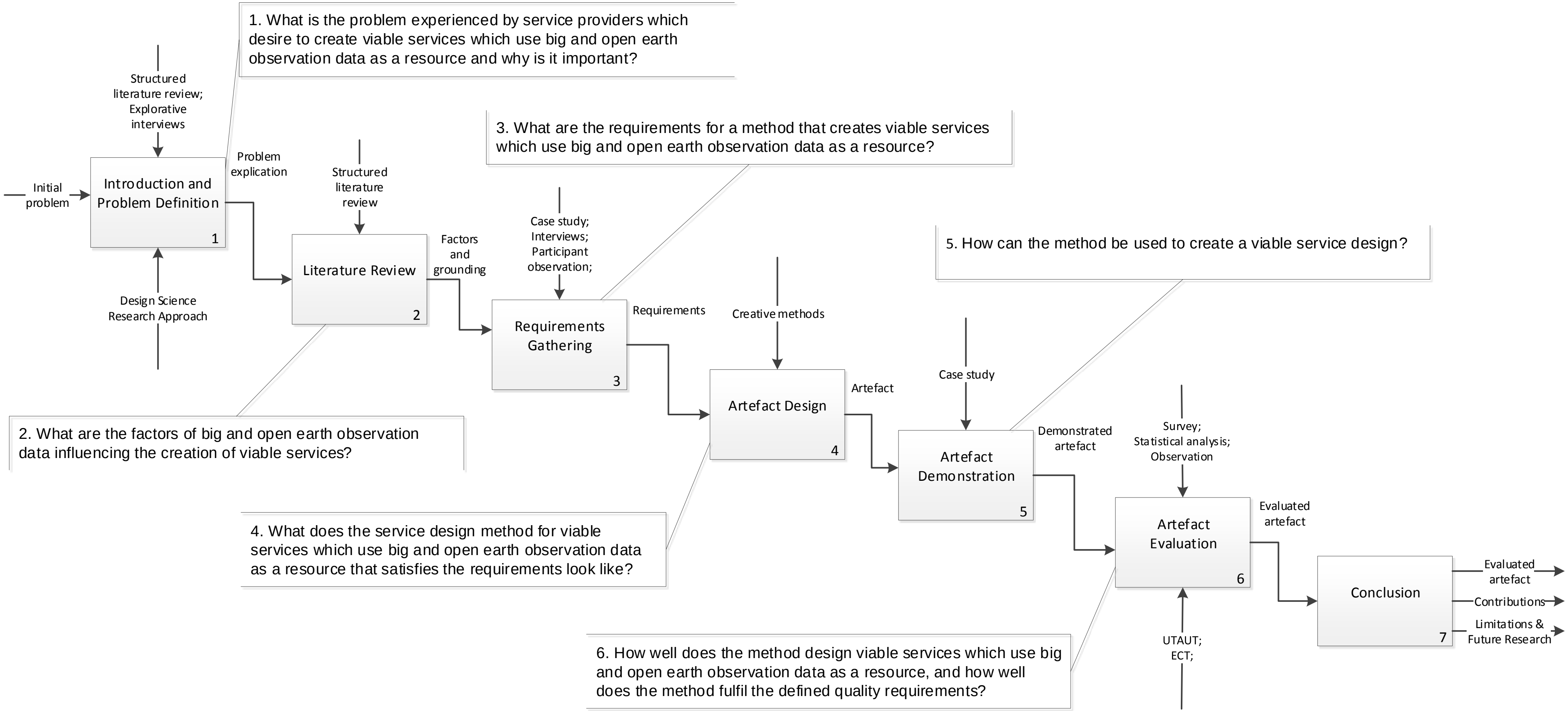


Figure 5: Research design overview - DSR approach applied to this research.

1.5 Contribution and Relevance

This research contributes a method for the design of viable services to the application domain of earth observation data applications, taking into account the big data and open data characteristics of the data. As discussed earlier, within the earth observation application domain, there is no method for the creation of viable services.

On a practical level, the method provides to organizations or individuals the guidance to design services based on big and open earth observation data. Specifically, possible end users are IT integration and consultancy companies such as CGI (the company sponsoring this research) or Capgemini. Alternatively, the method could be used by start-up companies which develop a highly specialized service or by general consultancy companies for a client offering earth observation services. Indirect beneficiaries of this method are the ESA and NASA open data hubs, as the design and deployment of viable services based on big and open earth observation data will lead to an increased use of their data and will allow them to deliver their promise on value creation.

In terms of the academic contribution, the method for viable service design is a level two design science research contribution providing knowledge as operational principles (Gregor & Hevner, 2013) (see Figure 6). This artefact directly corresponds to the fourth knowledge gap: a structured method to guide the design of a viable service for earth observation applications using big and open earth observation data is absent in the searched literature. The third knowledge gap concerning the factors of big and open earth observation data that influence the viability of service designs is addressed during the process of the creation of this method, as the factors are identified and researched in the second chapter of this thesis. The first two knowledge gaps on the existence of viable services have overlap, as the big and open earth observation focus of this thesis is part of the earth observation domain in general. By applying the designed method in the demonstration in chapter 5, this research contributes a viable service design of an earth observation application which used big and open earth observation as a resource. Thus, all identified knowledge gaps are expected to be served with this research.

Table 1. Design Science Research Contribution Types

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

Figure 6: DSR contribution types from (Gregor & Hevner, 2013, p. 342).

From a viable service design perspective, the method allows for viable service design in a new application domain. Viable service design methods are regularly adapted to application domains in order to better serve the needs of this specific domain, as is the case for mobile services or IPTV services (Bouwman, De Reuver, & Schipper, 2008; Bouwman, Vos, & Haaker, 2008; Bouwman, Zhengjia, Van der Duin, & Limonard, 2008). Furthermore, this research identifies influencing factors on viable service design for big data, open data and earth observation data. These factors contribute to the understanding of the big and open earth observation data application domain, which to the knowledge of the author has not been covered by service design literature. From the perspective of applied earth observation sciences, the method provides the ability to continue the development of the algorithms and applications into client-oriented services. Currently, the domain is generating large amounts of possible applications which are designed for and by experts in the field (Karmas et al., 2016). From the perspective of open data research, the method provides more insights into value creation from a service provider perspective. Currently, open data lacks structured methods for viable service design and is generally studied from an end user perspective instead of service provider perspective (Janssen et al., 2012; Janssen & Zuiderwijk, 2014; Zuiderwijk & Cligge, 2016).

1.6 Research Paradigm and Perspective

As indicated in the formal title page, this thesis is in partial fulfilment of the master degree of Complex Systems Engineering and Management (CoSeM) at the faculty of technology, policy and management (TPM) in Delft. CoSeM is a name which may not bring the same kind of associated imaged to mind which does other engineering degrees, such as applied chemistry or aerospace engineering. The essence of the CoSeM program is the systems engineering, a term best described by Sage and Armstrong Jr (2000) as "a human, organizational, and technology-based effort that is inherently multi-disciplinary" (p.3) to "define, develop and deploy systems" (p.2), whereas a system is "a group of components that work together for a specified purpose" (p.5). Such as system can be anything, such as software development projects, airport operations or management information systems. The idea of complex systems comes from the concept of a multi-stakeholder system, where one stakeholder with an interest desires to reach an objective and will have to bridge the gap from current situation to the desired situation considering the possibly opposed interests of other stakeholders as well as technological uncertainty (Enserink et al., 2010). Using the previously stated definitions, the author considers a systems engineer someone who takes a holistic perspective and sees the relations between components of a system, proposing an intervention for a specified purpose that considers information from multiple relevant disciplines and considers the interests of multiple relevant stakeholders.

The beliefs and assumptions held by the researcher about reality and its relations to humans about knowledge and its existence in relations to observers are called respectively ontological and epistemological beliefs. These, in turn, have a great impact on the research methods and results and deserve their own chapter to clarify the position of the author. Positivism entails the belief that reality exists independently and of human beings and is therefore observable from a distance. The researcher should be free of values and can observe the objective truth at a distance, preferably making use of quantitative surveys and experimentation. Interpretivism contrasted to positivism and affects social phenomena which, as the paradigm argues, do not exist independently from humans. Social actions have subjective meanings and purposes. Therefore, interpretivist research is not possible without understanding the views and interpretations of the people involved (Johannesson & Perjons, 2014).

This research is taking an interpretivist perspective on research. The main reason for this is that the artefact, i.e. a service design method, thrives on the differences of perspective between the different stakeholders within the research, especially their perspective on commercial value. The interpretivist paradigm allows for the differentiation between values from an individual's perspective, something which a positivist perspective with value as an objective measure would now allow. Basically, the value is "what a buyer will pay for a product or service" (Chesbrough & Rosenbloom, 2002, p. 534), arguing that only if a buyer perceives a product or service of higher value than the seller, the transaction can take place. This is opposed to positivist value theories, such as the labour theory of value proposed by Riccardo in the eighteenth century stating that every object has an inherent value because of the amount of work required to achieve the product or service as is (Stigler, 1958). However, as the provision of digital services is automated, the actual marginal labour for digital service provision is nihil (see section 2.2.1 on page 16 for definitions and characteristics of digital services), making this type of positivist theory unsuitable for this research.

1.7 Conclusion

This first chapter on the introduction and the problem definition of this research provided a set of knowledge gaps, from which a research objective is defined. The knowledge gaps are identified using a structured literature review of academic literature and explorative, unstructured interviews at a service provider, the problem owner of this research. The resulting research objective is "to design a method targeted at service providers for the creation of viable services which use big and open earth observation data as a resource". Using the design science research approach, the research objective is transformed into a set of research questions that each result in logically related research activities. These activities are each assigned their own chapter, and their relations are depicted in the overall research design in Figure 5 on page 11. The expected contribution of the research, i.e. the method for viable service design, is a second level information systems artefact (Gregor & Hevner, 2013). And the artefact, as well as the process of its design, is expected to fill all the defined knowledge gaps. Finally, the perspective and paradigm of this thesis are detailed, as the thesis is using an interpretivist paradigm and takes a systems engineering perspective.

2 Literature Review

This literature review chapter is the second phase of the research and will answer the research question "What are the factors influencing the creation of viable commercial services based on big and open earth observation data?". The objective of the literature review is to provide grounding for the research methods in the requirements gathering section. By doing so, this chapter will also provide the reader with an understanding of the current state of research on the topic of viable services. The grounding consists of understanding viable services and of identifying big and open earth observation data factors which influence service design. These can be used as sensitising concepts in the next chapter for requirements gathering. The method for this section is a structured literature review, for which the approach is detailed in the first subsection. This is followed by the execution of this approach through a number of searches on open data, big data, earth observation data and viable service design the results of which are presented in the four following subsections. A small conclusion section summarizes the main outcomes and how these relate to the rest of the research. Figure 7 summarizes the research activity of this chapter.

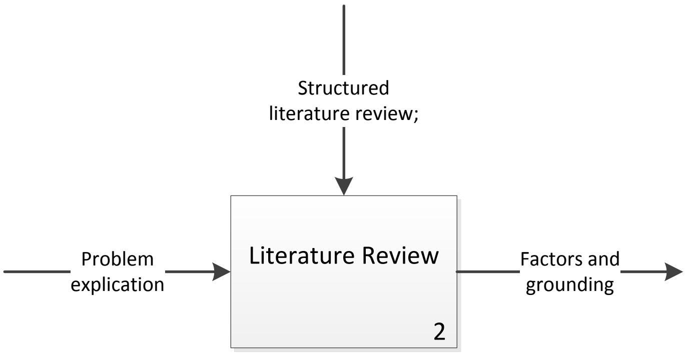


Figure 7: Research design for the Literature Review chapter

2.1 Literature Review Approach

As established in the first structured literature review (section 1.2.2 on page 3), the focus area of big and open earth observation data does not yet contain many articles, resulting in the author being unable to obtain the information required for the answering of the research question from purely this focus area. This is why the search areas are broadened. In addition to the searches in the previous literature review, Table 4 below is expanded into the areas of open data (area A in Figure 8) and the overlapping areas of big data (areas D, and E in Figure 8). These areas are searched for viable services and business models, like in the previous search. The whole domain of big data (area "B") is excluded from the search for business models (search term 10 in Table 7 below), as the number of results is too high to process, as additionally, it does well as not provide results that contribute to the answering of the research question. This is likely due to the term 'big data' being used as a buzzword.

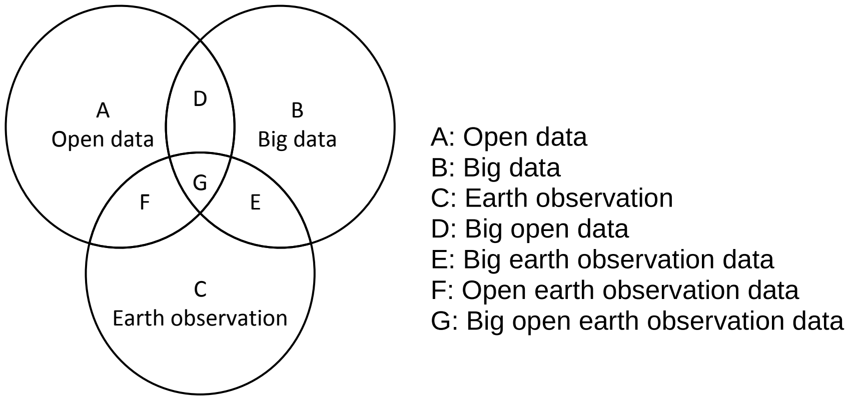


Figure 8: Venn-diagram of research areas

Table 4 below is extended with searches number 7-14 from the searches perfumed previously and summed in Table 2 on page 4. The keywords used for these searches are as follows: search number seven and eight uses the search term of "open data" respectively with "viable service" and "business model" using the AND operator. Searches number nine and ten focus on the big data area, which similarly to the two previous searches have the keywords "big data" and "viable service" (#9), and "big data" and "business model" (#10). The following searches combine "big data" and "open data" respectively with "viable service" and "business model" (searches #11 and #12). The final two searches use the keywords "big data" and "earth observation", respectively again with "viable service" (#13) and "business model" (#14). Again, articles that were selected were considered to be relevant based on the relevancy criteria of accuracy (i.e. is the information free from errors), authority (i.e. are the authors and the publishers credible and trusted), objectivity (i.e. is the source factual and methodological), currency (i.e. whether the information is up to date), and coverage (how comprehensive and encompassing is the information) (Metzger, 2007).

Table 4: Extended literature searches and results

#	Literature search term	Figure 8 equivalent	#results found	#results selected
1	Big and open earth observation data	G	6	4
2	Earth observation viable services	C	1	1
3	Earth observation commercial services	C	16	5
4	Earth observation economic value	C	12	6
5	Earth observation commercial value	C	1	0
6	Earth observation business model	C	13	7
7	Open data viable service	A	0	0
8	Open data business model	A	45	22
9	Big data and viable service	B	0	0
10	Big data and business model	B	290	0
11	Big open data viable service	D	0	0
12	Big open data business model	D	5	5
13	Big earth observation data viable service	E	0	0
14	Big earth observation data business models	E	0	0

The results will be analysed twofold: all viable service models and methods which occur within the search results will be presented in section 2.2 Viable Service Design to present the reader with the state of the art on viable service design. This section will include the backward and forward searches (as detailed in section 1.2.1, Figure 1 on page 3) to present knowledge from both the most recent and the original articles. Then, these search results are used to identify the factors of big data, open data and earth observation data that influence viable service design. These factors are presented by topic in sections 2.3 for open data, 2.4 for big data, and 2.5 for earth observation data.

2.2 Viable Service Design

This section on viable design presents the state of the art on viable service design. It first defines the concept of a service, a digital service and a viable service, whilst also detailing the kernel theory of service-dominant logic. Then, a summary of each of the encountered models for viable services is presented and contrasted.

2.2.1 Services, digital services and viable services

A service is the generally intangible result of a series of processes aimed at providing a form of benefit to someone who also participated in the processes (Edvardsson & Olsson, 1996; Fitzsimmons et al., 2008; Shostack, 1982;

Williams et al., 2008). A benefactor (i.e. the client) of a service will not gain any ownership of anything physical and will consume the service the moment it is produced, as services can't be stored (Bouwman & Fielt, 2008). Furthermore, "no service occurs unless customers apply the offering […] in context" (El Sawy & Pereira, 2013). Because of the non-physical aspect, the use in context, and the co-creating characteristic, services are heterogeneous and making quality control before delivery impossible. Instead, quality standards can be set based on the outcome and judgement by the consumer of the service (Bouwman & Fielt, 2008; Edvardsson & Olsson, 1996). Finally, it is impossible to transfer or resell a service, making the four core characteristics of a service its intangibility, inseparability, heterogeneity and perishability (Bouwman & Fielt, 2008). A new service is defined as "an offering not previously available to customers that results from the addition of offerings, radical changes in the service delivery process or incremental improvements to existing service packages that customers perceive as new" (Johnson, Menor, Roth, & Chase, 2000, p. 2).

A special form of a service which has gained importance is the digital service (Akkermans et al., 2004). Digital services are encountered daily such as Gmail[4], the e-mail service by Google, an instant-messaging service for smartphones such as WhatsApp[5] or payment services such as PayPal[6]. Such a digital service is defined as a service delivered "through a process that is stored as an algorithm and typically implemented by networked software" (Hofacker, Goldsmith, Bridges, & Swilley, 2007, pp. 16-17). An alternative definition of digital service states that the service must be "provided through a digital transaction" (Williams et al., 2008, p. 507), specifically, Internet Protocol (IP) based internet. This research will continue with the first definition because it is not bound to the specific technology of the internet protocol, nor excludes services which are offered locally but still through a digital medium. Digital services can be any kind of service accessed at any time by a consumer through self-service where the consumer of the service interacts with a tangible digital medium such as a smartphone or a computer in order to access the service (Chang & West, 2006). Because the digital service is based on an algorithm which is delivered equally to all who use it, the service is essentially homogeneous (Hofacker et al., 2007). Digital services are based on information which is non-excludable in supply (Krishnan, Smith, & Telang, 2003), meaning that they can be easily copied and shared. Furthermore, one server delivering the service can reach a lot of consumers of the service (Bouwman & Fielt, 2008; Hofacker et al., 2007).

In recent years, and possibly because of the growing importance of digital services in the economy, the perspective on the analysis of services is shifting. The kernel theory of service-dominant logic proposed by Vargo and Lusch (2004) shifts attention away from goods as the central unit of exchange and manufacturing as the main value-creating activity, to services as the fundamental economic activity. This new perspective on services is embodied in the statement by Theodore Levitt that customers do not want a drill, but they want a hole in the wall (El Sawy & Pereira, 2013, p. 5): the focus is not the product but the result.

Viable services are, based on the definition of viability provided by Sharma and Gutiérrez (2010), services which provide sufficient incentives to all stakeholders involved in the value network of the service (clients, suppliers, distributors, investors, etc.) to continue the cooperation and the service delivery. In other words, all stakeholders need to create value with their actions in the value network and retain sufficient value when the benefits and costs are distributed amongst the network. Chesbrough and Rosenbloom (2002) argue that the creation of value, i.e. viability, from a feasible technology requires a business model; allowing the assertion that feasibility is a requirement for viability.

2.2.2 Viable service and business models

Within the searched literature, five frameworks are identified which are able to describe the creation and exchange of value between stakeholder. These are the VISOR business model. The e3 value model, the STOF model, the VIP framework and the business model CANVAS. This subsection will present the core elements of each of these frameworks and compare their contributions.

The first to be discussed is the VISOR business model. VISOR is an acronym for the concepts it contains, all of which are interrelated: Value proposition, Interface, Service platforms, Organizing models, and Revenue and Cost Sharing (El Sawy & Pereira, 2013; Sharma & Gutiérrez, 2010). Together these can result in the "real value proposition" (El Sawy & Pereira, 2013, p. 24) by subtracting from the value proposed to the customer the value retained (i.e. revenue generated) by the service provider and the "real cost of delivery" (p. 24) by adding the cost of the interface, the processes and relationship and the service platform to enable the delivery.

[4] https://www.gmail.com
[5] https://www.whatsapp.com
[6] https://www.paypal.com

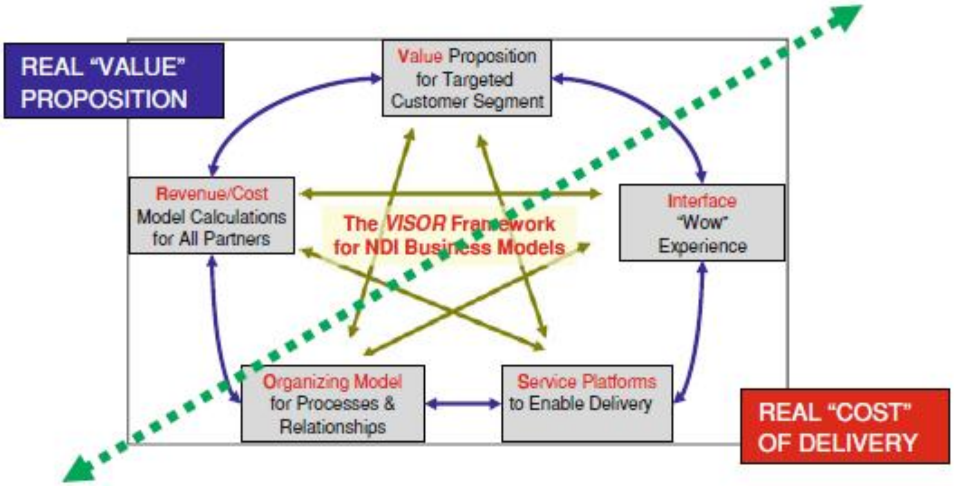


Figure 9: VISOR business model framework from El Sawy and Pereira (2013, p. 24)

Whilst VISOR acknowledges the strong ICT components of a digital service, its focus lies on the interface between the value delivery of the service and the access by the customer (Sharma & Gutiérrez, 2010).

The second model for the design of viable services is the e^3-value model. Akkermans et al. (2004) specifically present the model for digital services' business models and the model depicts the value exchanges between actors, such as clients or different departments within organizations. The focus is on exchanges and compositions (Akkermans et al., 2004) and is accompanied with a modelling notation in which the core concepts of the model are integrated (see Figure 10) (Gordijn, Akkermans, & Van Vliet, 2001). These core concepts are the following: an actor, a value object to exchange between actors, a value interface though which an exchange can take place, a value port to indicate the desire to provide or request an object of value, a value exchange where two ports are connected by exchanging the object of value, a market segment in which objects of equal value are offered or requested, and finally the value activity which provides the value for the actor(see also the legend in Figure 10 below) (Akkermans et al., 2004; Gordijn et al., 2001; Gordijn, Petit, & Wieringa, 2006).

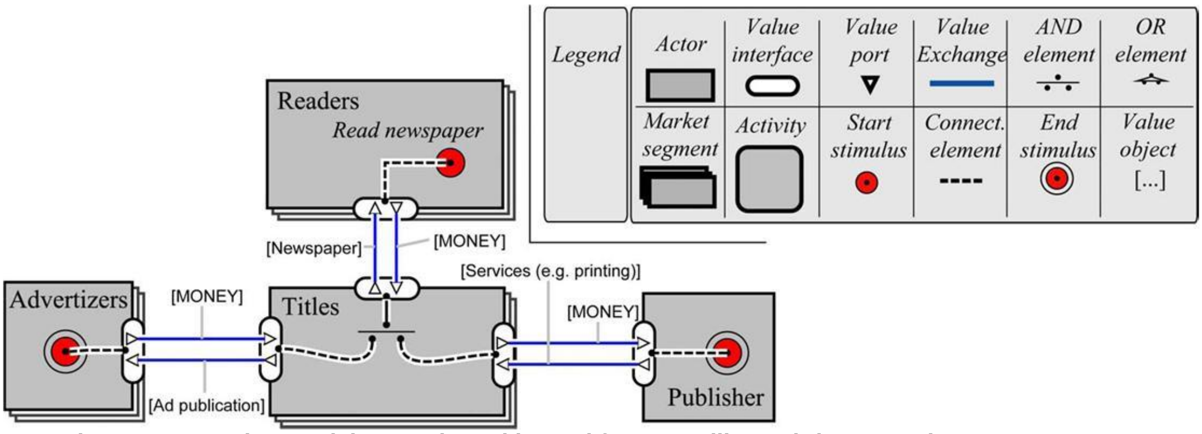


Figure 10: e3 value model example and legend from Gordijn et al. (2006, p. 5)

The strength of the e^3-value model is in its clear exchange modelling. However, the focus is on exchanges and excludes technical architectures and the question whether the exchange is practically possible. Also, relations between actors are only transactional, excluding the description of dependencies or informal relations.

Next is the CANVAS business model, proposed by Osterwalder (2004) in his doctoral thesis. The CANVAS contains the concepts of key activities, key resources and the partner network as infrastructure, the value proposition as an offering, the customer segments, customer channels and customer relationships in the category of customers, and finally the cost structure and revenue streams under the category of finance. The CANVAS is represented graphically as a set of building blocks which logically relate to each other through an underlying meta-model (see Figure 11 below) (Osterwalder, 2004; Osterwalder & Pigneur, 2010).

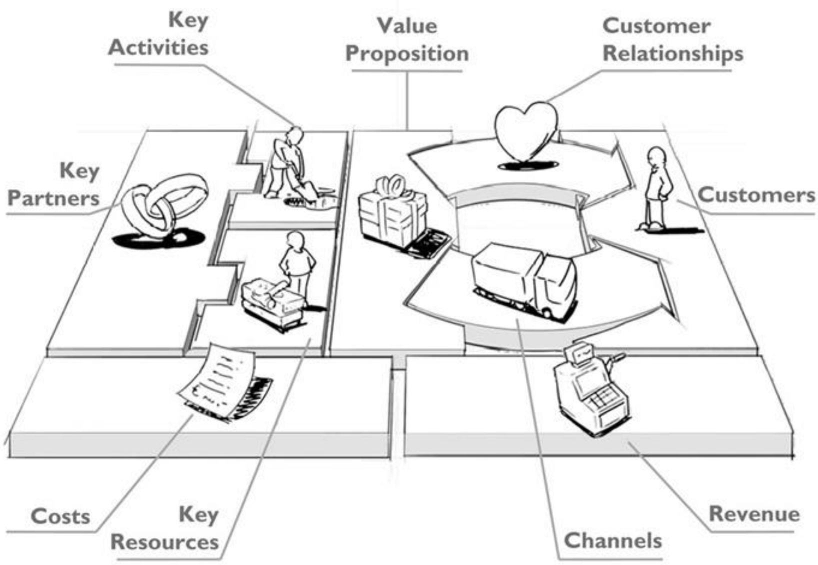


Figure 11: business model CANVAS graphical representation from Osterwalder and Pigneur (2010, pp. 18-19)

The business model canvas is considered a highly popular tool outside of academic research because of its simplicity, as practitioners can fill in a template with post-it notes during a brainstorm session (De Reuver, Bouwman, & Haaker, 2013). However, the model is lacking a structured approach and does not allow for inter-organizational exchanges and value co-creation as it adheres to a linear concept of value creation. This is especially visible in the way customers are treated differently from partners, whilst one of the core concepts of the service states that the service is created together with the customer (Shostack, 1982), creating an overlap with the partner stakeholder.

The next model is the STOF business model, which builds the business models for services in the four parts which build the acronym STOF: Service, Technology, Organization and Finance (Bouwman & Fielt, 2008, p. 29). In essence, it presents a set of concepts and trade-offs which are minimally required to build viable services in each of the four STOF-domains. The objective is to create value for the customer as well as retain part of this value for the service providers, which can consist of multiple stakeholders co-creating value. Unlike the VISOR model and the e^3-value model, the STOF business model allows for a stronger description of the technical architecture in the technology domain, instead of only describing a service delivery system (Bouwman, Faber, Fielt, Haaker, & De Reuver, 2008).

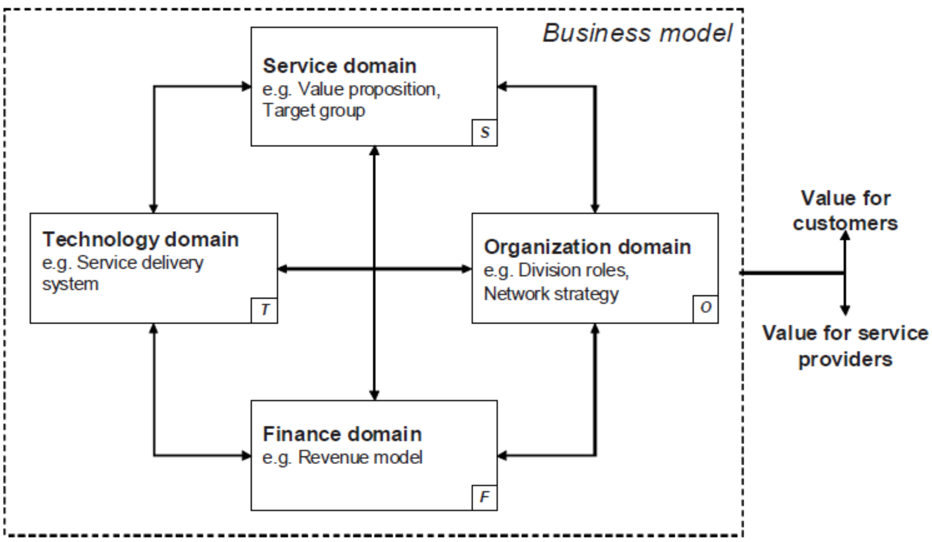


Figure 12: The STOF model (Bouwman, Faber, Haaker, Kijl, & De Reuver, 2008)

The STOF model does not prescribe any visualizations or representations of its trade-off concepts, making the representation abstract and not as simple to use as e.g. the business model CANVAS. At the same time, it has a method to guide service designers through the modelling procedure (De Vos & Haaker, 2008) and the lack of a prescribed visualization allows for the use of other tools, such as the Archimate modelling language (Lankhorst, Proper, & Jonkers, 2009) for the technical architecture or the value network for the inter-organizational value flows (Allee, 2008).

Finally, the concepts of Value, Information, and Processes are included in the acronym of the VIP framework. The VIP framework does not position itself as a business model, but in between business models and operational models which describe the practical realization of a service in detail (Solaimani & Bouwman, 2012). It can be used to identify whether there is a conflict between the value objectives and the operational processes designed, or between multiple stakeholders or to perform a requirements elicitation for the operational model based on the business model (see Figure 13 below).

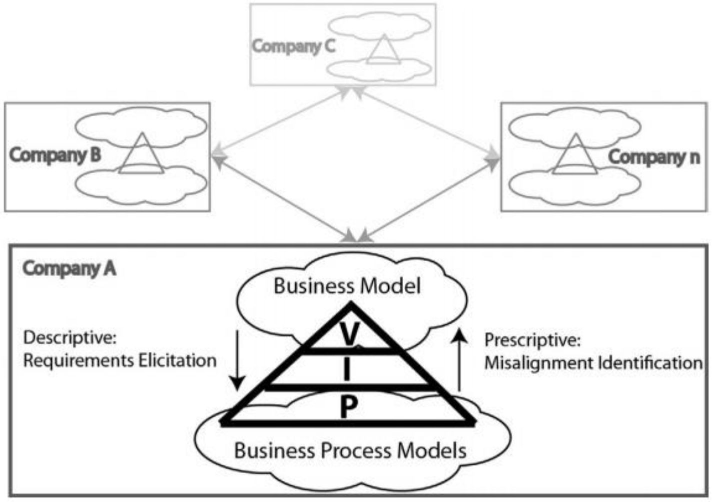


Figure 13: VIP framework aligning business model and operations from Solaimani and Bouwman (2012, p. 670)

The VIP framework exists to bridge the areas of business modelling and operational modelling. The focus is on the link between business models and information exchange processes between providers and clients, not the system building aspects as is the case in e.g. the STOF business model (Azam, Li, & Ahmad, 2006; Solaimani, Bouwman, & Itälä, 2013). Furthermore, this intermediate positioning makes VIP abstract and not very accessible to practitioners.

In conclusion, five models and their core concepts are briefly presented in this subsection. Many contain similar concepts, as e.g. the value proposition or value offering is a common concept in all of the models. The differences are in the details, as VISOR focusses on delivery and interfaces, whereas the e^3-value model focusses on the modelling of the exchange. CANVAS has a low entry barrier and recognisable overview yet lacks any operational modelling and only has a single-stakeholder view. STOF combines four perspectives as domains and provides a set of trade-offs essential to a business model as well as a method for designing the business model, yet lacks clear boundaries on what should not be included. Ultimately, the VIP framework is the odd one out, as it is not a business model but a framework to align business models with operational models and architectures. Table 5 below depicts these differences.

Table 5: Overview of viable service and business model frameworks

	Core Concepts	Focus	Visualization
VISOR	Value proposition, Interfaces, Service platforms, Organizing models, Revenue and Cost Sharing, each with more detailed concepts	Interface of value delivery to customer	Conceptual relations only
E^3-value	Actor, value object, value port, value interface, value exchange, value offering, market segment, value activity	Modelling how value is exchanged	E^3-value ontology: value exchange Input/output diagrams
CANVAS	key activities, key resources, partner network, value proposition, customer segments, customer channels, customer relationships, cost structure and revenue streams	Simple overview of business logic in a company	CANVAS template
STOF	Service, Technology, Organization, and Finance domains, each with a number of trade-offs to balance or strategy	Integrating four perspectives on business models as domains	Conceptual relations only

VIP	Value, Information, Processes	Aligning operational processes realising the value of the actual value goals throughout multiple stakeholders.	Conceptual relations only

This table of comparison is used in section 3.1.4 on page 30 to select a model to structure the case studies in that chapter. The following sections of this chapter present the characteristics of open data, big data and earth observation data and identify the factors that influence the value creation within viable service design models, such as the ones presented above.

2.3 Open data

This subsection presents the findings of the searches on open data, beginning with a discussion on what open data is and how it is used in practice. Then, the results on open data business models are presented, followed by a small overview of the factors that affect service design that could be identified from the open data literature. The result is set of open data factors influencing viable service design.

2.3.1 Open data definition and research

Open data is defined slightly differently across different articles and authors. Here, this research will settle with the most basic definition. This states that open data is any form of data that is both freely accessible and freely usable for any kind of purpose (Berners-Lee, 2009; Bonazzi & Liu, 2015; Janssen et al., 2012). Other definitions include other characteristics, such as the requirement of machine-readability (Zeleti, 2014), which others include in the definition of linked open data, not open data (Berners-Lee, 2009; Bonazzi & Liu, 2015). Yet another definition states that the essence of open data is its funding through public means (Janssen et al., 2012). This view is not out of the ordinary, considering that open data is frequently linked to open government, transparency, and freedom of information (Attard et al., 2016a; Jetzek, Avital, & Bjorn-Andersen, 2014; Susha, Grönlund, & Janssen, 2015). It is worth remembering that open data does not mean government transparency and vice-versa, but that the right application of open data policies combined with institutional culture can result in proactive governmental transparency (Janssen et al., 2012). It is unlikely to be coincidental, that the value creation from open data has a significant focus on public values, such as increased transparency, improved democratic accountability, higher participation of citizens, improvement of public services for citizens, better policy making and the creation of trust in government, versus economic value creation such as economic growth through improvement of services and new sectors through innovation and creation of new services (Attard et al., 2016c; Janssen et al., 2012; Zuiderwijk, Helbig, Gil-Garcia, & Janssen, 2014). However, open data is not the same as open government. In fact, open data can originate from the private sector (Buda, Ubacht, Janssen, & Sips, 2016) and that most of the data that is published by governments are non-political, such as weather information and public transport schedules (Yu & Robinson, 2012). In order to not have conflicting or mixed definitions of open data and other initiatives, this research will define open data as the common denominator: data which is freely available and freely usable. This definition has impacts on the governmental aspects of the data and not any technical format or any requirements for the processing of the data, which will be different from source to source.

2.3.2 Open Data Business Models

Within the search results of the open data business models, a number of articles are concerned with the observation of emerging practices in empirical settings and the identification of patterns and roles within the business models. For example, there is the research on 'infomediary' business models providing enhanced access to open data (Janssen & Zuiderwijk, 2014). Six types of value-adding concepts have been identified for governmental open data: networking, capturing, adding, returning, proposition and management (Zeleti, Ojo, & Curry, 2016). It is difficult to pinpoint the exact moment where monetary value is created with open data. This has led to the need to analyse the value creation with open data in terms of a network in an ecosystem, where each actor in a network contributes towards the value generation which is monetized outside of the network (Attard, Orlandi, & Auer, 2016b; Immonen, Palviainen, & Ovaska, 2014a). The importance of open data provider and consumer roles in open data are also stressed by other authors (Latif, Saeed, Hoeer, Stocker, & Wagner, 2009). A review of current business models in open data describes that the value proposition in open data is based around data quality, data availability, data integrity, infrastructure provision and analytics for a specific purpose (Zeleti, 2014; Zeleti, Ojo, & Curry, 2014). Where the latter two are arguably not value propositions of open data but of data in general. An extensive study by Yu (2016) identifies and relates a large number of concepts related to value in open data business models, but because of a lack of approach and its size, the framework is difficult to apply. A further study provides cases which go into more detail about how a service is delivered and to which customers. This is a valuable concretization of business models in the open data research, yet it is a description of the current practice, not the design for a new service (Zimmermann & Pucihar, 2015).

The value creation concept in the business models stresses that the open data is a public good, being non-rivalrous, not excludable, having high fixed costs at almost zero marginal cost, which means it cannot be sold directly (Jetzek, Avital, & Bjørn-Andersen, 2013; Lindman, 2014). Consequently, value creation on open data is performed through adding consultancy services, conversion services (i.e. cleaning and preparing data for analysis) and application development on top of providing the open data (Lindman, 2014; Lindman, Rossi, & Tuunainen, 2013). Based on this public good characteristic, value creation in open data is compared to value creation and business models in open source software (Ladstätter, 2015; Lindman, 2014). One major issue in the creation of services on based on the open data is the lack of quality assurance, varying from the sustainability of the data supply (Jetzek, 2017) and the quality of the data (Immonen, Palviainen, & Ovaska, 2014b), which create risks for commercial service providers which provide services to clients with a guaranteed minimal level of service (i.e. Service Level Agreement or SLA) (Immonen et al., 2014b). Considering the difficulty of generating direct revenue from the open data, one cluster of research concentrates on the possible revenue models for open data platforms which offer the public good of open data. Which vary from sponsored, advertisement-based, freemium and premium models (Bonazzi & Liu, 2015; Duval & Brasse, 2014). Notable is the argumentation from the perspective of a governmental geo-data collector that the cost to create an e-commerce infrastructure to sell their data would make their data as expensive as existing premium offers where the client pays full price for the data. As a result, the government agency should prefer an open data publishing model in order to be able to provide a public good and make itself relevant to society (Ladstätter, 2015).

A further common topic amongst the articles is the linking of open data with other issues, such as intelligent transportation, biotech and smart cities (Giovani, 2017; Kostiainen, Zulkarnain, Leviäkangas, & Hautala, 2013; Mrazovic et al., 2016; Walravens et al., 2016), including one article that provided a detailed service design, but unfortunately no approach for designing services (Guesmi, 2014). In smart cities and biotech-related articles, the open data is not a core product but could enrich existing products and services. For intelligent transport, the papers call for the opening of data from (semi-) private transportation providers in order to create applications that allow for more intelligent transportation.

The final common topic consists of two articles which are based on big and open earth observation data, in line with the main topic of this thesis. One reassesses the earlier observation made in this thesis that the applications of big and open earth observation tools require commercialization into services. The article describes a report generator for land usage and population statistics based on a location, presenting mainly its technical workings but failing to specify commercial services, simply stating that it will receive income from advertisement, profit from the commercial application and payments for infrastructure utilization (Mildorf, Charvát, Ježek, Templer, & Malewski, 2014). The second article from this cluster is a review of smart farming based on big data from especially internet of things based sensors, but also including open data sources. The article concludes that the availability of data analytics for farming will change yet again the way farming is performed, addressing the need for new business models which allow a fair balance between the farmers and providers of the smart-farming applications (Wolfert, Ge, Verdouw, & Bogaardt, 2017).

2.3.3 Influencing factors

Throughout the literature on open data and open data business models, several factors influencing the design of services have been identified. The first, and most notable, is the public good characteristic of open data, which makes it both non-rivalrous and non-excludable. Unlike private datasets, the data itself cannot be sold and its possession does not have any inherent value. However, handling open data does involve relatively high fixed costs since data collecting, storing and processing infrastructure is required. Once such infrastructure is in place, the cost of serving a single user, i.e. the marginal cost, is close to zero. Also due to its free and 'provided as is'-nature, there is no guarantee for the future availability and continuation of open data supply. This is valid for both whole open data infrastructures as well as smaller sets of data or individual data points. The latter also touches on another issue that affects the open data services: the quality of the data is not guaranteed.

Table 6: Open data characteristics affecting service designs

Characteristic affecting service design	Source
Non-rivalrous, non-excludable (public good)	(Jetzek et al., 2013; Ladstätter, 2015; Lindman, 2014)
High fixed cost/ low to marginal cost structure	(Jetzek et al., 2013; Ladstätter, 2015)
No supply assurance / continuation at risk	(Immonen et al., 2014b; Jetzek et al., 2013; Zeleti, 2014; Zeleti et al., 2014)
No quality level guaranteed, data is provided as-is	(Attard et al., 2016c; Immonen et al., 2014b; Zeleti, 2014; Zeleti et al., 2014)
Mutual information asymmetry: providers do not know what users need and users do not know how open data can help.	(Foulonneau, Turki, Vidou, & Martin, 2014; Janssen et al., 2012; Janssen & Zuiderwijk, 2014)

2.4 Big data

This section of big data presents the findings in the literature, starting with the definition of what big data is and how it is currently used in services. Then, the technical aspects of big data that influence services are presented. All identified big data factors influencing service design are then summarized in the last subsection.

