Danai Skournetou

# BUSINESS VIABILITY OF GALILEO COMMERCIAL SERVICE

JYVÄSKYLÄN YLIOPISTO
TIETOJENKÄSITTELYTIETEIDEN LAITOS
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# ABSTRACT

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Currently, the business of location based service providers largely depends on the existing Global Navigation Satellite Systems (GNSSs), i.e. GPS and recently also GLONASS. Not only are these two systems operated under the discretion of the US and Russian military, respectively, but they also give only best effort guarantees on accuracy and availability. Because of this and given that LBS providers increasingly rely on positioning information, EU is preparing the launch of Europe's own GNSS platform, Galileo, which is expected to be fully operational around 2020. Besides the free-of-charge basic service, a Commercial Service (CS) with advanced characteristics will be offered at a premium-rate to service providers. The business case behind the launch of Galileo assumed that part of the investments would be recouped by having service providers pay for the enhanced characteristics of CS, i.e. higher positioning accuracy, signal authentication capability and service guarantee. However, as yet, it is still highly unclear whether service providers are in fact interested to pay for accessing CS signals, especially because the access to civil satellite navigation signals has been traditionally free-of-charge. Motivated by the lack of research in this area, this thesis seeks an answer to the question "*What are the factors contributing to the willingness of service providers to adopt the future Galileo Commercial Service?*" To answer this, we analyzed secondary data through desk research as well as conducted in-depth interviews with key stakeholders. Specifically, we found that the factors contributing to the willingness of service providers to adopt CS are the key value drivers, other value determinants, demonstrated usefulness, approaches alternative to Galileo CS, and reverse salients. In overall, it appears that service providers are reluctant to make any serious preparations for adopting CS, as they indicate there are too many uncertainties. In order to increase the chances of adoption, we suggest clarifying the value proposition of CS as well as creating awareness of it early on and focusing attention either on getting governments on board to create trust and reputation for CS or on service providers directly.

Keywords: Galileo, Commercial Service, Location-based Services, Business viability, Service providers

# TIIVISTELMÄ


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Tällä hetkellä kaupalliset paikkatietopalvelut ovat riippuvaisia olemassa olevista maailmanlaajuisista satelliittipaikannusjärjestelmistä (GNSS), kuten GPS:stä ja GLONASSista. Nämä järjestelmät toimivat Yhdysvaltojen ja Venäjän hallinnon alaisina, eivätkä anna takuita palvelun tarkkuudesta tai saatavuudesta. Johtuen tästä ja siitä, että paikkatietopalveluja tarjoajat toimijat luottavat yhä enenevissä määrin paikannustietoon, EU on valmistelemassa Euroopan omaa GNSS-järjestelmää Galileoa, jonka on tarkoitus olla täydessä toiminnassa vuoden 2020 paikkeilla. Järjestelmä tulee tarjoamaan sekä ilmaisen että kaupallisen palvelun (CS), jonka lisäominaisuuksia tarjotaan palveluntarjoajille lisähintaan. Galileoa laukaistaessa oletettiin, että osa järjestelmän rahoituksesta saataisiin palveluntarjoajien maksamista CS-lisäominaisuuksista, kuten suuremmasta tarkkuudesta, signaalin todentamismahdollisuudesta ja palvelun saatavuudesta. Tällä hetkellä on kuitenkin hyvin epävarmaa, että ovatko palveluntarjoajat kiinnostuneita maksamaan CS-lisäominaisuuksista, koska siviilisatelliittinavigointijärjestelmien käyttö on tyypillisesti ollut ilmaista. Tähän liittyvä tutkimustoiminta on ollut vähäistä, joten tämä työ etsi vastausta kysymykseen ”Mitkä ovat ne tekijät, jotka vaikuttavat palveluntarjoajien haluun ottaa käyttöön Galieon kaupallinen palvelu (CS)?” Tutkimusta varten analysoimme toisen käden tietolähteitä sekä suoritimme syvähaastatteluja pääsidosryhmien kanssa. Havaitsimme, että kaupallisen palvelun (CS) käyttöönottohalukkuuteen vaikuttavat tekijät ovat arvoa kasvattavat tekijät, muut arvon määrittäjät, havainnollistettu hyöty, kaupallisten palvelujen (CS) vaihtoehdot ja ”käänteiset rintamakiilat”. Yhteenvetona voidaan sanoa, että palvelujentarjoajat ovat haluttomia tekemään merkittävämpiä valmisteluja kaupallisen palvelun (CS) käyttöönottamiseksi johtuen järjestelmään liittyvistä epävarmuuksista. Jotta käyttöönoton todennäköisyyttä voidaan lisätä, ehdotamme tietoisuuden lisäämistä kaupallisesta palvelusta (CS) jo aikaisessa vaiheessa. Toimissa tulee keskittyä joko valtioiden saamiseen mukaan lisäämään palvelun tunnettuutta ja luomaan luottamusta järjestelmään tai vastaavasti voidaan keskittyä myös suoraan palvelujentarjoajiin tarjoamalla heille esimerkiksi progressiivisia tai syrjimättömiä hinnoittelumalleja



Asiasanat: Galileo, Commercial Service, paikkatietopalvelut, liiketoiminnan kannattavuus, palveluntarjoaja

# PREFACE

The research work that led to this dissertation has been carried out during the years 2010-2011 and was financially supported by three difference sources: the Department of Communications Engineering, the Tampere Doctoral Program in Information Sciences and Engineering (TISE), as well as the EU Erasmus Program. The main part of the research has been performed at the Faculty of Technology, Policy and Management in Delft University of Technology (TUDelft) where I had been a visiting researcher for a three-month period, from November 2010 until January 2011. During this visit, part of the research was also done in collaboration with the Business Incubation Center (BIC) of the European Space Agency in Noordwijk, The Netherlands. Also, a big part of the work has been performed at the Department of Communications Engineering in Tampere University of Technology (TUT), Finland.

This thesis would not have this form without the support of many people therefore, I would like to take this opportunity and thank all those who contributed to its successful completion. First of all, I would like to thank the Assistant Professor Mark de Reuver (TUDelft) with whom I had the pleasure to closely collaborate on the research topic discussed in this thesis and who has provided me with valuable guidance and insightful comments along the way. I would also like to express my deepest gratitude to Prof. Markku Renfors (TUT) who stood by my wish to expand my research field and fully supported me in fulfilling it. Moreover, I would like to deeply thank Prof. Harry Bouwman (TUDelft) who accepted me in his team and made me feel warmly welcome during the research visit. I am also very grateful to my PhD supervisor, Adjunct Professor Dr. Elena Simona Lohan (TUT), whose continuous encouragement has been instrumental in the shaping of my research background. In turn, I would like to express my thanks and appreciations to my thesis supervisor, Prof. Jari Veijalainen, from University of Jyväskylä who has been very supportive and understanding during the writing of this thesis as well as provided me with guidance and many invaluable suggestions along the way.

Last but not least, I am thankful to my family and friends, as well as my loved, Artem, whose moral support has never wavered but given me much needed strength to complete this thesis.

## LIST OF PUBLICATIONS

This thesis consists of two peer-reviewed publications, which in the text are referred to as Publications [P1] and [P2]. Publication [P1] was published in the IEEE proceedings of an international conference while [P2] is a journal article.

**[P1]** Skournetou, D., De Reuver, M. & Lohan, E. S. (2011). Has the time to commercialize satellite navigation signals come? *In the IEEE Proc. of 15th International Conference on Intelligence in Next Generation Networks* (pp. 301-306). October 4-7, 2011.

DOI: 10.1109/ICIN.2011.6081094

**[P2]** De Reuver, M., Skournetou, D. & Lohan, E. S. (2012). Impact of Galileo commercial service on location-based service providers: business model analysis and policy implications. *Journal of Location Based Services, 7(2)*, 1-12.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| B2B | Business to Business |
| B2C | Business to Consumer |
| CAGR | Compound Annual Growth Rate |
| CNSS | Compass Navigation Satellite System |
| COSPAS-SARSAT | COsmicheskaya Sistyema Poiska Avariynich Sudov - Search And Rescue Satellite Aided Tracking |
| CS | Commercial Service |
| EC | European Commission |
| EGSC | European GNSS Service Centre |
| ESA | European Space Agency |
| FOC | Full Operational Capability |
| FP | Framework Program |
| GAGAN | GPS And Geo-Augmented Navigation system |
| GCS | Ground Control Segment |
| GDP | Gross Domestic Product |
| GEO | Geostationary Equatorial Orbit |
| GLONASS | GLobal Orbiting NAvigation Satellite System |
| GMS | Galileo Mission Segment |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GSA | Galileo Supervisory Authority |
| GSO | Geosynchronous Orbit |

| | |
|---|---|
| ICG | International Committee on Global Navigation Satellite Systems |
| IGSO | Inclined Geostationary Orbit |
| IOV | Initial Operational Capability |
| LBS | Location-Based Service |
| MEO | Medium Earth Orbit |
| MCS | Master Control Station |
| MHz | Mega Hertz (1 MHz = $10^6$ Hz) |
| OECD | Organization for Economic Co-operation and Development |
| OS | Open Service |
| PPP | Private Public Partnership |
| PPS | Precise Positioning Service |
| PVT | Position Velocity Time |
| QZSS | Quasi-Zenith Satellite System |
| SA | Selective availability |
| SoL | Safety-of-Life |
| SPS | Standard Positioning Service |
| QZSS | Quasi-Zenith Satellite System |
| USSR | Union of Soviet Socialist Republics |
| WTO | World Trade Organization |

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# 1 INTRODUCTION

## 1.1 Background

In 1991, Mark Weiser stated that "*The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.*" (Weiser, 1991). This statement depicted his personal vision of ubiquitous computing, where the influence of technology is all-pervasive. According to the author of this thesis, this metaphorical statement successfully illuminates the most profound technologies but not only them per se. It also describes the most critical technologies; those that people depend on and whose abnormal or interrupted operation has extensive impact. Every time a disappearing technology fails, it unveils itself and spreads confusion. The author believes that satellite based positioning is fast becoming such a profound disappearing technology.

A Global Navigation Satellite System (GNSS) is a combination of different technologies into a complex and massive infrastructure that (1) provides precise timing information and (2) enables users to compute their location on the Earth. When the first GNSS was developed, known as Global Positioning System (GPS), its purpose was to augment U.S. military weaponry in times of war. During the eighteen years passed after the GPS became operational, the GNSS landscape has changed significantly. In particular, the year 2000 was a decisive milestone in GNSS history when President Bill Clinton ordered Selective Availability (SA) to be turned off. SA was a feature that allowed GPS operatives to degrade the quality of the GPS civil signal and limit the horizontal positioning accuracy to approximately 100 meters (in 95% of the cases). This signal degradation was utilized as a measure to protect the security interests of the U.S. and its allies by globally denying the full accuracy of the civil system to potential adversaries (NGS, 2013). When SA was deactivated, the positioning accuracy increased by one order of magnitude and a new era begun where GNSS-based positioning was useful not only for the military and few professional service providers but also for civilians.

The earliest mass-market applications, those developed while SA was active, were mainly related to positioning at sea or directed to hikers. After SA was turned off, road vehicle applications became possible. In these, two major tasks are performed: (1) positioning (where am I?) and (2) navigation (how do I reach my destination?). Later on, the integration of Assisted-GPS chipsets into mobile phones allowed the expansion of the Location-based Services (LBS) market by reaching out to new user segments and innovative applications. According to the author's opinion, vehicle and mobile applications are the ones that helped to cross the chasm between the early adopters and the early majority. Moreover, the establishment of GPS receiver as a standard feature of every smart-phone is leading towards turning GNSS into a disappearing technology.

Nowadays, the variety of GNSS-based applications has greatly grown and positioning information is used not only for navigation but also for tracking objects or other people. Both end-user and professional markets are established and the sectors to which new applications are targeted include among others, entertainment, health and safety, security, agriculture, road-toll charging, maritime, etc. For instance, according to the 2012 GNSS Market Monitoring report (GSA, 2012), the global market for GNSS is growing fast and total enabled revenues are expected to increase at 13% Compound Annual Growth Rate (CAGR) between 2010 and 2016. It was also estimated that LBS handset sales make up the majority of shipments, approximately €170 million in 2020 up from €38 million in 2010. In general, the size estimates of the current LBS market pale almost into insignificance when compared to the socioeconomic benefits it already has. For example, accurate, inexpensive and ubiquitous access to outdoor location information has become indispensable for the logistics and transport sector, which in EU has an annual turnover of over 1 trillion €.

Nonetheless, the business of LBS providers largely depends on GPS and recently also on the Global Navigation Satellite System (GLONASS). Not only are GPS and GLONASS operated under the discretion of the US and Russian military, respectively, but they also give only best effort guarantees on accuracy and availability. Because of this and given that LBS providers increasingly rely on positioning information, the European Commission (EC) in collaboration with the European Space Agency (ESA) and the European GNSS Agency (GSA) is preparing the launch of Europe's own GNSS platform, Galileo, which is expected to be fully operational around 2020 (Europa, 2013, 24. July). Besides the free-of-charge basic service, a Commercial Service (CS) with advanced characteristics will be offered at a premium rate to service providers.

These characteristics are (a) higher positioning accuracy, (b) signal authentication, and (c) service guarantee. The high-precision characteristic is geared more towards the markets of topography, civil engineering, precision agriculture, cadastral surveying, etc., and will provide professional users with centimeter-level accuracy. The authentication capability will guarantee users that the computed position has not been tampered thus will enable the creation of GNSS-based insurance policies as well as the use of CS in road tolling and other critical applications (GMV, 2012, 19. December). Unlike the first two characteristics, the third one is not based on some advanced technology; instead it is of legal nature.

## 1.2 Motivation and research question

The business case behind the launch of Galileo (illustrated in figure 1) assumed that part of the investments would be recouped by having service providers pay for the use rights of CS signals (ESA, 2013b) and who will then decide on the specifics of the offered services (e.g. integrity data, differential corrections for local areas, precise timing services, the provision of ionosphere delay models, etc.) which will depend also on the final characteristics of the other services offered by Galileo (Navipedia, 2013, 19. June).