2.4.1 Big data definition and influences on service design

Big data is defined in literature through its characteristics, with the common denominators of high volume, high variety and high velocity (Gartner, 2013; Rodríguez-Mazahua et al., 2016; Sagiroglu & Sinanc, 2013). The high volume characteristic of big data refers to the large amount of data which require storage. The high variety refers to the different data types (such as text, image, and sensor) and the degree of structure of the data. Finally the characteristic of velocity refers to the real-time streaming of data, instead of working in batches (Rodríguez-Mazahua et al., 2016; Sagiroglu & Sinanc, 2013). Whilst volume, variety, and velocity are the most common, more articles expand the definition to include value and veracity. Veracity, or truthfulness, which refers to the amount of useless or wrong data points (i.e. "noise") that is in the data whilst the value refers to the inherent cost that is nowadays associated with the data, i.e. through purchase as a commodity or in storage and processing (Rodríguez-Mazahua et al., 2016). For future purposes, this thesis will use the definition by De Mauro, Greco, and Grimaldi (2016) which states that "Big Data is the Information asset characterized by such a High Volume, Velocity and Variety to require specific Technology and Analytical Methods for its transformation into Value" (De Mauro et al., 2016, p. 131). The supposed benefits of big data are improved business insights, core operating processes improvement, better and faster decision making (Rodríguez-Mazahua et al., 2016; Thomas & Leiponen, 2016) and have been applied in various domains: primarily business intelligence (Thomas & Leiponen, 2016), but also medicine (Khoury & Ioannidis, 2014), logistics, transport and infrastructure within the smart city (Puiu et al., 2016) and manufacturing within the industry 4.0 concept (Wang, Wan, Zhang, Li, & Zhang, 2016). Two concrete examples of big data are the Large Hadron Collider and Walmart. Walmart registers 1 million customer transactions every hour and stores about 2.5 petabytes of data whilst the Large Hadron Collider, the world's largest particle accelerator, generates up to 200 petabytes per experiment. One petabyte is 1000 terabyte or 1000000 gigabytes, which corresponds to 500 regular 2TB hard drives.

However, big data has its limitations, barriers, and impediments. Starting from a technical perspective, this large amount of data requires dedicated infrastructure for transfer and storage, as well as dedicated software (Katal, Wazid, & Goudar, 2013). Together with the resource-intensive analysis, the whole infrastructure and capability of performing analysis on big data come at a significant economic operation cost as well as initial investment costs (Rodríguez-Mazahua et al., 2016). On top of this, there is the risk that the results from the analysis eventually provide no or little additional value (Azevedo & Santos, 2009). To reduce these costs and to take full advantage of distributed computing techniques, thinking about whether to transfer the data, where and how to store the data and where and how to process the data is an essential part of big data processing (Katal et al., 2013). Storage or processing elements can be provided as a service by major information technology infrastructure providers such as Amazon, Microsoft and Google. This raises the next issue of security, commonly expressed in the trilemma between confidentiality, integrity and availability (Olivier, 2002). If the data is processed and stored somewhere other than at the owner of the data, is the confidentiality of the data adequate? How reliable are the results of an analysis processed somewhere else? And, considering the technology put in place to increase confidentiality and integrity of the data and data processing is the data still sufficiently available? Creating an architecture considering the remote storage or processing of data must be evaluated in terms of security as well as financially (Sagiroglu & Sinanc, 2013).

2.4.2 Influencing factors

From this section of big data, a number of influences on viable service design have been identified. The high fixed cost and relatively low marginal cost of the data processing, which influences cost structures. Big data also requires high computational resources for the processing and analysis of data, as well as networks capable of transferring large amounts of data and large amounts of data storage. Current technologies allow for decoupling of these three required resources to different locations. While this allows more flexible designs, it also raises security concerns, commonly expressed in the triad of confidentiality, integrity and availability. Privacy concerns are a specification of such confidentiality concerns but are of high importance because of the criminal laws that penalize privacy infractions. The table below provides a summary of the characteristics of big data that have been identified to affect the service designs.

Table 7: Big data characteristics affecting service design summary

Characteristic of big data affecting service design	References
Low marginal cost, high fixed cost structure	(Thomas & Leiponen, 2016)
Requires high computational resources	(De Mauro et al., 2016; Wagemann, Clements, Marco Figuera, Pio Rossi, & Mantovani, 2017)
Requires large storage and dedicated storage technology	(De Mauro et al., 2016; Katal et al., 2013; Wagemann et al., 2017)
Requires high network resources	(De Mauro et al., 2016; Wagemann et al., 2017)
Security design choices: the triad of confidentiality, integrity and availability	(Sagiroglu & Sinanc, 2013)
Privacy concerns	(Sagiroglu & Sinanc, 2013; Thomas & Leiponen, 2016)

2.5 Earth observation data

This section on earth observation data firstly defines earth observation data. This is followed by some of the more practical issues that arise in the use of earth observation data and an overview of examples of how earth observation data are applied and what insights can be gained from them, as well as issues that come up in its use. Finally, the factors of earth observation data that influence service design are summarized in the last subsection.

2.5.1 Definition and practical characteristics

The term earth observation data is used for data which contain information about the atmosphere and surface of the earth but is generally used to refer to satellite images of the earth (Koubarakis et al., 2016; Sutherland et al., 2012; Wulder & Coops, 2014). Examples of such earth observation data are the data collected by the ESA Copernicus and the NASA Landsat programs which contain visible light, near-infrared light and radar imagery (Santamaria et al., 2017)[7]. Having more than just visible light allows for image analysis under different circumstances, such as clouds which obstruct visibility and thus the visible light spectrum (Santamaria et al., 2017).

Because of their direct relation to the earth's surface, earth observation data have a coordinate reference and a timestamp to mark a unique observation at a specific area and time (Karmas, Tzotsos, & Karantzalos, 2015; Santamaria et al., 2017). However, coordinate systems may vary between data sets, data providers and data layers complicating the processing of earth observation data (Wagemann et al., 2017). If the differences in coordinate reference systems are caused by the use of different but well-documented standards, a transformation from one standard to another is sufficient. A concrete example is the combination of radar imagery in the Dutch airspace with publically available maps such as Open Street Map (OSM). Whilst the radar images are published with the Dutch Rijksdriehoekcoördinaten system as simple X and Y values with the city of Amersfoort at its centre, the OSM registers its locations as GPS positions with longitude and latitude on a worldwide scale, using degrees, minutes and seconds. Because both standards are well documented, conversion methods exist for recently taken measurements (Hoekendijk et al., 2015). The conversation between coordinate reference systems becomes more complex when the absolute coordinate reference system of GPS needs to be aligned with a relative coordinate reference system like the Dutch Rijksdriehoekcoördinaten reference system with data that lie back in time. This is due to the movement of tectonic plates and the resulting movement of land masses relative to each other and movement relative to the fixed GPS coordinate reference system. The scope of the Dutch Rijksdriehoekcoördinaten scope is limited to a quadrant that covers the Netherlands. This makes the whole system part of a single tectonic plane and thus is not affected by the relative movement of plate tectonics. In order to calculate between the different coordinate reference systems and within a global CRS over time, the concept of geological time has been introduced to measure where a specific location of the land mass was in the past at a given time (Gurnis et al., 2012).

Another important characteristic of the earth observation data in image form affecting services based on them is the spatial resolution. This is the amount of Earth's surface area covered by a single pixel in the satellite image. The higher the spatial resolution, the better the image quality is, but this also increases data size and thus computational requirements (Karmas et al., 2015, 2016). Currently, the Dutch National Space Office (NSO) uses 5 categories of accuracy: Atmospheric, low resolution, medium resolution, high resolution and very high resolution. Respectively, a pixel of an image in each category represents more than 1km, between 100m and 1km, between 10m and 100m, between 1m and 10m and below 1m for very high space resolution data, practically obtaining a spatial resolution of 30cm (see Appendix B, Examples of available earth observation data, on page 104, second entry). Additionally, the images are not only available in the visible light spectrum, but also in infrared and radar The high and very high spatial resolution data are considered big data and their characteristics overlap with the characteristics of big data described previously in section 2.4, requiring large amounts of storage, computing power and network resources (Karantzalos, Bliziotis, & Karmas, 2015; Karmas et al., 2015, 2016; Koubarakis et al., 2016). Apart from images, earth observation data also include point observations for e.g. height measurements. These are generally stored as vectors and are an important addition to the flat images taken from satellites. Using the height data, the satellite images can be corrected (see later segment on correcting earth observation images) or the data can be used stand-alone to create 3D models of an area once sufficient points are available.

2.5.2 Applications and issues

As portrayed in the introduction, there already exist many algorithms to identify a variety of objects on earth using the various images from the earth observation satellites. During the review of the literature, a number of research articles in a wide variety of areas on the feasibility of techniques have been encountered. These are enclosed in Appendix A, Table of Earth observation applications in literature on page 102. To provide some examples, it is possible to detect the amount of snow on a lake (Kadlec et al., 2016) or detect the kind of vegetation growing in certain areas by combining different spectral datasets with advanced data analysis technique (Barrett, Raab, Cawkwell, & Green, 2016). The quality of surface water can be indicated (Karmas et al., 2016; Read et al., 2017) as well as shipping routes

[7] See also the ESA Copernicus Open Access Data Hub: https://scihub.copernicus.eu/ and the Netherlands Space Office (NSO) portal for earth observation data sources https://www.spaceoffice.nl/nl/satellietdataportaal/externe-databronnen/.

mapped and individual ships traced (Gianinetto et al., 2016; Santamaria et al., 2017). The algorithms that perform these analyses are mutation detection algorithms and classifiers or cluster algorithms. Generally speaking, they detect a change of value in the numeric coding of the pixel (which determines which colour is visible) and, once a data analyst provided some interpretation and scoping of the data, the algorithms can classify or cluster certain pixels. To provide a more concrete example: the ‘snow cover on a frozen lake’ case can differentiate between the ice and the snow on top of ice because of the differences in colour. However, the area of analysis needs to be specified on beforehand by the analyst and a ground truth (i.e. saying what pixel is snow and what pixel is ice) needs to be provided (Kadlec et al., 2016). The snow case illustrates why the spatial resolution is important: the smaller the surface of the earth that can be measured in one pixel, the higher the accuracy of the prediction. However, before the satellite images are used for such an analysis, many corrective steps need to be performed. The first correction is correcting the image of the earth’s curving, followed by correcting for height differences. This process is called orthorectification (Leprince, Barbot, Ayoub, & Avouac, 2007). This also affects which pixel is assigned which location coordinate in the used coordinate reference system. If the objective is to identify objects or patterns on the surface of the earth, the image needs an algorithm which compensates the image for possible effects in the atmosphere (Nunes & Marçal, 2000). There are limits to the amount of correction that is possible. For instance, on a very cloudy day, the visible light spectrum is almost completely blocked and no correction can compensate for this effect. Algorithms exist to identify clouds and mark pixels in the images affected by clouds as unreliable (Ackerman et al., 1998). Other sources of unreliability could be the interference of radio waves from ground stations and satellite measurements (Santamaria et al., 2017). Satellite images as ‘products’ such as the images at ESA and NASA are generally already corrected, as orthorectification as already taken place and a coordinate reference system is applied to the data (Tucker, Grant, & Dykstra, 2004).

Another aspect of earth observation data is its update frequency. Satellites continuously circle the earth and continuously make observations, but not every location on earth is observed all of the time. There can be several days between each observation (Karmas et al., 2016; Santamaria et al., 2017). The ESA Copernicus program promises to, when fully operational, cover every area of the globe at least once every five days (Castriotta, 2017). This means that the service that is designed using the open earth observation data should be feasible with a once in every 5 days input, with the risk of some input being unreliable due to interference or clouds.

The focus of this thesis is open earth observation data, of which there are two suppliers: NASA with the LandSat program and ESA with the Copernicus program (Wulder & Coops, 2014). Currently, ESA is moving to become an open data infrastructure providing better reliability of access and increased transfer capacity, as well as expecting more Sentinel satellite data to be added to the data catalogue (Castriotta, 2017). The catalogue consists of medium-resolution space images as open data and additional resolutions are offered as a freemium service [8]. Private companies such as DigitalGlobe[9] or Airbus Intelligence Space and Defence[10] provide high-resolution earth observation data at commercial fees with service delivery guarantees. With medium resolutions available for free and high to very high resolutions available for sale, the spatial resolution can be considered a trade-off between the quality of service in terms of precision and accuracy versus cost. However, this thesis will focus on open access earth observation data, which is data that, by definition, does not have any acquisition costs for the service provider. Finally, there are many, smaller data analytics companies, such as the Dutch PPO Labs[11], which specialize fully in the optimization of algorithms, not on the value which is created with such algorithms.

2.5.3 Influencing factors

Table 8 below summarizes the previously discussed characteristics of earth observation data that affect the service design or service design process. Firstly, the use and standardization of the coordinate reference system, including its orthorectification is an important factor to consider in the handling of earth observation data. Any errors in this will cause the malalignment of the data, causing inaccuracies in the analysis. A second identified factor is the spatial resolution of the data. The higher this resolution, the more detail the data contains and the better the analysis. As earth observation satellites move around the earth in orbit and are not geostationary, images are not continuous and contain a notable update frequency. The issue of data modelling and semantics is related to what type of data is used and how it is presented, which requires standardization across the system, especially when data from multiple sources are involved. Finally, the data is highly multi-dimensional, as every area of observation contains multiple sensors and time updates.

[8] See the terms and conditions of the ESA open data portal:
https://scihub.copernicus.eu/twiki/do/view/SciHubWebPortal/TermsConditions

[9] See https://www.digitalglobe.com/

[10] http://www.intelligence-airbusds.com/

[11] http://ppolabs.com/

Table 8: Earth observation data characteristics affecting service design

Characteristic affecting service design	Reference
Coordinate reference system	(Santamaria et al., 2017; Wagemann et al., 2017)
Spatial resolution	(Karmas et al., 2016; Santamaria et al., 2017)
Update frequency	(Castriotta, 2017; Karmas et al., 2016; Santamaria et al., 2017)
Data model and semantics	(Santamaria et al., 2017; Wagemann et al., 2017)
Multi-dimensional data	(Wagemann et al., 2017)

2.6 Conclusion Literature Review

The objective of this Literature Review chapter is to provide factors of influence on viable service design, but also a description of the stare of the art of viable service design methods using the research question "What are the factors influencing the creation of viable commercial services based on big and open earth observation data?". This chapter also uses a systematic literature review, and continues the search of the previous chapter. The search in the previous chapter provided the insight that there is still very little academic literature on big and open earth observation data, the focus of this thesis. This requires analysing the three data areas of open data, big data and earth observation data separately for factors influencing viable service design. This is done, and the results of these searches are presented. Within these results, factors that affect viable service design are identified and presented at the end of each data subsection. A summary of these factors, which are used as sensitising concepts in the next chapter, is presented in Table 9 below. Furthermore, all of the viable service designs models and frameworks which were mentioned in the search results are presented. This is also used in the next chapter to select a viable service design model for grounding.

Table 9: Identified factors influencing viable service design

Open data	Big data	Earth observation data
Non-rivalrous, non-excludable (public good)	Low marginal cost, high fixed cost structure	Coordinate reference system
High fixed cost/ low to marginal cost structure	Requires high computational resources	Spatial resolution
No supply assurance/continuation at risk	Requires large storage and dedicated storage technology	Update frequency
No quality level guaranteed as data is provided as-is	Requires high network resources	Data model and semantics
Mutual information asymmetry: providers do not know what users need and users do not know how open data can help.	Security design choices: the triad of confidentiality, integrity and availability	Multi-dimensional data
	Privacy concerns	

3 Requirements Gathering

This third chapter of this thesis is aimed at obtaining the requirements for the artefact. The goal of requirements gathering is to outline the necessities of an artefact. The research question “What are the requirements for a method which creates viable services based on big and open earth observation data?” provides the guidance for this chapter. To answer this question, the big and open earth observation data factors influencing service design and the list of viable service design models obtained in the previous chapter are required. The principal research method for this the case study, in which interviews and participant observations are used for the information gathering. The result is a list of requirements which are used in the next chapter for the design of the artefact. Figure 14 below depicts this research design for this chapter.

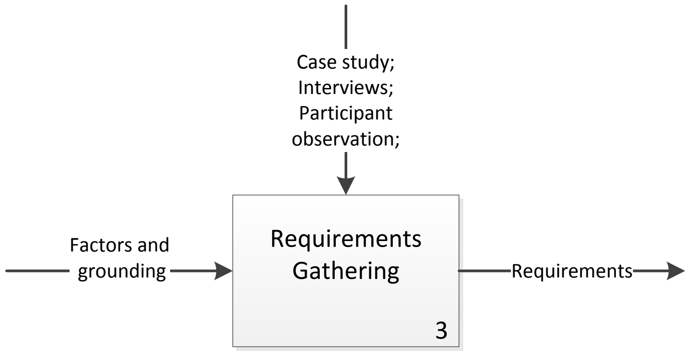


Figure 14: Research design for the requirements gathering chapter

This chapter firstly presents the argument for the chosen method of case studies for requirements gathering and details the case study approach with interviews and participant-observation, as well as the criteria for a case and interview selection. This is followed by a section on each of the case studies of the greenhouse monitoring in section 3.2, the Ems-Dollard estuary in section 3.3, and the migration radar in section 3.4. Finally, a summary of all the collected requirements is presented in the conclusion.

3.1 Requirements Gathering Approach

As indicated previously in the introduction and in the literature review chapters, there are to date few published peer-reviewed articles about viable service design for services based on big and open earth observation data. Within companies such as information system consultancies, information systems integrators, and smaller companies specialized in earth observation data, the practice of viable service design is not widespread either (see section 2.5.2 on page 24). The direct effect is that there are no people accessible to the researcher that can be identified as experts in viable service design within big and open earth observation data.

This lack of experts limits the eligible research methods for requirements gathering. The most common practice for requirements gathering is performing interviews, which are effective if the respondent is competent and applies time and effort (Johannesson & Perjons, 2014, p. 107). Because of the lack of experts on viable service design with big and open earth observation data, the research methods that do not require such input are considered for the requirements gathering. These methods are a case study, observation and document analysis (Johannesson & Perjons, 2014, pp. 107-108). A case study in requirements gathering allows for the deep analysis, identifying needs and practices of stakeholders over a longer period of time, even when these stakeholders do not explicitly name these (Johannesson & Perjons, 2014, p. 107; Yin, 2003). The disadvantages are that it is time-consuming, as well as very specific to the environment, limiting generalisability (p. 107). As the practice of viable service design isn’t commonplace yet, the author expects very few documents on which requirements can be based. Also, observations are good for the identification of additional requirements, but not as a primary method for identification. This is why a case study is selected as the main research method for the requirements gathering.

3.1.1 Case Study Approach

The approach of the case study is based on the propositions by Yin (2003) and Johannesson and Perjons (2014). The case study is exploratory in nature in an attempt to identify the requirements for the artefact (Yin, 2003, p. 5). The object of analysis is an organization, and individuals will be interviewed for information. This results in a case study set-up which should ask how and why an organization works (Yin, 2003, p. 76). Information gathering within the case study can be performed through the analysis of documentation, performing interviews and performing observations (Yin, 2003, p. 86). The analysis of documentation has the advantages that it can be reviewed repeatedly and exactly if the document is sufficiently accessible and neutral (p. 86). Interviews are targeted and highly insightful, but may contain a bias and inaccuracies due to poor recalls of the interviewee or poorly constructed question (p. 86). Observation, specifically participant observation, allows for coverage of the events within their context and provide insights into personal behaviour and motives, but could suffer from a bias due to the investigator's personal involvement. It also requires a lot of time (p. 86). This study will combine these research techniques where possible to reduce bias from the interviewees and the observer and to create a broader set of information sources.

Interviews are planned with people from the organization which desires to realize the service based on big and open earth observation data, as well as people from the organization which would use the service. Detailed criteria are listed below. The interviews are semi-structured and an interview guide is available in Appendix D on page 106. The factors from the previous chapter will be used as sensitising concepts together with the critical design issues from the STOF model within both the interviews and the observations. Furthermore, the STOF model is used to structure the case studies.

3.1.2 Case criteria

In order to select cases and the interviewees within the cases, the following criteria are formulated:

1) **The case involves one or more service providers which:**
    - **Have the desire to create a service using big and open earth observation data as a resource**
    - **Desire this service to be commercially viable**
    - **Are accessible by the researcher and**
    - **Are willing to cooperate and share the information required for this research.**

   This research is about the creation of a method for the design of viable services using open earth observation data as a resource. This first criterion states that a case must involve a company has plans or is already executing plans to create viable services with big and open earth observation data. This company must have a commercial motive and must provide access to the researcher so the requirements for the artefact can be obtained.

2) **The case involves one or more end users of the service which:**
    - **Are not specialized in the processing of big and open earth observation data,**
    - **Have a benefit by using the designed service,**
    - **Are accessible by the researcher and**
    - **Are willing to cooperate and share the information required for this research.**

   The second criterion is intended to select for cases in which the service consuming organization is unable or unwilling to create the service by itself but is interested in the service because it provides a benefit. The user of the service does not have to be the paying client, depending on the organizational arrangement. Furthermore, the end user needs to be sufficiently accessible by the researcher so the needs of the organization can be sufficiently studied.

3) **The case allows for the identification of requirements for the artefact of this research.**

   The objective of the case study is to identify requirements for the artefact of this research, the service design method for viable services based on big and open earth observation data.

4) **The exclusion criteria for the cases are:**
    - Cases that are insufficiently informative or are estimated by the researcher to not provide sufficient new insights are excluded.
    - Cases in which major information is unavailable are excluded
    - No more cases are accepted once current information within the cases is sufficient to generate requirements and additional cases are considered not to contribute sufficient new information to account for their marginal effort.

The author of this research has been allowed by CGI Netherlands B.V. to perform an internship within their company, providing access to their projects as a member of their organization. CGI is a company providing IT systems integrations with a department in Space, Defense, and Intelligence. This department has set up the so-called “Space Validation Lab” (SVL) to facilitate the creation of innovative services based on earth observation data from the ESA

Copernicus open data ties. They have a clear commercial goal and are actively pursuing service design. Of the cases at CGI, the author considered the cases below as fulfilling the criteria. The cases are presented in chronological order:

3.1.2.1 First case selection: Greenhouse monitoring

The first case is the greenhouse monitoring case where CGI is partnering with PinC Agro, an innovation subsidiary aiming to reduce the risks and increase the profit of clients of a major insurance company in the Netherlands, which has a large number of greenhouse installations in their insurance coverage. PinC Agro is interested in reducing the uncertainty of the greenhouse insurance and works together with greenhouse owners to achieve this. The specific interest is the ability to measure the amount of algae and predict algae growth in the water reservoir of the greenhouses because these algae can clog the irrigation systems of the greenhouses. Secondly, the Dutch soil is known for slowly shifting down relative to sea level, a phenomenon called ground subsidence. This causes structural integrity risks for the greenhouses themselves, and discovering such subsidence allows for targeted maintenance before damages occur. This case involves big and open earth observation data as well as an end user, the greenhouse owner, which is not specialized in processing data. Individuals involved in the case are willing to participate in the research, fulfilling all requirements for the case.

3.1.2.2 Second case selection: Ems-Dollard Estuary Water Quality

The Ems-Dollard estuary is a bay forming the border between the Netherlands and Germany. It has a unique ecosystem because of the sweet water flowing from the Ems river mixing with the salt water from the Wadden Sea and is essential in the algae, which form the basis of the food chain in the Wadden Sea ecosystem. Monitoring the water quality in this bay is essential and one of the Dutch Government's tasks according to the Natura2000 treaty between EU member states. This tender has been included even though there is no direct access to the end user because of the tender regulation forbidding direct communication between the researcher as a part of CGI and the government agency outside of the official tender information moment. However, these moments are recorded and transcribed, and the author has access to the documents indicating the governmental agency's position and the transcripts. Because of this, the position of the agency is considered sufficiently accessible, even though there is no direct access.

3.1.2.3 Third case selection: Migration radar

The migration radar project uses satellite imagery and social media data to track the flows of migration within the African continent. CGI wishes to create a viable service using the big open earth observation data and the statistical tools the Dutch Centre for Statistics (CBS). The interested clients and end-users are Dutch government ministries, especially safety and justice, as well as defence and economics. The big and open earth observation data is used, as well as multiple parties being involved in the creation of a viable commercial service. The ministries themselves are not specialized in processing data. Again, a direct line of communication to the end user is lacking, but with transcripts and documentation legally made public, the position of the end user can be sufficiently described.

3.1.3 Interviews

Semi-structured interviews are part of the information gathering methods within the case study. The interviewees for the cases are listed in Table 10 below. Interviewees were selected based on their knowledge level about the case, as well as their availability. No further interviews were held in a case when the information obtained appeared sufficiently complete. Interviews are semi-structured based on the protocol in the appendix, yet some non-structured interviews which provided insightful information have been added as well.

Table 10: Table interviewees per case

Case	Sources and interviewees
Migration radar	Data analyst and solutions architect at CGI Data Engineer at CGI Opportunity Leader and Manager at CGI General Manager at CGI
Greenhouse monitoring	Data analyst and solutions architect at CGI Data Engineer at CGI Opportunity Leader and Manager at CGI General Manager at CGI CGI partner at PinC Agro Greenhouse location manager at Sion
Water Quality	Software Engineer at CGI Data analyst and solutions architect at CGI General Manager at CGI Opportunity Leader and Manager at CGI

3.1.4 Viable service model selection

To structure the case studies and to further identify the requirements needed to design the method, one of the previously identified viable service models, i.e. business models, is selected. Table 11 below provides the overview of the different service models previously presented in section 2.2 on page 16). As established so far, the technical aspects of the service design with big and open earth observation data play a large role in the feasibility, and thus the viability of the service. In addition, the model should be able to structure inter-organizational relations and exchanges well, as critical resources are likely not to be owned by the service provider. The best example of this is the earth observation data itself, which is the most critical resource and external to the service provider.

Considering these criteria, a few models can already be excluded: The VIP framework is excluded because it has a different purpose than modelling viable services. The e^3-value model focusses on the exchange but lacks the technical modelling. CANVAS also the technical modelling, as well as the inter-organizational modelling required. This leaves the choice between VISOR and STOF. As the focus on VISOR is more on interfaces of service delivery instead of the technical architecture, STOF is chosen to structure the cases. STOF allows for the inclusion of a more detailed technical architecture which enables the description of not only the viability of the service but also the feasibility of the service.

Table 11: Overview of viable service and business model frameworks

	Core Concepts	Focus	Visualization
VISOR	Value proposition, Interfaces, Service platforms, Organizing models, Revenue and Cost Sharing, each with more detailed concepts	Interface of value delivery to customer	Conceptual relations
E^3-value	Actor, value object, value port, value interface, value exchange, value offering, market segment, value activity	Modelling how value is exchanged	E3-value ontology: value exchange Input/output diagrams
CANVAS	key activities, key resources, partner network, value proposition, customer segments, customer channels, customer relationships, cost structure and revenue streams	Single organization linear business logic	Concept template
STOF	Service, Technology, Organization, and Finance domains, each with a number of trade-offs to balance or strategy	Integrating four perspectives on business models as domains	Conceptual relations
VIP	Value, Information, Processes	Aligning operational processes realising the value of the actual value goals throughout multiple stakeholders.	Conceptual relations

As the STOF model has been selected for the structuring of the cases, the following subsection presents the detailed workings of the STOF model in detail.

3.1.5 STOF model in detail

The objective of the STOF business model is to capture value for the customer and for the service provider, which in return makes the service beneficial for all parties involved and, thus, viable (Bouwman, Faber, Fielt, et al., 2008, p. 83). As indicated previously, the STOF model consists of four domains: Service, Technology, Organization and Finance (see Figure 15 hieronder) and each of these four areas consists of several factors which can relate to other factors in the same or different domains. For example, the intended value concept of the service domain affects the technological architecture of the systems underlying the digital service, as well as influencing the value network in the organizational domain (Bouwman, Faber, Haaker, et al., 2008).

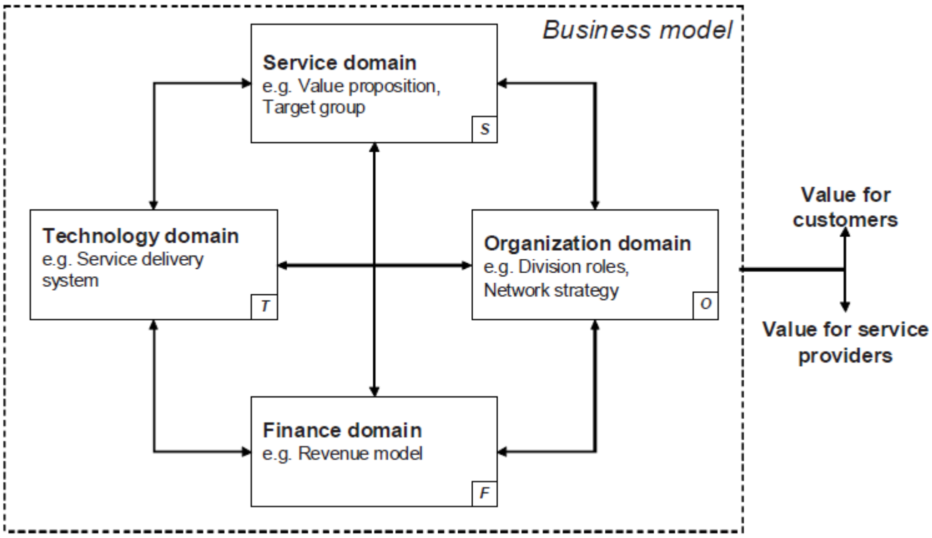


Figure 15: The STOF model (Bouwman, Faber, Haaker, et al., 2008)

In the STOF model, the value capturing for customer and service providers are called "Network Value" (p. 87) and "Customer Value" (p. 85) and to test whether these have been achieved, each value concept has four critical success factors (CSFs). CSFs are the factors that require being satisfactory results in order for the respective value concept to be achieved (Bouwman, Faber, Fielt, et al., 2008, p. 83). If a result on one of these is unsatisfactory, each CSF has one or more critical design issues (CDIs) which are design variables to be addressed. To illustrate the relation between value concept, CSF and CDI: To achieve the value for the service providers, i.e. the value concept "network value", one of the four CSFs is "acceptable profitability" which in turn is the balancing of the CDIs "division of cost and revenues" and "pricing" (p. 87).

As mentioned, every domain within STOF has their critical design issues which are the minimal set of design trade-offs or strategic decisions to create a viable service. Table 12 below describes the critical design issues of the service domain as described by Bouwman, Faber, Fielt, et al. (2008). It contains the four design issues of targeting, creating value elements, branding, and customer retention. The targeting of the service is about who the client is and who the user of the service is. The outcome should describe whether the service is aimed at a small niche and whether it is aimed at consumers or businesses. Furthermore, in more complex service design, the paying customer may differ from the user of the service and this should be explicated. The second service design issue is the value elements which are created for the client and the user if the latter is not the same. It should indicate how the service provides value. The third CDI is the branding of the service, which affects perceptions by the client and/or user of the service. For example, a service could be branded by the sales channel provider because of the good reputation with the clients, could be branded to the content because of its popularity, or could be branded to the creator of the service. The last element in the service domain is the customer retention, which is how continued or recurring use is stimulated. Examples are longer contracts periods or regular e-mail notifications. However, such mechanisms may cause irritation at the client and become counter-productive.

Table 12: CDIs for the service domain (Bouwman, Faber, Fielt, et al., 2008)

Critical Design Issue	Description	Trade-off
Targeting	How to define the target group? Who is the client, who is the user?	• Generic vs. niche service • B2C vs. B2B
Creating value elements	How to create value for the targeted users of the service?	• Technological possibilities vs. user needs and wishes
Branding	How to promote the brand or service?	• Operator vs. content brand
Customer retention	How to stimulate recurrent usage of service?	• Customer lock-in vs. customer annoyance

The second domain is the technology domain (Bouwman, Faber, Fielt, et al., 2008). For digital services, this is especially important as the service is created within the technical domain. The first critical design issue is security: creating barriers for entry to allow only authorized users is a direct trade-off with the ease of use of a service. The quality of service offered, which relates to aspects such as service availability, comes at a financial cost. The integration of the service within existing systems reduces the flexibility of the service design, as a 'green field' situation allows for optimization towards the single service. However, building based on existing systems can significantly reduce effort and cost if done correctly. The accessibility for customers is mostly a technical choice: can the service be accessed in a manner that is open, for example through standardized web browsers found on smartphones, laptops and other computers, or does the service require special hardware purchase, such as paid satellite television or the Apple operating system OSX. This decides the openness of the system. Finally, the management of user profiles personalizes the service to a specific user. This issue is opposed to other forms of the specification of the service, such as location-based adaption of contents and service provision (Bouwman, Faber, Fielt, et al., 2008). Table 13 below summarizes the technology CDIs.

Table 13: CDIs for the technology domain (Bouwman, Faber, Fielt, et al., 2008)

Critical Design Issue	Description	Trade-off
Security	How to arrange secure access and communication?	• Security vs. ease of use.
Quality of service	How to provide for the desired level of quality?	• Quality vs. cost
System integration	How to integrate new services with existing systems?	• Flexibility vs. cost
Accessibility for customers	How to realize technical accessibility to the service for the target group?	• Open vs. closed system
Management of user profiles	How to manage and maintain user profiles?	• User involvement vs. automatic generation

In the organizational domain summarized in Table 14 below, there are four critical design issues in the organizational domain. These are the partner selection, and the openness, governance, and complexity of the stakeholder network (Bouwman, Faber, Fielt, et al., 2008). Unlike the previous two domains, these concern strategic choices which need to be made in relation to other stakeholders. Firstly, the partner selection should provide a strategy on how partners are selected. Partners vary from suppliers to investors. The objective of the first CDI is to obtain access to resources that otherwise would be inaccessible or to obtain resources more cheaply from a different stakeholder to not use up a valuable self-held resource. The network openness describes whether being a supplier, investor, user or client is open to any interested party or whether there are limitations to joining the stakeholder network. This is closely related to the network governance, which describes who can join the network of stakeholders and who is in control of the network relations. An example of such network governance is the difference between the smartphones using the Apple iOS operating system or the smartphones using the Google Android operating system. Apple has strict controls on who can produce smartphones using iOS, whilst Google opens the network for hardware producers to use and adapt the Android operating system according to their needs, with only a few limitations. All these strategic choices create a greater or lesser network complexity, for example when too may suppliers or a too large chain of supply makes central stakeholders lose control of the network or access to resources.

Table 14: CDIs for the organization domain (Bouwman, Faber, Fielt, et al., 2008)

Critical Design Issue	Description	Strategic interest
Partner selection	How are partners selected?	• Access to critical resources and capabilities
Network openness	Who is allowed to join the value network?	• Desired exclusiveness, control, and customer reach of service
Network governance	How is the value network orchestrated? Who is the dominant actor?	• Customer ownership and control over capabilities and resources
Network complexity	How to manage increasing number of relations with actors in a value network?	• Controllability of value network and access to resources and capabilities

The final domain within the STOF model is the financial domain, with the four CDIs of pricing, the division of investments, valuation of contributions and benefits and the division of costs and revenues (see Table 15 below) (Bouwman, Faber, Fielt, et al., 2008). The pricing of the service should directly relate to the value elements from the first domain, as the pricing allows the service provider and its network of suppliers to achieve a return on the value provided to the client. However, other considerations may be at stake, such as a strategy to achieve a high market share which may require low pricing of the service. The division of investments is about who is investing and who takes the risk for the investments. This also returns in the valuation of contributions and benefits. In addition to risk-taking as a contribution, may other tangible and non-tangible contributions can be provided of which the value is sometimes hard to estimate. An agreement on the valuation that satisfies all partners is required. This is also true for the cost distribution, as all partners will be required to pay a cost in order for their contribution The strategic trade-offs between risk, valuation of benefits, valuation of costs and how the revenues are divided requires a delicate balance and a strategic approach.

Table 15: CDIs for the financial domain (Bouwman, Faber, Fielt, et al., 2008)

Critical Design Issue	Description	Strategic interests
Pricing	How to price the service for end-users and customers?	• Realize network profitability • Realize market share
Division of investments	How to divide the investments among business partners?	• Match individual partners' profitability and risk
Valuation of contributions and benefits	How to measure and quantify partners' contributions and (intangible) benefits?	• Fair division of costs and revenues
Division of costs and revenues	How to divide the cost and revenues among business partners?	• Balance between individual partners' profitability and network profitability

Finding the right balance for every trade-off or the right approach for every strategic interest for every CDI can be done by interviewing the service provider and the target customer of the service. This is where the STOF method comes in: it describes how to create the STOF model starting from a service concept in four steps: (1) a quick scan, (2) the CSF check, (3) the CDI design, and (4) the evaluation (De Vos & Haaker, 2008). Standardized questions are available for interviews which allow going through each of these steps (Haaker, Bouwman, Janssen, & de Reuver, 2017). The STOF approach authors emphasize that the method is useful in the early stages of service innovation because of the rapid validation of concepts to critical issues (p. 115). A weakness of the STOF method and model is that lacks structured ways of service concepts generation. The STOF method suggests a few research techniques such as desk research or semi-structured interviews.

3.1.6 Conclusion

The approach to the requirements gathering is a case study approach, in which observations will expand expert interviews in order to collect requirements on the artefact. Based on criteria, three cases are selected: the greenhouse monitoring case, the Ems-Dollard estuary water quality case and the Migration radar case. These will be structured using the STOF model, which is chosen from the previously selected viable service design models and presented in detail in this section.

3.2 Greenhouse monitoring Case

The first case concerns the monitoring of greenhouses with satellite data. In the Netherlands, greenhouses are high-tech agricultural production facilities with artificially maintained ideal conditions for the crop in production. These conditions consist of light intensity, humidity and temperature, amongst others. All these conditions are measured and when any of these rise or fall outside the scope of the ideal condition for the plant, actions are taken. Currently, such conditions are monitored based on on-site sensors and manual observations. Using satellite images to monitor greenhouses could provide extra benefits such as increased accuracy and precision of monitoring as well as doing so at a lower cost. CGI wishes to provide these services together with PinC Agro. PinC Agro provides innovative risk management services to greenhouse companies and can increase their service portfolio by also providing crop yield increasing services.

3.2.1 Service innovation

The very first observation made during the gathering of information is that there was no structured method for determining what services should be developed. Previous research by CGI on what would be possible included a brainstorming session with the contact at PinC Agro and with greenhouse owners. Whilst this initial contact gave the idea of monitoring the algae in water basins, the data scientists afterwards requested more details on the update frequency of the images required to assess whether it was feasible to build the service. This led the author to conclude that a more structured approach was required, and he would perform another interview with a different greenhouse owner. To guide the interview, the author used a list of capabilities which have been demonstrated in academic literature (see Appendix A on page 102) with the objective to find out whether these capabilities in any way are of any value to the company, as well as the sensitising concepts which he judged would affect the creation of a service, namely, the spatial resolution and the update frequency. The results of the interview are as follows:

Firstly, temperatures are important within greenhouses because crops have optimal temperatures for their growth. For example, the Phalaenopsis orchid which is cultivated by one of the interviewees requires 27-28°C in its growth period and 19-20°C in its flowering. However, maintaining such ideal conditions is difficult. Computer-guided models assist the greenhouse operator deciding which actions to take to maintain the optimal conditions as good as possible based on temperature and humidity sensors within the greenhouse. When the measurements of the sensors are considered doubtful, mobile measurements with an IR-camera can be performed to enrich the measurements which are automatically collected. On average, there is one sensor for every 1500m^2 of greenhouse surface which continuously collects data and sends it to a computer system running internal greenhouse climate models. Infrared imagery from the satellites can be used to detect temperatures using the infrared spectrum of observations. This could provide additional temperature information to more accurately monitor the internal climate of the greenhouse in addition to the current sensor technology, especially because of the concern that the temperature measurement by satellite may not be frequent enough to replace current temperature measurement systems.

Secondly, using the earth observation data, subsidence can be detected. This technology has been previously used in assisting the Dutch Hoogheemraadschap Rijnland with dyke inspections[12]. The Netherlands has soil which is very sensitive to subsidence, as for example in the south-western region of the Westland. This affects the mostly mechanized processes in the greenhouse where large tables of around $10m^2$ on which the plants grow are automatically moved. Another problem from subsidence and the resulting unevenness is that water supply and draining systems within a greenhouse stop working properly and get clogged. Once the first symptoms of such subsidence issues arise, manual measurements are performed to determine the scale of the subsidence, followed by whether the ground should be stabilized or increased. Whilst it is possible to monitor such subsidence in the open, the subsidence here is local within the greenhouse, meaning that the outer greenhouse structure can remain unmoved whilst smaller areas within the greenhouse do subside. Thus, subsidence measurement should be conducted within the greenhouse. The spatial resolution of around 1m and the frequency of at least every 5 days of freely available earth observation data are considered sufficient for this feature by the interviewees. Figure 16 below provides an impression of this subsidence detection capability where several points of observation are marked in a greenhouse and their relative moment measured over time.