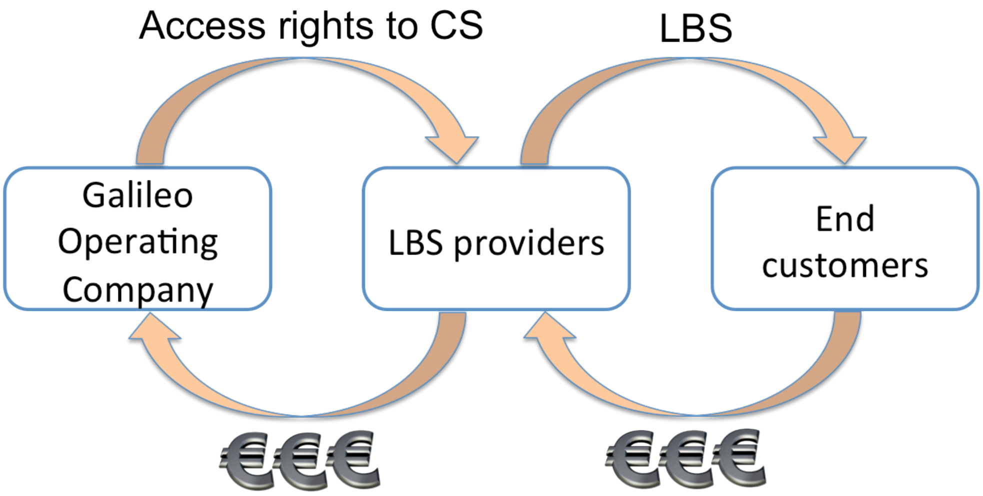


FIGURE 1 Presumed Galileo business model for CS

Therefore, CS signals will only be available to service providers who purchase a license to do so from the future Galileo Operating Company (GOC). However, as yet, it is still highly unclear whether LBS providers are in fact interested to pay for accessing CS signals for two main reasons. First, because the technical characteristics CS have not been clearly defined (e.g. which method will be employed for implementing the authentication mechanism and how to manage the encryption keys in a reliable and efficient way) thus the exact added value is to a large extent still unknown. Second, because the access to satellite navigation signals targeted for civilian use has been traditionally either free-of-charge or restricted only to military.

With respect to the first reason, in late 2012, the EU awarded an industrial consortium with a contract for conducting a study to define Galileo's future CS and specifically, the mission requirements of the high-precision and authentication characteristics. The consortium consists of three service provides; GMV who is responsible for the development of the CS demonstrator and the leader of the consortium, Logica who is in charge of the authentication matters and Helios, responsible for the business study and commercial plan (GMV, 2012, 19. December). However, the project is still on going and the results of it are expected in 2014 so at least until then, the uncertainties related to the technical implementation of CS remain.

As far as we are aware, there is no academic research on the business model viability of Galileo CS, which is surprising given (a) the dependence of LBS providers on reliable and accurate positioning information; and (b) the considerable amount of tax-payers money which has been invested in the Galileo system, one of the biggest space projects ever initiated in Europe. While the technological details of Galileo are often discussed in academic work, the business implications for the LBS sector have not been studied by academics or covered by popular press. We argue that the business impact of Galileo CS is highly relevant, given the sheer size of the LBSs market as well as the increased dependence of consumers and business on LBSs for their everyday activities.

To the best of our knowledge, there are only a handful of reports, mainly from consultancy agencies, that give a prediction on the business viability of Galileo system in general or specifically, on Galileo CS. For example, an independent study conducted by a private consortium (led by Pricewaterhouse-Coopers) for EC concluded that the Galileo project is economically justified as it will generate significant revenue and will achieve positive operating cash-flow just three years after beginning operation. In this study, two major sources of market revenue were identified; royalties from chipset (video, image and other data) sales and revenues from service providers (Europa, 2001, 23. November; PWC, 2003). Another study, this time from Helios, emphasized that achieving all four objectives set by EC for CS (i.e. to stimulate the wider GNSS market, to deliver a public service, to generate commercial revenues, and to ensure fairness to all) equally, in an existing market with competing service providers and products, is an extremely difficult task (Sage & Mitchell, 2010). Moreover, only in the context of a new emerging market and innovative service concept, the CS will be able to deliver substantial revenues and user benefits (Sage & Mitchell, 2010). Motivated by the lack of research in this area, this thesis seeks an answer to the following research question

*What are the factors contributing to the willingness of service providers to adopt the future Galileo Commercial Service?*

To study this research question, we analyzed secondary data through secondary research and conducted in-depth interviews with policy makers, service providers and industry experts. In interviews, we focused on how Galileo CS may impact the business models of those LBS providers who decide to adopt it along the four business model domains (Bouwman, Haaker & Vos, 2008) as well as how willingness to adopt and pay for the Galileo CS depends on such expected impacts. In this thesis, a business model is defined as the way an organization intends to create and capture value (Chesbrough & Rosenbloom, 2002; Bouwman, Haaker & de Vos, 2008). The four domains are the service domain (i.e. what new services would be enabled by Galileo CS?); technology domain (i.e. what are the merits of Galileo CS compared to present and emerging technology alternatives); organization and finance domains (i.e. what are organizational issues and financial risks that LBS providers face when adopting Galileo CS). We notice that while the willingness of service providers to adopt CS inherently depends on the added value perceived by the end users and how much they are willing to pay for, it was not deemed feasible to focus on the end users for two reasons. The first reason stems from the difficulty in acquiring a large enough sample of end users considering that these would not come from the consumer sector but from the professional sector, such as oil and gas exploration, finance, and others. The second reason is related with the fact that in addition to the many uncertainties surrounding the implementation of CS, it is up to the service providers to shape the exact service offering around CS. And as this service offering was too vague, especially at the beginning of our study, we decided to focus on the service providers who were more likely to provide relevant insights.

The main contribution of this thesis is answering the above-stated research question. This also provides an insight on whether it is realistic to expect that service providers would be willing to pay for Galileo CS, which in turn depends on the end customers' willingness to purchase LBSs exploiting the advanced characteristics of CS. This contribution is also crucial for policy makers as well as for the general public given that large investments are being made in the development and operation of Galileo system.

## 1.3 Thesis outline

The remainder of this thesis is organized as follows: Chapter 2 describes the methodology followed to answer the research question presented in this chapter. Chapter 3 overviews current and future GNSS where particular focus is put on Galileo, Europe's future own GNSS. Chapter 4 discusses the business models of existing and emerging GNSSs. Chapter 5 includes the results of this thesis which are documented in a collection of two peer-reviewed publications (the compilation of the publications included in this thesis can be found after the Bibliography). This chapter also includes a description on the author's contribution in each of the two published papers. Finally, Chapter 6 summarizes the main research outcomes, draws the conclusions, and suggests future research directions.

# 2 RESEARCH METHODOLOGY

The research methodology consists of both a desk (i.e. secondary) research and an empirical investigation. The former involves gathering and analyzing information already available in print or published on the Internet, such as technical reports, policy papers, market reports, scientific literature, magazines, and online news articles. In the latter, we try to draw empirical evidence from interviews with key stakeholders and experts in the GNSS field. While a questionnaire-based survey might have facilitated a larger sample, we considered interviewing as a better approach because it allows us to probe individuals' interpretations and even to gently challenge assertions. Moreover, as the willingness of service providers to adopt Galileo CS is linked to its impact on the business models of those services providers who decide to adopt it, we searched for suitable frameworks to design and execute our empirical study. The framework we utilized, the specifics of data collection and analysis, as well as the limitations of the research methodology are described in the following subsections.

## 2.1 Business model domains

While business models were initially often used in a loose and narrative manner (Magretta, 2002), in the recent years, several detailed frameworks have appeared in the literature that provide the key components and variables that comprise business models (Gordijn & Akkermans, 2001; Osterwalder & Pigneur, 2002; Bouwman, Haaker & Vos, 2008; Ballon, 2009). Compared to other business model frameworks (e.g. Gordijn & Akkermans, 2001; Osterwalder & Pigneur, 2002; Ballon, 2009), the framework from Bouwman, Haaker & Vos (2008) explicitly includes technology issues that enable a service offering as well as the organizational relationships between multiple actors in the ecosystem. As these elements are core in our study, we adopt their framework and subscribe to their business model definition. Specifically, a business model is defined as the way an organization intends to create and capture value and in their conceptualization of the STOF model, business models cover four domains:

- Service domain (S): a description of the value proposition (added value of a service offering) and the market segment at which the offering is aimed
- Technology domain (T): a description of the technical functionality required to realize the service offering
- Organizational domain (O): a description of the structure of the multi-actor value network required to create and distribute the service offering and to describe the focal firm's position within the value network
- Financial domain (F): a description of the way a value network intends to generate revenues from a particular service offering and of the way risks, investments and revenues are divided among the various actors in a value network.

These domains are illustrated in figure 2:

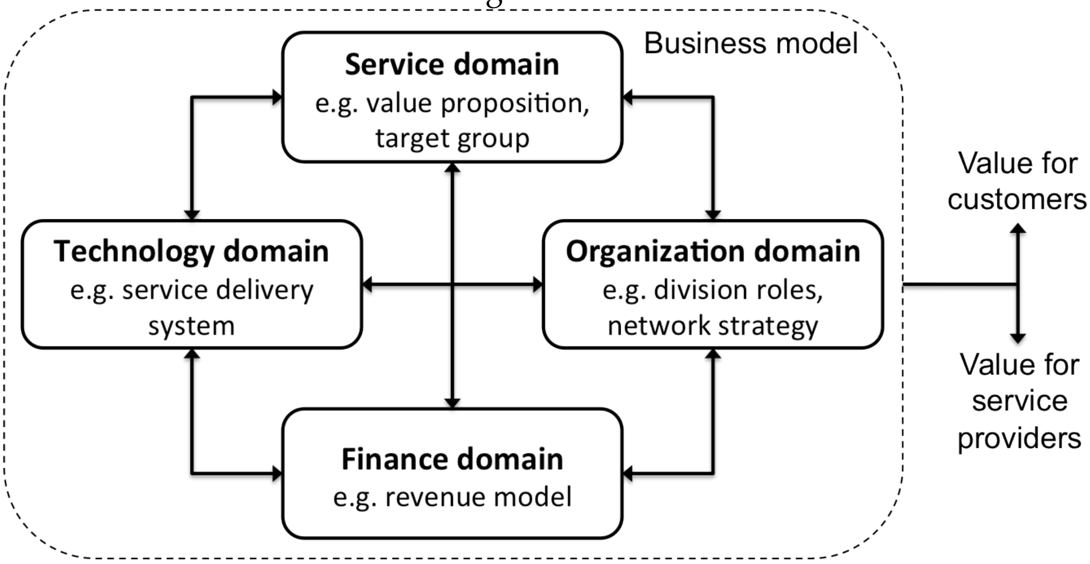


FIGURE 2 STOF framework (Bouwman, Haaker & Vos, 2008)

The core concepts of the service domain are customers (i.e. the person(s) paying for the service), end-users (i.e. the persons actually using the service), intended value (i.e. the value a provider intends to customers/end-users), delivered value (i.e. the value actually delivered to customers/end-users), expected value (i.e. the value customers/end-users expect), perceived value (the value customers/end-users actually perceive as receiving), market segments with their different needs/wishes/preferences, context in which the service is consumed, rate (i.e. the price to consume the service), effort (i.e. all non-financial efforts the end-user must take), and bundling of services. We notice that the term "value" is defined as the value derived from the actual use of a service and may include also indirect uses.

In the technology domain, the most important technology design variables and characteristics are the overall technical architecture, the backbone infrastructure (i.e. the medium and long range backbone network infrastructure), access networks (i.e. the first and second mile network infrastructures), service platforms (i.e. the middleware enabling different functions such as authentication, billing, data management, etc.), end-user devices, user applications, data streams over networks, and technical functionality.

The organizational domain describes the value network that is needed to realize a particular service offering. The relevant topics here are the value network, actors in the value network, their roles, interactions and relationships among actors, their strategies and goals, organization arrangements (i.e. formal or informal agreements among actors on how to divide and coordinate their activities), value activities (i.e. the activities that actors are supposed to perform in order for the value network to deliver the service), resources and capabilities (e.g. financial, social, organizational and technical).

The financial domain is the bottom line of the business model, with revenues on one side and investments, costs and risks on the other. The relevant topics in this domain are investment sources, costs, revenue sources, potential risks, pricing, financial arrangements among actors, and performance indicators to evaluate and manage the financial arrangements over time.

Business models have especially gained attention in the area of mobile telecommunications and mobile Internet services, which is not surprising given the evolving industry structure and technological landscape. The authors in Li & Whalley (2002) discussed the changing role of operators due to vertical disintegration and the subsequent impact on business models in the sector. Recently, the increasing role of device manufacturers and application stores has steered debate on how business models in the field are changing (Reuver et al., 2011; Holzer & Ondrus, 2011). Another reason why business models are often discussed in the mobile services domain is due to the struggle of service providers to come up with value-adding and viable mobile services.

In the context of mobile context-aware services (the category to which LBS are considered to belong), Reuver & Haaker (2009) have illustrated the relevance of the above four business model domains from Bouwman, Haaker & Vos (2008), leading us to structure the discussion of Galileo CS-related business models in this thesis along these four domains as well. Hegering et al. (2004) argue that a non-trivial context-aware service can only be realized by moving beyond the boundaries of single organization, i.e. require a value network of organizations. Killstrom (2007) suggest four generic business models for context-aware mobile services: an advertising-based model built around contextual advertising, a mobile extension model that extends the existing business of a company towards the mobile domain, a technology-based model that leverages new context-aware applications, and a contextualized content delivery model that delivers content based on user context. All these generic business models are generally complex, as they require the participation of partners providing context as well as content and/or partners from advertising.

Bouwman, Haaker & Vos (2008) argued that the critical success factors for business model viability indicate to what extent a business model is capable of creating (1) customer and (2) network value. With respect to the customer value, the critical success factors are compelling value proposition (i.e. the benefits delivered to the user of a service by its provider), clearly defined target group of people with similar needs/preferences/capabilities, unobtrusive customer retention (i.e. marketing strategies aimed at keeping customer but which do not create negative experiences to users), and acceptable quality of service. The critical success factors related to creating network value are acceptable profitability, acceptable financial and technological risks (e.g. return on investment uncertainty, technology availability, etc.), sustainable network strategy for securing access to resources and capabilities, and acceptable division of roles among firms (i.e. distribution and integration of roles within the firms participating in a business network).

The STOF model and the considerations specific to telecommunications and LBSs were used in the design and execution of the interview study, as it will be specified in the following subsection.

## 2.2 Data collection

In order to answer the research question presented in Section 1, we conducted interviews complemented by desk research (also known as secondary research). Interviews are particularly useful for getting the story behind a participant's experiences as the interviewer can pursue in-depth information around the topic. While the focus of our investigation, i.e. willingness of service providers to adopt Galileo CS, inherently depends on the added value perceived by the end users and how much they are willing to pay for, it was not deemed feasible to focus on the end users for two reasons. The first reason stems from the difficulty in acquiring a large enough sample of end users considering that these would not come from the consumer sector but from the professional sector, such as oil and gas exploration, finance, and others (in fact, this was also validated by the analysis of the interview data). The second reason is related with the fact that in addition to the many uncertainties surrounding the implementation of CS, it is up to the service providers to shape the exact service offering around CS. And as this service offering was too vague, especially at the beginning of our study, we decided to focus on the service providers who were more likely to provide relevant insights

In addition to service providers and in order to ensure that this selection was representative of the industry as a whole and not just a particular subsection, participants were chosen from the fields of academia, GNSS and generally LBS business, as well as research and consultancy firms. Specifically, some of those approached had also made various significant contributions in the development of professional LBSs which further ensured they represented a legitimate voice within the industry. We also interviewed people from the three public bodies involved in the development and exploitation of Galileo, i.e. EC, ESA, and GSA, which provided us with unique access to the insides of these driving forces as well as the opportunity to discover personal views versus the official position of an organization as a whole. The common denominator of all participants is that they were people who have a comprehensive understanding of GNSS and a degree of authority on the topic.