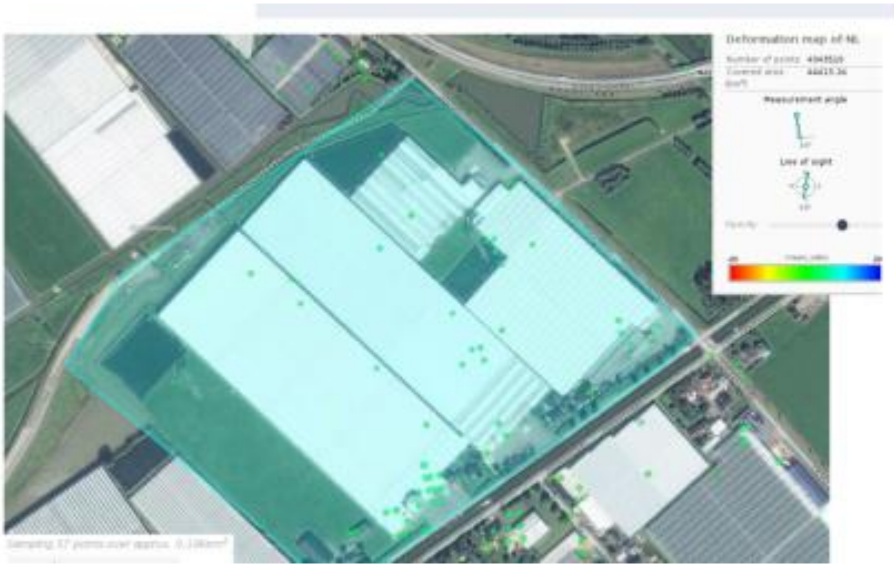


Figure 16: Subsidence detection capability testing for greenhouses

The third application in this case is the capability of measuring algae developments with earth observation data by comparing the amount of the red and blue spectrums of visible sunlight absorbed by chlorophyll during photosynthesis over time. As indicated previously, greenhouses have sophisticated water distribution systems which ideally distribute the exact amount of water required to the plants. To feed the watering system, greenhouses collect rainwater which may be stored in outdoor open-air water basins. The water is filtered and then directed towards the individual plants through small tubes which drip the water regularly to the plant. This system is sensitive for algae growth within the outdoor basin, as too many algae may overload the filtering system and cause algae to enter the tubing system. Here, they can clog the small tubes, restricting the flow of water to the plants causing a water shortage which leads to a loss of production. Furthermore, the cleaning of the tubing system is estimated to cost several ten thousands of euros. Measuring the algae production with earth observation data may provide the information whether the water form a basin is safe to use for production or whether the basin requires treatment. However, as pointed out by one of the interviewees, this issue can also be prevented differently. Directing the water into covered containers limits algae growth to a level which the filtering systems can maintain, meaning that this feature would compete with existing technical solutions.

The fourth and final idea is monitoring the crop growth within the greenhouse. Greenhouses are continuously growing in size and greenhouse operational managers are unable to continuously monitor the growth performance of all areas of the greenhouse. Some areas may underperform due to a large number of reasons, but all too often this is detected when the crops are harvested instead when they are still in growth. Identifying areas with growth performance issues relative to other areas in the greenhouse early on can result in earlier problem identification, improving the crop yield. The growth performance can be measured by the increase in leave mass or amount of photosynthesis within the

[12] https://www.spaceoffice.nl/nl/nieuws/220/verbeterde-dijkinspectie-met-behulp-van-satellietdata.html

greenhouse, similarly as is already done in open fields such as depicted in Figure 17 below. The spatial resolution of about 1m could be more than sufficient for this purpose since the large greenhouses span several tenths of hectares of productive surface. Whether the frequency of the freely available images of an image every 5 days is sufficient depends on the lifecycle of the crop, but could prove sufficient for crops with a lifecycle span of at least a few weeks. The measurements could be made more difficult because of light intensity reducing layers which are applied to the greenhouse in the summer months depending on the crop's tolerance for light.

Figure 17: Vegetation detection in an open field

3.2.2 Service domain

Using the information identified from the service innovation section, the service domain subsection discusses the STOF critical design issues of targeting of the service and the different value elements for the service idea described previously in the service innovation section. Furthermore, the critical design issues of branding and customer retention are discussed. The ideas suggested previously come down to a monitoring service for greenhouse companies. The monitoring allows for the active intervention in the climatic conditions in the greenhouse and assumes that the crops within the greenhouse are monocultures which have only one ideal climatic condition throughout the greenhouse. It is further assumed that these greenhouse companies are interested in the creation of new value elements and have the financial means and the willingness to pay for such value. This would make the greenhouse companies both the client as well as the user of the service.

Each of the four service ideas has different value elements which are of interest to the end user. For the first service idea of temperature measuring, the value element is 'additional temperature monitoring', which contributes to better a better internal climate which increases crop yield. The fourth service idea proposed in the previous subsection, the 'crop growth monitoring', could detect issues with crop growth early on, improving the crop growth issue detection. This, in turn, is expected to also result in a higher crop yield, which in turn is expected to improve the continuity of the greenhouse. The second service idea of subsidence detection reduces the risk that a subsidence remains undetected until it causes damages in the production. The third service idea of algae detection also is a risk-reducing value element: it reduces the risk that algae can cause damages by clogging the water supply. Both risks result, when triggered, in company damages affecting the continuity of the greenhouse. Figure 18 below depicts these expected effects in a causal relations diagram. In the diagram, the curved arrow indicates a causal relation in one direction, which can either be positive and marked with a "+", or negative and marked with a "-". Positive causal relations indicated that an increase at the beginning of the relationship will result in an increase in the effects-side of the relation (or vice-versa). A negative causal relation indicates that the increase of a factor has a decreasing effect on another (or vice-versa).

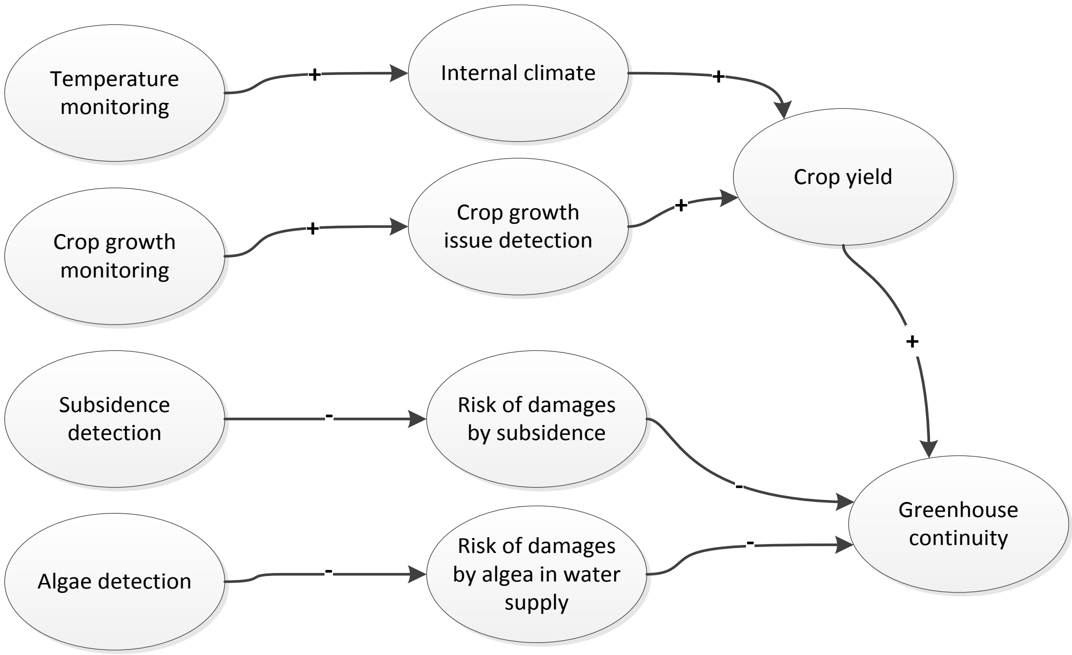


Figure 18: Value propositions (left) and their expected causal effects on the client

The CGI brand is currently not well-known within the agricultural business. However, the partner of PinC Agro currently has many clients and connections within the greenhouse agricultural sector and profiles itself as a risk-reducing and continuity improving consultant. By providing the service under the PinC Agro brand, the service could benefit from the current reputation that PinC Agro has within the sector on top of being able to disseminate the service more easily through the PinC Agro channels. Combining the service with existing PinC Agro services could also lead to increased customer retention without the mechanism being obtrusive. Furthermore, once the service truly adds value to the greenhouse company through increased crop yields or reduced risks, the added value is directly expressible in a cost-benefit analysis.

3.2.3 Technology domain

The service is provided by a digital system which equally requires a design. For the technological design of the service, a set of requirements are formulated based on the information collected in the interviews and the observations and are structured along the MoSCoW functional requirements prioritization technique. A MoSCoW states which functional requirements the system must have, should have, could have or won’t have in this specific version. Because this case concerns service ideas and it is yet unclear whether all features that are desired are possible, the must-have category only contains functionalities that are known to work. The should-have category contains the desired technical innovations and the could-have any extra’s that could improve the user experience. The won’t-have section contains elements that are excluded from this version.

Firstly, as a must-have functional requirement, the system must collect the earth observation data from the ESA data hub, where it is freely and openly accessible. This collected data must be clipped, i.e. only the location area that is relevant for the analytics must stay within the system, and all other areas are discarded to save space. This clipped earth observation data must be stored. In a later stage, the system must be able to run analytics on this data. These analytics must be stored as a time series to be able to measure the change over time. For the analytics, storage and transfer of the earth observation data and its resulting analyses, a cloud-based implementation is considered the only feasible technique. Furthermore, the system must only use a single coordinate reference system, which has been set at the Dutch Rijksdriehoekscoördinaten because of its high accuracy and simplicity, given that the only area of application is currently within the Netherlands. Finally, user accounts should allow greenhouse owners to access the information about their greenhouse and exclusively their greenhouse.

The should-have functional requirements contain the innovative elements of which is uncertain whether these are technologically feasible. Firstly, the system should measure the temperature of the greenhouse using the clipped infrared earth observation images. This measurement may provide imprecise temperature indications because of the changing conditions in an around the greenhouse. For example, a mobile cover in the greenhouse which can be automatically placed and removed can conserve temperature and humidity when deployed by increasing the insulation, which reduces the measured temperature in the IR-imagery. As long as these measurements are accurate, corrections can be applied using the knowledge about certain states within the greenhouse (e.g. insulation deployed or not) and the temperature sensors within the greenhouse for validation. The system should provide the measured temperature values to the climate control system of the greenhouse through an API. However, a functional component creating such corrections is not included in this version of the system design (see won't-haves). The third should-have concerns the possible feature of detecting whether the plants within the greenhouse are growing well or whether there could be any issues with plant growth. Measuring the plant growth progress can be done my measuring the changes in photosynthesis over time. If the photosynthetic activity increases over time, this indicates a growing plant mass. If some areas have better photosynthesis than others, this indicates that some areas are growing better than others. Using the smallest possible spatial resolution of the open earth observation data for this purpose should provide a better overview of plant growth over time than the current system of one sensor every 1500m^2. The fourth should-have feature is the subsidence measurement within the greenhouse. This may be one of the most challenging features to make feasible because interviews indicate that the ground in the greenhouse may subside independently from the greenhouse structure itself. The fifth should-have concerns the measurement of algae in the water. Measuring algae in water is done by measuring the amount of photosynthesis in the open air water basin, similar to the second requirement of photosynthesis measurement in the greenhouse. Storing the change in photosynthesis may indicate growth or decline of algae in the water basin. The values which result from the analysis of the images should be validated by the system using the values from the greenhouse sensors. The values that result from the analyses and the validations should be reported to the end user.

The could-have functional requirements mainly concern the user experience. Instead of just printing the values to a screen, the information could be presented to the end user using a Geo Information System (GIS) visualizer, offering a map of the analysed area and the analysis results as a layer on top of the map. To improve accessibility, the GIS system could be offered as a web service accessible by the user through the internet.

Functional requirements that are excluded from the current version but which may be required for correct functionality in a specific site are listed in the won't-have list. Instead of providing a web interface with the information in layers, integration with the greenhouse specific software would increase user experience even further. However, this won't be included because this is specific to every greenhouse and requires custom integration. The same is true for the possible requirement of correcting the temperature values for the different states of the greenhouse such as the deployment of a cover to increase insulation. Again, this is highly dependent on the specific greenhouse and requires on-site customization which is why this won't be included in the system

Table 16: MoSCoW list of functional requirements for greenhouse case

Must Have	• The system must collect the open earth observation data from the ESA data hub. • The system must clip earth observation data. • The system must store the clipped earth observation data. • The system must perform analytics on the stored and clipped earth observation data. • The system must store time series of the analysis and the clipped earth observation data. • The system must use a cloud-based implementation for storage, computation, and transfer of the earth observation data. • The system must use the Dutch Rijksdriehoekcoördinaten as the coordinate reference system. • The system must use user accounts to allow greenhouse owners to exclusively access the information of their owned greenhouse.
Should Have	• The system should measure the temperature of the greenhouse using infrared clipped and stored images • The system should provide the temperature values to the climate control system of the greenhouse through an API accessible by the climate control system. • The system should measure the amount of photosynthesis per smallest possible spatial resolution to indicate the amount of plant mass inside the greenhouse • The system should measure the amount of subsidence which takes place on the area of the greenhouse • The system should measure the amount of photosynthesis which takes place in the open water basin of the greenhouse to indicate the amount of algae in the water • The system should present the changes in photosynthesis in the greenhouse per smallest possible spatial resolution. • The system should present the level of subsidence per smallest possible spatial resolution of the open earth observation data. • The system should present the amount of photosynthesis in the water basin • The system should use the values reported by greenhouse sensors to validate the results of the analyses of the earth observation data. • The system should print the values from the analyses which are stored.
Could Have	• The system could present the greenhouse and water basin photosynthesis, the greenhouse temperature as well as the subsidence levels as levels over a map with a satellite image of

	the area. • The system could present the satellite image map and its information layers through a web service.
Won't have	• The system won't integrate the crop growth monitoring, subsidence detection and algae detection into existing greenhouse computer systems. • The system won't have a module for providing corrections to the temperature measurements based on states of the greenhouse.

The non-functional requirements for the system contain the security level, the quality of the service and the accessibility for the service. System security is a balance between confidentiality, integrity and availability, also referred to as the CIA-trilemma, as well as what is reasonably user friendly and within budget. Prioritization of the confidentiality, availability and integrity of the data results in design choices. Within the greenhouse case, the confidentiality of the data is the least important. If a rival greenhouse owner receives the information of the client greenhouse, the impact is low: this does not necessarily cause economic damages, nor does it disseminate personal information or cause injuries. The impact of the availability is higher, but still only moderate. Since the service does not replace any infrastructure but only expands it, the scenario of non-availability of the service would not cause any direct damages but could cause opportunity cost in which issues and risks remain undetected. The most important of the three is the integrity of the data. Based on the information, actions may be undertaken. This can vary from increasing or reducing greenhouse internal climate temperature, investing in the cleaning of a water basin with chemicals, investing time in discovering growth issues at certain areas or measure the exact amount of subsidence in certain areas. Taking such actions without the need to will respectively result in reduced crop yield, unnecessary costs, unnecessary labour and again unnecessary labour. Thus, integrity checks on the data may be valuable to lower the risk of intentionally manipulated data or accidentally corrupt data.

The technical architecture of the greenhouse monitoring system are summarized in the Archimate model in Figure 19 below. Its focus lies on the application components within the system and how data is retrieved, processed and presented. At the left had side, the data retrieval is performed from the ESA Copernicus data hub through its API by the collector, which is forwarded to the clipping application resulting in clipped EO data. The clipped data is analysed and results in the four services of algae measurements, temperature measurements, plant growth measurement and subsidence measurement. Authorized users can retrieve the analysis information for their own greenhouse location using a currently still unspecified mapping application.

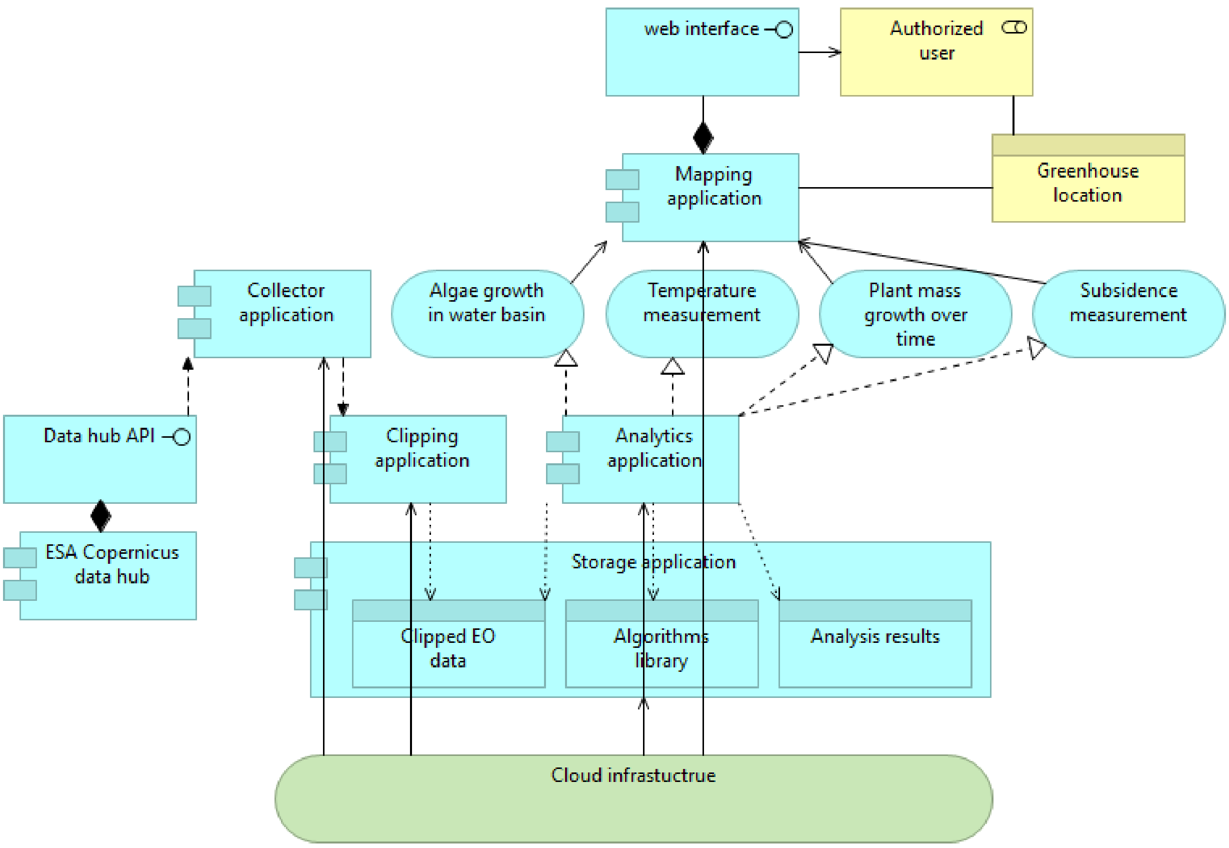


Figure 19: Archimate model of Greenhouse Monitoring system

3.2.4 Organization domain

The organization domain is focussed on the inter-organizational relations of organizations which are required to provide the service. This includes suppliers, investors, collaborators or different partners. In order to provide the service, the collaboration of CGI and PinC Agro is in need of earth observation data and the algorithms to analyze the data, as well as channels to provide the service to several greenhouse companies. Furthermore, an arrangement between CGI and PinC Agro is required. At the time of writing, the information is still uncertain, which is why this section will propose an organizational arrangement based on the observations.

The supplier of choice for the earth observation data is the ESA, which provides open access earth observation data through the Copernicus data hub. The data hub is an open data infrastructure, which means that the data is provided ‘as is’ and with the promise of future releases in form of ‘best effort’, yet without any guarantees or liability. Alternatives exist in form of commercial earth observation data, which have either higher spatial resolution, higher update frequencies, a service level agreement or a combination of the three. The way to perceive the data supply is not as a fixed open data, but more as a market-wide freemium model, where a certain quality is provided for free and everything better at a cost. The algorithms which are used by the data researchers at CGI on the earth observation data originate from university research groups and earth observation data analysis communities. As mentioned in the problem explication early in this thesis, research groups generally create algorithms which can identify very specific information within earth observation data but do not further develop this into a commercial service. Generally, the algorithms are published openly and freely, meaning they are available for modification and commercial reuse. CGI data engineers use, adapt and implement these algorithms. Commercial alternatives on the supplier side exist. Commercial earth observation providers provide a higher spatial resolution, as well as a service level agreement for availability of the data. However, their services are considered expensive. Furthermore, CGI requires a cloud infrastructure supplier is most likely be to be Microsoft with its Azure cloud service. An argument for using this service is the already existing relation between Microsoft and CGI, allowing for a lower price through economics of scale. Furthermore, many of the programmers are already familiar with the platform and are fluent in the programming languages required.

For the distribution of the service, PinC Agro can use its current channels with greenhouse companies. PinC Agro is established in the market and has the resources to maintain relations through account managers with many greenhouse owners. Its brand is also known within the sector, with greenhouse companies willing to present themselves alongside PinC Agro to demonstrate their innovativeness. CGI does neither have these contacts nor the reputation of an established brand in the sector. For these reasons, PinC Agro could handle customer relations, branding and distribution of the service.

The proposed division of the organizational arrangement where CGI is in charge of the contacts with suppliers, whilst PinC agro performs the customer relations allows for a division of the network complexity. The only arrangement still required is between CGI and PinC Agro. Both parties have indicated willingness to co-invest in the service and thus also share some of the risks. This would allow for the arrangement where CGI builds and creates the service, delivering it as a white-label service to Pinc Agro which can then distribute the service. PinC Agro would provide funds as a share for the realization of the service and CGI would provide a minimal service level guarantee in form of a service level agreement. The formal relations chart for the greenhouse case (Figure 20 below) summarizes this proposal. On the bottom and left side of the figure, the suppliers are illustrated which provide their services to CGI. At the right side are the greenhouse owners, which act as client and user towards PinC Agro. On both the supplier side and the user side, the network is open. However, the complexity of the network is limited because of the division of functions between PinC Agro and CGI.

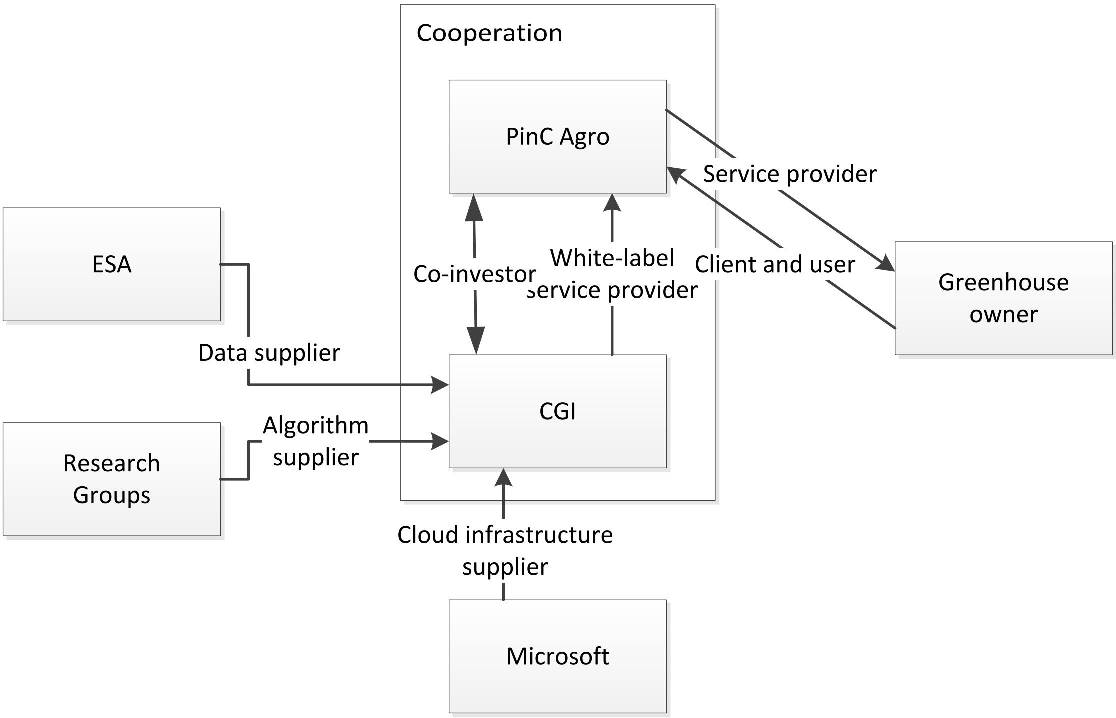


Figure 20: proposed formal relations greenhouse case

3.2.5 Finance domain

The financial domain of the STOF model covers the pricing model, the division of investments, the valuation of contributions and benefits and the divisions of costs and revenues. As indicated previously in the organizational arrangement, the inter-organizational aspects are not yet definitive. Furthermore, the access to financial data was limited, meaning this section can only be executed in qualitative terms.

Starting with the cost structures in the organizational arrangement, the costs of CGI are principally the cloud infrastructure and their own employees, both due at monthly intervals. As the data and the algorithms are open data and open source, no costs are due. If PinC Agro provides the service to customers and performs the billing for the service, a part of these revenues should be given to CGI for the compensation of costs. As both CGI and PinC agro have co-invested in the service, the profits of the service should be shared. Negotiations between these parties allow for the determination of quantified distributions. The pricing model for the greenhouse monitoring service itself is planned to be a monthly fee, like most of the costs are. The amount to be priced could depend on the surface to be monitored, as the size of the greenhouse can be assumed roughly proportional to the revenue of the greenhouse owning company. An additional pricing factor can be added to the crop that is to be monitored, as it is assumed that every crop has a different profit margin. This would provide some value-based pricing. Furthermore, every new type of crop will require recalibration of at least the plant growth monitoring tool by CGI since plant growth is different for every type of plant.

These value exchanges are depicted in Figure 21: Proposed value network in Greenhouse monitoring case below where service provisions are marked with black arrows and financial exchanges in red arrows. PinC Agro provides the greenhouse monitoring service to the greenhouse owners in return for a monetary fee. A part of this fee is provided to CGI which needs to pay Microsoft as a supplier. The ESA and the research groups have provided their services as open data or open source which means no financial compensation is required.

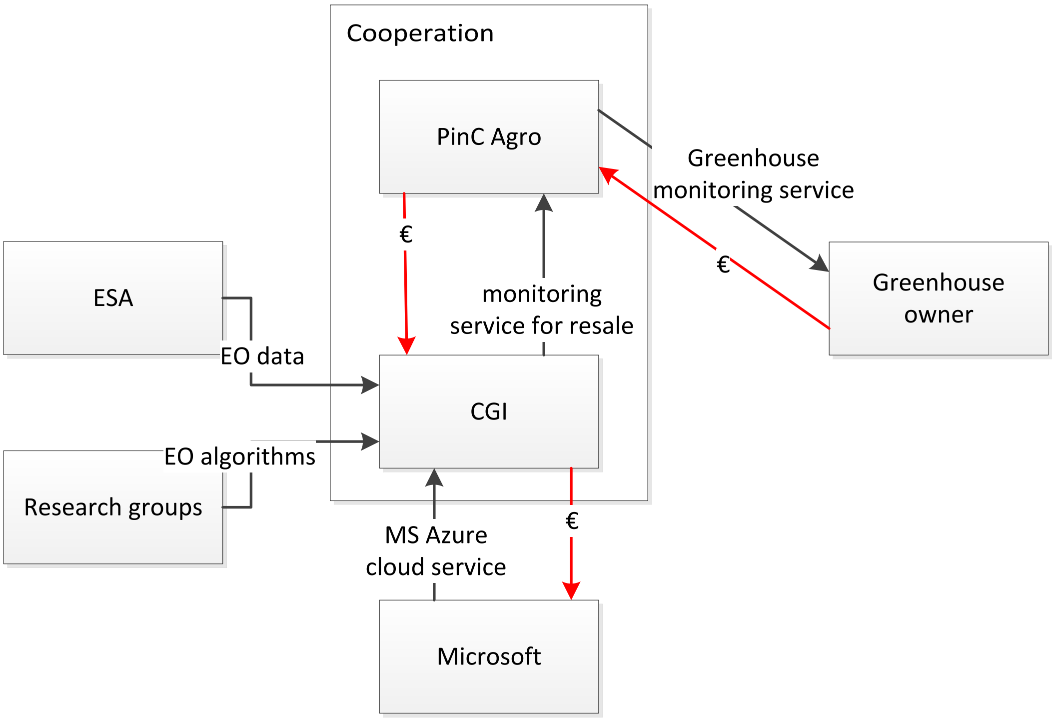


Figure 21: Proposed value network in Greenhouse monitoring case

The risks in the financial and organizational area are mostly on the supplier side. The advantage of open source and open data are that there are no cost for the acquisition of the data set itself, which however comes at the disadvantage of not having service level agreements resulting in uncertainties about future data provision or compatibility with future systems. The risk of termination of the open data infrastructure can be reduced by providing feedback to ESA about the economic value which is created with their open data which can result in increased political commitment by national governments and the European Commission to continue to fund the ESA open data infrastructure (as previously indicated in the literature review in section 2.3 on Open data). Furthermore, commercial alternatives to data providers exist, but these may significantly increase the spending. A change in the cloud service provision could be costly but manageable as there are competitors to Microsoft's Azure, like the Amazon Cloud or more local data centre infrastructure providers. Finally, the risks on the client side are expected to be limited, as there are a significant number of potential clients that are already paying for PinC Agro's services and are interested in the monitoring service as well. This reduces dependency on single customers. This setup also allows for future services to be designed on top of the current monitoring services. For instance, the combined knowledge about crop growth in a certain area can provide statistics about relative performance between competing greenhouses. The analysis of this information can be performed by CGI, allows PinC Agro to offer additional consulting services on crop yield improvement to greenhouse owners.

3.2.6 Case additions to requirements gathering

This section on observations contains the contributions of this case in terms to the artefact of this research. Firstly, the identification of a service innovation phase additionally to the STOF model is the first major contribution of this case to the artefact requirements. The sensitising concepts of spatial resolution for earth observation data and update frequency play an important part in the initial judgement of whether a service could be considered feasible at all. In the technical domain, the inclusion of the confidentiality, integrity and availability (CIA) triad allows the identification of security priorities: Instead of assuming that the data should just be confidential, the security priorities in this case required an approach similar to industrial control systems which prioritize availability and integrity of data. This security design trade-off also allows a more structured approach to the computation requirements of the system of where to store, compute and how to transfer data. The inclusion of a single coordinate reference system was almost tacit knowledge within the earth observation data analysts, which led to only communicating this when challenged on this issue. Including this in the design issues should allow for better communication between stakeholders. In the organizational domain, the STOF model and method provided sufficient grounding to analyse the case. The risk of the discontinuity of open data infrastructures has been included within the analysis, as well as the apparent graduation between free open earth observation data and the more qualitative commercial earth observation data. As the analysis did not include quantitative financial information, not all critical design issues of the STOF model were completed.

To summarize, the following requirements for the method to design viable services based on big and open earth observation data have been identified in this case:

Service innovation requirements:

- The method must be able to guide the process of generating new application ideas in a structured manner.
- The service innovation process must provide information on what is currently possible with earth observation data analytics (i.e. “capabilities”) to the service designer.
- The service innovation process should enable the service designer to link capabilities with core business processes of the potential user of the service.
- The service innovation process must consider the limitations of earth observation data in terms of spatial resolution and update frequency.

Service domain requirements:
- The service design must describe the elements of the service that create value for the user.
- The service design must describe how the service can be positioned and presented.

Technology domain requirements:
- The service design should contain the trade-off of confidentiality, integrity and availability in the technical domain to identify architectural design principles.
- Besides considering the flexibility versus cost of system integration, the service design should consider where to store, process and how to transfer data as a trade off with security, flexibility and cost.
- The service design should include the considerations on the coordinate reference system within data modelling for explication of tacit knowledge.
- The service design should include a clear design of the technology that processes data flows.
- The service design should consider the quality of the open data input.

Organizational domain requirements:
- The viable service design should provide insight in the inter-organizational relations of all stakeholders relevant to the service design
- The viable service design should describe the effects of a disruption of the open data supply

Financial domain requirements:
- The viable service design should provide at least qualitative description of the value exchanges between all relevant stakeholders to the service design.
- The viable service design should provide at least a qualitative description of the risks for each relevant stakeholder of the service design.

These and the requirements gathered from the other cases in this chapter are provided in a complete overview in the conclusion of this chapter. This concludes the first case, which is followed up by the second case on the water quality for algae in the fragile ecosystem in the north-east of the Netherlands: the Ems-Dollard estuary.

3.3 Ems-Dollard Water Quality Case

The Ems-Dollard estuary is a bay along the northern German-Dutch border and has a unique ecosystem of Wadden plates which flood with salt water from the sea and sweet water from the Ems River. The algae growth in the estuary is the first link in the food chain of the Wadden Sea ecosystem and thus essential for the existence of other animals. Within the Dutch Rijkswaterstaat, the idea came up to see whether earth observation data could be used to better measure the water quality of the estuary. This idea has been released as a Small Business Innovation Research (SBIR) tender that CGI is bidding for as the main contractor. The SBIR tender already defines a problem for the interested contractors to solve in a phased approach: firstly a feasibility study, then a viability study and ultimately a service rollout phase. With each phase, the maximum number of bidders in a phase is reduced by one, so three bidders are doing the feasibility study only one bidder is awarded the rollout phase.

The problem of the tender is explained in the next subsection of service innovation, and the service viability design issues in the service domain subsection. This is followed by a significant technological domain description because of the strong technological element of the service and also a significant organizational description because of the changing inter-organizational relations with every phase of the tender. Finally, the financial section will be discussed in qualitative terms and the observations from this case and its contribution towards the research artefact are discussed.

3.3.1 Service innovation

In line with the requirements form the previous case description, this case will also have a service innovation section to describe how the idea for the service is generate and what the service should be able to accomplish. At the origin of the service is the EU Natura2000 treaty, which provides the legal obligation for the Dutch government to disallow a deterioration of the water quality in marine areas such as Ems-Dollard estuary. The government body responsible for the monitoring of the area is the Rijkswaterstaat (RWS). Currently, RSW sends out a crew on a boat to check selected points in the water for nine parameters which indicate the quality of the water. However, this provides only very localised measurements (“point measurements”) and is labour intensive. RWS is interested in a commercial solution which allows for full surface measurements of all the 9 parameters, preferably at a reduced cost. The request is put out as an SBIR tender by the Rijksdienst voor Ondernemen (RVO) on the request of RWS. The RVO agency executing the SBIR is the Netherlands Space Office (NSO). CGI has taken the initiative for a consortium with the earth observation software provider ImageM and the research group for ecophysiology of plants and micro-organisms at the Rijksuniversiteit Groningen (RUG). At the time of writing, the consortium has been awarded the first phase of the tender together with two other competing consortia.

To measure the water quality, RWS requests that the values of nine parameters for the whole surface of the Ems-Dollard estuary are reported in frequent intervals. The nine parameters are defined in the tender call and are as follows: (1) the temperature of the water surface, (2) incoming radiation into the water, (3) the concentration of suspended particle matter (SPM), i.e. particles which drift in the upper layer of the water, (4) the concentration of coloured dissolved organic matter (CDOM) in the water, (5) the coefficient for light half value layer, in which the solar radiation intensity is halved, (6) the concentration of pelagic microalgae, (7) the surface temperature of ebbed Wadden plates, (8) the type of sediment on ebbed Wadden plates, and, (9) the concentration of benthic microalgae.

3.3.2 Service domain

The STOF critical design issues (CDIs) in the service domain are the targeting of the service, the value elements of the service, the branding of the service and the customer retention. Some of these already well-defined or less relevant because of the structure of the SBIR tender. In this case, the value elements for the service are clearly stated by the tender call. Specifically, this is the whole-surface monitoring of the Ems-Dollard estuary, as opposed to measurements on several specific spots, and performing such measurements at lower costs. Furthermore, the service is custom made for a specific problem of RWS, the user of the service, which also defines the targeting of the service clearly. However, in the final phase of the tender the client and user structure changes. The juror of the tender, the NSO, is judging whether the proposal fulfils the criteria of the tender call and if so, awards the tender and transfers the funds. This puts the NSO into a client position, as it partially finances the service development and decides whether it should continue. Customer retention is in the short term equal to moving to the next phase of the tender, as the tender creates the obligation for the calling party to accept the deliverable when it satisfies the requirements set out in the initial tender call. The STOF design issue of branding is relevant as the companies which bid on the tender may not have a bad reputation or lack public trust.

3.3.3 Technology domain

The technology domain describes all the technical aspects of the service, which include its functional requirements and the non-functional requirements such as its security, the quality of the service and the service accessibility. The main objective of the Water Quality SBIR tender is to encounter technical solutions for the problem which has been described by RWS. The functional requirements for the technical elements of the viable service design are listed in the MoSCoW, Table 17 below. These functional requirements are derived from the requirements to the service from the tender call, the interviews held and the observations by the author obtained through participation in meetings and access to description documents.

The Must-have section of the MoSCoW contains all the essential functional requirements for the technical design. Firstly, the NSO provides high-resolution space data for this tender for free. This data would otherwise be subject to payments and retrieving this data from the NSO data hub is an essential functionality. Then, sorting these large amounts of data somewhere where it can then be accessed for further processing. From the interviews it became clear that there is no alternative to a cloud based solution for retrieving, storing and performing computations on the earth observation data. The earth observation data may come in different snapshot sizes depending on the supplier and the satellite that took the image, so the image needs to be clipped. Whilst requiring computation, this is in effect reducing the storage requirements and future network transfer requirements. Retrieving the newest satellite data once a day is considered sufficient for this case. Then, the satellite imagery is analysed by a series of algorithms in order to obtain values for the nine parameters. For example, the change in red and blue visible light reflection in the water could indicate a change in algae levels within the water, as algae absorb only the red and blue spectra of visible light. For such the detection of a growth or reduction in algae, a time series of images need to be compared. Furthermore, the values obtained from the computations need to be validated using the current measurement instruments which use produce point measurements but are normed according to standards and thus have an expected reliability. The historical and current values of these 9 parameters are to be presented, but the format is not specified. For the feasibility study (phase 1 of the SBIR tender), it is even sufficient to provide the information that a value can be measured and provide some kind of support for this information. In the second phase of the tender, and thus the development process, the values should be reported automatically instead of requiring manual instructions from the analysts. A single coordinate reference system (CRS) must be used within the system, this allows for earth observation images to align precisely even though spatial resolutions may differ between images. Based on previous experiences and compatibility, the CRS of choice are the Dutch Rijksdriehoekcoördinaten. Values calculated from the algorithms should also receive coordinates from the same CRS. Finally, the system should allow for multiple users, but must restrict access to authorized users. Finally, there is currently no requirement for the system to be integrated with other, existing IT systems within the first two phases of the tender. Later implementation may follow, but for the moment a stand-alone service fine.

Table 17: MoSCoW of functional requirements for the Ems-Dollard Water Quality case (phase 1 and 2 of the SBIR tender)

Must Have	• The system must access and retrieve the earth observation data from the NSO data hub. • The system must store the earth observation data from the NSO data hub and make it available for analysis and presentation within the system. • The system must select the areas of interest from the retrieved data ("clipping"). • The system must process the earth observation data using algorithms to identify values for the each of the nine parameters • The values identified for the parameters must be validated with values from the normed point measurement tools. • The system must present the current and historical values for the nine parameters • The system must use a cloud based implementation for storage, computation and transfer of the earth observation data. • The system must use a single coordinate reference system • The system must restrict access to only authorized users.
Should Have	• The system should clip the data by only processing areas of interest. • The system should use the Dutch Rijksdriehoekcoördinaten as coordinate reference system. • The system should assign coordinates to values calculated from the analysis of the images. • The system should allow multiple users to access the dashboard. • The system should automatically process the data and report the values for the nine parameters
Could Have	• The system could have the capability to access and retrieve data from other data sources. • The system could present the values through a web portal.
Won't have	• The system won't have rights management for differentiation between end users. • The system won't be integrated in other IT systems

The system requirements above are the basis for the architecture of the system below, which is modelled in ArchiMate (See Figure 22 below). The architecture is a design based on the analysis of the requirements above.

At the left of the diagram is the NSO space data hub with an API that allows for application-level retrieval of the earth observation data. This data retrieval is performed by the collector application. The clipping application takes data from the collector and removes the non-relevant geographical areas of the data. This clipped EO data is less voluminous than the raw NSO space data and is put into the storage. The analysis application can access this data as well as an algorithm library and execute pre-defined analyses on the clipped data in order to generate analysis results. The clipped EO data can be visualized by the ImageM visualization server with the analysis results added as a layer on top of the image. The visualizations are accessible to an end user through a web interface. The collector, clipping, analysis, storage and ImageM applications are running on a cloud service to provide sufficient storage, computation and networking capacity to the system.