To determine the number of interviewees, we used the saturation principle (Miles & Huberman, 1994), i.e. we stopped interviewing additional persons after no additional insight was gained. Based thereon, we conducted 14 semi-structured, in-depth interviews during the spring of 2011. Typical job descriptions of interview participants include chief executive officer, market monitoring officer, business consultant, project manager, and professor. All interviews but one were conducted in a location of the participant's choosing while one of the participants provided his answers in written because a face-to-face meeting was not possible.

In the beginning of each interview, we briefly described the Galileo system (see Section 3.1). Then, we explained that Galileo CS would be offered at a premium-rate to LBS providers in exchange for improved accuracy, signal authentication and service guarantee. The interview questions were structured based on the STOF model thus all four dimensions were covered. Specifically, regarding the service domain of the business model, we asked the interviewees how higher positioning accuracy, signal authentication and service guarantee would impact their services, and how these impacts would differ across service categories and target groups. Regarding the technology domain, we asked the interviewees whether they are aware of any alternatives to CS features and if yes, which ones. Regarding the organization and finance domain, we asked the interviewees to identify organizational and financial risks associated with the adoption of CS platform, if any.

The interviewees were allowed to make sidesteps and elaborations and their responses were recorded in audio using a smartphone (with their permission) in order to facilitate the transcription process. The process of transcribing also allows the researchers to become acquainted with the data (Reissman, 1993). After the transcriptions were completed, we submitted them to the interviewees in order to reduce errors and clarify possible misunderstandings.

## 2.3 Data analysis

The results of the interview study were analyzed using a thematic content analysis technique. This involved identifying key themes within each answer and then counting the number of times each theme occurred overall. Quotes also provide a way to back up the claims made through the thematic analysis technique. In order to facilitate the analysis process we used Atlas.ti (version 6.2) which is one of the most frequently used software for structuring the qualitative analysis of interview material. The use of a software tool in analyzing qualitative data can reduce analysis time, make procedures more systematic and explicit and permit flexibility and revision in analysis procedure (Tesch, 1989). An important step in the process of data analysis is the identification and annotation of the various concepts, known as coding. While analyzing the interview transcripts, we focused on the key concepts such as positioning accuracy, signal authentication and service guarantee. However, to prevent premature closure we kept an open mind to explanatory factors beyond the conceptual model and coded them as well (Miles & Huberman, 1994).

After completion of the coding stage, we merged codes referring to similar concepts and removed others that were not considered essential. In order to ensure the applicability of the merging actions, we looked at the quotations attached to each of the codes and checked whether the merged code does indeed describe all the quotations. When the final code list was formed, we identified logical connections between codes and the nature of their relationship. Using one of the Atlas functions, we generated a network of codes, which is a visual illustration of the various concepts encountered during the interviews and their interconnections. In order to facilitate the data analysis, we identified categories of codes with common characteristics and grouped them into code families. This structuring not only improves the visual quality of the network by reducing the complexity but also introduces a hierarchy, which can serve as a guidance model.

## 2.4 Methodology limitations

One potential limitation of the above-described research methodology is the relatively small size of interviewees. Ideally, quantitative research would have also taken place by performing a wider scale survey of end user desires and concerns but due to the limitations described earlier as well as the differing levels of understanding of user knowledge about GNSS, it was felt that a widespread survey would not provide accurate results. It is also possible that the thematic analysis could have had different results if it had been conducted by another researcher as the element of interpretation is involved in deciding which answers follow which themes. However, while this could have had a slight effect on the exact number expressed in the rate of occurrences it is unlikely that the factors identified to contribute to the willingness of service providers to adopt CS would have changed significantly.

# 3 GLOBAL NAVIGATION SATELLITE SYSTEMS

## 3.1 What is GNSS?

A GNSS is a combination of different technologies into a complex infrastructure that (1) provides precise timing information and (2) enables users to compute their location on the Earth. It is a massive infrastructure with global coverage and impact. According to the glossary of the Organization for Economic Co-operation and Development (OECD), an infrastructure is defined as the system of public works in a country, state or region, including roads, utility lines and public buildings. However this definition limits the scope of the infrastructure to at most within a country's borders thus it is not suitable to be used in the context of our study. In fact, a universally accepted definition has remained elusive and the interest reader is referred to the work of Torissi (2009) who studied the various definitions and classifications reported in the literature. In this thesis, we adopt the distinction of economic and social infrastructures introduced by Hansen (1965). Specifically, an economic infrastructure is defined as infrastructure that promotes economic activity such as roads, electrical lines and water pipes. On the other hand, social infrastructure promotes health, educational and cultural standards of the population, which include schools, clinics, and parks among other things (DBSA, 1998). Naturally, economic and social infrastructures can overlap (Fourier, 2006) and we believe that nowadays, GNSS has pervaded our life to such extent that can be considered as both an economic and social infrastructure. However, in this thesis we focus mainly on the economic impact of GNSS (see Chapter 4).

The experience gained from the existing GNSSs has demonstrated the advantages of satellite navigation to the extent that, for example, in the USA, GPS is regarded as the fifth utility, alongside water, electricity, gas and telephone. Therefore, also other geopolitical entities, such as EU, China, and India understood the advantages of such a global system and initiated the development of their own GNSS as an attempt to enter the GNSS-enabled market and gain political independence. In this chapter, we describe the various existing and emerging GNSSs and make a high-level comparison of some of their key features.

## 3.2 Galileo

Galileo is Europe's initiative for a state-of-the-art global navigation satellite system that would allow the European Union to reap the economic and strategic benefits (EC, 2013). Galileo will provide a highly accurate, guaranteed global positioning service under civilian control and would cut the dependency of Europe on GPS or other GNSSs. Such dependency is extremely valuable considering that the availability of the most widely used system, GPS, cannot be taken for granted. For instance, in 2004, the U.S. President George Bush established plans for temporarily disabling GPS satellites during future national crises to prevent terrorists from using the navigational technology (STO, 2013). Moreover, gaining such independence has been one of the main reasons for developing Galileo as about 6%-7% of Europe's Gross Domestic Product (GDP) is currently, according to the EC Head of Satellite Navigation, Paul Flament, totally dependent on GNSS (Gutierrez, 2013, 30. April). In particular, a further assessment about EU's dependence on GPS showed that delivery services (e.g. fleet management and parcel tracking used by freight forwarders) have 100% reliance, utilities (e.g. electricity grids utilizing satellite navigation timing for synchronization) have 60% exposure, communications (e.g. around 400 million smartphones containing a GPS chips were shipped globally in 2010, 15% of which in the EU) have 40% exposure, banking and finance (i.e. money transactions that are stamped with GPS time) have 35% exposure, and agriculture (e.g. spraying on the bigger farms in the EU is done by GPS assistance) has 10% exposure (Amos, 2011, 1. February).

### 3.2.1 Governance of the system

Figure 3 shows the current overall governance of Galileo, the development of which has been orchestrated by three public bodies: the European Commission, the European GNSS Agency, and the European Space Agency (EGSC, 2013). EC represents the general interest of the EU and is responsible for the political dimension and the high-level mission requirements. In particular, it initiated studies on the overall architecture, the economic benefits and the user needs for Galileo. GSA is currently responsible for a variety of tasks such as the successful commercialization and exploitation of Galileo, ensuring the security accreditation of the system, promoting satellite navigation applications and services, and ensuring the certification of the system's components (GSA, 2013a). ESA's responsibility covers the definition, development, and in-orbit validation of the space segment and related ground element. EC and ESA have signed a delegation agreement by which ESA acts as design and procurement agent on behalf of the EC. In addition to these three public bodies, plenty of private and public organizations mainly in European Member States are taking part in the development of the Galileo system.

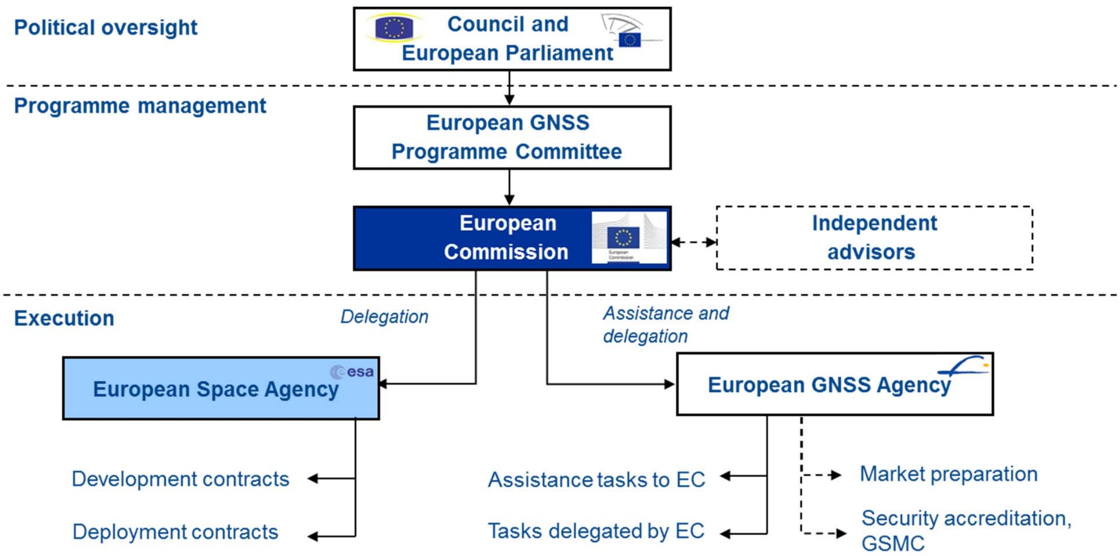


FIGURE 3 Current Galileo governance (Lisi, 2013)

Galileo should have been operational by now but the project has run into myriad of technical, commercial and political obstacles, including early objections from the US, who thought a rival system to GPS might be used to attack its armed forces. In fact, the venture came very close to being abandoned in 2007 when the public-private partnership put in place to build and run the project collapsed (Amos, 2011, 18. January). Based on the most recent estimates, Galileo is expected to be fully operational in 2019–2020 (Crop, 2011).

### 3.2.2 System and service description

The space segment of Galileo will consist of 30 Medium Earth Orbit (MEO) satellites, equally distributed in three orbital planes inclined at an angle of 56° to the equator. The core of the Galileo ground segment will be two control centers which will manage "control" and "mission" functions, supported by dedicated Ground Control Segment and Ground Mission Segment, respectively (ESA, 2013a). The Galileo user segment translates the signals into services for the final users and it is composed by technologies (e.g., receiver technologies), added-value services (combined with communication, mapping, pricing services) and user applications. Galileo will provide worldwide and independently from other systems the following four services (ESA, 2013b):

**Open Service (OS)**
OS makes use of the open signals, based on which the user of a Galileo receiver can obtain positioning, velocity, and timing information free of direct user charges (Navipedia, 2012, 23. February). This service is suitable for mass-market applications, such as in-car navigation and hybridization with mobile tele-

phones. OS is accessible to any user equipped with a Galileo enabled receiver, with no authorization required. The timing service is synchronized with UTC when used with receivers in fixed locations and can be used for applications such as network synchronization or scientific applications (EC, 2002).

While up to three separate signal frequencies are offered within OS, cheap single-frequency receivers will be used for applications requiring only reduced accuracy, i.e. around 15 m and 35 m of horizontal and vertical accuracy, respectively (Navipedia, 2012, 23. February). When more than one signal is used from each satellite then the positioning accuracy could be improved to around 4 m and 8 m of horizontal and vertical accuracy, respectively. The positioning accuracy in OS mode is expected to be comparable or in some cases even higher than the one offered by C/A Global Positioning System (GPS) signals (e.g., the signal used to bear OS is expected to be more robust in environments prone to heavy multipath propagation such as urban canyons). However, because OS will be interoperable with other GNSS civil signals, it would be possible to facilitate the provision of combined services for enhanced performance (EC, 2002). There will be no service guarantee or liability from the Galileo Operating Company on the Open Service.

**Safety of Life service (SoL)**

SoL will offer better performance than the one offered by OS through the provision of timely warning to the user whenever the position solution falls outside the acceptable margins. SoL is mainly meant for safety-critical applications, such as maritime, aviation and rail, where guaranteed accuracy is essential especially in areas where services provided by traditional ground infrastructure are not available (ESA, 2005). A worldwide seamless service will increase the efficiency of companies operating in a global basis, e.g. airlines, transoceanic maritime companies.

SoL will be offered openly and the system will have the capability to authenticate the signal (e.g. by a digital signature) to assure the users that the received signal is the actual Galileo signal. This system feature, which will be activated if required by users, must be transparent and nondiscriminatory to users and shall not introduce any degradation in performances (EC, 2002).

**Commercial Service (CS)**

CS provides added value services on payment of a fee and it is based on adding two signals to the open access signals available through OS. This pair of signals is protected through commercial encryption, which is managed by dedicated CS service providers who would act upon a license agreement between them and the GOC. Access is controlled at the receiver level, using access-protection keys (Navipedia, 2012, 19. June). Within CS, users will be offered data access via an authentication mechanism (yet to be defined), higher data rate throughput (i.e., the average rate of successfully received data), higher accuracy compared to OS, and service guarantee (i.e., on the liability of the service).

The authentication capability of CS would enable the development of anti-fraud applications. For instance, fishing regulators require better systems for tracking fishing vessels in order to monitor whether they are operating fairly and legally, according to regulations. However, the availability of various spoofing technologies allows those who do not want to follow the regulations to bypass the existing control systems (e.g. by spoofing the GNSS receiver onboard thus sending the wrong positioning information to the monitoring authorities). Such fraud cases could be avoided with the use of CS as it would enable reliable monitoring by the relevant authorities. With respect to accuracy, it is expected CS to enable a cm-level in contrast to the meter-level of accuracy offered by GPS. Such accuracy level can be extremely beneficial for surveyors or oil platform operators, where helicopter transport is vital. Services within CS will be developed by service providers, which will buy the right to use the commercial signals from the Galileo Operating Company (GOC) and then charge the users for accessing these services (ESA, 2005). CS is considered to be the main source of revenues for the GOC.

**Public Regulated Service (PRS)**
PRS is addressed to limited to a specific user segment, which requires high continuity of service and controlled access (e.g., meant for police, coast-guards, security services, firefighters, etc.). It will be encrypted and designed to be more robust, with anti-jamming mechanisms and reliable problem detection (Navipedia, 2012, 19. June). Civil institutions will control the access to the encrypted PRS. Access by region or user group will follow the security policy rules applicable in Europe. The need for PRS results from the analysis of threats to the Galileo system and the identification of infrastructure applications where disruption to the Signal in Space (SiS) by economic terrorists, malcontents, subversives or hostile agencies could result in damaging reductions in national security, law enforcement, safety or economic activity within a significant geographic area. PRS will be operational at all times and in all circumstances, including during periods of crisis. Each Member State wishing to use PRS will set up a “Responsible PRS Authority” which will manage and control end-users as well as the manufacture of PRS receivers. In turn, coordination on a European level will guarantee consistency and conformity with the high level of security required. (Navipedia, 2012, 19. June).