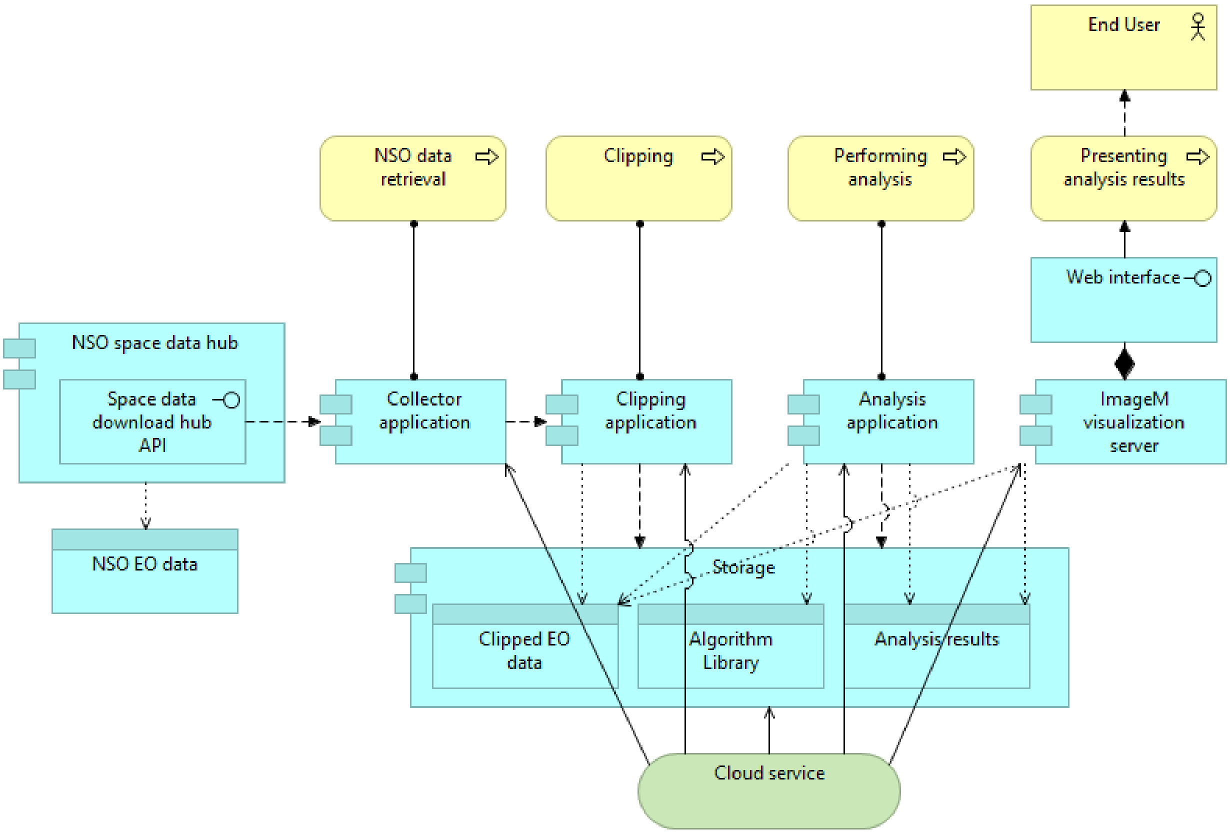


Figure 22: ArchiMate model of required application components for the Ems-Dollard Water Quality case.

Using the cloud infrastructure and a web interface should allow for a good accessibility to the service through any popular browser. Alternatively, web page elements from the interface can be embedded in web portals, allowing for a degree of integration with existing systems through middleware if this is desired. Security concerns that were voiced focused on three cases: erroneous data gathered by the collector, malicious algorithms in the library or unauthorized access to the analyses results. The risk of erroneous data can be partially mitigated by input sanitation of the collector. However, in case of a breach at the NSO data hub such erroneous data may still enter the system. Putting resource limitations and restricting the access possibilities of the algorithms when executed could provide a limited defence against malicious algorithms. Finally, using the software by ImageM with existing user access control should reduce unauthorized access.

Taken together, this design should provide proposals for the design issues of security, system integration, accessibility and management of user profiles. The Quality of service depend heavily on the results of the feasibility study, i.e. whether the objectives of the service innovation can be obtained with the spatial resolution and the update frequency.

3.3.4 Organization domain

The organizational domain describes the way the partner selection is performed, as well as describing the network openness, its governance structure and its complexity. Again, the structure of the SBIR tender provides strong guidance in the organizational domain. Besides specifying the user and the client as previously discussed in the service domain subsection, the SBIR tender also specifies that there should be a 'leading party' who is the point of contact for the NSO. Once a tender has been awarded, the network is closed for further participants until the next phase. For this section, the expansion of dynamic STOF models (De Reuver & Bouwman, 2008) will be used. This states that a change in regulations or the environment will make the STOF model change as well, requiring a more dynamic approach to modelling. The phased approach of the tender allows for shifting partner cooperation and different service exchanges.

In the first phase of the tender, the feasibility study, every consortium has to deliver a feasibility study with limitations to the NSO, which supplies the data for the study. The NSO provides a limited form of open data within the Netherlands only. Earth observation data of the Netherlands with spatial resolutions which are only available on the commercial market are bought by the NSO and provided to organizations within the Netherlands, creating a club-like open data provision. Making use of commercial earth observation data, the NSO can also provide availability guarantees, but only for as long as the contracts are available. For visible light spectra, this is only until 2019 for the and until 2020 for radar-based images. Funding for the NSO depends on political priorities and thus the continuation of the high-resolution data provision in uncertain. Falling back on the lower resolution ESA earth observation data or a commercial alternative may be required in such a situation. CGI takes the role of first party in the tender and is thus the lead service developer for the eventual client RWS. To assist in the development, CGI has contacted a research group within the University of Groningen (RUG) called “Ecofysiologie van Planten en Micro-organismen binnen het GELIFES instituut van de Universiteit Groningen”. This group in the RUG provides expert knowledge on the biological processes of the algae growth in the area. A second contributor is the company ImageM, a reseller of earth observation data visualization software. However their software is not yet required in this first phase of a feasibility study. To stay in the consortium and provide value, their expertise on the processing of earth observation data is provided to CGI.

In the second phase of the study, the viability of the service as well as a service prototype needs to demonstrate to the eventual client of RWS. NSO continues their role as data supplier for the service but is no longer in charge of evaluating the tender. ImageM can provide the visualization software as the service prototype provided to RWS will be based on its visualizations. The RUG will continue to provide their application domain knowledge to CGI. Figure 24: SBIR Phase 2 service provision per stakeholder below depicts these updated relations.

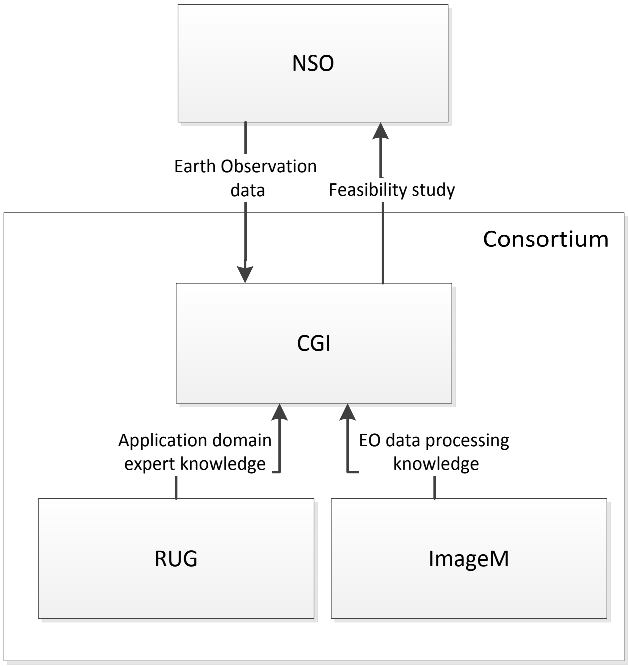


Figure 23: SBIR Phase 1 service provision per stakeholder

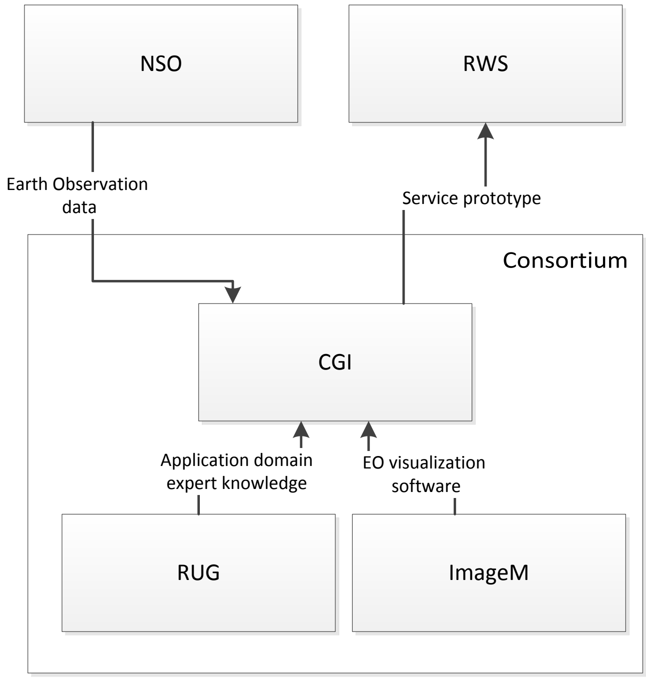


Figure 24: SBIR Phase 2 service provision per stakeholder

Unfortunately, the consortium with CGI was not awarded the rollout of the service, which is why there is no third phase description of the service. To summarize the relations, the structure of relations over all phases of the service design is depicted in the Figure 25 below.

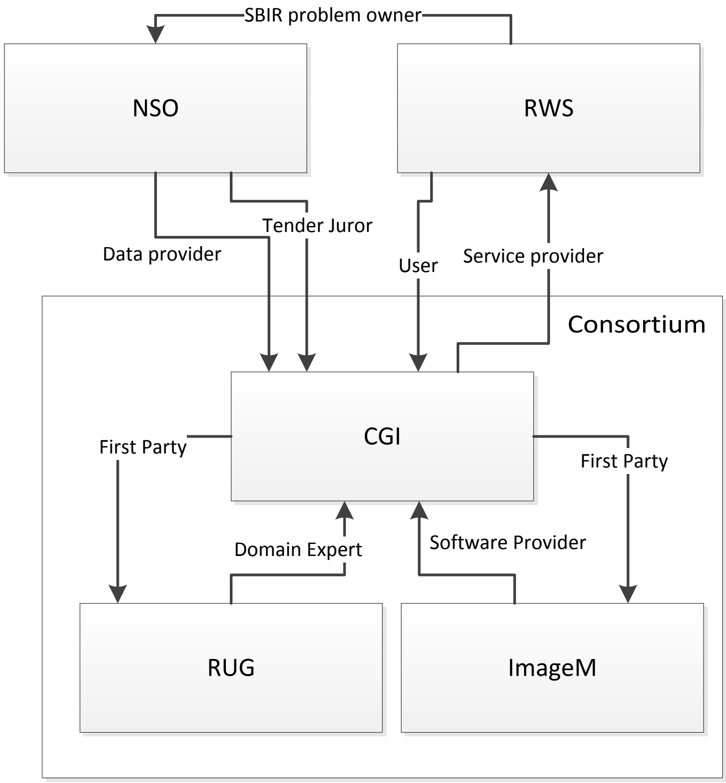


Figure 25: Overall formal relations between stakeholders

3.3.5 Finance domain

The finance domain specifies the financial aspects of the viable business model, such as pricing, the division of investments, the valuation of contributions and benefits and the resulting division of costs and revenues. Some financial details are known quantitatively, because this concerns a public tender. However, not all details are known, which is why the financial domain, like in the previous case, will be covered qualitatively.

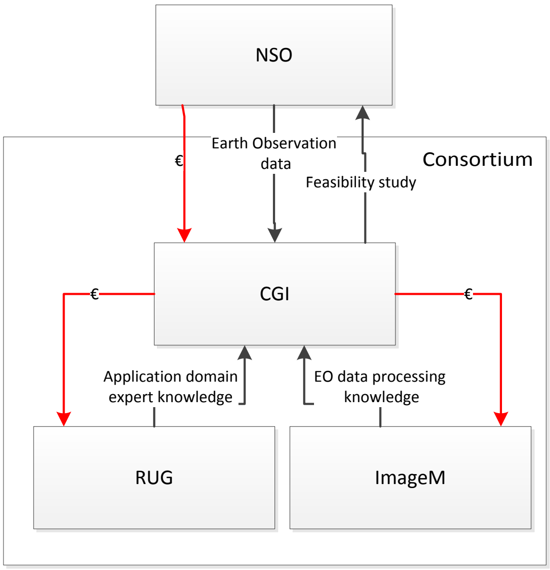


Figure 26: Value network SBIR phase 1

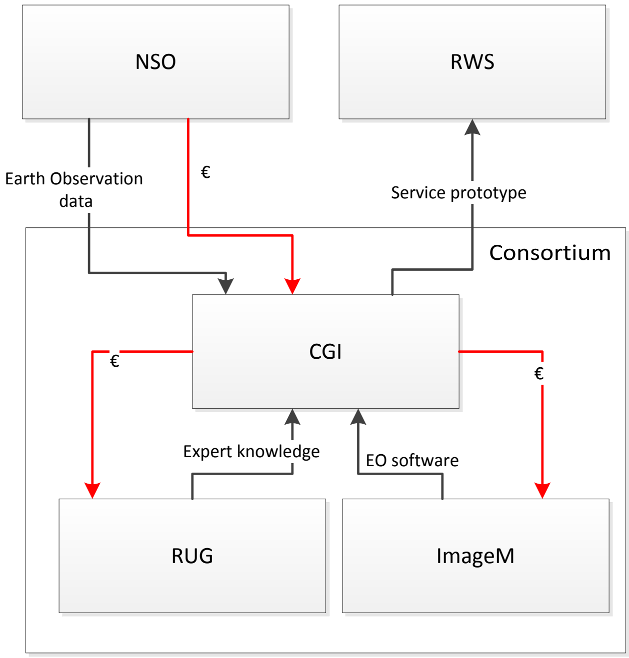


Figure 27: Value network SBIR phase 2

In the first two phases of the SBIR tender, the lead party receives a single lump sum payment for a feasibility study, followed by a further lump sum for a prototype development. In the third phase, the SBIR allows for a buy-option by a governmental agency, but this is not an obligation. In the Ems-Dollard Water Quality case, the lump sum is €30.000 for the first phase and €70.000 for the second phase. If the second phase would have been successful, the pricing model for the service would be open and under consideration by the prospective client RWS. However, as the service proposal did not make the final round, this is not the case.

3.3.6 Observations and requirements

A first observation is that the SBIR tender already structures the service innovation and service domain sections. Whilst this section on service innovation was highly useful in the Greenhouse Monitoring Case, the added benefit of this phase in this case was limited due to the tender structure which clearly defined the context of use, the capabilities required and how the service should look like. Therefore, the innovation section at the beginning should be modular from the rest of the method to allow for selective usage of the service innovation phase depending on the case. The tender did however demonstrate the need for the ability to describe dynamics within a viable service because of the phased approach. This is especially relevant for the organizational and financial domains, as well as the prioritization of functional system requirements in the technology domain. It also demonstrated a special approach for services for government approaches, which are only aimed at one client and have a substantive risk of termination because of the knockout structure of the tender. Furthermore, the whole service is based on basis that there is a law requesting its existence. This is an artificially created demand and may be terminated with the change of the laws, which can occur every few years with a new government. Whilst this specific case is based on an international treaty on climate and thus its sudden termination is less likely, the service is still highly specific and tailored for one client only.

In addition to the requirements previously identified in section 3.2.6, the following requirements are identified:

Service innovation

- The service innovation phase should be modular so it can be used independently from the rest of the viable service design method.

Service domain

- The targeting of the service to government clients (B2G) must be added in the design trade-off.

Organization domain

- The method should allow for the modeling of dynamic stakeholder relations.

Financial domain

- The risks of tender failure or service termination should be included in the descriptions for business to government services.

This concludes the second case, adding to the requirements collected at the end of this chapter. The next case concerns the monitoring of human migration flows using earth observation capabilities and non-EO data.

3.4 Migration Radar Case

The third case to be studied is the migration radar, which has the objective of tracking migration flows, mainly at the borders of the Schengen Zone, the common European frontier. The idea for this service combines earth observation data with social media data and is a proposal for the ESA tender call AO8644 for a feasibility study. The tender calls for an application which uses to use big data to identify migration flows. The objective of such information is to strengthen the European Union’s border security response. The feasibility study should result in a feasible and viable commercial service combining earth observation data and some other form of big data. CGI has been awarded the tender together with the Centre for Big Data Statistics (CBDS) of the Dutch government’s central bureau for statistics (CBS). The service is of interest to the European common border protection agency Frontex as well the Ministry of Foreign Affairs and the Ministry of Security and Justice in the Netherlands. They hope that information about incoming migration flows may help to better allocate resources for border protection and resources to assist asylum seekers. However, the service is already of interest to many other stakeholders who monitor any kind of human transport flow.

As this again is a tender case, the initial problem definition for the feasibility study is already given. Yet the service developed has attracted interest because of the possible wider generality of the core technology. The value of this service is detailed in the service domain section, and the technology in the technology domain. The generality of the application creates new challenges in the organizational domain in form of a complex client network. Finally, the finances are described qualitatively and the requirements for the artefact of this research presented.

3.4.1 Idea generation

The ESA tender specifies that the service should provide the timely information on migration flows and rates and that big data analysis should be used to attain this purpose. The type of big data is not specified, but since the tender is published through ESA, there is a tacit assumption that the service should use earth observation data from ESA.

Currently, the ESA Copernicus data hub provides medium resolution space images are capable of identifying patterns that resemble camping sites. Ideal would be high to very high space resolutions, which allow for the identification of single objects, such as tents, cars or even car tracks. Currently, only medium resolution images are available to the project. To enrich the satellite images, CGI and the CBS are using publicly available social media information, as refugees and migrants are known for using social media to communicate among each other. The most public and open available social media is Twitter, which is also used by refugees and additionally may contain location data when this is turned on. Other social media such as Facebook or Google do not (anymore) allow large-scale extraction of the data shared outside of their respective platforms through an API without paying license fees. This is a severe limitation to the use of this data.

Monitoring the entire Eurasian and African continent for migration flows is considered too extensive for this project by both CGI as the ESA tender jurors. Fortunately, migration flows follow the paths which contain infrastructure for mobility and facilities for migration, such as camp sites. These camp sites and routes are known to Frontex and are shared with CGI, allowing for incremental expansion of the service. The focus of CGI and the CBS is therefore to estimate the number of migrants that use these routes and at what point of the route they are currently located. The idea is to use the satellite images of these camp sites in a time series and detect mutations in the activity. Detecting these relative changes over time can estimate the amount of people at a given time within these sites. Furthermore, using sentiment analysis on the tweets (text messages published on twitter) from the same location is expected to indicate the motivation for migration of the area. A positive sentiment is assumed to indicate a high motivation for migration, resulting in a high percentage of people expected to move to the next point in the migration route. A negative sentiment could be caused by practical issues that reduce the ability to move on or the general motivation to continue the migration, which is assumed to result in a lower estimated percentage of people that are continuing to the next point in the route.

3.4.2 Service domain

The service offers improved predictions on how many migrants try to enter Europe and through which routes these attempts are taking place. Receiving this information early allows the border protection agency Frontex to better monitor and manage the external borders of the common European borders. The service is targeted at Frontex, but the information of where and how many migrants will arrive is also valuable to national agencies of the EU states that are responsible for providing shelter and assessing the validity of an asylum request. Effectively planning the resources to provide shelter and necessities is important, as the migrants require basic humanitarian conditions whilst allocating too much causes wastefulness which is politically sensitive. In the Netherlands, municipalities provide the shelter and necessities, whilst the Dutch Immigratie- en Naturalisatie Dienst (IND) processes administrative processing of the migrants. However, this is only true for the Netherlands. Other EU countries have different agencies that carry the responsibilities of caring for the migrants as well as processing their requests. Furthermore, the Dutch Ministry for External Affairs (Ministerie voor Buitenlandze Zaken or BuZa for short) is interested in monitoring the effectiveness of their foreign policy actions. Creating stable and better living conditions in foreign counties is expected to reduce the number of migrants from that country. So monitoring the flow of migrants is an indicator for the effectiveness of the foreign policy.

Frontex is the main targeted user of this service and the Dutch IND is the secondary client, like the Dutch Ministry for External Affairs. The potential users which are out of scope for this case research are the Dutch municipalities and 27 other EU states with their respective national structure. Figure 28 below summarizes the expected value elements for each stakeholder. The dashed elements are out of scope of this case.

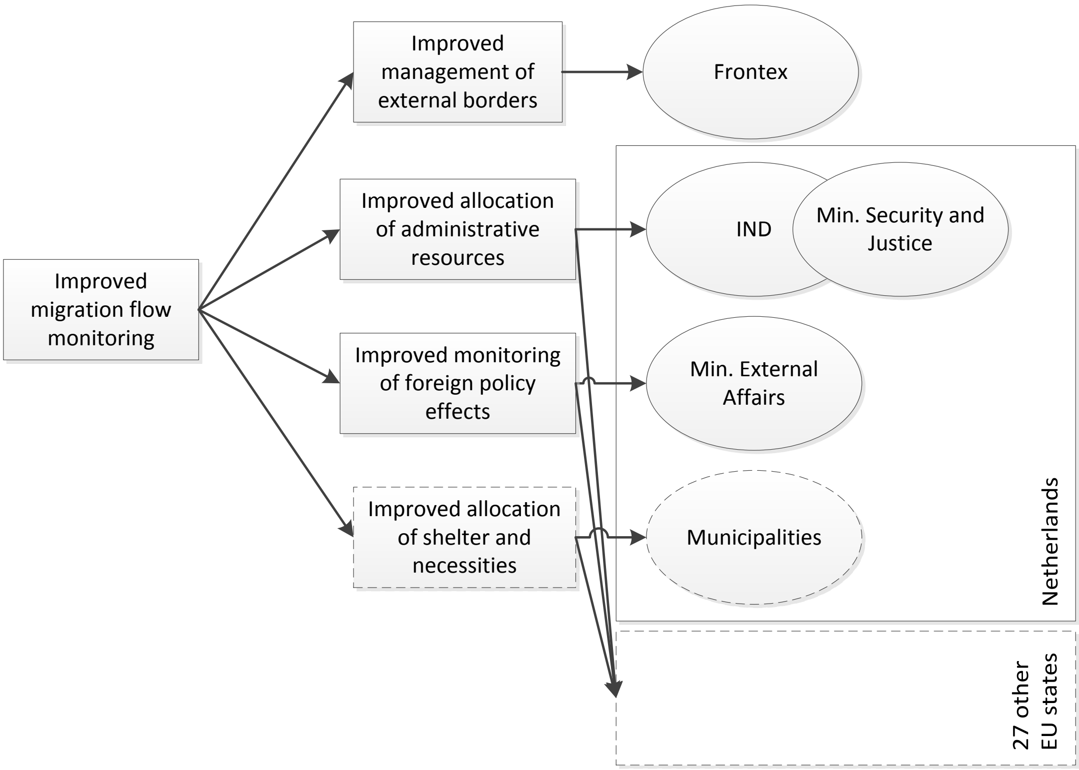


Figure 28: Expected value elements (centre left) for different stakeholders (right).

The service is branded as cooperation between the data analytics experts of CBS and the service oriented information technology integrator CGI. As this is a tender, the customer retention is equal to fulfilling the tender requirements better than any competitors. In further phases where the service is expanded to other possible governmental clients, the branding of reliable and public-private partnership between the CBS and CGI is considered powerful by the people involved in the case.

3.4.3 Technology domain

On the technology level, CGI is tasked with implementing the two different analysis techniques of sentiment analysis and mutation identification and combining these. In order to create such a system that is capable of such analytics, several application components are required. Table 18 below shows the functional requirements that have been identified through the interviews and observations in a MoSCoW prioritization.

Firstly, the system must be able to retrieve data from the ESA data hub, which are available through an API. The clipping application removes all areas from the retrieved data which are considered of no further interest for the following analyses. Areas which are considered of interest are entered into the system by a data analyst and originate for the intelligence of Frontex and ESA. Within these areas of interest, mutation analysis is performed. The mutation analysis algorithms detect changes within the earth observation images and can be trained to detect changes in specific types of objects. In this case, changes in size of known camping sites are essential. At the same time, a dedicated commercial social media application with primary API access retrieves Tweets from twitter and performs a sentiment analysis. Coosto is such a commercial program and is available through a licence that the CBS is willing to share with CGI. The Coosto application is not only available to perform the sentiment analysis and report the results to the main application; it is also capable of accessing the commercial API tweet stream of Twitter. This commercial API stream allows for continuous monitoring without interruptions (which are included in the public free version). The time, location and sentiment of the tweets need to be stored in the system in order to be available for other application components. The data will eventually be presented as layers on an Open Street Map (OSM) application, which has been selected because, as an open source application, parts of it can be copied to a private cloud service and layers can be projected over it. The layers containing the information of camping site growth and the sentiment still require plotting, which a separate application component performs and again stores back in the system.

Migration flow tracking is considered to be politically sensitive and at the same time is considered having a high impact on national security policy; the case requires special security considerations. Considering the issue of security in terms of confidentiality, integrity and availability, confidentiality is most important, followed by integrity and ultimately availability in terms of risk impact. A breach in confidentiality can result in the information about migrant flows and routes to get into the hands of traffickers and migrants. Because of fear of being tracked by authorities, both may favour more dangerous but non-monitored routes or try to seek out new routes. This again directly affects the number of casualties amongst migrants. A breach of data integrity which harms the reliability of the data input could result in allocating resources at the wrong place, in incorrect quantities or at the incorrect time. Besides from being costly, this resource allocation politically sensitive, an important factor since almost all stakeholders are affected by public opinion. Ultimately, the unavailability of the system may cause certain flows to go undetected for the time of the unavailability. However, since migration flows are processes that take several months at least, unavailability for several hours is considered still acceptable. The confidentiality requirement is also reinforced by the Dutch ministries, which have stated reluctance for the system to run on the cloud infrastructure of a commercial provider because of the risk of the data being hosted outside of the Netherlands, or at the very least the European Union. CGI has proposed secure cloud solution developed within a different department for as long as the project is still in the feasibility and viability development phase. In a later phase where the service would be commercially deployed, certain elements such as storage could be modularized and migrated to more secure sites. The result of the security considerations is that there is a strong user account control and access is completely restricted. Once the service will be further deployed, additional security requirements are needed. This is reflected in the could-have functional requirement of storing the results of the analysis in a non-cloud storage which is more secure but does not detail any further requirements as these are not gathered yet. A feature that won't be included is the integration with other systems. Since there is currently only a demand for an advanced demonstration of capabilities, it is unclear yet what the systems of the client are and how the migration radar could be integrated.

Table 18: MoSCoW of functional requirements for the migration radar case

Must have	• The system must collect earth observation data from the Copernicus open access data hub through the API • The system must clip the earth observation data retrieved from the Copernicus data hub to the sites which are identified as 'of interest'. • The system must store the clipped earth observation data from the sites of interest. • The system must retrieve tweets which are from the locations of interest. • The system must perform a sentiment analysis on the tweets. • The system must store the location, time and sentiment of the processed tweets. • The system must use user accounts to keep access limited to authorized users. • The system must use the OSM coordinate reference model.
Should have	• The system should use the Coosto system licenced and provided by CBS for twitter extraction and sentiment analysis. • The system should use a mutation detection algorithm to identify changes in size of camp sites. • The system should plot changes over time in camp size as a layer over a map. • The system should plot the tweets of interest as a time dependent layer over a map. • The system should use a closed OSM fork to graphically present and map the different information layers • The system should be accessible through a web-based browser • The system should use a secure cloud system located within the Netherlands
Could have	• The system could store analysis results in secure non-cloud storage sites
Won't have	• The system won't be integrated in existing information technology systems of the client.

Figure 29 below illustrates the system architecture focussed on the application components. At the left and right outer ends are respectively the ESA Copernicus and Twitter APIs which provide the data. The Coosto commercial twitter analysis applications stores the results in the general storage, as does the data clipper application. The stored data are analysed and plotted into a layer for display on top of the OSM mapping system. An addition to the system is that the whole application runs inside a secured cloud environment on top of a commercial cloud infrastructure provider. This should increase security of the processed data. Authorized users can access the web interface of a private OSM fork running on the secure cloud container.

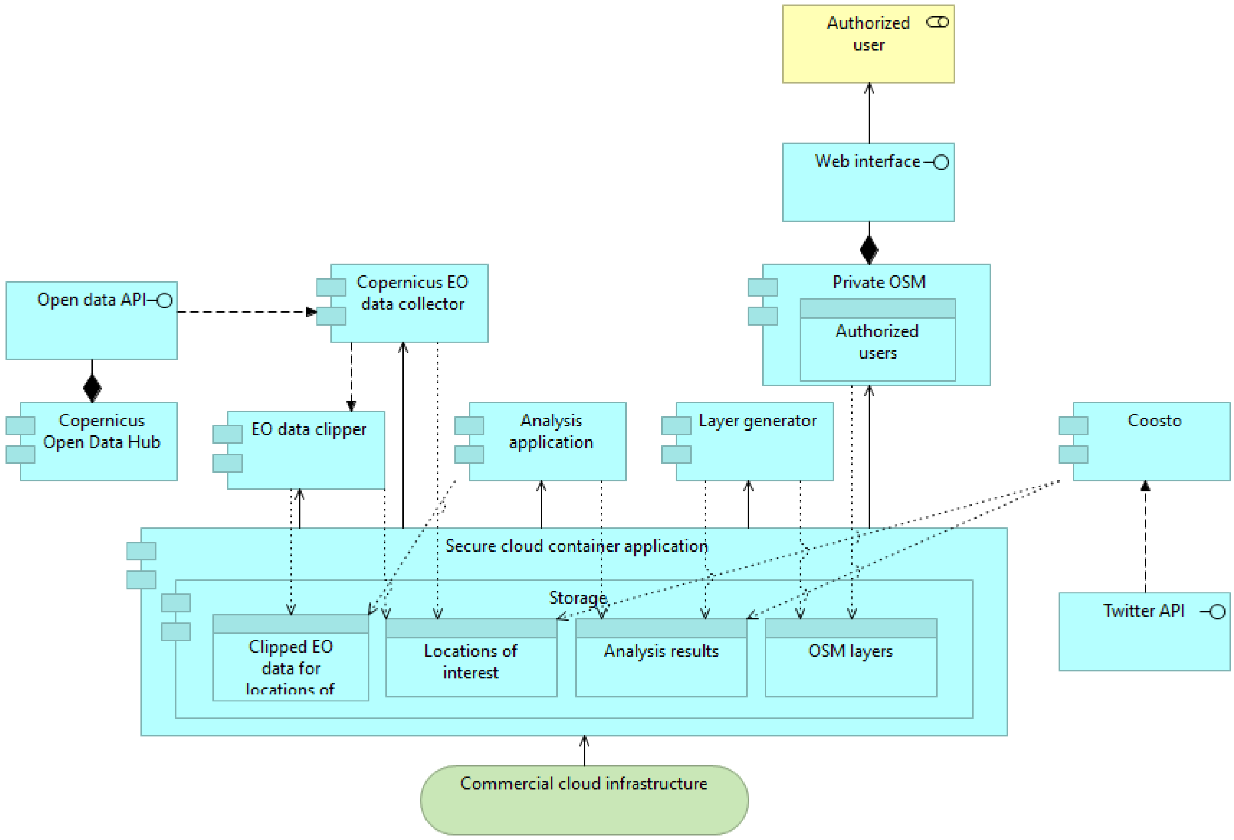


Figure 29: Archimate model of Migration Radar case

3.4.4 Organization domain

The organizational domain and partner relations are highly dynamic because of the changing phases of the tender. The first phase of the tender, the feasibility phase, the structure is still quite simple. In the second phase, the demonstrator phase, more stakeholders show interest and influence the project. Finally, the planned commercialization again changes role distribution amongst the stakeholders.

In the first demonstration phase of the tender, the supplier of the earth observation data is the ESA which also is in charge of providing judgement on the tender awarding and continuation. CGI serves as the primary contractor for the feasibility tender whilst the CBS is registered as the subcontractor, with the responsibility of providing the Coosto licence and expert knowledge on social media data analysis. The relations within the initial feasibility tender are illustrated in Figure 30: Formal relations ESA tender migration radar during tendering below.

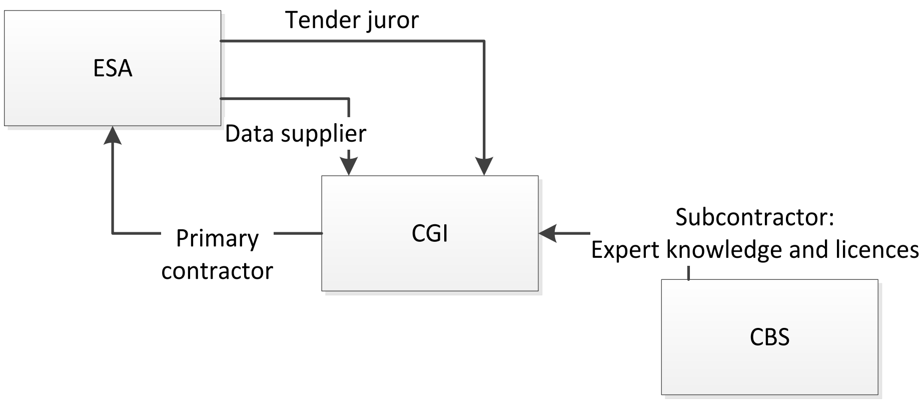


Figure 30: Formal relations ESA tender migration radar during tendering

However, the tender is only a temporary arrangement. Once the feasibility study of the tender is successful, the demonstration phase begins. Here, the eventual clients and users of the service make themselves known and communicate their requirements for the service. The prospective users and clients are Frontex, the IND together with the Dutch Ministry of safety and Justice (Min. V&J) and the Dutch ministry of foreign affairs (Min. BuZa). As long as the project is still in the demonstrator phase of the tender, ESA provides half of the required funding and remains in the client and tender juror role, taking input from the three prospective clients. The other half of the funding is put up by CGI and the CBS. Only once the tender is fully completed do the client roles switch to Frontex, IND, Min. V&J and Min. Buza. They then become full paying clients and the users of the service. CGI is the main service provider, supported and supplied by CBS. ESAs role changes from client and supplier to just the supplier of the earth observation data through open access. This also opens up the supply side of the service, allowing for other earth observation data providers to enter take part. Not illustrated is the supplier of the cloud infrastructure which is generic in nature. Figure 31 below shows the prospective formal relations between the stakeholders in the prospective after tender situation.

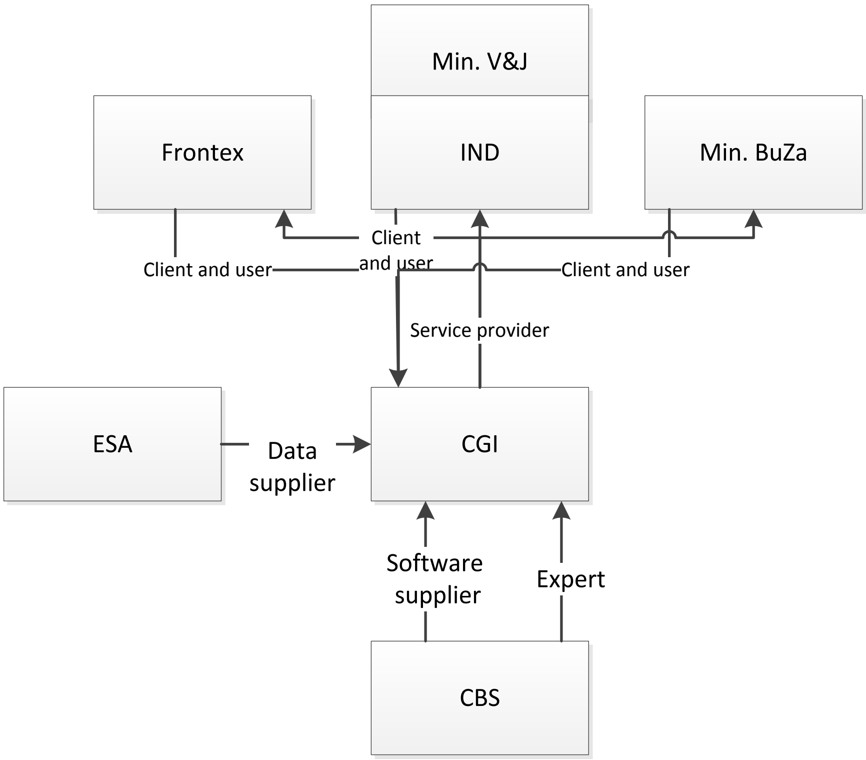


Figure 31: Formal relations for the migration radar after the ESA tender

In addition, a large number of political actors currently not involved, but may become so later on. Since this topic concerns migration, activist NGOs may influence the political parties to which the Dutch ministries are responsible. Secondly, privacy advocates may address concerns about the capability of the tracking of groups of people, and depending on the success of the service, the capability of tracking individuals. The interest of such actors is currently very low, so they are not included in an extensive analysis. However, their influence could result in major changes in the privacy standards of service design. Examples of such actors are Amnesty International for human rights, Stichting vluchteling for refugees, Oxfam Novib for global poverty and Bits of Freedom for privacy-related issues.

3.4.5 Finance domain

With the tender still being in the feasibility phase, the financial aspects of the project mainly focus on the investments required for the service and the risks entailed.

The ESA feasibility and demonstrator phases of the tender respectively provide 100% and 50% of the costs up to an absolute limit. The remaining 50% of the service development cost are invested by CGI. A return in investment element will therefore be part of the cost structure of CGI. Further cost structure elements are the costs for the Coosto software licence provided by the CBS, the expert hours by the CBS in form of consultancy hours and monthly costs for the generic cloud infrastructure. Figure 32 below provides an overview of the financial relations during the feasibility tender of ESA. The financial risk of overspending are taken by CGI, as the CBS has a limited liability over losses and the ESA has a maximum amount of contribution for the tender phases. In case of a failure of the service, risks are mainly at ESA, since they are providing the tender in form of a lump sum payment.

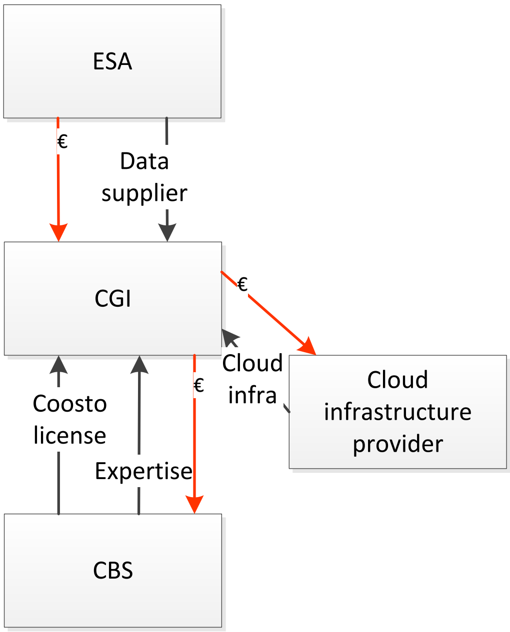


Figure 32: Value network migration radar during tender phases

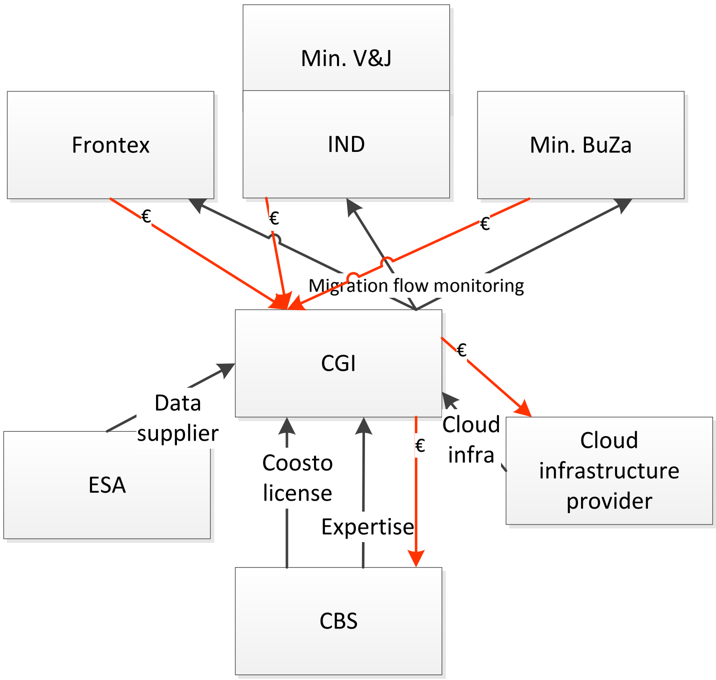


Figure 33: Value network migration radar after tender is completed

After the tender has been completed, clients take over the role of financier. These are expected to be Frontex, IND, Min. V&J and Min. BuZa, each paying a monthly fee for the service. ESA changes into a data supplier and the CBS remains unchanged, as well as the yet unknown cloud infrastructure provider. It is likely the system will be scaled at this point as well, increasing the costs for the clout infrastructure as well as the revenue collected. The financial risks in the after-tender phase are located at CGI, who is contracting the infrastructure and handles the client relations. These relations are depicted in Figure 33 above.