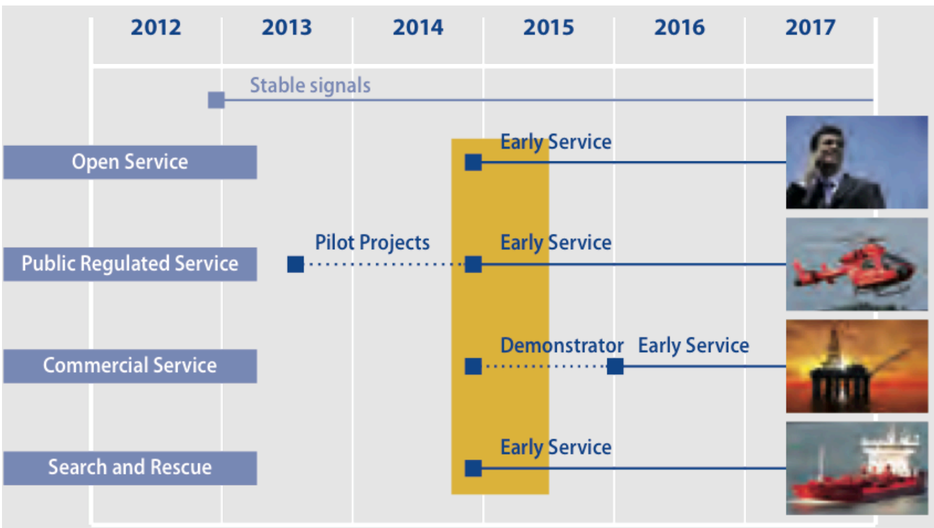

FIGURE 4 Preliminary schedule for Galileo services (GSA, 2013b)

The preliminary schedule for Galileo services in shown in figure 3. In addition to the above four services, the Galileo support to the search and rescue service represents the contribution of Europe to the international COsmicheskaya Sistyema Poiska Avariynich Sudov - Search And Rescue Satellite Aided Tracking (COSPAS - SARSAT) co-operative effort on humanitarian Search and Rescue activities (ESA, 2013b; COSPAS, 2013). Specifically, ESA has appointed the Aerospace & Defence division of Capgemini, one the global leaders in consulting, IT services and outsourcing, to implement the ground segment of the Galileo search and rescue system which will locate these people in around ten minutes under operating conditions of more than 99.8%, compared with several hours under the previous arrangements (Capgemini, 2013, 28. February).

Although Galileo will be self-contained, the performance of its services will be enhanced thanks to its interoperability with other systems such as GPS and GLONASS. Furthermore, the services offered by Galileo contribute, in particular, to the development of trans-European networks in the areas of transport, telecommunications and energy infrastructures. Hence cooperation with other countries providing satellite navigation services will help to maximize benefits for users, the public or the economy as a whole (EC, 2013).

### 3.2.3 Phases of Galileo program and budget allocation

The implementation of Galileo system is shown in figure 5.

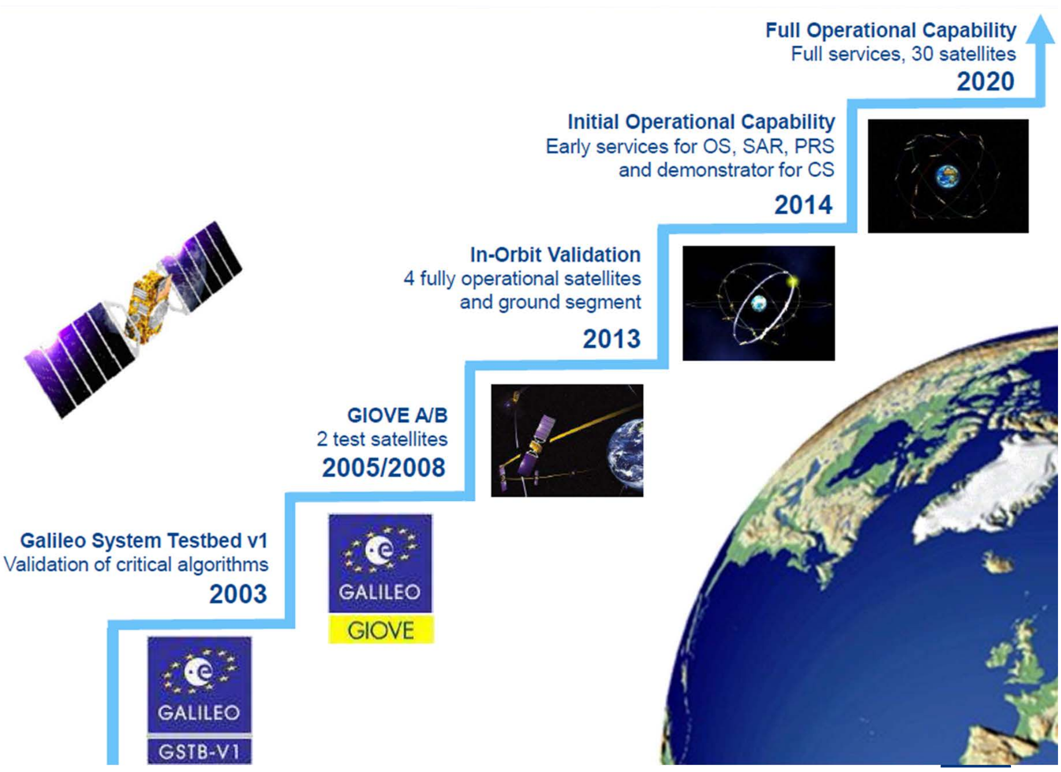


FIGURE 5 Implementation plan of Galileo system (Lisi, 2013)

Specifically, the Galileo program consists of four phases (Crop, 2011; Europa, 2011, 23. May):

1. **Definition phase** - During this phase, the basic elements of this project are defined. The definition phase spanned during the years 2000 and 2001 and was financed by EU and ESA. The EU contribution to this phase was around €80 million coming from the 5th Framework Program and s similar amount was contributed by ESA.
2. **Development and validation phase** – This phase is also known as the Initial Operational Capability (IOV) and is expected to complete in 2014-2015. When Galileo reaches IOV, a constellation of 18 satellites will be available and early services for OS, PRS, as well as support to COSPAS - SARSAT will be offered. Total costs of the development phase which was launched in 2003 under the auspices of the ESA and is currently ongoing were initially estimated at €1.1 billion, equally shared between ESA and the EU. However, costs have since increased to around €2.4 billion, with the EU, providing €560 million to remedy the Programs' budget shortfalls.
3. **Deployment phase** – In this phase, also known as Full Operational Capability (FOC), the constellation will be complete and all services will be available. FOC is expected in 2019-2020 and is entirely financed by the EU's budget. Of the total €3.4 billion made available, €560 million were required to finance cost overruns in the development and validation phase (i.e. IOV phase) while around €2.4 billion are earmarked for the deployment phase of Galileo.
4. **Exploitation phase** – This is the phase where services are offered; it is scheduled to begin in 2014 and to be complete by 2020.

The completion of the constellation for the provision of all Galileo services is estimated to require a further €1.9 billion beyond 2014, including €1.18 billion for the deployment of the construction and launch of the remaining satellites. Moreover, the Commission is also preparing for an additional €1 billion in costs per year for the period 2014 to 2020 (Seidler, 2011, 21. October). So far, additional financing has been required to replenish the budget assigned for the completion of Galileo. On the request of Member States, parts of this budget were used to cover financial shortfalls in the development and validation phase managed by ESA. Another factor has been the worldwide increase in launch costs, exceeding the initial estimates for the Galileo program (Europe, 2011, 18. January). Moreover, increasing security constraints, which affect all critical infrastructures, such as telecommunication networks, financial systems, power grids, etc., have also impacted Galileo (EOS, 2009; EC, 2013c). Finally, competition in a number of work packages has not been as strong as was initially hoped for (Europe, 2011, 18. January).