3.4.6 Observations and requirements

This case contains two major characteristics that are interesting for the final artefact of this study. Firstly, it combines earth observation data with non-EO data, specifically the social media data from twitter. This further stretches technical the technical architecture towards more flexibility and different data inputs. A second aspect is the high generality of the value element created. This results in a possible explosion of the client stakeholders, each again contributing to the complexity of the stakeholder field. A minor aspect is the security requirements imposed by the clients. Especially Frontex, which maintains military grade information security levels, challenges the cloud infrastructure required for earth observation data processing. Also, the structure of the ESA tender with limited funding and liability for certain parties puts specific financial risks at different stakeholders. However, in terms of requirements for the artefact, the case does not provide a low of new input. The requirements concerning the capability of setting guiding design principles based on security choices and detailing technical systems architectures has already been covered previously. New is the requirement for non-EO data to be processed and joined with earth observation data in the technical architecture and presentation.

Technical domain:

- The service design should be able to describe a technical architecture in which both earth observation data and other forms of data are processed.
- The service design method should allow the service designer to consider the privacy of anyone affected by the service design.

3.5 Non-functional requirements

In addition to the functional requirements for the artefact identified within each of the cases, a set of non-functional requirements are added to the artefact as well. As argued by Johannesson and Perjons (2014), there are functional requirements that describe which functions an artefact should have in order to address a specific problem and there are non-functional requirements divided into structural and environmental requirements. The structural requirements are requirements towards the internal validity of the artefact whilst the environmental requirements are about the qualities of the relationship of the artefact with its environment (p. 109). These additional non-functional requirements will be used for design but especially the evaluation in chapter 0 on page 65. Only the requirements that are applicable to a method type of artefact are used.

The structural qualities for a method are (p. 109):

- Coherence
- Modularity
- Conciseness

The coherence concerns the logical, orderly and consistent relation of the individual elements of the artefact. If the consistency is low, elements of the artefact do not fit in with the rest. Modularity refers to whether the individual elements of the artefact are sufficiently individual of each other that they can be considered components. Their functions should not overlap and the coupling between parts should be low. Finally, the artefact should be sufficiently concise, meaning that no redundant or abundant element should be contained (Johannesson & Perjons, 2014, p. 109).

The environmental qualities for a method are (p. 111):

- Generality
- Completeness
- Effectiveness

The generality of the artefact describes the degree to which an artefact is applicable to other application domains. This is especially important as the functional requirements gathering relies on non-generalizable case studies. The completeness concerns the degree to which all elements that are required to solve the problem for which the artefact has been designed are present within the artefact. Finally, effectiveness refers to the degree to which the artefact is able to achieve its goals, i.e. to solve the problem it has been created for (Johannesson & Perjons, 2014, p. 111).

3.6 Conclusion Requirements Gathering

This chapter on the requirements gathering aims at collecting all the requirements required for the method to be designed and answers the research question "what are the requirements for a method which creates viable services based on big and open earth observation data?". The approach for answering this question is a case study in which interviews and observations are used for information gathering. The previously in chapter two identified factors of influence on service design are used as sensitising concepts in the interviews. Furthermore, the summaries of the different viable service models are used to identify the STOF model as the most fitting to structure the earth observation cases based on the large technical aspect of the earth observation services. Then, the three cases of Greenhouse monitoring, Ems-Dollard Water Quality and the Migration Radar are presented, each identifying functional requirements for the artefact of which the design choices are detailed in the next chapter. During the case studies, almost all influencing factors of big and open earth observation data identified in the second chapter have either explicitly been recognized by interviewees as important or have been observed to be of importance. An example of this is the coordinate reference system which was identified by an interviewee as highly important but only when asked specifically about this. All the factors that were recognized either through observation or through interviews are processed in the requirements for the artefact. Additionally, non-functional quality requirements are added to the list of requirements, which is presented in full below.

3.6.1 List of requirements

In order to design a method that allows for the creation of digital services both viable and feasible, the method needs to fulfil the following requirements

- The method must allow the designer to describe the value creation for the customer of the service
- The method must allow the designer to describe the value retention for the provider of the service
- The method must be able to guide the process of generating new ideas for the application of earth observation capabilities in a structured manner.
- The method must be able to describe the essential elements that concern the service delivery to the customer.
- The method must be able to describe the essential elements that concern the technical aspects which realize the service.
- The method must be able to describe the essential elements that concern the inter-organizational coordination which realise the service.
- The method must be able to describe the essential elements that concern the financial aspects of the service.

The first two requirements originate from the definition of a viable service and the next five from the components that are important for the description of a viable service that should be technologically feasible and is resulting from cooperation with more than one stakeholder.

The Greenhouse monitoring case has allowed the identification of the requirements for the service innovation phase, which corresponds with the third requirements of the previous list. The list has been expanded with the requirements from the oil tank monitoring case, summarizing the requirements as follows:

- The service innovation component of the method must provide information on what is currently possible with earth observation data analytics (i.e. "capabilities") to the service designer.
- The service innovation component of the method should enable the service designer to link capabilities with core business processes of the potential user of the service.

- The service innovation component of the method must consider the limitations of earth observation data in terms of spatial resolution, update frequency, and cost
- The service innovation component of the method should be modular so it can be used independently from the rest of the viable service design method.

The essential elements of the service delivery are summarized in the service domain requirements:

- The service design must describe the elements of the service that creates value for the user.
- The service design must describe how the service can be positioned and presented.
- The targeting of the service to government clients (B2G) must be added in the design trade-off

Technology domain requirements:

- The service design should contain the trade-off of confidentiality, integrity, and availability in the technical domain to identify architectural design principles.
- Besides considering the flexibility versus cost of system integration, the service design should consider where to store, process and how to transfer data as a trade off with security, flexibility and cost.
- The service design should include the considerations on the coordinate reference system within data modelling for explication of tacit knowledge.
- The service design should include a clear design of the technology that processes data flows.
- The service design should be able to describe a technical architecture in which both earth observation data and other forms of data are processed.

Organizational domain requirements:

- The viable service design should provide insight in the inter-organizational relations of all stakeholders relevant to the service design
- The viable service design should describe the effects of a disruption of the open data supply
- The artefact must be able to describe dynamic inter-organizational relations

Financial domain requirements:

- The viable service design method should allow a designer to describe the pricing strategy for the service
- The viable service design method should allow the designer to provide a qualitative description of the value exchanges between all relevant stakeholders.
- The viable service design should provide at least a qualitative description of the risks for each relevant stakeholder of the service design.
- The risks of tender failure or service termination should be included in the descriptions for business to government services.

Additionally, the non-functional requirements are:

- The viable service design method should be coherent (Coherence).
- The viable service design method should be modular (Modularity).
- The viable service design method should be concise (Conciseness).
- The viable service design method should be more widely applicable (Generality).
- The viable service design method should be complete (Completeness).
- The viable service design method should be effective (Effectiveness).

4 Artefact Design

The objective of this section is to detail the design and justify the choices that led up to the design as it is. In doing so, the answer to the research question “what does the viable service design method for big and open earth observation data that satisfies the requirements look like?” will be given. Using the requirements from the previous chapter and creative methods for the design, the outcome of this chapter is a method which will allow service designers to create viable services based on big an open earth observation data, also referred to as the artefact of this thesis.

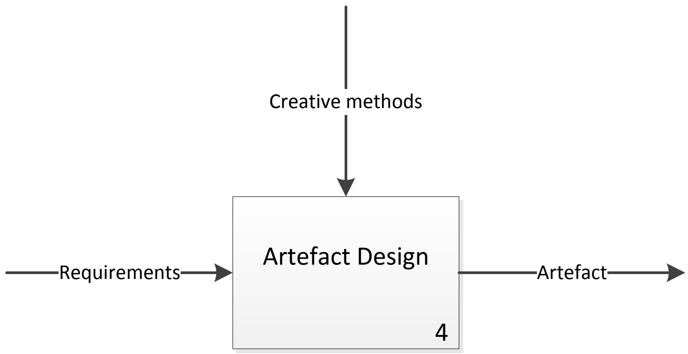


Figure 34: Research design for the artefact design chapter

The first section in this chapter will detail the design approach, after which the principle design choices are presented and justified. Then, an overview of the artefact is given and a detailed description of how every requirement is processed within the artefact is described.

4.1 Artefact Design Approach

The artefact design approach follows the 4 activities of imagine and brainstorm assess and select, sketch and build, and justify and reflect suggested by Johannesson and Perjons (2014). The ‘imagine and brainstorm’-activity is a divergent activity where solution ideas are generated. ‘Assess and select’ is a convergent thinking activity reducing the amount of possibilities to the one included in the ultimate design. In the ‘sketch and build’-activity, previous ideas are described and the artefact is developed, with the design decisions justified in the ‘justify and reflect’-activity. This chapter will focus on the justification and reflection on major design decisions which have shaped the final outcome, after which a detailed description of each of the components of the artefact is presented.

4.2 Principle design decisions

This subsection of the design chapter details and justifies the major design decisions of the artefact.

With the consideration that the method should produce a viable design but cannot go through extensive validation, it is more practical to take an existing and validated viable design method and apply it to the application domain using the functional requirements. The STOF method is previously selected as the viable design method above VISOR, VIP, CANVAS and the e^3-value model. Whilst all models lead to a viable service design, the STOF model concentrates on core trade-offs which require balancing and leaves a lot of space for the technical description of the service. The exact means of how to describe these trade-offs is up to the designer. In the cases above, several diagrams have been used to illustrate sections of the STOF model. For example, the causal relations model has been used to illustrate the relations between service offering and value for the customer. The Archimate model focussed on the application layer with data flows is used to illustrate the technical architecture of the services. Finally, the formal relations model and the value network are used to illustrate the organizational and the financial domains respectively. This flexibility of the STOF model is an important reason to continue using this viable design model with accompanying method instead of the alternatives.

A second major design decision is the addition of a “service innovation”-phase, which is service innovation method for earth observation data based services. The STOF method does not provide a lot of guidance in the creation of new service ideas, mainly in the aspect of making it viable. However, the greenhouse case demonstrates that it is very valuable to have guidance in what is possible with the earth observation data analysis and what not to quickly find possible applications and exclude impossible ones. The added value of this phase is limited in service designs which originate from tenders, which is why it should be a modular addition to the big and open earth observation data applied STOF model. This service innovation phase is named SIMEO for the abbreviation of Service Innovation Method in Earth Observation. As the phase is modular, it may be interesting to add it to one of the non-selected viable service design models in a future research.

4.3 Artefact Composition: SIMEO-STOF

This section describes the step by step composition of the method for viable service design in the domain of big and open earth observation data. First, an overview of the relations between the identified data factors, the requirement and the artefact is given, after which every component of the model is discussed in detail in the following subsections.

As indicated previously at the end of the third chapter, almost all of the factors influencing earth observation data could be processed into a requirement for the artefact which has now been named the SIMEO-STOF method. Figure 35 below provides an overview of the three data types and their characteristics and how they relate to the SIMEO-STOF method. The big data factors mainly relate to the technological aspects of the service design: the storage of the data, as well as the computational and network resources and the security have are technological aspects of the service. The cost structure associated with big data is a financial aspect, and the issue of privacy is linked to the organizational domain. The open data factors are spread over these three domains of the STOF model. The discontinuity of the data is an organizational issue, as new suppliers and arrangements need to be made. The cost structure of open data affects the financial aspects of the model whilst the quality of the data is mainly a technological issue which then affects other areas within the service design. Ultimately, the information asymmetry phenomenon which has been identified as a factor for open data is not exclusive to just open data but probably to any data science application as non-specialized is not aware of the capabilities of the data. This factor is processed as a requirement for the service innovation method section itself. The earth observation data factors of spatial resolution and the update frequency are processed as requirement for the service innovation method, whilst the identified factors of the coordinate reference system and the data semantics are explicated within the technology domain.

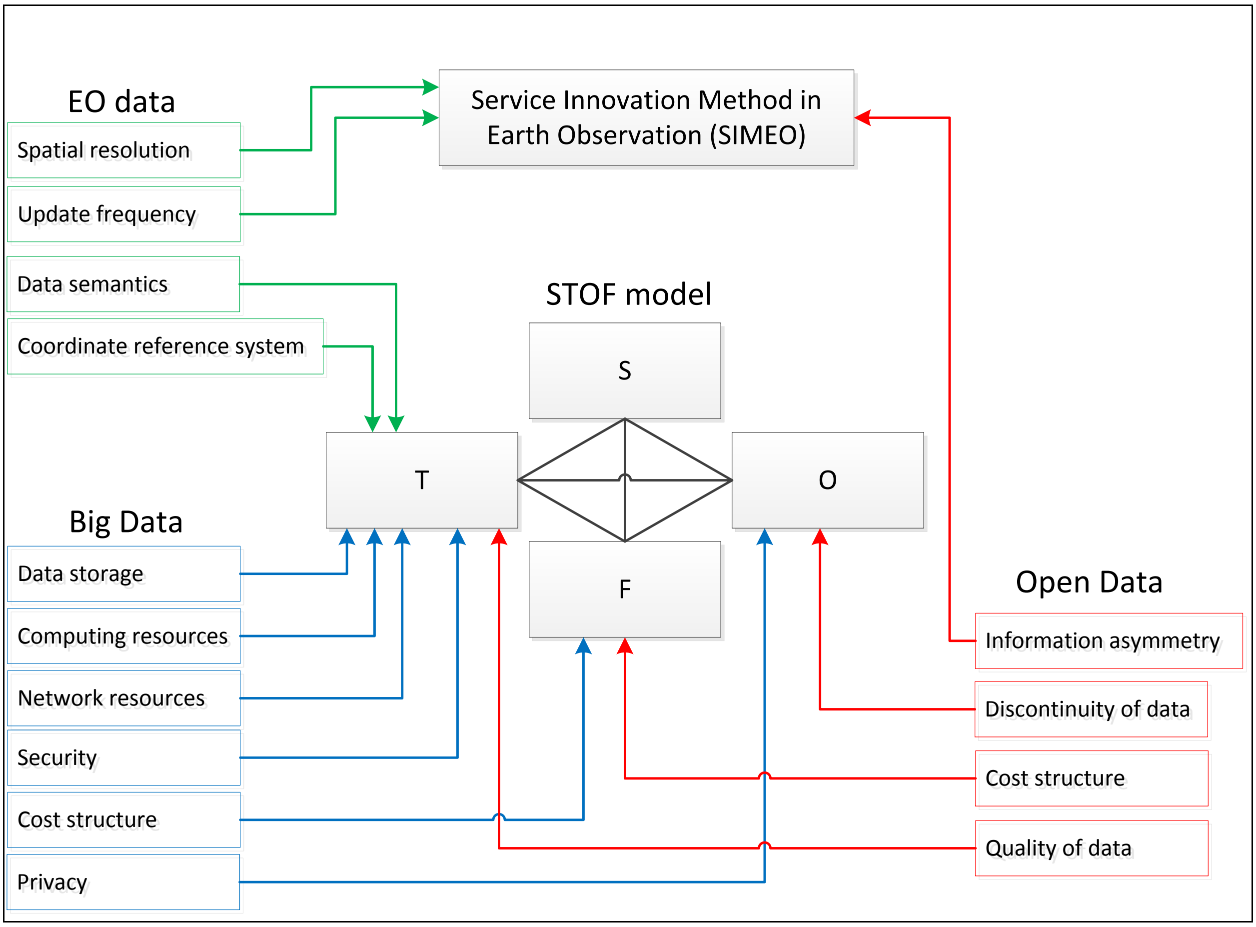


Figure 35: Data factors and their relation to the SIMEO-STOF method

How each of these factors, together with the additional requirements is processed in the individual components of the SIMEO-STOF method is detailed in the following subsections.

4.3.1 Designing the innovation phase design

The innovation phase of the method is a new addition and has no basis in a previous method. Its objective is to provide guidance to a service designer on the creation of service ideas which are likely to be feasible and viable. The requirements which have been identified for this section are as follows:

- The service innovation component of the method must provide information on what is currently possible with earth observation data analytics (i.e. “capabilities”) to the service designer.
- The service innovation component of the method should enable the service designer to link capabilities with core business processes of the potential user of the service.
- The service innovation component of the method must consider the limitations of earth observation data in terms of spatial resolution, update frequency, and cost
- The service innovation component of the method should be modular so it can be used independently from the rest of the viable service design method.

In order to satisfy these requirements, the service innovation method firstly contains a list of previously executed applications of earth observation analytics. This serves as a reference for known earth observation capabilities. Table 19 below contains an excerpt of the full table in the appendix and details the capability of snow detection on a frozen lake with the type of earth observation data that has been used to achieve this analysis. In this case, the images are Medium Resolution Imaging Spectrometer (MRIS) satellite images, which range from visible light to near-infrared.

Table 19: Excerpt of the table in appendix A

#	Case name	EO capability	EO data type
1	Extracting Snow Cover Time Series Data from Open Access Web Mapping Tile Services	• Detecting Snow on a frozen lake	ESA - MRIS

Once an earth observation capability of interest has been selected, the characteristics of the data type which are used within that specific capability are presented to the service designer. Table 20 below is again an excerpt of a larger table, detailing the supplier, spatial resolution, the update frequency and update delay as well as the cost of the data. The table includes further columns, such as the operating conditions of the satellites. This information allows the service designer to ask specifically whether a capability would be considered feasible within the limitations of the earth observation data required. In the example of the snow detection, the MRIS data is used and this originates from the ESA as open data. The spatial resolution is 3 meters and the update frequency 3 days. A consultant using this information would need to consider whether the spatial resolution and other characteristics are sufficient for the application at the client. Alternatively, if other similar yet commercial data sources would exist, this would also be listed.

Table 20: Excerpt of the table in appendix B

Name	Supplier	Spatial resolution	Update frequency	Cost
MRIS	ESA	Medium (3m)	3 days	Free / open data

A consultant could pre-select a number of capabilities which he or she deems most promising before talking with a potential client to make the most out of an initial conversation. The outcomes of this phase are a number of earth observation capabilities with could be worth implementing. Following this method should not only allow the service designer to achieve the outcome more efficiently, it should also enable the designer to communicate more clearly with the data analysts applying the capability to the new potential case of the client. The method can be considered a form of check-list with the essential elements required for the new service.

In conclusion, the first part of the SIMEO-STOF method guides a service designer through the service idea generation phase. It firstly presents a list of previously applied capabilities in earth observation, from which the designer can make a selection for a potential client. Discussing what is possible and what is valuable to a potential client, the limitations of each capability are presented, also as a trade-off between resolution, update frequency, and cost. Figure 36 below visualizes this process.

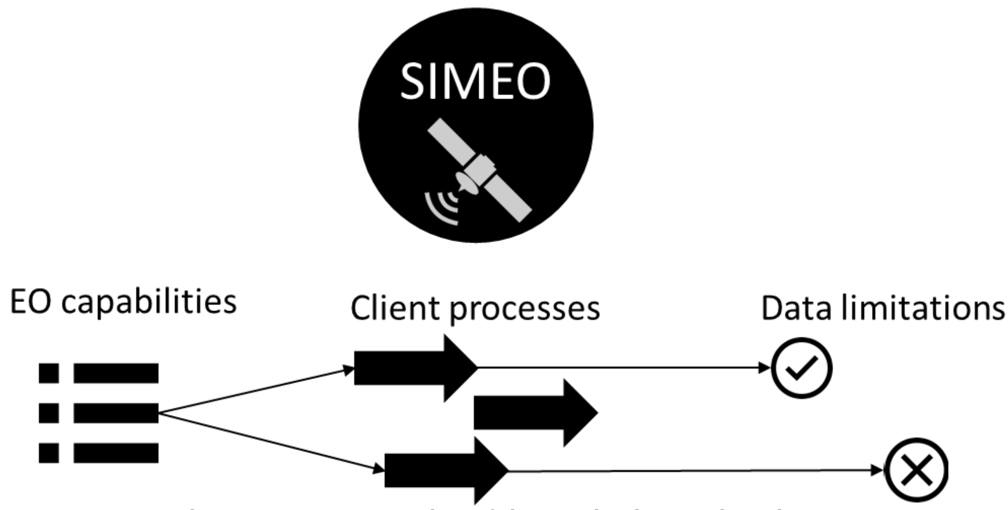


Figure 36: Demonstration of the service innovation phase

4.3.2 Service domain design

With a clear service idea present, the service designer can begin the designing of the viability part of the service. The objective of this domain is to define the service itself as well as the benefactor of the service. In order to do so, the following requirements have been identified for the service domain:

- The service design must describe the elements of the service that create value for the user.
- The service design must describe how the service can be positioned and presented.
- The targeting of the service to government clients (B2G) must be added in the design trade-off

These requirements largely overlap with the existing service domain in the STOF model. The requirement of describing the element creating value for the user is equivalent to the second CDI of value elements. Where applicable, the case studies in this thesis used a causal relation diagram as a visualization of how the service offering contributes towards the creation of value at the client. Whilst the STOF model does not prescribe such visualization, it helps in the understanding of where and how value is created. It also assists with the presentation and positioning of the service. This second requirement is covered by the critical design issue of branding within the STOF model. The inclusion of the business to government (B2G) in the targeting CDI is done because of the differences observed within the cases between tender-based B2G cases and the more organically developing B2B cases. The service offering in the tender cases is highly specialized and based on a political or legal need, whilst the two B2B cases the offering is based on a cost-benefit analysis of whether the service contributes to the company.

Table 21: CDIs for the service domain from Bouwman, Faber, Fielt, et al. (2008) for SIMEO-STOF.

Critical Design Issue	Description	Trade-off
Targeting	How to define the target group?	• Generic vs. niche service • **B2C, B2B or B2G service**
Creating value elements	How to create value for the targeted users of the service?	• Technological possibilities vs. user needs and wishes
Branding	How to promote the brand or service?	• Operator vs. content brand
Customer retention	How to stimulate recurrent usage of service?	• Customer lock-in vs. customer annoyance

The differences in B2B and B2G also affect the customer retention mechanism: after successfully achieving all objectives in the tender contract, the government must become a client, whilst a company may still deny. The STOF model as is satisfies almost completely the requirements for the artefact; the only addition is the business to government (B2G) in the targeting.

Figure 37: image representing the service domain

4.3.3 Technology domain design

The second domain is the technology domain, which has the objective to describe the technical aspects of the digital service. The application domain of big and open earth observation data requires extensive description of the technology and its requirements are formulated as follows:

- The service design should contain the trade-off of confidentiality, integrity and availability in the technical domain to identify architectural design principles.
- The service design method should allow the service designer to consider the privacy of anyone affected by the service design.
- The service design should consider where to store, process and how to transfer data as a trade off with security, flexibility and cost.
- The service design should include the considerations on the coordinate reference system within data modelling for explication of tacit knowledge.
- The service design should include a clear design of the technology that processes data flows.
- The service design should be able to describe a technical architecture in which both earth observation data and other forms of data are processed.

These requirements resulted in several additions to the technical design, illustrated in Table 22 below. Firstly, the simple security versus ease of use trade-off in the original critical design issue of security is insufficient. The cases studied included industrial control systems where integrity and availability play an important role, not just the idea of security as a general term. Using the specification of confidentiality, integrity and availability against ease of use allows the designer to illustrate a service architecture that has a better fit with the needs of the client. A further addition to the security design issues is the privacy: with increasing accuracy of the earth observation data, the privacy of observed may be breached. This is especially concerning in the migration radar case, where the observation of migrants without their consent or even their knowledge could be an ethical and legal issue. Maintaining privacy is a technical issue, but also continues into the organizational domain when it comes to liabilities and role distribution.

The quality of service receives the specification of the quality of the data versus cost. This is because of the observed freemium model open earth observation data and commercial earth observation data, allowing a gradient of continuity between low-quality free open data and high-quality closed commercial data. Open data comes ‘as is’, and may contain errors or missing data points. This affects the quality of the service, but also the data input into the system. The existing design issue of system integration remains highly valid, as a service can offer more value to a user when it is seamlessly integrated within existing systems, such as current monitoring systems.

A major newly identified critical design issue is the system computation architecture and data flow. The big data aspects of the earth observation data impose severe limitations on the ease of the data handling, as moving the data around requires a lot of resources for storage and time. Cloud infrastructure for storage and computation is a must, as well as high-capacity networking if the data should be transferred regularly. Alternatively, new system architectures are developed where the storage or computation is performed elsewhere. For example, a future integration could lead to an algorithm only requesting the data points required for analysis, instead of the whole set of data, offsetting storage, reducing bandwidth and reducing computational requirements. However, this also needs to be balanced with the security requirements and would come at a cost. As for the last two requirements, the STOF model does not prescribe any modeling technique for presenting the architecture, which leaves the choice of such modeling up to the service designer. This research used the application layer of the ArchiMate modeling language (Lankhorst et al., 2009) to illustrate data flows and principal application components of a systems’ architecture. This allowed satisfying both the need of modelling the data flow as well as describing how different system integration should be accomplished.

Table 22: CDIs for the technology domain from Bouwman, Faber, Fielt, et al. (2008) for SIMEO-STOF.

Critical Design Issue	Description	Trade-off
Security	How to arrange secure access and communication?	• Confidentiality vs. Integrity vs. Availability vs. ease of use. • Privacy
Quality of service	How to provide for the desired level of quality?	• Quality vs. cost

		○ Quality of data vs. cost
System integration	How to integrate new services with existing systems?	• Flexibility vs. cost
System computation architecture and data flow	How to arrange the storage, processing and network resource requirements?	• Cloud infrastructure vs. distributed function architecture
Accessibility for customers	How to realize technical accessibility to the service for the target group?	• Open vs. closed system
Management of user profiles	How to manage and maintain user profiles?	• User involvement vs. automatic generation
Data models	What coordinate reference system to use and what data model to use?	• Coordinate reference system type • Data semantics

The accessibility for the customers continues to stay within the design issues, as does the management of the user profiles. Data models are added to the CDIs because of the importance of data processing within the service design. Data models need to be streamlined across different suppliers and the coordinate reference system for the service needs to be set in order to be able to create analytics using data from different sensors, suppliers and possibly even using non-earth observation data.

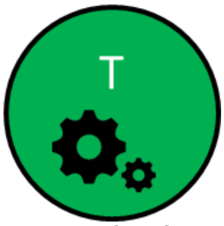


Figure 38: image representing the technology domain

4.3.4 Organization domain

The organization domain covers all inter-organizational relations. Its objective is to provide a clear overview of the roles and mutual responsibilities within the organizational arrangement, as well as what resources and activities are offered to the stakeholder arrangement. The requirements for the organizational domain are as follows:

- The viable service design should provide insight in the inter-organizational relations of all stakeholders relevant to the service design
- The viable service design should describe the effects of a disruption of the open data supply
- The artefact must be able to describe dynamic inter-organizational relations

The STOF model already satisfies most of these requirements yet does not specify a form of communication or modelling for these CDIs. Not dictating a form of visualization or communication provides flexibility, but only when the designer is aware of the possibilities that exist for the presentation. In this research, a formal relations chart is used to illustrate the relations between stakeholders besides textual descriptions. However, other forms of presentation could include the 'partner analysis tool', created in the context of the Envision research group on business model innovation of which the author has been a participant[13]. The tool divides the stakeholders in the organizational arrangement into four groups depending on their role in the network and also categorizes them according to their importance, all represented in a 4-segment layered circle. The importance of a partner selection strategy is shown in the different cases, such as the greenhouse and oil monitoring case where respectively a partner and a supplier are included in the stakeholder arrangement to gain access to the resource of sales channels or putting internal resources to a better use. Network openness is important in some cases, but mainly because of the aspect of network complexity and manageability, not yet because of strategic behaviour. The real addition to the organizational domain is the governance in case of a discontinuity of the open data provision. This would mean that the service as designed can no longer be provided and alternatives, probably commercial need to be identified. This affects service quality, as well as the organizational arrangements between stakeholders.

Table 23: CDIs for the organization domain from Bouwman, Faber, Fielt, et al. (2008) for SIMEO-STOF.

Critical Design Issue	Description	Strategic interest
Partner selection	How are partners selected?	• Access to critical resources and capabilities
Network openness	Who is allowed to join the value network?	• Desired exclusiveness, control, and

[13] The tool is published on the busienssmakeover.eu website https://www.businessmakeover.eu/platform/envision/tool-detailed-view?id=f6a1edce7ea84edex-515e165ex1580afbbf8dx-5baf

		customer reach of service
Network governance	How is the value network orchestrated? Who is the dominant actor?	• Customer ownership and control over capabilities and resources • Discontinuity of open data provision
Network complexity	How to manage increasing number of relations with actors in a value network?	• Controllability of value network and access to resources and capabilities

The cases have furthermore demonstrated that the organizational arrangement may change strongly over time, especially when government tenders introduce phased approaches to feasibility studies. The STOF model is capable of describing and analysing such dynamic relations (De Reuver & Bouwman, 2008) and can even be extended to include roadmaps which detail the steps and logical order of the transitions between dynamic relations (De Reuver et al., 2013).

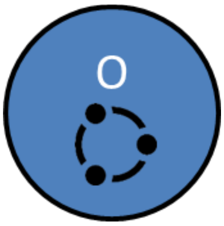


Figure 39: Image representing the organization domain

4.3.5 Financial domain

The limited access to financial data in the case studies limits the requirements that could be identified for the financial domain. Nonetheless, the following requirements are formulated:

- The viable service design method should allow a designer to describe the pricing strategy for the service
- The viable service design method should allow the designer to provide a qualitative description of the value exchanges between all relevant stakeholders.
- The viable service design should provide at least a qualitative description of the risks for each relevant stakeholder of the service design.
- The risks of tender failure or service termination should be included in the descriptions for business to government services.

The first requirement relates to the first critical design issue of pricing and initiates the thinking about pricing strategy and structure. Because of the low marginal cost of open data (it is free) and the high cost of maintaining a big data cloud infrastructure, the possibilities for pricing models and strategies could be limited. Describing these limitations is important for the choice of the right strategy.

The qualitative description of the value exchanges is included in the STOF model as well, mainly through the latter three critical design issues of division of investments, valuation of contributions and benefits and the division of cost and revenues. This issue of the division of investments is especially important for future analysis, such as business model stress testing which is also possible with the STOF model (Haaker et al., 2017). It is also concerned with the distribution of risk amongst the stakeholders, which corresponds to the last requirement for the financial domain and provides the addition of the case of failure to sell the service or become contractor under a tender. How to valuate a contribution and how the costs and revenues are shared are not discussed quantitatively in the cases but should be for a viable service design. Table 24 below shows the CDIs for the financial domain of the SIMEO-STOF method.

Table 24: CDIs for the financial domain from Bouwman, Faber, Fielt, et al. (2008) for SIMEO-STOF.

Critical Design Issue	Description	Strategic interests
Pricing	How to price the service for end-users and customers?	• Realize network profitability • Realize market share • Account for relatively high fixed cost • Account for relatively low marginal cost
Division of investments	How to divide the investments among business partners?	• Match individual partners' profitability and risk, especially in case of service failure
Valuation of contributions and benefits	How to measure and quantify partners' contributions and (intangible) benefits?	• Fair division of costs and revenues
Division of costs and revenues	How to divide the cost and revenues among business partners?	• Balance between individual partners' profitability and network profitability

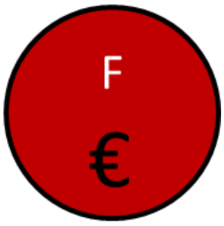


Figure 40: Image representing the finance domain

4.4 Conclusion of Artefact Design

This section concludes the fourth chapter of this theses in which the design is detailed and the design choices are justified answering the question “what does the viable service design method for big and open earth observation data that satisfies the requirements look like?”. This question is answered by presenting the SIMEO-STOF a method which allows service designers follow a structured method to arrive to a service design for big and open earth observation data. The presentation of the artefact is divided into 5 subsections, each for one component of the artefact: service innovation, service domain, technology domain, organizational domain and finance domain. In each of these subsections, the requirements are addressed one by one by explaining the design choices made. Figure 41 below presents the method as a coherent whole, where the SIMEO phase precedes the Service (S), Technology (T), Organization (O), and Finance (F) phases. Future designs could include other models as its basis, as the SIMEO-STOF model is designed modularly and the factors influencing the model are presented separately in chapter 2.

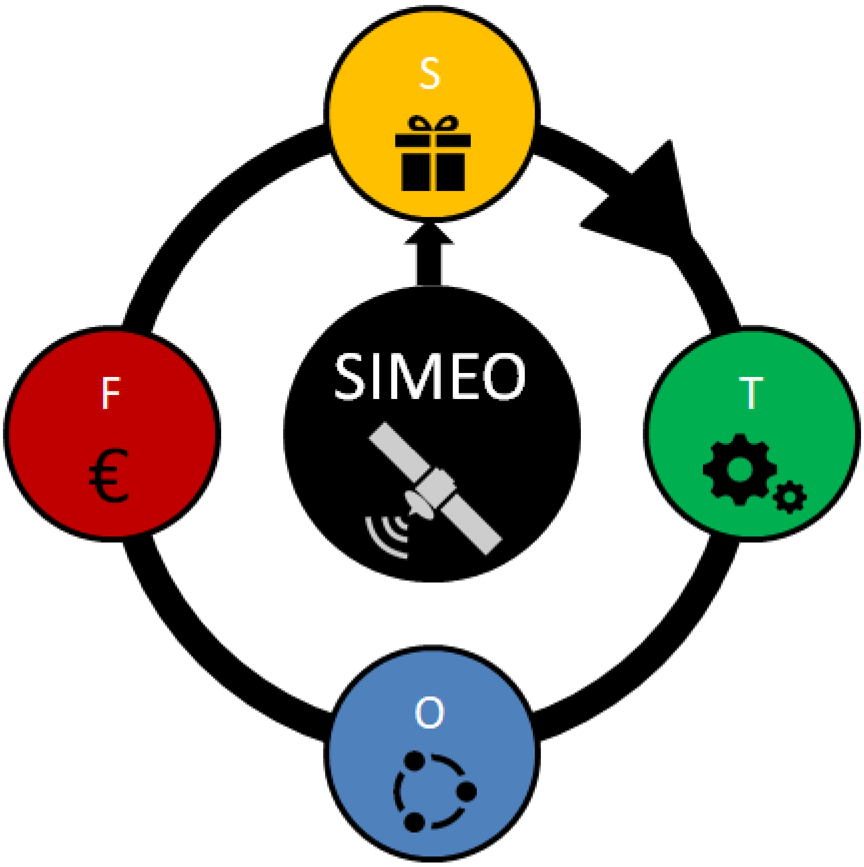


Figure 41: The SIMEO-STOF method

5 Artefact Demonstration

In this chapter on artefact demonstration, the SIMEO-STOF method will be applied to a case. Doing so will allow a demonstration of the feasibility of the artefact, following the research question of “How can the method be used to create a viable service design?”. The outcome of this chapter is a demonstrated artefact, which is used for closer evaluation in the next chapter. The used research method is a case study. Figure 42 depicts the research design for this artefact demonstration chapter.

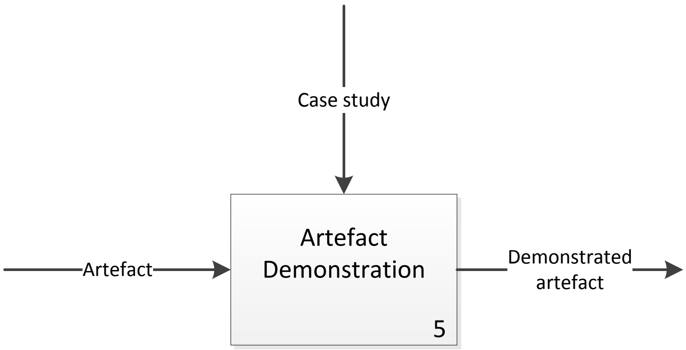


Figure 42: Research design for the Artefact Demonstration chapter

Firstly, the approach for the demonstration is detailed in the next section, followed by the case in which the use of the artefact is described, as well as the case itself. Observations about the case are noted and will be used for evaluation in the next chapter. Finally, the chapter is concluded.

5.1 Demonstration Approach

In order to apply the SIMEO-STOF method, a case suitable for its application needs to be found. In doing so, the selected case must comply with the same selection criteria as previously set in section 3.1.2. Specifically, the case involves one or more service providers which have the desire to create a viable service using big and open earth observation data as a resource. The case is also accessible to the researcher and has a service provider which is willing to cooperate and share the information required for this research. Furthermore, the case must involve at least one end user who is not specialized in the processing of big and open earth observation data and wishes to use the service because it is beneficial to the end user. The end user also must be accessible to the researcher, as well as willing to cooperate and share information. Finally, the case must not have been used to gather requirements.

The demonstration case which has been selected is the monitoring of oil tanks in the harbour of Rotterdam with earth observation imagery for VTTI, the Rotterdam daughter company of a worldwide crude and processed oil transhipment company called ETT. VTTi wants to monitor the subsidence of their oil tanks because this causes deformations in the otherwise round oil tank. This causes two issues: Firstly the roof of the tank which floats on top of the contained oil can no longer move up or down in a deformed oil tank. And secondly the deformations reduce the structural integrity of the oil tanks structure, increasing the risk of spoilage. VTTi is a logistics and asset management company and is not specialized in processing big and open earth observation data. Their technical manager is the contact person for CGI and is available to the research as well as willing to participate in this research. The researcher is accompanied to the end user interview with the VTTI technical site manager by a consultant from CGI. Furthermore, CGI employees are interviewed on how CGI is providing the service. The interviewees for the Oil Tank Monitoring case are listed in Table 25 below.

Table 25: Interviewees for the Oil Tank Monitoring case

Case	Sources and interviewees
Oil Tank monitoring	Data analyst and solutions architect at CGI Junior data engineer at CGI General Manager at CGI Opportunity Leader and Manager at CGI Technical site manager at VTTI

The case itself will combine descriptions of the case at hand as well as descriptions of how the artefact has been used. The result is a set of observations, as well as additional suggestions for improvement.

5.2 Oil Tank Monitoring Case

Like the greenhouse monitoring case used to identify requirements in chapter 3, the oil tank monitoring case has a company as a client instead of a government actor. The company ETT with its Rotterdam daughter company VTTI specializes in the transhipment and storage of crude and processed oil and they have an interest in a monitoring service for their assets which make the storage and transhipment possible. Other global daughter companies exist and could require monitoring in the future. This client interview with the technical site manager from VTTI, in this case, has been performed by a consultant from CGI. The first subsection of service innovation illustrates the problem context and the service idea, followed by the service domain section detailing the value elements for which stakeholder and the branding of the service. This is followed by a technical design detailing the data flows and systems required. The organizational domain shows the inter-organizational relations, of which the value exchanges and financial risks are detailed in the financial domain.

5.2.1 Service innovation

VTTI operates in the harbour of Rotterdam, from which the transhipment company has the assets in form of tanks, piping and docking areas for ocean oil tankers and inland water tank barges. The oil products can be off- and unloaded from oil tanker ships for sea ships as well as barges for inland waterway shipping and need to be stored in circular oil tanks (see Figure 43 below). The larger oil tanks have a diameter of 45m and can be heated, as the more viscose oil products such as heavy fuel oils require constant heating to enable transhipping. The tanks have a fixed roof protecting against rain and atmospheric influences, and an internal roof floating on top of the stored oil product. This floating roof moves up and down with the tank depending on the level of contents and keeps gasses contained within the product and limits the pollution of the environment as well as the pollution of the product.

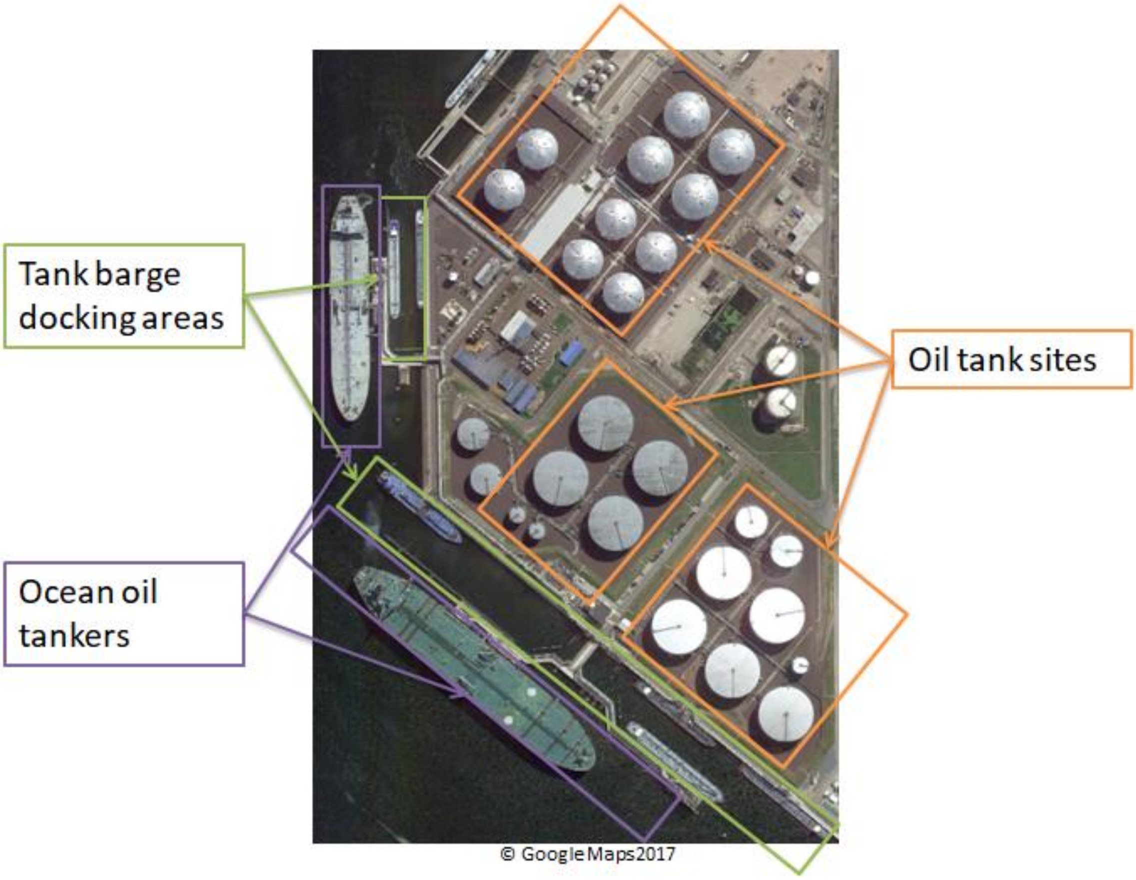


Figure 43: Optical satellite image of area with indication of sites

The whole site needs to be compliant with the Dutch PGS29 regulation which sets the safety standards for dangerous goods. This amongst others requires a high structural integrity of the tanks and piping system, as well as protective measures and evacuation protocols. Audits for the PGS29 regulation are annual. The interviewee at the company stated explicitly how important these guidelines are, noting that the oil tanks are “like coke cans” and “only 6mm thick at the top”. Dams around the oil tank site contain any spillage that could occur and signs on site indicate evacuation routes and demonstrate safety regulations.

The safety standards and inspections create a level playing field with competing companies, but the competition in the sector is high. The competitive advantage comes from a combination of client-oriented services allowing for time-critical transportations and a global network. Having unexpected maintenance which shuts down part of the storage capacity greatly affects this service offering. Not only does such maintenance mean a loss of income during the time of maintenance, it also decreases the reliability of the company, which affects future sales. However, being able to better predict the maintenance allows for improved planning and reliability of the service provision to clients.

The biggest issue with the oil tanks is deformations in the structural integrity because of subsidence. If an oil tank shifts due to subsidence, it causes tensions within the thin plating of the tank. If these tensions become too big, the oil tanks may rip and spill their contents. Also, having deformations in the tank may cause the floating roof to malfunction, resulting in the escape of gasses between the continuously circular roof and the deformed oil tank walls. Furthermore, the roof may get stuck, reducing capacity. The subsidence of the oil tanks can be measured accurately with a time series of radar images, as identified through the list of capabilities in appendix A (on page 102) and the expertise of the fellow interviewer from CGI. The consultant from CGI additionally offered the idea of placing reflectors on the tanks so specific points of the tank can be identified more clearly and thus their subsidence relative to each other calculated even more precisely. As the tanks are several meters in diameter, the even a medium spatial resolution should be more than sufficient to detect subsidence. Subsidence is furthermore a phenomenon which spans several months, if not years, which makes an update frequency of several days acceptable. The piping which transports the oil products could also be monitored, as their structural integrity is just as important for a safe transhipment.

Going through the list of capabilities, a further possible application is the use of temperature monitoring on the pipes transporting the oil between the tanks and the ships. As the oil products are generally heated, the pipes and oil tanks are insulated. If any area of pipe has a difference in temperature, this may indicate that the insulation of that area is working worse than another. Such an indication is worthy of inspection, as it may indicate corrosion of the pipe. Single pipes rarely exceed a meter in diameter, but several pipes going in the same direction may have this width. Thus, a medium sized spatial resolution could be sufficient. The usage of the pipes is also an issue which spans months or years, so an update frequency of every few days is sufficient. A final identified application is the air quality monitoring for leak detection. It is possible to identify gasses which differentiate from surrounding air, even possible to identify a few gasses. However, it is uncertain whether the update frequency is sufficient to make any meaningful service out of this capability. If a dangerous gas is leaking, the action should be within hours, not days, which is the general update frequency for the satellite images. Furthermore, the consultant from CGI noted that many of the satellite images have a delivery delay, meaning a time passes before images made from a satellite are actually published through a portal.

5.2.2 Service domain

The service idea from the previous subsection is the offering of the monitoring of oil tank and oil piping structure subsidence, the monitoring of oil pipe temperature and air quality monitoring, assuming all service elements are feasible. None of these directly lower costs or increase revenue of the company. However, the subsidence monitoring and the temperature monitoring allow for the improved detection of maintenance needs. This again allows for improved maintenance planning. It is this improvement in maintenance planning that allows performing maintenance at a lower price and allows better communication of available storage and transhipment capacity to clients. The latter is especially important, as the interviewee noted that an ocean tanker that is chartered for over 50.000€ a day and has a delay will go to the competitors the next time. Frequent unexpected maintenance harms the company reputation and thus its existence. Lowering the cost of maintenance also allows for improved company continuity. Finally, the air quality monitoring will allow for a better incident detection and response. As indicated previously in the service innovation subsection, safety is taken seriously within the sector as the risks are significant and the impact of something going wrong with dangerous goods is very large. Good incident response increases the reputation of a company and thus its continuity.

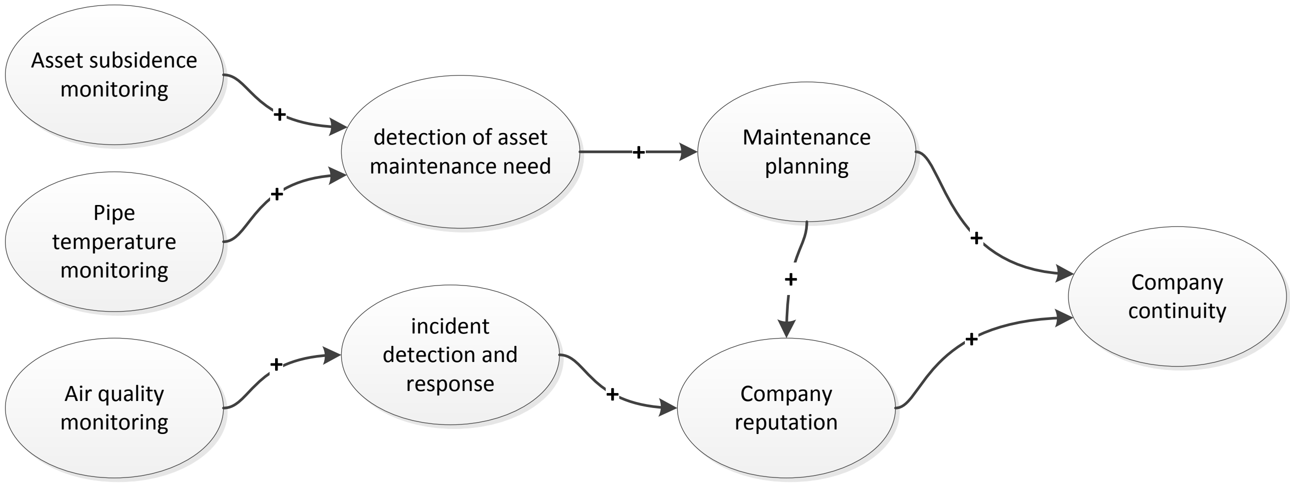


Figure 44: Value elements and expected causal relations for oil tank monitoring case

This service element of asset and air quality monitoring is aimed at companies which own and operate transhipping and storage installations for crude and processed oil, like VTTi. VTTI is willing to work together with CGI and become the launching customer of the service. The branding of the service will be performed by CGI. Currently, CGI has no partners with whom to distribute or co-brand the service with. Since the current company structure and strategy prefers to have a single client with a large project instead of several smaller clients, finding such a partner should be a priority. This partner should provide sales channels as well as a name which has brand recognition and strengthens the perceived service value. Since the service is site-specific and tailored to the needs of individual clients, having an account manager for the client relations is favourable. Specific customer retention mechanisms are not yet identified.

5.2.3 Technology domain

This subsection of the oil monitoring case describes the technical elements of the proposed service design. Firstly, the security design principles are described based on the trade-off between confidentiality, integrity and availability. Then, the system requirements are described with the accompanying architecture depicted in ArchiMate.

To describe the trade-off between confidentiality, integrity and availability a small analysis based on only the impact of each of these three is performed. In this case, a breach of confidentiality would mean that information about the state of the oil storage is public, which means that competitors are also aware of the conditions and when maintenance would be necessary. Whilst this could lead to competitors planning their maintenance more strategically, this is not a situation which fundamentally harms the continuity of the company. Thus, the impact of a breach of confidentiality is not considered high. A breach of integrity, on the other hand, is more serious. Malicious data about the state of the site could be reported which may lead to false positive or false negative detection of issues. Respectively, these issues result in unnecessary maintenance cost. As the monitoring service does not replace any actual safety inspections, the safety of the staff and the environment is not considered to be at risk. Finally, the impact of unavailability of the monitoring depends on the time of the unavailability. As the update frequency is a matter of days and not seconds, the system can be available for several hours without any significant impact. Long-term unavailability results in the value elements mentioned previously in the service domain not being achieved. As all the value elements contain improvement of current capacities, the impact isn't very high either. Based on these security considerations, the most important security characteristic is the integrity of data.

Besides the importance of integrity for the user of the system, the requirements for the system (see Table 26 below) are also similar to the greenhouse case. ESA, the main data provide, does currently only permit downloads of their data products, which means that sufficient infrastructure must be in place for the handling of these large amounts of data. Firstly, the system must be able to collect earth observation data from a source, which is the ESA open data hub. This data must then be clipped, stored and analysed, of which the results again must be stored. These results must then be presented to the user and a cloud-based infrastructure must be used for the analysis. A crucial difference, however, comes with the worldwide operations of the parent company ETT, which has other sites to monitor in every notable global harbour. Thus, the system must use a global coordinate reference system. This global reference system should be the GPS system, as this is a global standard for referencing to geolocations. The ESA earth observation data comes structured with ontology and is of sufficiently high quality for this issue, whilst coming at no additional cost of data acquisition. However, ESA does not provide any computing power on their data infrastructure as of yet, creating the requirement to collect the data itself from ESA.

Table 26: Functional requirements in MoSCoW structure for the Oil Tank monitoring case

Must have	• The system must collect earth observation data from the Copernicus data hub through the API. • The system must clip the collected earth observation data. • The system must store the clipped earth observation data. • The system must perform analysis on the clipped earth observation data. • The system must store the results of the analysis. • The system must present the results of the analysis to the user. • The system must use user accounts to provide authorized users access to exclusively their own company sites. • The system must use a cloud infrastructure to retrieve, store and analyse the earth observation data. • The system must use a global coordinate reference system
Should have	• The system should measure the subsidence of oil tanks over time at a designated location • The system should measure the subsidence of pipe structures over time at a designated location • The system should measure the temperatures of pipe structures over time at a designated location • The system should detect any abnormalities in the gas composition in the areas surrounding the tanks and pipes at a designated location • The system should graphically present the values of the subsidence and the movement on a map. • The system should use the GPS coordinate reference system. • The system should be able to retrieve the analytics of an external provider for subsidence detection as a layer in a map and present this graphically.
Could have	• The system could present the analysis results through a web service. • The system could detect which gasses specifically are present around the assets of a designated location
Won't have	• The system won't integrate with current client monitoring systems.

The 'must have' and 'should have' elements of the requirements list form the core of the system, which is minimally required to offer functionality to the client and user. Specifically, the system should measure the subsidence of the oil tanks and the pipe structures as well as the temperature of the latter over time. Furthermore, the system should detect whether the gasses around the assets are containing the regular mixture of gasses for natural air, or whether the mixture of gasses is abnormal, which could suggest a leak. An expansion of the feature could be the detection of the exact gasses present at the site. To facilitate the interpretation of these measurements, the results should be presented graphically. This could be through a web service for increased ease of access.

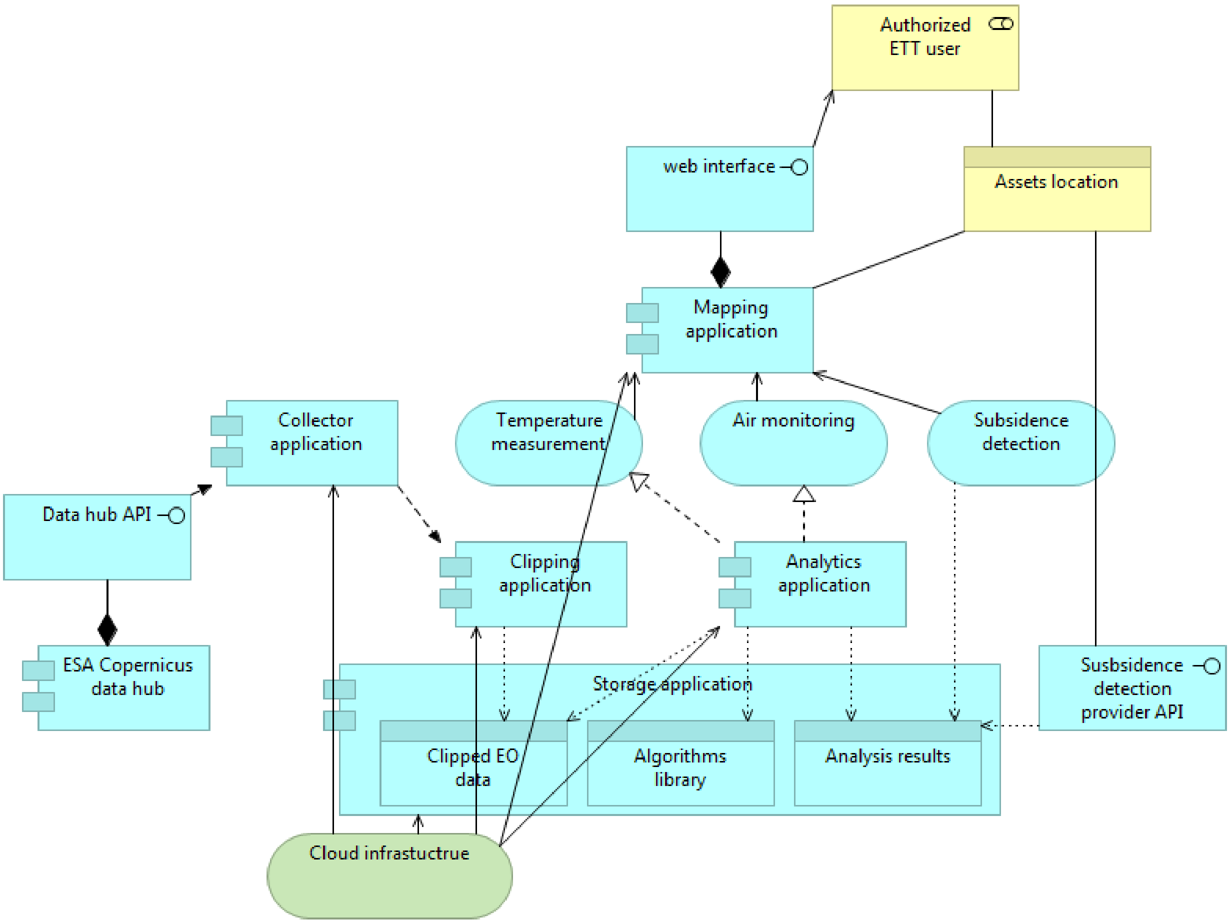


Figure 45: Archimate model of oil tank monitoring case

As is further detailed in the organizational and financial subsections of this case, the consultant from CGI considered that the subsidence detection by radar was not something that CGI should develop in-house, but rather should look for a provider which can supply this element as a service. The service from this supplier is assumed to be provided as a layer on a map with GPS coordinates and supplied through an API which requires GPS area coordinates as an input. Currently, there has been no need expressed by the potential client to integrate any service into existing information systems within VTTI. All of these requirements have been modelled into the Archimate model in Figure 45 above.

5.2.4 Organization domain

As indicated in the introduction to this case, the client is a company and the service delivery is not structured by a tender. This results in a partner network that is similar to the greenhouse monitoring case in 3.2 on page 33, expect that CGI does not have a partner for distribution and an extra supplier.

On the supplier side, ESA again provides the earth observation data as the medium sized resolution space images are considered sufficient for the realization of the temperature measurement and possibly as well for the monitoring of the gasses in the air surrounding the assets. Microsoft has again been selected as the infrastructure provider because of the experience of programmers and the economics of scale. This also slowly creates a lock-in to the vendor, as more and more of the systems are optimized for the Microsoft systems. Finally, on the supplier side, DigitalGlobe is assumed to provide the service of detecting subsidence with their own satellite images. Digital Globe is a commercial provider of earth observation images and analytics and can provide the required service through an API. This has the advantage for CGI of easy integration and not having to go through a full development cycle for the functionality of subsidence detection in order to focus on the integration of services.

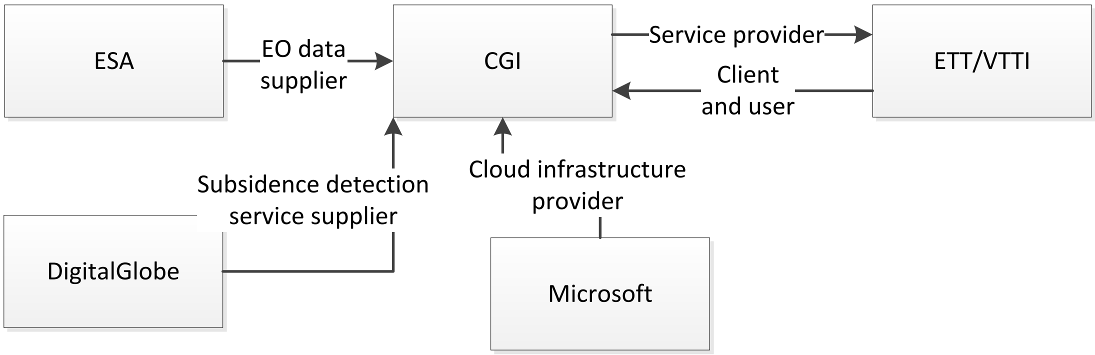


Figure 46: Formal relations for the Oil Tank Monitoring case

VTTI, the Rotterdam daughter company of ETT, is both the client and the user. Once the service is delivered and considered successful by VTTI, other daughter companies of ETT in other areas of the world could become the next clients. Furthermore, other companies owning and maintaining oil tanks for storage such as major oil companies could be potential customers. Currently, CGI has no partner on the distribution side like in the Greenhouse Case. The major difference is that because of DigitalGlobe as a supplier, CGI can shift its attention from capability development towards system integration and the offering of services. This slightly increases the partner network complexity but maintains the governance strictly within the power of CGI. The formal relations are depicted in Figure 46 above.

5.2.5 Finance domain

This financial domain subsection of the oil monitoring case describes qualitatively the value flows, including financial exchanges, between stakeholders as well as the risk distribution amongst them. As CGI is at the centre of the stakeholder arrangement, it is also at the centre of the value flows. The suppliers of ESA, DigitalGlobe and Microsoft all provide their services to CGI, and the latter two receive a fee for providing this. CGI then integrates these services and provides this as a single one to VTTI. VTTI then pays CGI for this service. All costs of CGI as structured as monthly fees, so it makes sense structuring the pricing to VTTI as a monthly fee as well. The added value of CGI on top of the already existing services is in the combination and specification of the services from the different parties to the needs of the client.

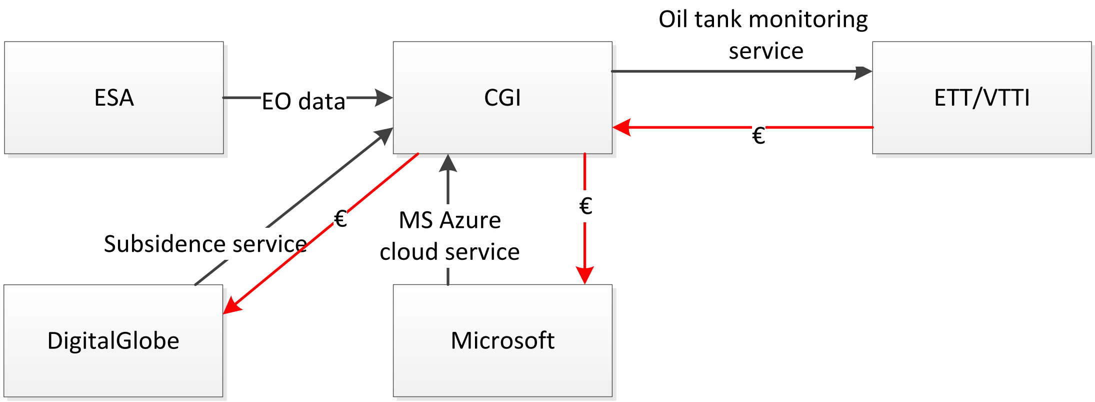


Figure 47: Value network for the oil tank monitoring case

Being at the centre of the arrangement, CGI is also responsible for all the risks if these may trigger. These include, but are not limited to, the risk of the termination of the open data infrastructure by ESA, the risk for investing in the realization of the service and any interruptions that may occur at the side of any supplier, although the latter is partially covered by an SLA.

5.3 Observations and suggested improvements

This section explicates observations from the application of the SIMEO-STOF method, as well as reflecting on the application of the artefact. Firstly, the discussion will turn to whether the design is viable, followed by what would be missing to make it so. The result is a set of suggested improvements based on this demonstration case study.

Is the service design above a viable service design? I.e. did the method create a viable service design? Looking at the definition of a viable service design as defined in this thesis; the service needs to be feasible as well as having sufficient incentives for all stakeholders to continue the service provision (see also the Terminology on page number ix). So is the service feasible, i.e. is it practically executable? The answer depends per service idea. The subsidence detection of the oil tanks is highly likely to be feasible, as this the application of existing technology without any new additions. Only the application is different. The monitoring of the oil pipes could be more difficult, as the surface structure of the oil tanks isn't as homogenous as the oil tank. The feasibility of the temperature of the oil piping and the atmospheric monitoring is uncertain, as these have several new additions of technology. Therefore, the conclusion is that the service is probably partially feasible. Now to consider whether it is viable: The final answer depends on the quantification of the finances. Currently, the price of the subsidence measuring service from DigitalGlobe is unknown to the researcher, as is the cost of other infrastructure required. Furthermore, the maximum willingness to pay of the client has not been quantified either. However, the researcher expects that this can more easily be estimated by a manager at CGI once the costs of the DigitalGlobe service are known, as this is expected to be a variable cost. However, due to the opportunity of monitoring all ETT daughter companies worldwide and possibly other companies with oil tanks, such as Shell or BP, the single instance of the service to VTTI does not need to be profitable. Therefore, the service is most likely to be viable.

In reflection, "most likely to be viable" is not a very powerful statement. However, the author would argue that the SIMEO-STOF method at least allows the reduction of the uncertainty on the viability of the service to a few variables. The knowledge of what variables the viability of the service hinges is, arguably, already a great benefit to a service provider planning to create a viable service.

Furthermore, this demonstration case study allowed for the identification of improvements. Thanks to the conversation with the consultant from CGI, it was possible to identify the delivery delay, i.e. the time between the measurement of the data point and the actual availability for analysis, as a characteristic of earth observation data. This is a practical limitation but can have large consequences for the service design as some applications of earth observation data may be time-critical. Also, during the identification of possible data sources related to this case, the author came across a not yet detected limitation of earth observation data: the operating conditions of the satellite. Depending on the type of satellite and its orbit around the earth, the satellite may not be able to reach certain areas. An example of this is the ALOS PALSAR satellite, which collects radar-based images and is in orbit around the equator and is unable to take images of the earth's poles because of the angle and orbit (Rosenqvist, Shimada, & Watanabe, 2004).

The following improvements to the artefact are suggested based on this demonstration:

- The service innovation component of the method must consider the limitations of earth observation data in terms of the delivery delay of the data.
- The service innovation component of the method should consider the limitations of the operating conditions of satellites.

5.4 Conclusions

The objective of this chapter is to demonstrate the use of the artefact by applying it to a case. This activity answers the research question "How can the method be used to create a viable service design?". To answer this question, the SIMEO-STOF method is applied to the case named the oil tank monitoring, where VTTI, an oil transhipment company in the harbour of Rotterdam, is interested in services monitoring their assets. The availability of the assets is key, as the service quality and reliability are essential in a market of the almost homogeneous service of transhipment but infrastructure investments are very high. The result is a proposed service design for the monitoring of the subsidence of oil tanks and oil tank piping in order to better predict the maintenance required on the assets.

As for the SIMEO-STOF method, its application allowed for the identification of viable services the identification of where the value of these services lie, as well as providing the principles of a technical architecture and an overview of the strategic resources required for the service. The financial viability of the service could only be indicated in qualitative terms since quantitative financial information in the case is not available. The result is a service design which is most likely to be viable. More importantly, the method allows for the identification of issues which are crucial to the viability of the service design, allowing a service designer to focus on resolving these above other issues. Specifically these issues in the VTTI case are the price of a resource acquisition from a partner and the cost of the IT infrastructure.

Besides the service design, the application of the method allowed for the identification of additional suggested improvements. This is firstly the addition of the data delivery delay: Time-critical applications, such as the suggested air quality monitoring, can only provide value if the data is sufficiently up to date. Besides the time required for analysis, the delay between the capturing of the data by the satellites until the availability as a data product is an important factor for such up to data analysis. A second improvement is adding the operation limitations of a satellite, as not all earth observation data cover all areas of the globe. This could affect the capability of offering a value to a client in the service innovation phase. These suggestions are processed into the artefact design.

6 Artefact Evaluation

This chapter describes the evaluation of the artefact designed in the previous chapter and the objective of the evaluation is to determine whether an artefact which solves the problem for which it has been designed and whether it fulfils the requirements (Johannesson & Perjons, 2014; Venable, Pries-Heje, & Baskerville, 2012). This twofold objective is also contained within the research question which this chapter will answer, specifically: "How well does the method design viable services based on big and open earth observation data, and how well does the method fulfil the defined quality requirements?" Figure 48: Research design for the evaluation depicts that for this section, the artefact from chapter 4 will be used, as well as the quality requirements from chapter 3. The outcome is an evaluated artefact.

The first partial objective is to determine how well the artefact, the SIMEO-STOF method, designs viable services based on big and open earth observation data. Part of this research question is already answered in the previous demonstration chapter, as the method generates a 'probably viable service design' (see section 5.3 on page 71). To fully answer how well the artefact designs viable services, this chapter will look at the intended use of the artefact. The reasoning here is that when service designers intend to use this artefact to design viable services, it must contribute positively in doing so. This part will also be evaluated through a survey using the combined approach of the Expectation Confirmation Theory (ECT) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Thong, Chan, Hu, & Brown, 2011). The other part of the evaluation objective and the research question is on whether the method fulfils the requirements previously defined. Instead of evaluating all individual requirements separately, the evaluation will focus on the non-functional requirements which will be integrated into the UTAUT-ECT model. This two objective approach allows evaluating the external validity of the artefact through the future use intention as well as the internal validity of the artefact through the quality requirements.

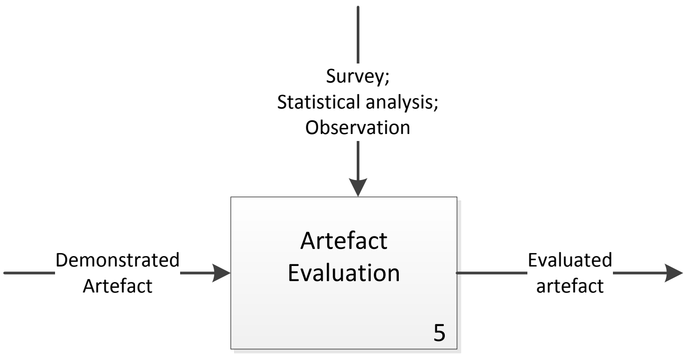


Figure 48: Research design for the evaluation chapter

The choice for the survey and observation as methods for the evaluation, as well as how the named theories are applied to these methods within this research is detailed in section 6.1 Evaluation approach. This section also contains postulations on the relations between the different parts of the evaluation based on the literature and the approach used to process the survey results and draw conclusions from the data. The results of the survey are then presented in section 6.2 and the observations are presented and interpreted in section 6.4.

6.1 Evaluation approach

Before detailing how the evaluation is executed, the methods for the evaluation need to be selected. This is done in the first section, 6.1.1 Evaluation method selection, where based on the characteristics of the artefact and the type of evaluation that is performed. From the eligible evaluation methods, the survey and participant observation are selected. How these are applied to this research is detailed in sections 6.1.2 and 6.1.3. Specifically, section 6.1.2 contains the integration of the UTAUT and ECT theories in the survey and what relations are postulated between the qualities of the artefact and the usage beliefs and intentions of the target group for the artefact. The last subsection, 6.1.3., describes the objectives of the observations.

6.1.1 Evaluation method selection

Venable et al. (2012) provide a categorization scheme for evaluations as an extension to the design science research paradigm, allowing a researcher to select an evaluation method based on the state and purpose of the artefact. This evaluation method categorization contains two dimensions, which will be presented shortly and placed within the context of this research. The first dimension is the opposition between naturalistic and artificial. An evaluation is considered to be naturalistic when it aims to evaluate the artefact in its real environment (i.e. "involves real users, using real systems to solve real problems" (Johannesson & Perjons, 2014, p. 139)). This is opposed to artificial where the artefact is excluded from its environment as is the case in a laboratory. As this artefact will be evaluated with the target group within its environment, the evaluation is naturalistic in this dimension. The second dimension of classification is ex-ante and ex-post. Ex-ante means that the artefact is evaluated "without being used or fully developed" (Johannesson & Perjons, 2014, p. 138) and ex-post requires it to be deployed (p. 138). As the artefact has not been deployed – merely demonstrated - the evaluation of the artefact should use a naturalistic and ex-ante evaluation method. This category of evaluations is characterized by being effective, having a high external validity and is fitting for socio-technical artefacts (Johannesson & Perjons, 2014, p. 142). The disadvantages are as supposed higher cost and lower internal validity (p. 142). Evaluation methods available for naturalistic ex-ante evaluations are action research, focus groups and interviews (p. 142). However, due to a lack of availability of experts, the author could not pick one of these strategies. Instead, the author selected from the other research methods for naturalistic environments, which include case study, ethnography, survey, and participant observation (p. 142).

For the evaluation of SIMEO-STOF, a combination of surveys and participant-observations is chosen. Whilst a participant-observation could achieve great depth of analysis, it could be limited by the perspective and competence of the observer which is part of the processes (Johannesson & Perjons, 2014, p. 144). A survey, on the other hand, can provide more structure and generalizability whilst suffering less from a bias. However, a survey could also result in shallow responses because of a lack of motivation to answer the questions in detail (p. 143). Furthermore, this combination is relatively time efficient and is available because of the possibility of a presentation in front of employees of CGI in the space sector. This allows for interaction and discussion during the survey and the possibility of having more complete surveys by actively motivating everyone present at the presentation at taking part in the surveys. Other methods considered are a case study or interviews. A case study is not chosen because an actual implementation is out of the scope of this research in both functional scope and time, and a demonstration has already been performed in the previous chapter, of which the results are discussed in this chapter as well. Interviews are not performed because of the earlier mentioned limited availability of the consultants for a one-on-one interview style evaluation.

The presentation at CGI is a once a month lunch presentation opportunity where an employee can present voluntarily a private or work-related topic in front of their colleagues. As an intern at CGI, the author used this presentation to demonstrate his work at the company and at the same time to perform the evaluation. The audience at the presentation are employees of CGI in the space department at Rotterdam. Although the method is aimed at consultants working at this department, the audience at the presentation also includes programmers, application testers, on-site integrators and managers. The event took place at the CGI office in Rotterdam on the 26th of October 2017 from 12:00 to 13:00.

6.1.2 Evaluation approach using a survey

The survey is aimed at evaluating the attitude of service designers towards future use of the method as well as evaluating whether the method fulfils the requirements. Two theories in information systems research, the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Expectation-Confirmation Theory (ECT), allows us to measure the usage intentions and beliefs. Venkatesh et al. (2011) propose a model in which the two theories have been merged to combine the two theories' strengths and this merged theoretical model will be used within this research.

The Expectation-Confirmation Theory (Bhattacherjee & Premkumar, 2004) tests the usefulness beliefs, disconfirmation of previously held beliefs and attitudes by participants towards an information system before and after the use of an information system. This multi-stage model allows for the measurement of beliefs and attitudes over time, as there may be multiple repetitions of the after use testing with repeated use of the information system. This idea that attitudes will change based on the information provided is one of the central additions of ECT to information systems evaluations. The Unified Theory of Acceptance and Use of Technology (Venkatesh, Morris, Davis, & Davis, 2003) takes a broader view at why information systems are used by incorporating not only expected utility, but also the expected effort required, the social factors that push people to use systems, and the facilitating conditions that indicate whether people have the resources and knowledge necessary for the use of the system. The greatest addition to information systems evaluation by UTAUT is the broader, contextual view on information systems use. Combining both the temporal perspective of ECT and the contextual perspective of UTAUT into a new model is done by Venkatesh et al. (2011). This provides a much richer model for the prediction of continued information systems use.

The applicability of UTAUT-ECT to the SIMEO-STOF requires extra scrutiny. Within academic literature, UTAUT, ECT, and the combined UTAUT-ECT model have been widely used to assess the intended or continued use of instantiations or implementations of technology (Venkatesh et al., 2003; Venkatesh et al., 2011; Zuiderwijk & Cligge, 2016). These are classified by Gregor and Hevner (2013) as level one information system artefacts. However, the SIMEO-STOF model is a level two information systems artefact, as previously argued in section 1.5 on page 12. According to Venkatesh et al. (2011), the ECT-UTAUT evaluates a information system on whether it assists gains in "job performance" (p. 528) as well as whether this is worth the cost of doing so and whether the social and practical environment supports or hinders the use of the artefact. The author argues that the UTAU-ECT model is applicable to the specific level two information system artefact of a method as well. Firstly, a method also has a job performance expectancy, as the user of a method expects some form of benefit by following the method. This following of the method comes at some sort of cost, most likely to be time. SIMEO-STOF is furthermore designed for a problem owner, implying that the social influences and environmental influences of that problem owner affect the use of the method. Therefore, the author argues that the UTAUT-ECT theory is applicable for the evaluation of a DSR information system method as well.

Implementing the UTAUT-ECT combination has a first practical downside: the inclusion of all UTAUT concepts at several moments in time creates the necessity of large-scale surveys, especially since the quality requirements of structural coherence and environmental quality requirements are to be evaluated as well. This in turn requires a lot of willingness and time from potential participants, as well as participants that can be tracked over a larger period of time during their use of the artefact. The limited access to the participants at the CGI lunch session after the event has taken place, as well as the time limitation of one hour for both presentation of the method and the survey requires some adaptation of the model. The disconfirmation stage will be omitted because the evaluation should focus primarily on the actual intended use of the artefact instead of the change in personal beliefs. Furthermore, the concept of 'continuance intention' is removed and simple 'post usage attitude' will be used to further reduce questions. Whilst this may seem counter-intuitive due to the goal being the measurement of intended continuity, the continuance intention is formulated from a first-person perspective ("I will use…") whilst post use attitude is formulated from a third-person perspective ("it is good to use…"). Because the audience is expected to not only contain service designers, the attitude towards usage should suffice for continued usage intentions. A second major adaptation is that there is no actual use of the method during the session. There is a presentation of the SIMEO-STOF method, after which it will be evaluated. Asking about the prior expectation of the SIMEO-STOF model is difficult, as it is a new design and there is no similar method available to design services based on big and open earth observation data. To mediate this, prior expectations to a more general description of the SIMEO-STOF model are asked, specifically "a method for the creation of viable services based on big and open earth observation data".

The adaptation of the UTAUT-ECT model from Venkatesh et al. (2011) together with the artefact quality requirements described in Johannesson and Perjons (2014) are combined into the model in Figure 49 below. The left side of the model indicates the pre-presentation beliefs about a generic structured method for the design of a viable service based on big and open earth observation data and the attitudes of the interviewees towards the use of such a method. The concepts that are used to measure these beliefs and the attitude are: perceived usage (PU), expected effort (EE), social influence (SI), facilitating conditions (FC) and pre-presentation attitude (AT). Then, the artefact is presented and the quality requirements of the artefact are evaluated. For structural qualities, these are coherence (Coh), modularity (Mod) and conciseness (Con). Environmental qualities are completeness (Com), effectiveness (Effe) and generality (Gen). After the artefact quality evaluation, the post-presentation usage beliefs are surveyed. These questions are identical to the pre-presentation usage beliefs, except that the general expression of "a method for the creation of viable services based on big and open earth observation data" has been replaced by "SIMEO-STOF". To differentiate between the pre- and post-presentation concepts, these have been assigned the respective suffixes 'a' and 'b'. Each of the concepts is divided into three statements which can be answered through a 5-point Liker scale. The survey protocol with the questions and the Likert scale options are annexed in appendix E on page 108.

The application of the UTAUT-ECT theory on pre-presentation and post-presentation phases instead of pre-usage and post-usage phases of is, as far as the author can tell, not performed before. Furthermore, the relation between quality requirements of an artefact to the usage beliefs on the artefact is not included in the theories and it has not yet been applied to a second level DSR IS artefact. Therefore, this evaluation will propose several relations between these concepts. Figure 49 illustrates these proposed relations.

The first proposition is the positive relation between pre-presentation usage beliefs and the pre-presentation attitude. It is based on the combined UTAUT-ECT theory (Venkatesh et al., 2011) with theorizes a positive relation between pre-usage beliefs and pre usage attitude. The proposition P1 is as follows:

P1: Pre-presentation beliefs have a positive influence on pre-presentation attitude.

Again, based on the combined UTAUT-ECT theory is a second proposition: the supposed relation between pre-presentation usage beliefs and post-presentation usage beliefs. In the theory, this relation exists between pre-usage and post usage of an information system (Venkatesh et al., 2011). The second proposition for this evaluation is that the pre-presentation beliefs have a positive influence on the post-presentation usage beliefs (P2) (Venkatesh et al., 2011):

P2: pre-presentation beliefs have a positive influence on the post-presentation usage beliefs

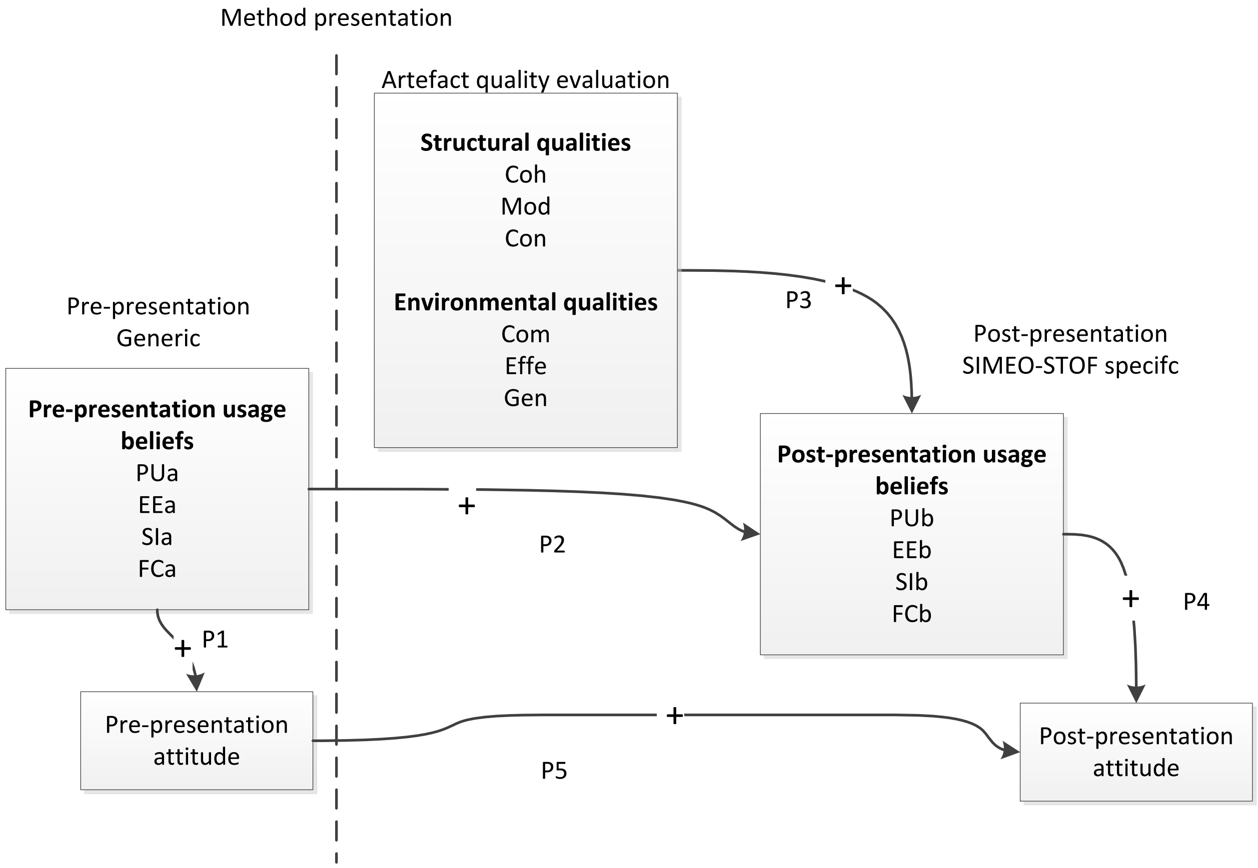


Figure 49: Survey design based on Venkatesh et al. (2011) and Johannesson and Perjons (2014)

The third proposition concerns the relation between the structural and environmental quality requirements of the artefact and the post-presentation usage beliefs. These quality requirements that check for internal validity by evaluating the form of the artefact and external validity by evaluating the completeness for the environment, the effectiveness of the artefact and the generality, i.e. the ability to apply it elsewhere. Scoring high on these qualities results in a high quality artefact. The author proposes that a high quality artefact will result in a higher perceived usefulness that results from the use of the artefact. Also, the artefact should be usable at a reduced effort. However, a high quality model should not affect social influences and facilitation conditions, as these are concepts that arise from the context of use, not the artefact itself (Venkatesh et al., 2003). The author formulates the following propositions for the relation of the artefact quality on the post-presentation perceived usefulness and expected effort (P3):

P3: the structural and environmental qualities of the artefact have a positive influence on the post-presentation usage beliefs

The final set of propositions are again based on the combined UTAUT-ECT model by Venkatesh et al. (2011) in which there is a positive relation between the pre-usage attitude towards the artefact and a positive relation between the post-usage beliefs on artefact use and post-usage attitude. Applied to this research, this would mean a positive relation between pre-presentation usage attitude and post-presentation usage attitude, as well as a positive relation between post-presentation usage beliefs and post-presentation usage attitude.

P4: post-presentation usage beliefs have a positive influence on post-presentation usage attitude

P5: pre-presentation usage attitude has a positive influence on post-presentation usage attitude

As indicated previously, all concepts on beliefs, attitude and quality requirements will contain at least three questions, each of which will be surveyed in form of 5-point Likert scales. The Likert scale is an ordinal scale and thus cannot be used to calculate means and correlations. This means testing the propositions is not directly possible, unlike with interval and ration type scales (Allen & Seaman, 2007; Field, 2009; Warmbrod, 2014). Only summarized scales can be considered to be continuous when multiple variables are used to measure the same concept (Allen & Seaman, 2007). Based on the recommendations of Warmbrod (2014), the initial results of the Likert scale data will be presented in a frequency table indicating percentages per response option which can be used to draw conclusions. Then, the variables are summarized per respondents into their concepts and a Cronbach Alpha analysis is performed to check for the reliability of the concepts. If the concepts pass the test by having a sufficiently high reliability ($\alpha \geq 0.8$), the scales can be used to draw conclusions and used for descriptive statistics including mean, median, variance and standard deviation. From here, the propositions presented above can be tested, similarly to Venkatesh et al. (2011).

For the execution of the survey, several tools are used. Firstly, the survey is implemented in the MentiMeter web application[14] which allows respondent to reply to the survey questions using their own smartphones, tables or laptops. Results can be shown directly to the audience, which facilitates the discussion required for the evaluation using observations (described in section 6.1.3 below). Furthermore, the results will be available digitally in a machine readable format, facilitating the data preparation. The statistical evaluation of the results will be performed with R and Rstudio. To create visualizations of the output generated by R and to calculate initial frequency tables, Microsoft Excel is used.

6.1.3 Evaluation approach using participant observation

Not all requirements and evaluation objectives could be fitted within the survey. In order to cover the evaluation of the remaining empirical requirements of the artefact, participant observation combined with unstructured interviews are conducted during and after the presentation with the participating audience. During the presentation and the survey, the audience is encouraged to ask questions and comment about the model. Discussion will be encouraged by presenting intermediate results and asking for opinions.

6.2 Survey Evaluation Results

This section presents and discusses the evaluation results from the survey. This is done by firstly presenting a general overview of the participants and the data, as well as the reliability of the scales of the data. Then, the descriptive statistics in form of histograms are presented and discussed. The last subsection is dedicated to the the testing of the propositions and the conclusions that can be drawn from these.

6.2.1 Audience, model response and reliability

The evaluation session attracted an audience of 25 people at its peak, with a few latecomers and early departures. This caused for a few missing values at the beginning and near the end of the event. On average, every question had 24 respondents, with a maximum of 25 and a minimum of 22. Whilst in terms of statistical analysis this sample size is small, it should be quite representative of the department of space at CGI, which has about 50 employees. The respondents consist primarily of young people, aged between 20 and 34 (65%). The large majority of the respondents are male (83%). All of the respondents are either employees or subcontractors of CGI, since the presentation room was located within a non-public area of the CGI Rotterdam office. Whilst respondents have not been asked for their role within the company, the author could identify parts of the audience having management functions, software programming functions and software testing functions as well as the actually targeted group of service designers in their function of consultants. A full descriptive statistics overview of the data as well as the data cleansing procedure can be found in the appendix G.2 on page 112.

Before diving into the results and what can be interpreted from them, the reliability of the results needs to be established. This is done using the measure of Cronbach's alpha (α), which measures whether the data of a certain concept correlates sufficiently with itself in order to be able to conclude that all data points measure the same concept. This should be done for each scale and each scale should have at least 30 responses. However this is not the case in the data with the N_{min} at 22 and N_{max} at 25. The analysis is carried out nonetheless, with the possibility of strange results in unreliable scales (Field, 2009). If the value of Cronbach's alpha is equal or higher to 0.8, the scale is considered to have a very high reliability ($\alpha \geq 0.8$). If Cronbach alpha is less than 0.8 but equal or higher to 0.7 ($0.8 > \alpha \geq 0.7$) the scale is considered reliable. A score on Cronbach's alpha between 0.7 and 0.6 is considered the minimally acceptable for continued analysis ($0.7 > \alpha \geq 0.6$). Everything smaller that 0.6 ($\alpha < 0.6$) is considered unreliable and cannot be used to generate any reliable conclusions (Field, 2009; Warmbrod, 2014). Thus, all unreliable scales will be discarded. The Table 27 below provides the scores of each of the scales.

Table 27: reliability analysis of scales using Cronbach's alpha

Name	Scale	Composing	α	Reliability
Perceived Usefulness (a)	PUa	PU1a, PU2a PU3a	0.60	Acceptable
Expected effort (a)	EEa	EE1a, EE2a, EE3a	0.74	Reliable
Social influence (a)	SIa	SI1a, SI2a, SI3a	0.66	Acceptable

[14] See https://www.mentimeter.com/ for detailed descriptions and a demonstration of the tool.

Facilitating conditions (a)	FCa	FC1a, FC2a, FC3a	0.32	Unreliable
Attitude (a)	ATa	AT1a, AT2a, AT3a	0.80	Very reliable
Coherence	Coh	Coh1, Coh2, Coh3	0.90	Very reliable
Modularity	Mod	Mod1, Mod2, Mod3	-0.13	Unreliable
Conciseness	Con	Cos1, Cos2, Cos3	-0.32	Unreliable
Completeness	Com	Com1, Com2, Com3	0.82	Very reliable
Effectiveness	Effe	Effe1, Effe2, Effe3	0.92	Very reliable
Generality	Gen	Gen1, Gen2, Gen3	0.83	Very reliable
Perceived Usefulness (b)	PUb	PU1b, PU2b, PU3b	0.87	Very reliable
Expected effort (b)	EEb	EE1b, EE2b, EE3b	0.87	Very reliable
Social influence (b)	SIb	SI1b, SI2b, SI3b	0.92	Very reliable
Facilitating conditions (b)	FCb	FC1b, FC2b, FC3b	0.80	Very reliable
Attitude (b)	ATb	AT1b, AT2b, AT3b	0.94	Very reliable

The scales for pre-presentation facilitation conditions (FCa), modularity (Mod) and conciseness (Con) are considered unreliable and will be excluded from further analysis and conclusions. A few pre-presentation scales are just reliable enough to pass, whilst all of the post-presentation usage beliefs and attitudes scales are considered very reliable.

6.2.2 Method quality evaluation

With the scales for modularity and conciseness being too unreliable for further analysis, the quality evaluation of the method will continue with the structural quality of coherence and the environmental qualities of completeness, effectiveness and generality. Respectively, the scales for each of these concepts have been plotted in histograms in Figure 50 for coherence, Figure 51 for completeness, Figure 52 for effectiveness, and Figure 53 for generality. These figures should be read as follows: on the x-axis is the summed score of a 5-point Likert scale, which will range from a minimum of 3 to a maximum of 15 for coherence, completeness and effectiveness and from 4 to 20 for generality, because this scale has four questions that have been summed. The y-axis of frequency indicates the number of respondents whose sum equals a specific score in the histogram. Low scores represent disagreement or negative attitudes towards a concept, mid-range scores represent ambivalence or no opinion on the concept and higher scores represent agreement or positive attitudes towards the concept. A positive evaluation will be considered any evaluation with at least 11 points on a 15-points scale, as this would be equivalent to answering at least two of the three questions of the scale positively. Neutral or ambivalent are the scores 8 to 10, and negative evaluations are 7 or lower.

With the knowledge of interpreting the histograms, the first scale of measuring the structural quality of coherence for SIMEO-STOF in Figure 50 can be discussed. It indicates that most respondents agree that the method is coherent, with 52% of respondents having a sum of at least 11 points (i.e. a positive response) for this quality. The environmental quality of completeness of the method is more controversial amongst the respondents with respondents almost equally agreeing and disagreeing on its completeness. Specifically, 24% of respondents think it is complete, 32% think something is missing and the remaining respondents are neural or ambivalent. Considering the discussions on the completeness of the method (which are described in the participant observations in section 6.4on page 81), a cause for the controversialist of the completeness could lay in the desired further expansion of the method by people initially not involved in the cases studied (see Figure 51).

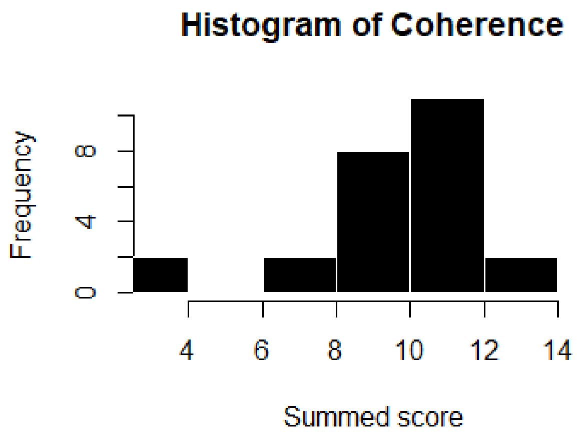


Figure 50: Histogram of results on Coherence

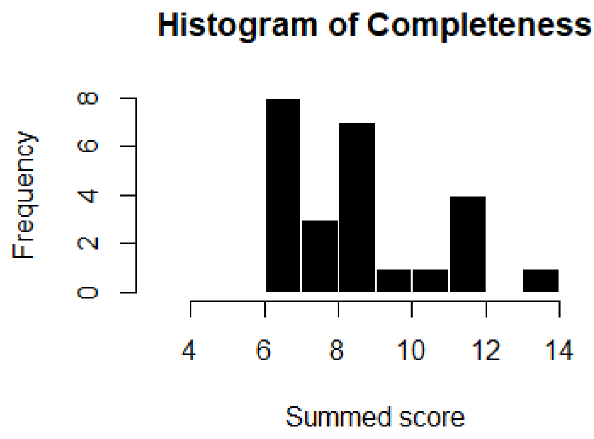


Figure 51: Histogram of results on Completeness

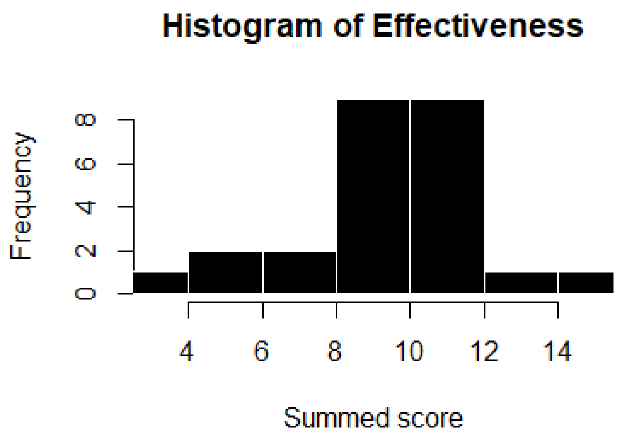


Figure 52: Histogram of results on Effectiveness

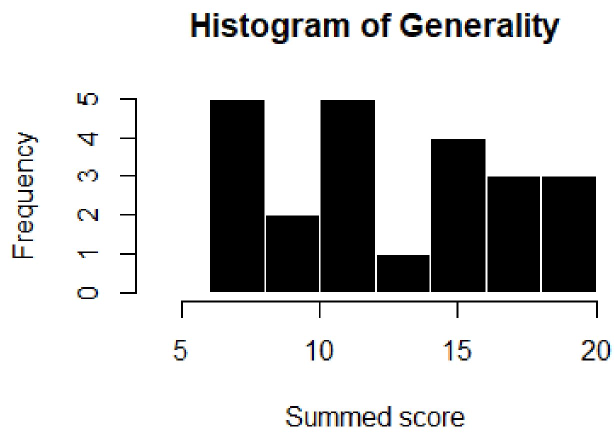


Figure 53: Histogram of results on Generality

Respondents are mildly positive about the effectiveness of the method, considering that 44% rated the effectiveness with 11 points or higher and an equal percentage remained neutral or ambivalent on the effectiveness (see Figure 52). Finally, the respondents seem yet again divided over whether the method is applicable to commercial earth observation data and outside of CGI, with participants being slightly more positive than negative. Because this is a scale from 4 to 20 points, negative judgements are defined as 9 and lower and positive judgements are defined as 15 or higher. Scores of 10 to 14 included are considered neutral. Using these scores, 43% of respondents are positive on the generality of the method, whilst 26% think that the method is not usable outside of its environment. 31% of respondents remained neutral (see Figure 53 and more detailed reporting on every question in Table 33 on page 113).

Considering only the histogram scores, it is hard to conclude with condescended that the artefact is fulfilling its requirements. Already having excluded two scales because of their unreliability, the completeness seems not attained and the generality is controversial. The effectiveness and the coherence are rated positively at least.

6.2.3 Method continued use beliefs and intention

This subsection discusses whether the artefact will be continued to be used. This is measured through the continued usage belief of the artefact, which contains the scales for post-presentation perceived usefulness (PUb), the expected effort (EEb), the social influence (SIb) and the facilitation conditions (FCb) together forming the usage beliefs part. The future use intention is measured through the attitude towards future use after the presentation (ATb). All of these scales have passed the reliability test (see section 6.2.1 page 77).

Of the respondents, 36% perceive the artefact as useful for the design of viable services with big and open earth observation data, 50% are neutral and 24% perceive the artefact as not useful (see Figure 54). Respondents do not expect a lot of effort in handling the artefact, with 50% of respondents providing positive responses.

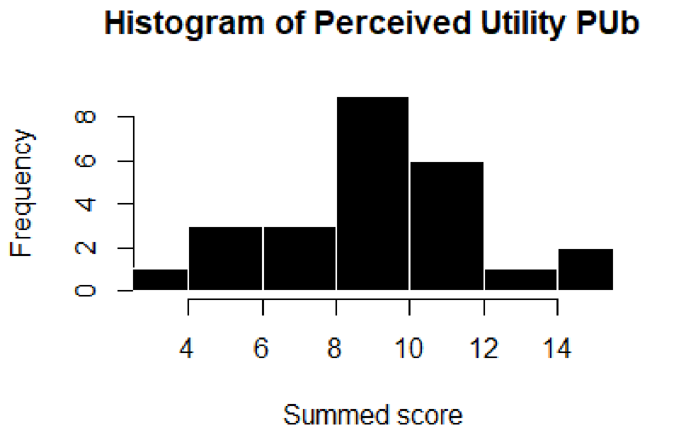


Figure 54: Histogram of results on post-presentation perceived usefulness

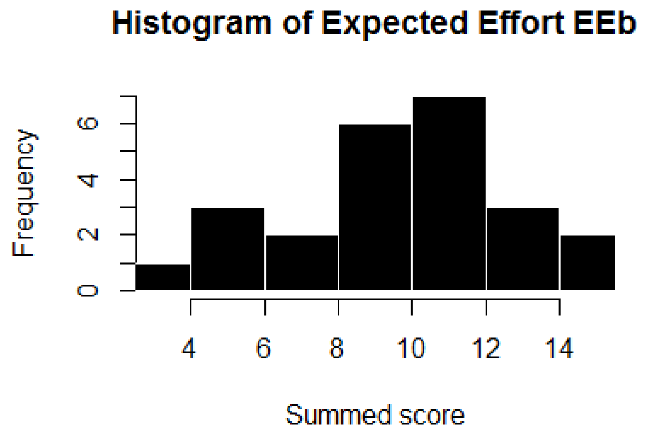


Figure 55: Histogram of results on post-presentation expected effort

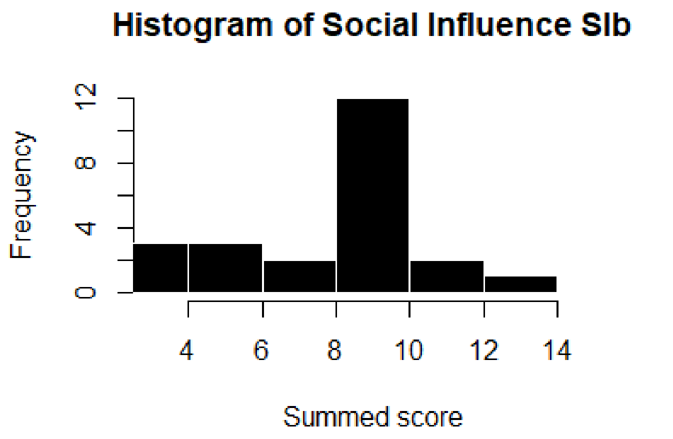


Figure 56: Histogram of results on post-presentation social influence

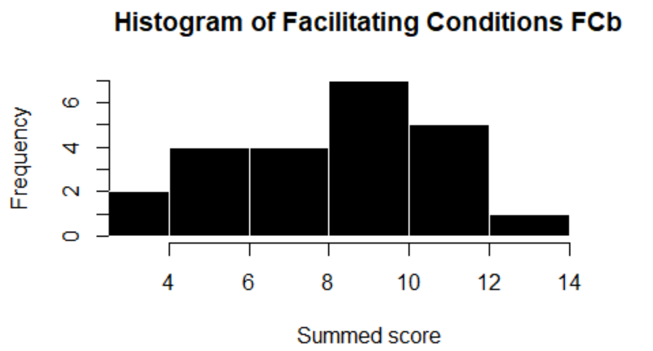


Figure 57: Histogram of results on post-presentation facilitating conditions

Respondents do not feel pressured or motivated by their colleagues to use the artefact, with 61% of respondents remaining neutral or ambivalent and a further 26% disagreeing with any form of social influence (see Figure 56). The facilitating conditions at CGI Space for the use of the artefact are also controversial with a slight tendency towards the negative. 30% of respondents think the facilitating conditions are insufficient, 56% are neutral or ambivalent and 26% are positive about the facilitation conditions (Figure 57).

Overall, the attitude towards the use of the method is positive. The majority of respondents (59%) think positive of the use of the SIMEO-STOF method to design viable services whilst only 17% have a negative opinion towards its use (Figure 58 below). The positive attitude towards the use of the artefact allows the conclusion that the artefact is considered to support service designers to create viable services, thus fulfilling its main objective.

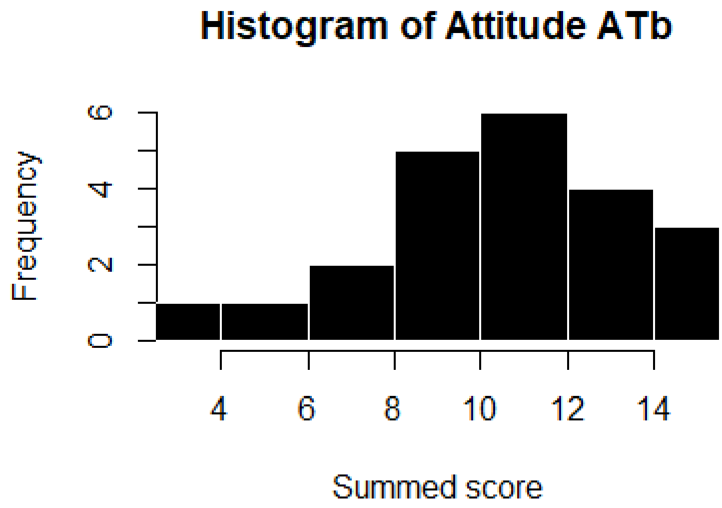


Figure 58: Histogram of results on post-presentation usage attitude

6.3 Propositions Discussion

This section discusses the propositions of the UTAUT-ECT model applied to this research which is postulated in section 6.1.2. Firstly, the limited number of respondents in the survey does not allow for any statistical analysis beyond descriptive statistics. Whilst no correlations and confidence interval data is available, the descriptive statistical data and the observations will be used for the discussion of the propositions.

The first proposition, P1, states that pre-usage beliefs have a positive influence on pre-usage attitude. The histograms in Appendix F.3 page 110 do not provide any evidence to the contrary, as positive to very positive ratings of pre-presentation are accompanied by a positively rated attitude towards the pre-presentation attitude. Observations did not contribute to this postulation, which suggests that further research is needed on this relation. The second proposition, P2, states that pre-presentation beliefs have a positive influence on the post-presentation usage beliefs. Histograms presented previously in section 6.2.3 provide the impression that the usage beliefs are more ambivalent after the presentation, as the histograms provide a more scattered image of the scores, perhaps indicating more disillusionment for some and surpassing expectations for others. Nonetheless, without clear statistics, this proposition also requires further research. The lack of sufficient responses to perform correlation analysis is also affecting the third and fourth proposition. The third proposition states that the structural and environmental qualities of the artefact have a positive influence on the post-presentation usage beliefs. Within the discussions at the evaluation session, the completeness did come up, but with different objectives in mind, different opinions were given on whether the completeness was achieved. However, the histogram patterns seem similar to a certain degree, and certainly, do not indicate that positive reactions on the non-functional requirements of the artefact result in the lower intention of use. A similar conclusion can be drawn for the fourth proposition, which states that post-presentation usage beliefs have a positive influence on post-presentation usage attitude. There is no evidence to suggest that there is a negative relation, as the histograms follow more or less the same pattern. This, however, does not mean a positive relation either, as the lack of responses does not allow drawing a conclusion. Further research with more responses would be required to perform statistical analysis. The last proposition, P5, states that the pre-presentation usage attitude has a positive influence on post-presentation usage attitude. When comparing the histograms of the attitudes at the two different moments, the post-presentation attitude seems to be lower and more spread out. Again, further research will be required.

In conclusion, the lack of correlation and hypothesis testing statistics make it difficult to word strong statements on the propositions. From what can be identified is that the pre-presentation constructs appear not to have a positive effect on post-presentation constructs (P2 and P5). Propositions 1, 3 and 4 do not show a negative trend, but further research is required to make clearer statements. Considering these results, the addition of the two-phase ECT evaluation has not resulted in any additional findings. Future evaluations may as well use only the UTAUT concepts together with the non-functional requirements and only provide the addition of the two-phase ECT model when the evaluation includes an ex-post evaluation after actual use and implementation of the artefact. However, it is doubtful this is feasible, as this would require a large number of implementations to attain the number of results in a survey that allows for more than descriptive analytics.

6.4 Observations and Suggested Improvements

This subsection details all the observations and suggested improvements that rose during the evaluation as well as combining these with the findings from the previous demonstration of the artefact in section 5.3 Observations and suggested improvements on page 71. Firstly, the observations from the evaluation session are described, after which these remarks are compared with the findings from the artefact demonstration. Then, the suggested improvements for the artefact are listed.

During the presentation of the method in which also a demonstration of the artefact has been given, the audience entered on several occasions into a discussion. These discussions are described here as observations made by the researcher. The first observation made is that there were different expectations to the objective of the method. One participant in a management function expressed the vision of further automating the innovation phase, so capabilities of SIMEO-STOF can be linked to companies based on keywords in the public information of such companies (e.g. websites). This would essentially remove or reduce the requirements for the role of a service designer. The same person also suggested that the method should allow for a novice in the service design to use and design methods. The author asked this person about possible requirements that this objective should entail, asking whether the automated variant should scrape websites in order to identify possible clients and the earth observation capabilities they require and automatically send them an offer for a service. The participant agreed with this idea, leading a different participant in a management function express doubts about the feasibility of such automation and said that human analytical skills would still be required. The argument was settled with the agreement that consultant would still be required to execute the SIMEO-STOF method, but that the method definitely guided consultants in the right direction for the design of viable services. A second observation made is that the only CGI consultant with whom the author used the SIMEO-STOF method (see section 5.2: Oil Tank Monitoring on page 66) was a strong proponent of the method. He actively wanted to react to questions of his colleagues during the presentation and stated his perspective on the added value of the method. Specifically, this added value would be the check-list like the structure of the "SIMEO"-section of the method, allowing for a specialist consultant like himself to identify innovative applications outside of his own speciality.

The differences of opinion on the completeness of the artefact are most likely due to differences in opinion about the objective of the artefact. However, if taken for the objective for which it has been designed, i.e. the guidance of service designers for the creation of viable services using big and open earth observation data as a resource, the positive feedback from the consultant is directly related to this objective. As the other discussions of possible improvements are related to different objectives that the one the artefact has been designed for, the SIMEO-STOF method fulfils its objective. Improvements could be aimed at the completeness and the generality of the SIMEO-STOF method, as well as better communicating what the model should include.

6.5 Conclusions

The research question for the evaluation of this research is "How well does the method design viable services based on big and open earth observation data, and how well does the method fulfil the defined quality requirements?". The fulfilment of the requirements is measured by the quality requirements in and whether it solves the explicated problem by whether people would use the SIMEO-STOF method for viable service design with big and open earth observation data. To answer this research question on the evaluation of the artefact, a survey and observations have been conducted, as well as drawing from the artefact demonstration conclusions.

Firstly, the part of the research question asks how well the SIMEO-STOF method designs viable services which use big and open earth observation data as a resource. This is primarily measured by the intention of use by the potential future users in addition to the results of the demonstration. As concluded in the demonstration chapter earlier, the application of the method resulted in a design which is 'probably viable', with added benefit being especially in identifying on which variables the viability of the service hinges. Over 59% of respondents having a positive attitude towards the use of SIMEO-STOF for viable service design and employees which are likely to use the artefact within CGI provide strong vocal support and interest in the artefact. Thus it can be concluded that the SIMEO-STOF method solves the problem of designing viable services based on big and open earth observation data at least sufficiently or better.

The second part of the question is aimed at the internal validity of the artefact by assessing whether the requirements of the artefact have been met. This has been evaluated by a survey on the non-functional quality requirements of modularity, conciseness, coherence, effectiveness, generality and completeness. Coherence and effectiveness have been rated positively and slightly positive, whilst the generality of the method is controversial and the completeness slightly negative. The modularity and the conciseness of the method could not be tested due to unreliable measurements. In the discussions which accompanied the evaluation, the components which are supposedly lacking are discussed, but these mostly concerned a desired future objective, not the current. This may have influenced the rating of the completeness. Nonetheless, this leaves us unable to draw a strong conclusion on whether the SIMEO-STOF method fulfils all of the requirements.

Improvements could focus on the completeness and generality of the SIMEO-STOF method, as these were rated least positive of the evaluated non-functional requirements. Adding the observation that participants in the discussion considered different, more advanced future objectives for the artefact, the questions of “completeness for what objective?” and “generality for what purpose?” should be included in future research.

7 Conclusion

This final chapter concludes this thesis by determining whether the objective of this research has been fulfilled. The objective of this chapter is to provide an overview of the results, their meaning in a broader context and their limitation. Firstly, the previously set research questions will be restated and answered by providing the most important findings of this research. Then, the contributions of the research are presented to see whether the knowledge gaps identified in section 1.2.5 on page 6 are filled. The limitations and open discussions within this research are addressed in section 7.3, which also provides suggestions for future research after the discussion of a limitation.

Figure 59: Research design for the conclusion chapter

7.1 Answers to the Research Questions

In this section, the research questions are reiterated and their answers presented. The objective of this research is to design a method for the creation of viable services based on big and open earth observation data. This objective is structured using the design science research approach, resulting in six research questions. All these four questions are answered and its results discussed one by one.

7.1.1 Problem Demarcation

The first research activity is the problem demarcation which is guided by the research question "What is the problem experienced by service providers which desire to create viable services which use big and open earth observation data as a resource and why is it important?". Besides answering this question through a structured literature review and explorative interviews, the choice for the design science research approach is made. Not only is a research structure with all individual research questions provided in Figure 5 on page 11, it also sets the objective of this research.

To formulate the research objective, knowledge gaps were identified through the earlier named research method of a structured literature review. The knowledge gaps state that within the narrow focus area of big and open earth observation data, as well as in the larger area of applied earth observations, no viable service using a structured method for its design has been found. An analysis of these results concluded that the factors of big and open earth observation data that influence the viability of service designs are not identified within the searched literature either. Together with the insights obtained from the explorative interviews, the lack of a structured method to guide the design of a viable service for earth observation applications using big and open earth observation data became apparent in both the searched literature and in the practices of the interviewees. The result is the formulation of the problem statement as follows:

The objective of this research is to design a method targeted at service providers for the creation of viable services which use big and open earth observation data as a resource.

It has furthermore been established that this research creates a method as defined by Gregor and Hevner (2013) as a second level information system artefact.

7.1.2 Literature review

The second research question is as follows: "What are the factors of big and open earth observation data influencing the creation of viable services?". This research question originates directly form the third knowledge gap on the lack of knowledge on big and open earth observation data factors influencing viable service design. In order to answer this research question, an expansion of the structured literature review previously executed to extract the knowledge gaps is performed. As the combined area of big and open earth observation data does not yet exist in literature, the three areas of big data, open data and earth observation data are surveyed separately, resulting in the list of data factors influencing service design per data type summarized in the Table 28: Influencing data factors from section 2.6: Conclusion Literature Review below. These factors contribute to the understanding of the area of big and open earth observation data.

Table 28: Influencing data factors from section 2.6: Conclusion Literature Review

Open data	Big data	Earth observation data
Non-rivalrous, non-excludable (public good)	Low marginal cost, high fixed cost structure	Coordinate reference system
High fixed cost/ low to marginal cost structure	Requires high computational resources	Spatial resolution
No supply assurance/continuation at risk	Requires large storage and dedicated storage technology	Update frequency
No quality level guaranteed; data is provided as-is	Requires high network resources	Data model and semantics
Mutual information asymmetry: providers do not know what users need and users do not know how open data can help.	Security design choices: the triad of confidentiality, integrity and availability	Multi-dimensional data
	Privacy concerns	

Furthermore, current viable service design literature is reviewed by performing backwards and forward searches on the viable service concepts within the set of articles which are used to describe the influencing factors. The result is a comparison of five viable service models: the VISOR model specializing in value delivery interfaces, the E^3-value model specializing in modelling how value is exchanged, the CANVAS model specializing in easily modelling the logic of a single firm, the STOF model which integrates the four perspectives of Service, Technology, Organization, and Finance into a business model, and finally the VIP framework which aligns a given business model with operational processes to realize the business model. Table 29 below repeats the overview presented in section 2.2.2 on page 17.

Table 29: Overview of viable service and business model frameworks

	Core Concepts	Focus	Visualization
VISOR	Value proposition, Interfaces, Service platforms, Organizing models, Revenue and Cost Sharing, each with more detailed concepts	Interface of value delivery to customer	Conceptual relations only
E^3-value	Actor, value object, value port, value interface, value exchange, value offering, market segment, value activity	Modelling how value is exchanged	E^3-value ontology: value exchange Input/output diagrams
CANVAS	key activities, key resources, partner network, value proposition, customer segments, customer channels, customer relationships, cost structure and revenue streams	Simple overview of business logic in a company	CANVAS template
STOF	Service, Technology, Organization, and Finance domains, each with a number of trade-offs to balance or strategy	Integrating four perspectives on business models as domains	Conceptual relations only
VIP	Value, Information, Processes	Aligning operational processes realising the value of the actual value goals throughout multiple stakeholders.	Conceptual relations only

7.1.3 Requirements Gathering

The third research question is answered in the requirements gathering chapter and is as follows: “What are the requirements for a method that creates viable services which use big and open earth observation data as a resource?” The objective is to identify requirements for the artefact and the research method used is the case study, in which observations and interviews are used for information gathering. Furthermore, the STOF model is selected to structure the cases based on its best fit to the kind of services which are designed. The cases are selected based on whether these contain at least a service provider that wishes to create a viable service using big and open earth observation data as a resource and a client that wishes to use such a service but is not specialized in creating such services by themselves. Furthermore, both parties are willing to cooperate with the research and are accessible by the researcher. Based on these criteria, three cases at the information technology consulting and integration company CGI have been selected, where CGI takes the role of future service provider. These cases are the Greenhouse Monitoring case, Ems-Dollard Water Quality case, and the Migration Radar case. The cases each provides requirements, which are all listed in section 3.6.1 on page 55 and are used in the next chapter for the design of the artefact.

7.1.4 Artefact Design

The artefact design chapter is guided by the research question “What does the service design method for viable services which use big and open earth observation data as a resource that satisfies the requirements look like?” and is answered using a combination of creative methods instead of formalized research methods. The method is represented by the image in Figure 60 below, which depicts the Service Innovation Method for Earth Observation (SIMEO) integrated with the STOF model. The method is explained here below as well as the additions to the STOF model to better represent the key aspects of viability for earth observation applications which use big and open earth observation data as a resource.

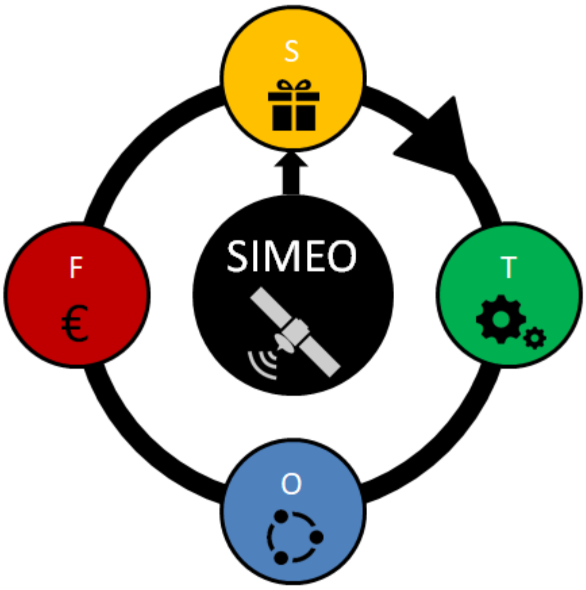


Figure 60: The SIMEO-STOF method

The method consists of five phases; the SIMEO phase in which the service idea is created and checked rapidly. Thanks to a list of known capabilities in earth observation applications, ideas can be discussed rapidly and in a structured manner, allowing for the identification of service possibilities that have not been previously considered by service designers. Then, a list of limitations of earth observation data should directly provide feedback about the feasibility of a service idea. Services that are considered likely to succeed by the service designer and valuable to the client can proceed to the next phase. In this next phase, the service domain phase, the targeting, value elements, the branding and the customer retention mechanisms are discussed. The issues to balance are whether the service is a generic or a niche service and whether it is a consumer, business or government aimed service for. The second issue is how the value proposition creates value for the client and user is portrayed in this section. Thirdly, the branding of the service concerns whether the brand of the content, the service provider or, if applicable, a sales channel should be used for promotion. Ultimately, the mechanisms for customer lock-in should be considered as to not annoy the customer excessively.

In the second phase, the technology domain phase, a large number of issues are considered to come to a first version of the system architecture. Firstly, the security principles are set, which is a trade-off between confidentiality, integrity, and availability. A second principle for the architecture is the handling of big data, specifically how the computation, storage and transfer of data or functionality and programming should take place. Specifically for the earth observation data, the coordinate reference system standard and data ontology standard should be selected in advance based on the sources of data and where the service should operate. Other concerns in the technology domain are the quality of the system, including the data, versus the cost of maintaining the system as well as to what degree the service should be integrated with existing, possibly legacy, systems as well as the openness of the system and the management of user profiles.

In the organization domain phase, the inter-organizational strategies of the service design are defined. These concern firstly the partner selection and how critical resources for the service are accessed. Secondly, how exclusive the access to the designed service or supply for the service is, is described in the network openness. The control over the resources in the network, including what to do in case a resource supply is discontinued is described in the network governance. This especially includes the contingency plan of what happens when open data supplies are discontinued. Ultimately, the controllability of relations in the network is discussed in the network complexity. As the number of clients and suppliers grow, the control exercisable on the stakeholders of the value network may significantly lower.

Finally, in the financial phase, the value retention and pricing strategies are discussed. The pricing allows for the retention of the value created for the client and should retain this value for the whole value network as to create the incentives for continued cooperation within the value network. At the same time, other interests can be considered, such as the desire to attain a market share. As the main resource for the service is big and open data, the pricing strategy should account for a relatively high fixed cost for maintaining infrastructure at a low marginal cost for data acquisition. Following all steps finishes the first iteration of the SIMEO-STOF method. If required, further iterations can take place, in which elements of the viable system design are reviewed.

7.1.5 Artefact demonstration

The demonstration phase shows the feasibility of the artefact by applying it to a case. The research question to guide this section is "How can the method be used to create a viable service design?". The previously described SIMEO-STOF method is applied to the 'oil tank monitoring case' at VTTI, a crude and processed oil transhipment company located in the harbour of Rotterdam. The application of the method resulted in a service design which is most probably viable. However and maybe, more importantly, the design allows identifying the issues on which the viability of the design hinges. For the demonstration case, these issues for the VTTI case are the price of a service resource acquisition in form of subsidence monitoring from a partner and the cost of the IT infrastructure.

A consultant form CGI present at the client interview in the first phase of the SIMEO-STOF method application also praised the structured idea generation. Because of his specialization in one type of earth observation data applications, the structured passing of other ideas allowed for the identification of more ideas than just his specialized area. He noted that because of his specialization, he would more easily overlook other areas. Thus, SIMEO-STOF allows service designers to identify more potentially viable ideas.

Furthermore, additional improvements of functionality for the artefact could be identified. Firstly is the addition of the delivery delay of the data, which indicates the time between the capturing of a data point and the time when the data point is ready for analysis by the service provider. Furthermore, some satellites do not operate in certain conditions, such as areas with high lateral degrees (the Earth's poles) which are out of range of the sensors or the limitation that some spectra of light cannot travel through clouds.

7.1.6 Artefact evaluation

The last research activity is the evaluation of the artefact. This activity is guided by the research question How well does the method design viable services based on big and open earth observation data, and how well does the method fulfil the defined quality requirements?". This research question prescribes two objectives in the evaluation: the evaluation of the internal validity of the artefact through the fulfilment of quality requirements and the evaluation of the external validity by evaluating whether the artefact realizes its objective.

The research methods for the evaluation are participant-observations and a survey. The survey is held amongst CGI employees during a presentation which includes a demonstration of the SIMEO-STOF method. To evaluate the internal validity, the six quality requirements of the artefact are surveyed. These are coherence, modularity, conciseness, generality, completeness, and effectiveness. Each quality requirement is considered a concept for which three statements are created, which survey participants can answer on a 5-point Likert scale. For the external validity, the combined universal theory of acceptance and use of technology (UTAUT) and expectation-confirmation theory (ECT) as described by Venkatesh et al. (2011) is used. This allows for the measurement of the construct 'attitude towards use', which is used as a measurement of whether the employees would consider using the SIMEO-STOF method. The argument is that employees would only consider its use if the SIMEO-STOF method does contribute to the creation of viable services. Additionally, propositions are created to combine the quality requirements with the UTAUT-ECT model. However, due to a lack of responses these propositions can only be discussed in qualitative terms and the results of the survey only provide descriptive statistics.

The results show, all things considered, a positive evaluation of the attitude of use as of the quality of the artefact. The initial statistics on the quality requirements of the artefact provide a mixed image, which the scales of conciseness and modularity considered not reliable enough, the scales of generality and completeness indicating a mix of positive and negative responses and finally coherence and effectiveness slightly positive. However, when questioned about the completeness, it surfaced that some respondents already envision an objective which exceeds the research objective for which the artefact mas been designed and based their judgment of lacking completeness on this advanced objective. Furthermore, the attitude towards the use of the artefact is considered positive (see Figure 61 below), but highest interest in the artefact was taken by the employees who would eventually use it.

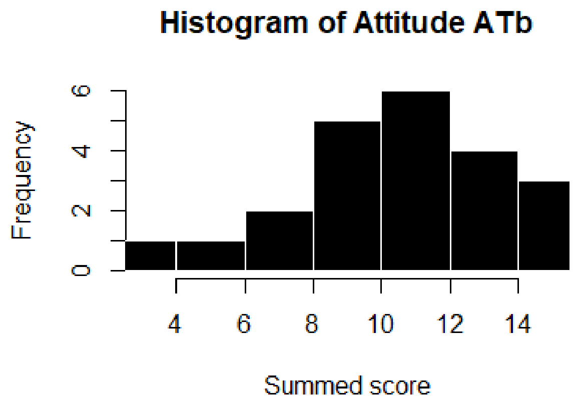


Figure 61: Histogram of results on post-presentation usage attitude

The evaluations do indicate that there is room for improvement, especially considering that participants in the discussion already envision future and more advanced uses for the artefact. This is on top of the more practical functional improvements which have been identified during the demonstration of the artefact.

7.2 Contributions

This section discusses the societal and academic contribution of the results in this thesis. Specifically in this section, the discussion on whether the knowledge gaps, formulated initially in section 1.2.5 on page 6, has been filled by the research presented in this theses. The knowledge gaps are firstly restated after which the contribution is presented. Then, the overall contributions are discussed using the framework of design science research contributions proposed by Gregor and Hevner (2013).

7.2.1 Knowledge gaps and contributions

The first and second knowledge gaps concerned the lack of viable services which used a structured method for their design in the academic literature of respectively the narrow focus area of big and open earth observation data as well as in the larger area of earth observations. These knowledge gaps are overlapping, as the searched area of the first knowledge gap is part of the searched area on which the second knowledge gaps is based. This research addressed these knowledge gaps by providing a demonstration of the SIMEO-STOF artefact in chapter 0 on page 65 (see also section 7.1.5 Artefact demonstration). The demonstration of the artefact results in viable service design which has been created using a structured method. Thus, the author considers the first two knowledge gaps are to be filled.

The third knowledge gap concerns the lack of factors of big and open earth observation data which influence the viability of a service design within the searched academic literature. By extending the literature review search beyond the focus area of big and open earth observation data to the three areas of big data, open data and earth observation data individually, a number of factors could be identified (See Table 28 in section 7.1.2 above). This list is not considered definitive, but all of these factors found resonance within the cases studied and were integrated within the artefact (see also section 4.3 on page 58). These factors should contribute to the general understanding of big and open earth observation data and the creation of viable services based on this type of data. The third knowledge gap is also considered fulfilled by the author.

The fourth knowledge gap concerns the actual lack of a structured method to guide the design of viable services which use big and open earth observation data as a resource. The absence of this method is noted both in the searched literature and to the knowledge of interviewees of a company wishing to create such services in explorative interviews. The artefact of this research, the SIMEO-STOF method directly addresses this knowledge gap. The proposed method can provide a design of a service using big and open earth observation data as a resource, which is likely to be viable (See chapter 5) or at the very least reduces the question of whether the design is viable to a number of issues which the service designer can resolve.

7.2.2 Discussion of academic contributions

Gregor and Hevner (2013, p. 338) propose questions for discussion of contributions within design science research. These are firstly cited, after which the contributions are discussed within the scoping of this question.

The first question is “are the problems discussed in the paper of substantial interest? Would solutions of these problems materially advance knowledge of theory, methods or applications?” (Gregor & Hevner, 2013, p. 338). The problem discussed in this research is the lack of viable service design for services using big and open earth observation data as a resource. Considering the market size, importance and growth potential of this type of services (Denis et al., 2017), the general absence of service design literature within earth observation literature is notable. The advancement of service design within the earth application domain directly enriches the service design literature with a fast growing, and possibly society-changing domain.

The second question is “does the author either solve these problems or else make contributions toward a solution that improves substantially upon previous work?” (p. 338). The SIMEO-STOF method tailors an existing business model and viable service design method for big and open earth observation data applications. This is tailoring in itself is an academic contribution which improves substantially on previous work, as demonstrated by De Reuver et al. (2008) in the context of mobile services. The SIMEO-STOF thus improves substantially on the previous work by Bouwman, Faber, Fielt, et al. (2008) for application in the earth observation domain and additionally solves the problem of the lack of methods for viable service design in the context of earth observation data and applications.

The third and final question for discussion “Are the methods of solution new? Can the proposed solution methods be used to solve other problems of interest?” (p. 338). Overall, application of the design science framework approach within this thesis is not a fundamentally new method of solution. However, within the evaluation activity a new method of solution has been attempted: the application of the UTAUT-ECT theory to a method on a technology instead of the technology itself. This is an expanded application of the existing theory. Though unfortunately no statistical analysis could be conducted due to a too low number of respondents, the application of at least UTAUT to a method instead of a technology implementation appears feasible and further research could perform the lacking statistical analysis.

7.2.3 Discussion of societal contributions

Practically, the SIMEO-STOF artefact contributes most to current or aspiring service providing stakeholders. The method allows a company like CGI to firstly identify more service ideas, gather the information on the service idea in a structured manner as to gain more complete information, and finally more rapidly assess the viability of a service design. Secondary beneficiaries are the open data hubs from ESA and NASA, as the use of the SIMEO-STOF method by service designers would lead to more viable services and consequentially to more open earth observation data use. Furthermore, other beneficiaries are more upstream suppliers of earth observation services, such as DigitalGlobe. A breakthrough in the value-added EO services market would allow suppliers of this market to grow as well.

7.2.4 Conclusion

In conclusion, this thesis tackles a problem of substantial interest, advancing the knowledge of methods and applications within the viable services and earth observation research areas. It does so by improving upon the STOF model for the domain of earth observation application and building a method for the design of viable services. The notable novelty in the method of achieving this artefact is in its evaluation, where the UTAUT-ECT model is used as a method for technology implementation instead on a technical implementation itself. Due to a low number of respondents, the use of at least the UTAUT model could not be validated statistically. The SIMEO-STOF method itself has a number of societal influences, specifically on (aspiring) service providers of value-added earth observation services. Further beneficiaries could be open space data hubs and commercial suppliers of space data, which benefit from growth in the value-added earth observation services market.

7.3 Limitations and Future Research

This section explicates choices made during this research and the limitations of the research and the resulting artefact. Detailing these is important to discover future application and research to improve the current SIMEO-STOF method. Suggestions for future research are added after each description of a limitation.

What is the difference between big data, open data and earth observation data?

The focus of this research is the application domain of big data, open data and earth observation data. However, unlike the Venn-diagram in the second chapter might suggest, the delimitations of the three data types are not that strict. First, there is a strong case that practically all modern earth observation data are also big data (Zotti & La Mantia, 2014). Furthermore, the earth observation data market as a whole has adopted a freemium model, in which the ESA Copernicus and NASA Landsat programs offer their data under a public licence, but EO data of higher quality, e.g. a higher spatial resolution, needs to be bought from a private provider[15]. This creates a continuum between the freely available open earth observation data with medium spatial resolutions and the commercial earth observation data with higher resolutions. Whilst these differences at some points may appear value, the literature clearly states different priorities which can be associated with each data type: earth observation data is the application domain, and it is all about the possibilities which can be created applying the data (Karmas et al., 2016), Big data focus more on technical aspects, as in how to process, store and transfer all of this data (Thomas & Leiponen, 2016) and lastly open data is mainly focussed on data governance aspects, such as societal and economic benefits (Janssen et al., 2012).

[15] https://www.spaceoffice.nl/nl/activiteiten/satelliettoepassingen/satellietdataportaal/

Rather than being fundamentally different, each of the three data types bring challenges on a different levels: to governance, to the data's contents and quality, and to technical processing. Further research could focus on identifying more characteristics of big and open earth observation data. It could also check for conflicting characteristics between the three data domains which could lead to the identification of trade-offs within this data domain.

How applicable, i.e. generalizable, is the method in different environments?
Case studies have limited generalization by nature (Yin, 2003), and the case studies used in this research are additionally limited because they are all performed from the perspective of CGI as a service provider, thus it is possible that CGI-specific requirements have ended up in the design. For example, CGI works on a billable hour structure, meaning employees are expected to have a percentage of hours performed on a project which creates revenue. Internal, service developing projects do not have this revenue, which is why CGI is looking for co-investors or tender-based innovation assignments. The more classical form of product development with initial investment with an external investor seeking a return on the investment itself is therefore not considered. However, the author considered the four cases as a whole to be sufficiently diverse and does not think that the fact that all cases are from a CGI perspective will limit the applicability of the method to other companies.

For future research, applying the SIMEO-STOF method at cases in other companies should be a priority to improve the demonstration of the generality of the artefact. Firstly, applying the method to a company similar to CGI could demonstrate that the requirements are not CGI-specific. Then, application of the method in cases involving a start-up company or an SME could improve the generality of the artefact for different kind of service providers. On the client side, no business to consumer (B2C) case is included in the requirements gathering cases. As the STOF model and method is able to design services targeted at consumers as well, the author expects that the SIMEO-STOF method is generable to consumer-focused service design as well. Applying the method to non-satellite based earth observation data, such as drone captured data, could be the next step towards improved generality.

Applicability for other use than asset monitoring
In reflection, the SIMEO-STOF method has almost exclusively been used for asset monitoring, with the exception of the Migration Radar case. The Migration Radar case, however, would not have to use the 'SIMEO'-phase of the method as the idea for the method has been largely pre-structured by the ESA tender. Future research could focus on whether the SIMEO-phase could be used for other service idea generation than asset monitoring service generation.

Limitation to spatial earth observation data
This research has limited itself to the use of big and open earth observation data from ESA and NASA, which is satellite-based. However, there are many other sources of earth observation data, such as pictures taken by planes or drones, sensors on weather balloons etc. Many of the issues encountered with these data would be the same, such as the requirement for orthorectification and geo-positioning of images. Drones could furthermore offer higher quality images with higher spatial resolution and better update frequencies yet may have operating limitations because of higher cost and no-fly zones such as the dangerous goods areas in the harbour of Rotterdam (where the oil tank monitoring case is located).

Further research on use of other earth observation sources would be required to extend the generality of the SIMEO-STOF method to non-satellite earth observation images. A concrete suggestion would be the use of a drone for the collection of earth observation images, as these are probably come most close to satellite-based images. Other applications could combine several internet of things devices monitoring their environment as a data source.

Limitations of the case study approach and results
Case studies are a powerful tool for requirements gathering, but also highly time-consuming. Finding the right amount of detail to make the case sufficiently right but at the same time making sure additional time spent leads to meaningful results is a tricky balance to make. Certain choices are made, detailed here. Firstly, the security risk analysis of confidentiality, integrity and availability is used to provide priorities within the technical design. However, the analysis is performed on a pure qualitative impact basis whilst not considering likelihoods. Whilst this approach reduces the time spent on the analysis of the security requirements, it is also prone to inaccuracies as a highly likely but low impact issue may be worse than a high impact but very low likelihood risk (Jones, 2006). Secondly, the financial elements of the case studies are performed qualitatively and not quantitatively. This is mainly due to the limitation that the researcher did not receive sufficient access to financial data in order to create a meaningful quantitative analysis. The limitation in exact finances limits the predictive qualities of the service design, as for example no exact prices can be offered to clients in order to evaluate whether the proposed service brings enough value. However, mapping the value elements of the client and estimating the order of magnitude of pricing and client benefit may suffice for the initial viability estimations of the service design. Thirdly, because of the rules surrounding tenders in progress and the researcher's association with CGI, the tender based cases of migration radar and Ems-Dollard water quality lack direct interviews from end users. However, the officially released documents are, by law, a reflection of the position of the client and contain the replies to the questions of all tendering parties. This results in publicly accessible documentation

of the complete perspective and needs of the client, a situation seemingly preferable to semi-structured interviews. The references and metadata of all the documents used are attached in Table 31: Case Documents on page 108.

The choice for access to information at CGI this research has led to reduced accessibility of other information, such as information on informal relations or tacit knowledge at the government agency. Part of this reduced access is due to the 'live action' characteristic of the design and information gathering, as the author gathered the information during tendering or active design of services. The lack of certain perspectives could be resolved in two manners in a future research: A ex-post investigation of the service creation may be conducted, which would allow e.g. the government agencies to release certain information which is no longer restricted by tender law. Alternatively, the researcher could take a more neutral perspective in the hopes it provides access to all parties in the tender process.

Design choice limitations

Throughout this thesis, the STOF model has been chosen above other viable service design methods as this is the single model which appeared most fitting for the quite technical earth observation services. However, the combination of models has not been considered within this thesis, but could be of value. For example, future designs could combine an more technical architecture language such as ArchiMate (Lankhorst et al., 2009) with e.g. the VISOR model focussing on client interfaces (El Sawy & Pereira, 2013) and still use the SIMEO-phase in front for the service idea generation.

Limitation of the evaluation approach and results

During the survey, a participant expressed difficulties with understanding and responding to the questions adding that he did not follow higher education and thus had difficulties understanding the questions. Reactions from the audience were supportive and agreeing. The level of education has not been asked for in the survey, but it is known to the author that the people working at the CGI space department have mixed educational backgrounds, mostly in Dutch higher vocational education for information technology ("HBO IT"). This may have led to a large number of people providing the 'neither agree nor disagree' option in the survey or responding incoherently. What could be indicating the latter is that both the scales where one of the three questions is formulated as a negative are considered not reliable after the Cronbach alpha test. Whilst there is no statistical evidence to support the proposition that because of the difficulty of the questioning for the audience some of the results may have become unreliable, it may be valuable to correct for educational levels in future surveys. Another limitation of the evaluation is the limited number of responses in the survey. This limited the statistical analysis to proposition testing, as other linear regression models could not be executed. The survey had been chosen due to the researcher being unable to perform other evaluation methods, which would have had preference above a survey. Specifically, the author calls for further evaluation of the artefact with a focus group and through interviews. These are the research strategies that are most appropriate for the naturalistic ex-ante type of evaluation in this thesis (Venable et al., 2012).

Concerning the evaluation theory and far as the author can tell, the combination of UTAUT-ECT has been applied to this research in two novel ways: firstly by evaluating the intended use of a method, i.e. a second-level information system artefact, and not an actual technology implementation. And secondly by not measuring the expectation of a single technology towards use of a technology, but my measuring the expectation of a class of information system to a specification of an information system. As indicated, the survey did not have sufficient responses on order to test the model which resulted from the novel application. This resulted in a very strong limitation of the research, as the model which resulted from UTAUT-ECT applied to this domain could not be tested and this no strong conclusions can be drawn from it. The author calls for future research which applies the novel applications individually in separate researches, both with sufficient responses to be able to perform statistical analysis.

Another addition to the UTAUT-ECT model has been the linking of the quality requirements on the usage beliefs. Again, because of limited responses in the survey these relations could not be tested. However, this approach could identify the quality aspects of the artefact in which an improvement would have the highest impact on the objective of increased artefact use. For example, if the completeness of the artefact would be rated relatively low but would have a high correlation with the perceived usefulness of the artefact; focusing attention towards the improvement of the completeness would yield the greatest improvements.

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Appendices

Contain detailed information.

A. Table of Earth observation applications in literature

The table below provides an overview of the cases of usage of open earth observation data from the literature review.

Table 30: Cases of EO usage

#	Case name	Citation	Description	EO capability	EO data type
1	Extracting Snow Cover Time Series Data from Open Access Web Mapping Tile Services	(Kadlec et al., 2016)	Using satellite imagery, snow coverage on a lake is measured.	• Detecting Snow on a frozen lake	Optical images - MRIS
2	Upland vegetation mapping using Random Forests with optical and radar satellite data	(Barrett et al., 2016)	This research used satellite images to map where vegetation is located in mountainous, high altitude areas	• Detecting vegetation type	Optical and radar (SAR)
3	Water quality data for national-scale aquatic research: The Water Quality Portal	(Read et al., 2017)	By measuring how the light reflects off the water, oil or algae can be detected and water quality can be measured.	• Algae detection in water • Oil detection on water	Optical images (RGB)
4	FireHub	(Karmas et al., 2016)	Wildfire detection and monitoring, smoke dispersion forecasting	• Smoke detection	Atmospheric monitoring
5	Global forest watch	(Karmas et al., 2016)	Quantification of global forest change to manage and conserve landscapes. Objective is to halt forest loss	• Forest change detection and quantification	Unknown
6	Remote Agri	(Karmas et al., 2016)	Using satellite imagery in different spectra, many factors on the health of crops can be identified, improving crop yield	• Crop health detection	Landsat optical RGB432, RGB654. RGB543
7	Remote Water	(Karmas et al., 2016)	Sensoring of chlorophyll-a in water surfaces, which indicates algae and cyanobacteria	• monitoring of surface water reserves	Unknown
8	The European Flood Alert System	(Thielen, Bartholmes, Ramos, & de Roo, 2009)	Weather forecasting data combined with soil type, land use, topography and river channel networks (latter four obtained through satellite images).	• Flood alerts	Weather forecasting model ECMWF – EPS
9	Copernicus Emergency Management Service -	(European Comission, 2017)	Events classified as an emergency, such as natural disasters, are located and	• Emergency event mapping	Unknown

	Mapping		registered on a map.	• Emergency risk mapping	
11	Maritime shipping route observation	(Gianinetto et al., 2016)	Because of their relative slow pace and large size, ships are identifiable and trackable with satellite imagery. This technology can be applied for monitoring piracy, smuggling, fishing and migration.	• Detection of large ships • Detection of shipping routes	Multispectral SAR (radar)
12	Mediterranean maritime shipping route observation	(Santamaria et al., 2017)	Using Sentinel-1 data from the ESA Copernicus project, large and medium sized ships were detected and tracked with big open earth observation data.	• Detection of medium to large ships • Detection of shipping routes	SAR images
13	Monitoring of temperature and humidity levels in cities	(Tsinganos et al., 2017)	Using EO, one reported project monitors the temperatures and humidity in cities to provide information to gather information about possible health crisis and increased energy usage.	• Probabilistic humidity • Probabilistic temperature	• Local observation post data • Processed (unknown) EO data

B. Examples of available earth observation data

Name	Type	Supplier	Space resolution	Update frequency	Update delay	Operating conditions	Cost
MRIS	Spectroradiometer	ESA	Medium (3m)	1-2 days	Unknown	Blocked by clouds	Free
ALOS AVNIR-2	Near-Infra Red	ESA	10m	14 days	Unknown	Cannot operate > 88.4 deg.N.lat.; >88.5 deg.S.lat.	Free
PALSAR/ ALOS-2	Radar	JAXA	10m	14 days	Unknown	Cannot operate > 87.8 deg.N.lat.; >75.9 deg.S.lat.	Unknown

C. Protocol for Interviewing End Users

This is the interview for the end user as described in section. The objective is to obtain new ideas for services based on earth observation data considering the sensitizing concepts identified in the literature review. This protocol is based on the STOF method from De Vos and Haaker (2008) and Haaker et al. (2017)

C.1. Opening and introduction

The interviewee is explained the intent of this interview: The collection of ideas which can be transformed into viable services using earth observation data from satellites, which has recently become openly and freely available. My research is dedicated to create not just services, but to make these viable, i.e. economically interesting for both the user and the supplier of the service. The interviewee is requested consent for the interview to be recorded.

- What is your name?
- Which organization do you work for and what are your responsibilities?

C.2. Identifying service ideas ("SIMEO")

The interviewee is informed that earth observation data are analysed with data analytics, and that The interviewer presents the interviewee with one of the previously selected capabilities that the interviewer considers applicable.

- As you may know already,
- Please name a process you are aware of that requires an asset that is detectable within the spatial resolution.
    - How is this asset used?
    - What kind of information do you monitor about this asset?
- When is the information useful to you? [non-functional requirements]
    - How do you want to receive it? [integration and availability]
        - Is there any system you would like to have the information integrated with?
    - How often do you need the information? [availability]
    - What is your margin of error on this information? [reliability]
    - What happens if you do not receive this information [reliability]
- What would you benefit by receiving this information? [expected value]

C.3. Closing remarks

- Are you aware of any similar services that would satisfy your information need?
- Do you have any additions?
- Are there any documents that would support this interview?

D. Protocol for Interviewing Service Providers

The following protocol is used for the interviews as part of the assessment for viability and feasibility. The target of the interview is the service provider of the potential new service. The questions are based on the STOF method and concepts from De Vos and Haaker (2008) and Haaker et al. (2017).

D.1. Introduction

The interviewee is explained that during this interview, the STOF method will be used. This method allows for the design of viable services by solving a number of critical issues in the service, technology, organizational and financial domain. This interview will go through them step by step. If the interviewee does not need to be an expert on all fields as multiple interviews can complement each other. The interviewee is requested authorization of recording, after which the introductory questions are asked:

- What is your name?
- What organization do you work for?
- What is your role within the organization?

D.2. Questions relating to the Service domain

- Who is the user?
  - And is the customer different from the user?
  - If so, who is the customer?
- What is the service being offered to the user?
  - And if the customer is different from the user, what is the value for the customer?
- What in what environment is the service being used?
- What is the customer or user prepared to pay?

For the following sections, I am going to ask you to judge how satisfactory a few concepts are that are essential for viable services are dealt with. This will be done on a Likert scale from 1 to 5, where (1) strongly disagree, (2) disagree, (3) neither agree nor disagree (4) agree and (5) strongly agree. Then, follow up questions on these judgments are asked.

- The target group is well defined
  - [1-5] :
  - How are you currently targeting your users?

- The value proposition for the target group is compelling
  - [1-5]:
  - What are the current value elements that compose the value proposition?
  - What is the branding you currently envision?

- The customer retention in place is unobtrusive
  - [1-5]:
  - What is your current mechanism for customer retention?

D.3. Questions relating to the Technology domain

- The quality of the service is acceptable
  - [1-5]
  - What is your service quality level?
  - What is your level of system integration?
  - What is your current security
  - How do you resolve the computational, storage and network requirements of the data?
  - What data model do you use?
  - What coordinate reference system is used?

D.4. Questions relating to the Organizational domain

- The strategy the organization I come from pursues with its partners is sustainable
  - [1-5]
  - How is the network governance organized?

- The division of roles in the network of partners is acceptable
    - [1-5]
    - How do you select your partners?
    - How is responsibility and liability organized within the network?
    - Who in the network of partners is responsible for the privacy matters?

D.5. Questions relating to the Financial domain

- The risks related to the service provision are acceptable
    - [1-5]
    - What is the division of investments?
    - How do you assure the availability of the service to your clients?
    - How do you assure the reliability of the service to your clients
    - How do you cope with the risk of the discontinuity of the open data supply?

- The profitability of service is acceptable
    - [1-5]
    - What are the value contributions and benefits across the partners?
    - What is the division of cost and revenues across the partners?
    - Pricing model
        - How do you generate income considering that the open data is freely obtainable by everyone?
        - How do you (plan to) cope with the fixed costs of a data infrastructure?

D.6. Closing remarks

- Are there any documents that would support this interview?

E. Case documents

This appendix contains a list of documents which do not originate from the knowledge base but from the application domain. They may not have a clear author and may contain errors, but are essential sources of information for the case studies. The documents can vary from tender calls and procedures to presentation slides.

The documents are especially used to support the client/user perspective in the tender cases where direct contact between client and contractor is strictly regulated. However, the regulation includes the requirement for the tendering stakeholder to clearly describe its objectives towards the service that should be designed. This allows for a clear picture of the client perspective without direct contact.

Table 31: Case Documents

#	Document name	Document contents	Source / retrieval path	Used in
5	Hoe werkt SBIR?	Web page detailing the SBIR process and phases / HTML web page retrieved on 18/09/17	https://www.rvo.nl/subsidies-regelingen/sbir/hoe-werkt-sbir	Ems-Dollard Water Quality case
6	Nota_van_inlichtingen_sbir_waterkwaliteitsvariabelen	Reply to questions concerning tender / PDF document	https://www.rvo.nl/sites/default/files/2017/05/Nota_van_inlichtingen_sbir_waterkwaliteitsvariabelen.pdf	Ems-Dollard Water Quality case
7	SBIR Oproep RWS Satellietdatagebruik voor waterkwaliteit Eems Dollard	Tender Call with deliverable and process specification / PDF document	https://www.rvo.nl/sites/default/files/2017/04/SBIR_Oproep_RWS_Satellietdatagebruik_voor_waterkwaliteit_Eems_Dollard1.pdf	Ems-Dollard Water Quality case
8	Presentatie SBIR RVO NSO	Tender presentation slides / PDF document	https://www.rvo.nl/sites/default/files/2017/05/Presentatie_SBIR_RVO_NSO_170510.pdf	Ems-Dollard Water Quality case
9	Presentatie RWS Informatiebijeenkomst NSO SBIR 10052017	Tender presentation slides / PDF document	https://www.rvo.nl/sites/default/files/2017/05/Presentatie_RWS_Informatiebijeenkomst_NSO_SBIR_10052017.pdf	Ems-Dollard Water Quality case
10	Satellietdatagebruik voor monitoring waterkwaliteit Eems-Dollard estuarium	Web page detailing the SBIR process and phases / HTML web page retrieved on 18/09/17	https://www.rvo.nl/subsidies-regelingen/sbir/overzicht-sbir-oproepen/satellietdatagebruik-waterkwaliteit-eems-dollard	Ems-Dollard Water Quality case
11	Invitation to tender: Big data applications to boost preparedness and response to migration	ESA Tender call description web page / HTML page retrieved on 04/10/17	https://business.esa.int/opportunities/invitation-to-tender/big-data-applications-to-boost-preparedness-and-response-to-migration	Migration Radar case
12	ESA “open competition” proposal guide	ESA web page detailing procedure and financing of tenders once accepted / HTML page retrieved on 04/10/17	https://business.esa.int/proposal-guide-open-competition	Migration radar case

F. Evaluation questions

The appendix contains the questions which are asked during the evaluation session. As noted in the main text, the questions are based on (Venkatesh et al., 2011) and (Johannesson & Perjons, 2014). The survey is divided into three phases: question on the generic usage beliefs of a structured method for the design of viable services using big and open earth observation data, questions on the quality requirements of the artefact and questions in the usage beliefs for specifically the SIMEO-STOF method.

Unlike Venkatesh et al. (2011), the concept of trust will not be included in the concepts, as the method does not exchange or store private information. It merely provides a structure for obtaining and processing and judging the information. As this question is fully adapted for professional purposes, the social influences in the UTAUT questions are specified to “colleagues” instead of “people”.

F.1. Pre-presentation variable questions

Descriptive variables

- Gender [Female – Male]
- Age [-19 ; 20-34 ; 35-49 ; 50-64 ; 65+]
- I am currently using *a structured method for the design of a viable service based on big and open earth observation data.* [No - Yes]

Pre-presentation generic perceived usefulness (PUa):

- PU1a: Using *a structured method for the design of a viable service based on big and open earth observation data* would enable me to design services **more quickly** compared to my current practice.
- PU2a: Using *a structured method for the design of a viable service based on big and open earth observation data* would make it **easier** to design services compared to my current practice.
- PU3a: Using *a structured method for the design of a viable service based on big and open earth observation data* would enable me to design services more **effectively** compared to my current practice.

Pre-presentation generic effort expectancy (EEa)

- EE1a: I would find it **easy to use** *a structured method for the design of a viable service based on big and open earth observation data* to design services
- EE2a: **Learning to use** *a structured method for the design of a viable service based on big and open earth observation data* to design services *would be easy for me.*
- EE3a: I would be **easy for me to become skilful** at using *a structured method for the design of a viable service based on big and open earth observation data* to design services.

Pre-presentation social influence (SIa)

- SI1a: **Colleagues who influence my behaviour** would think that I should use *a structured method for the design of a viable service based on big and open earth observation data* to design services.
- SI2a: **Colleagues who are important to me** would think that I should use *a structured method for the design of a viable service based on big and open earth observation data* to design services.
- SI3a: **Colleagues who are in my social circle** would think that I should use *a structured method for the design of a viable service based on big and open earth observation data* to design services.

Pre-presentation perceived facilitating conditions (FCa)

- FC1a: I would **have the resources necessary** to use *a structured method for the design of a viable service based on big and open earth observation data* to design services.
- FC2a: I would **have the knowledge necessary** to use *a structured method for the design of a viable service based on big and open earth observation data* to design services.
- FC3a: I would have **access to a person which could assist me with difficulties** encountered whilst using *a structured method for the design of a viable service based on big and open earth observation data* to design services.

Pre-presentation attitude (ATa)

All things considered, using *a structured method for the design of a viable service based on big and open earth observation data* to design services would be…

- AT1a: bad idea ... good idea
- AT2a: foolish move … wise move
- AT3a: negative step … positive step

F.2. Method quality variables

These are based on the structural and environmental qualities of artefacts as described in Johannesson and Perjons (2014). All structural and environmental qualities that apply to the method have been included except for efficiency, which is already questioned in the Perceived Usefulness and Effort Expectancy in the pre- and post-presentation questions.

Structural quality coherence (Coh)

- Coh1: The components of the method are logically related
- Coh2: The components of the method are in order
- Coh3: The components of the method are consistent

Structural quality modularity (Mod)

- Mod1: The components of the method are not overly related to each other
- Mod2: The components of the method can easily be replaced and recombined
- Mod3: The components of the method are internally highly related

Structural quality conciseness (Cos)

- Cos1: The method does not contain components which are unnecessary
- Cos2: A component of the method does not contain functions which can be derived from other components
- Cos3(-): There is redundancy in the method

Environmental quality completeness (Com)

- Com1: The method contains all components required for viable service design
- Com2: Each component in the method contains sufficient elements to create a viable service design
- Com3(-): The method is missing components for viable service design

Environmental quality effectiveness (Effe)

- Effe1: The method allows for the design of viable services
- Effe2: The method allows for the design of services based on big and open earth observation data
- Effe3: The method allows for the design of viable services based on big and open earth observation data

Environmental quality generality (Gen)

- The method allows for the design of viable services with commercial earth observation data
- The method allows for the design of viable services with non-satellite (e.g. drone-based) earth observation data
- The method would be applicable to future cases at CGI
- The method would be applicable to future cases at other companies than CGI

F.3. Post- presentation variable questions

Post-presentation generic perceived usefulness (PUb):

- PU1b: Using *SIMEO-STOF* would enable me to design services **more quickly**.
- PU2b: Using *SIMEO-STOF* would make it **easier** to design services.
- PU3b: Using *SIMEO-STOF* would enable me to design services more **effectively**.

Post-presentation generic effort expectancy (EEb)

- EE1b: I would **find it easy to use** *SIMEO-STOF* to design services
- EE2b: **Learning to use** *SIMEO-STOF* to design services **would be easy** for me.
- EE3b: I would be **easy for me to become skilful** at using *SIMEO-STOF* to design services.

Post-presentation social influence (SIb)

- SI1b: **Colleagues who influence my behaviour** would think that I should use *SIMEO-STOF* to design services.
- SI2b: **Colleagues who are important to me** would think that I should use *SIMEO-STOF* to design services.
- SI3b: **Colleagues who are in my social circle** would think that I should use *SIMEO-STOF* to design services.

Post-presentation perceived facilitating conditions (FCb)

- FC1b: I would **have the resources necessary** to use *SIMEO-STOF* to design services.
- FC2b: I would **have the knowledge necessary** to *SIMEO-STOF* to design services.
- FC3b: I would have **access to a person which could assist me with difficulties** encountered whilst using *SIMEO-STOF* to design services.

Post-presentation attitude (ATb)
All things considered, using *SIMEO-STOF* to design viable services would be…

- AT1b: bad idea ... good idea
- AT2b: foolish move … wise move
- AT3b: negative step … positive step

G. Detailed evaluation results

This section in the appendix contains the detailed evaluation results

G.1. Data Cleansing

The MentiMeter software initiated more sessions than people present, probably due to people experimenting with the tool and reconnecting several times. These sessions were empty and consequently deleted from the set. Furthermore, one participant indicated his session closed and reconnected. Two sessions in MentiMeter followed this pattern and were merged. Several demonstration questions which did not have a purpose in the survey but were intended to familiarize the audience with the tool were deleted from the set.

G.2. Descriptive statistics of the responses

Table 32: Descriptive statistics of the responses

	N	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
gender	23	1.17	0.39	1.0	1.11	0.00	1	2	1	1.61	0.62	0.08
age	23	2.35	0.78	2.0	2.26	0.00	1	5	4	1.61	3.51	0.16
priorUse	23	1.26	0.45	1.0	1.21	0.00	1	2	1	1.02	-1.00	0.09
PUa	24	11.79	2.00	11.5	11.75	2.22	9	15	6	0.24	-1.12	0.41
EEa	24	10.88	2.31	10.5	10.80	2.22	7	15	8	0.45	-0.96	0.47
SIa	25	9.56	2.27	10.0	9.71	1.48	3	14	11	-0.72	0.96	0.45
FCa	25	9.84	2.10	10.0	9.86	1.48	6	15	9	-0.14	0.11	0.42
ATa	25	12.04	2.75	13.0	12.29	2.97	5	15	10	-0.72	-0.43	0.55
Coh	25	9.96	2.61	11.0	10.29	1.48	3	14	11	-1.30	1.53	0.52
Mod	24	9.58	1.21	9.0	9.50	1.48	8	12	4	0.51	-0.87	0.25
Con	24	9.54	1.28	9.0	9.45	1.48	8	12	4	0.38	-1.07	0.26
Com	25	8.88	2.24	9.0	8.76	2.97	6	14	8	0.51	-0.76	0.45
Effe	25	9.96	2.64	10.0	10.14	2.97	3	15	12	-0.70	0.38	0.53
Gen	23	13.26	4.29	12.0	13.21	5.93	6	20	14	0.02	-1.35	0.89
PUb	25	9.48	2.87	9.0	9.43	2.97	3	15	12	0.03	-0.38	0.57
EEb	24	10.08	3.02	10.5	10.15	2.22	3	15	12	-0.39	-0.54	0.62
SIb	23	8.13	2.67	9.0	8.21	1.48	3	13	10	-0.56	-0.35	0.56
FCb	23	8.52	2.74	9.0	8.63	2.97	3	13	10	-0.27	-0.96	0.57
ATb	22	10.73	3.18	11.5	10.94	3.71	3	15	12	-0.54	-0.47	0.68

Table 33: Likert scale responses for every variable in absolute numbers and percentages

Var	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree	Var	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree
PU1a	0	2	4	13	5	PU1a	0%	8%	17%	54%	21%
PU2a	1	1	7	8	7	PU2a	4%	4%	29%	33%	29%
PU3a	0	0	5	11	8	PU3a	0%	0%	21%	46%	33%
EE1a	1	0	11	5	7	EE1a	4%	0%	46%	21%	29%
EE2a	0	2	9	7	6	EE2a	0%	8%	38%	29%	25%
EE3a	0	2	12	7	3	EE3a	0%	8%	50%	29%	13%
SI1a	2	4	8	10	1	SI1a	8%	16%	32%	40%	4%
SI2a	1	1	10	11	2	SI2a	4%	4%	40%	44%	8%
SI3a	3	5	8	9	0	SI3a	12%	20%	32%	36%	0%
FC1a	0	6	7	10	2	FC1a	0%	24%	28%	40%	8%
FC2a	3	3	8	8	3	FC2a	12%	12%	32%	32%	12%
FC3a	0	6	10	4	5	FC3a	0%	24%	40%	16%	20%
AT1a	1	0	5	11	8	AT1a	4%	0%	20%	44%	32%
AT2a	1	2	3	7	12	AT2a	4%	8%	12%	28%	48%
AT3a	1	2	4	8	10	AT3a	4%	8%	16%	32%	40%
Coh1	2	2	6	13	2	Coh1	8%	8%	24%	52%	8%
Coh2	2	2	12	9	0	Coh2	8%	8%	48%	36%	0%
Coh3	2	0	10	12	1	Coh3	8%	0%	40%	48%	4%
Mod1	0	2	11	10	1	Mod1	0%	8%	46%	42%	4%
Mod2	1	4	14	5	0	Mod2	4%	17%	58%	21%	0%
Mod3	0	3	14	6	1	Mod3	0%	13%	58%	25%	4%
Cos1	0	3	13	7	1	Cos1	0%	13%	54%	29%	4%
Cos2	1	5	14	3	1	Cos2	4%	21%	58%	13%	4%
Cos3	3	6	12	3	0	Cos3	13%	25%	50%	13%	0%
Com1	0	9	11	4	1	Com1	0%	36%	44%	16%	4%

Com2	0	4	16	4	1	Com2	0%	16%	64%	16%	4%
Com3	1	7	8	7	2	Com3	4%	28%	32%	28%	8%
Effe1	1	3	9	10	2	Effe1	4%	12%	36%	40%	8%
Effe2	1	3	9	11	1	Effe2	4%	12%	36%	44%	4%
Effe3	2	2	9	11	1	Effe3	8%	8%	36%	44%	4%
Gen1	2	2	9	6	5	Gen1	8%	8%	38%	25%	21%
Gen2	2	4	9	4	5	Gen2	8%	17%	38%	17%	21%
Gen3	2	3	7	6	5	Gen3	9%	13%	30%	26%	22%
Gen4	2	5	8	2	6	Gen4	9%	22%	35%	9%	26%
PU1b	1	5	9	7	3	PU1b	4%	20%	36%	28%	12%
PU2b	1	6	8	8	2	PU2b	4%	24%	32%	32%	8%
PU3b	2	6	8	6	3	PU3b	8%	24%	32%	24%	12%
EE1b	1	7	5	7	4	EE1b	4%	29%	21%	29%	17%
EE2b	2	3	3	13	3	EE2b	8%	13%	13%	54%	13%
EE3b	1	4	8	8	3	EE3b	4%	17%	33%	33%	13%
SI1b	3	3	12	4	1	SI1b	13%	13%	52%	17%	4%
SI2b	3	4	11	5	0	SI2b	13%	17%	48%	22%	0%
SI3b	4	6	11	2	0	SI3b	17%	26%	48%	9%	0%
FC1b	2	8	7	5	1	FC1b	9%	35%	30%	22%	4%
FC2b	3	6	7	5	2	FC2b	13%	26%	30%	22%	9%
FC3b	3	3	12	4	1	FC3b	13%	13%	52%	17%	4%
AT1b	1	3	5	8	5	AT1b	5%	14%	23%	36%	23%
AT2b	1	3	7	7	4	AT2b	5%	14%	32%	32%	18%
AT3b	1	2	6	7	6	AT3b	5%	9%	27%	32%	27%

G.3. Histograms of pre-presentation use

This section contains the histograms of pre-presentation perceived utility, effort expectancy, social influence and facilitating conditions. It contains the data of all reliable pre-presentation scales for usage beliefs.

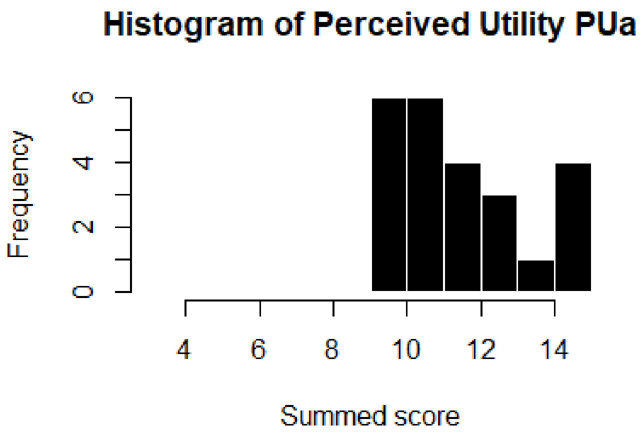

Figure 62: Histogram of the summarized score for pre-presentation perceived usefulness PUa

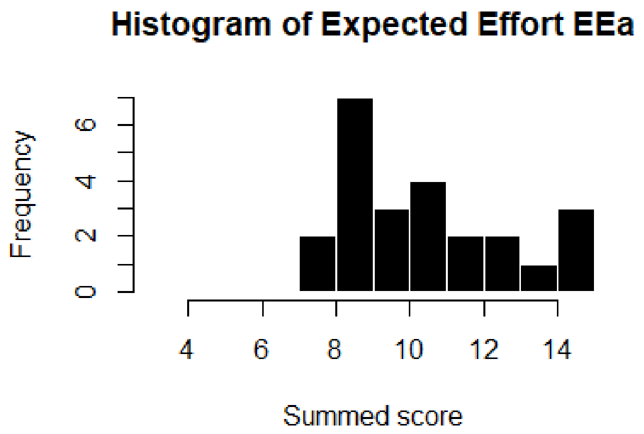

Figure 63: Histogram of the summarized score for pre-presentation expected effort EEa

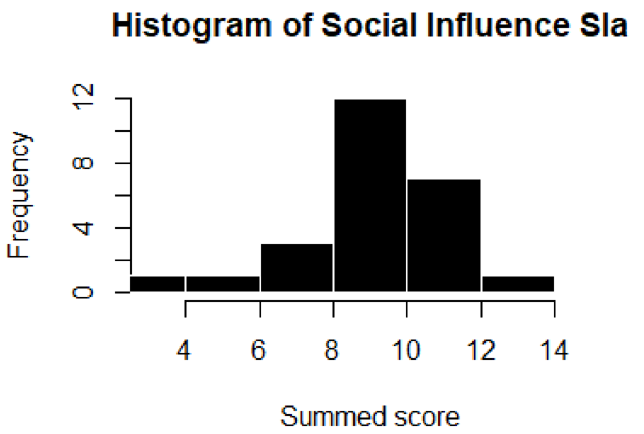

Figure 64: Histogram of the summarized score for pre-presentation social influence SIa

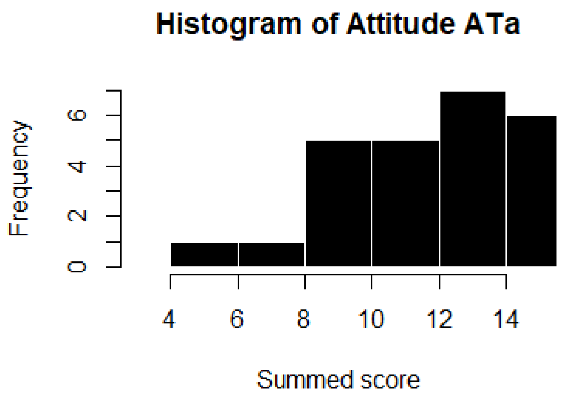

Figure 65: Histogram of the summarized score for pre-presentation attitude ATa