The cost of operating Galileo can be broken down into the costs of operating the infrastructure, maintaining or replacing the components that have a limited lifetime and evolving the system in line with user requirements. On the basis of calculations jointly elaborated with ESA, the total annual operating costs of Galileo are expected to lie at €590 million (Europa, 2011, 23. May).

## 3.3 GPS: The beginning of GNSS era

### 3.3.1 History of GPS

Global Positioning System (GPS) represents one of the great technological advancements. In 1973, Navy and Air Force programs, directed by U.S. government, were combined to form the Navigation Technology Program which acted as the basis for the development of GPS. The first four satellites were launched in 1978 while in April 1995, the U.S. Air Force Space Command formally declared the GPS as a system with Full Operational Capability where each satellite transmitted two signals; one for military use and one for civilian use.

Although GPS was initially intended for military use only, the Congress, with the support and guidance of the U.S. President Reagan, directed the Department of Defense (DoD) to promote the civil use of GPS. It is stated that a major factor toward civilian access to GPS has been a tragic accident that happened on 1st September 1983, when a commercial airplane of Korean Airlines was flying from Anchorage to Seoul but strayed off course into the airspace of the Union of Soviet Socialist Republics (USSR) and was shot down by a soviet fighter jet. As a result, all 269 passengers and crew were killed. Two weeks later, US President Reagan proposed GPS be made available for civilian use (through free access to the civilian signal) to avoid navigational error ever again leading to similar tragic events (Rutan, 2006; TomTom, 2013).

In 1990, the DoD activated the functionality of Selective Availability (SA) causing a variable error on the civilian signal that deliberately degraded the positioning accuracy for unauthorized users. The reason for enforcing SA stemmed from the results of the tests performed with user equipment which showed that the achievable positioning accuracy was much higher than initially anticipated (Doucet & Georgiadou, 1990). In particular, it was expected that an accuracy of no better than 100 meters could be achieved using the civilian signal (called Coarse/Acquisition signal and denoted as C/A) while the results showed that a commercial receiver could achieve approximately a 20-30 meter range of positioning accuracy versus the 10-20 meter range of accuracy achieved based the military signal (called Precision signal and denoted as P(Y)).

In the following years, various differential GPS services were developed using the civilian signal which significantly increased the positioning accuracy and largely mitigated the SA effect. Specifically, these services utilized a network of fixed, ground-based reference stations to broadcast the difference between the positions calculated using GPS civilian signals and their known fixed position. The widespread growth of differential GPS services in combination with the U.S. military's active efforts to develop alternative technologies for denying GPS service to potential adversaries on a regional basis led to another important landmark in the history of GPS operation; in May 2000, U.S. President Bill Clinton ordered SA to be turned off (Defree, 2013, 2. May). This led to a significant increase in the positioning accuracy and in turn, enabled the development of GPS-based services such as standalone positioning and car navigation, as well as established GPS as a free-access utility.

### 3.3.2 System description

GPS is a Global Navigation Satellite System (GNSS) that comprises of three segments (USNO, 2013a): (a) Space segment, (b) Ground segment, and (c) User segment. These segments are illustrated in figure 6:

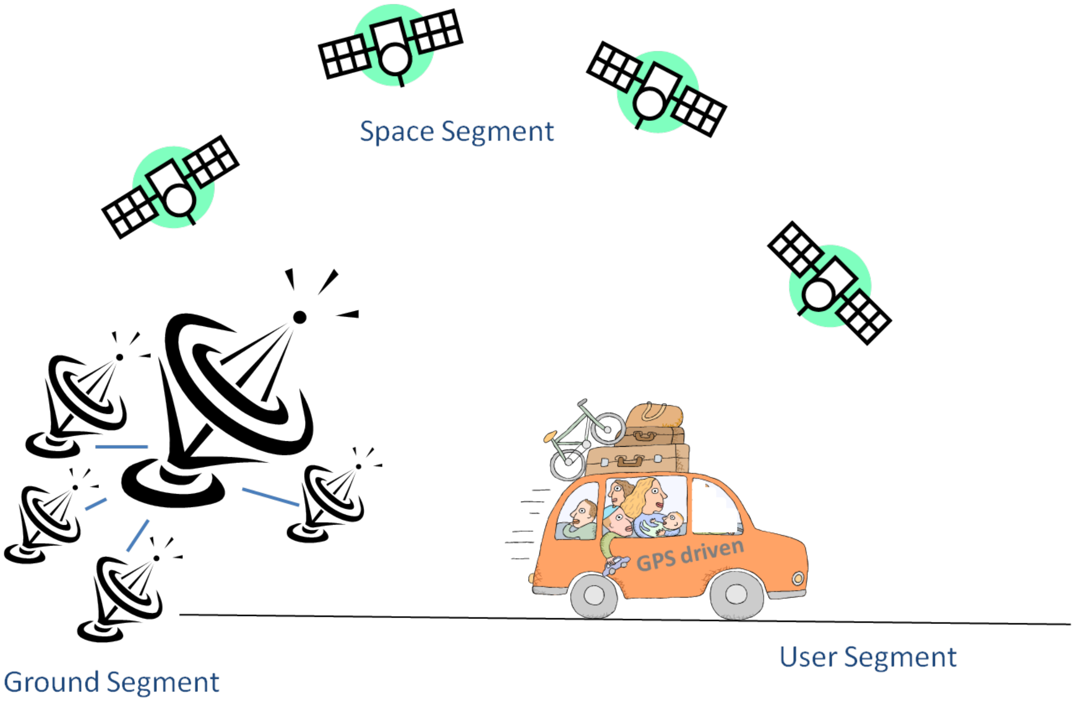

FIGURE 6 GNSS segments

GPS space segment consists of 24 MEO satellites located at an altitude of approximately 20200 km and equally distributed in six orbital planes characterized by an inclination angle of 55 degrees. The ground segment includes the Master Control Station (MCS), five monitor stations, and three ground antennas. Each station has several GPS receivers that continuously track the visible GPS satellites. The monitor stations passively track all satellites in view, accumulating ranging data which is processed at the MCS and used to determine satellite orbits and to update each satellite's navigation message. The updated information is then transmitted to each satellite via the ground antennas. The user segment consists of the GPS receiver equipment that is used to compute user's Position, Velocity and Time (PVT).

GPS currently offers two types of services: a Standard Positioning Service (SPS) for public use and an encoded Precise Positioning Service (PPS), dedicated solely for military use NCO-PNT, 2013). The former is offered via the civil signal C/A transmitted in the L1 frequency band centered at 1575.42 MHz and the latter, via the P(Y) signal transmitted at both the L1 and L2 frequency bands with the latter centered at 1227.60 MHz. It is also important to emphasize that although GPS and in general GNSS technology is mostly known as a means for computing the three-dimensional position, it also provides a critical fourth dimension - time. Precise timing information and synchronization are crucial in a variety of technical and financial operations such as in wired and wireless communication systems, electrical power grids, financial transactions, etc. For example, GPS time is used by the U.S. Federal Aviation Administration to synchronize reporting of hazardous weather from its weather radars and by wireless telephone and data networks to synchronize their base stations. Hollywood studios are also incorporating GPS time in their movie slates, allowing for unparalleled control of audio and video data, as well as multi-camera sequencing (NCO-PNT, 2013).

### 3.3.3 GPS modernization

Since the time SA was turned off, the demand for GPS service was steadily growing as well as alternative GNSS systems were introduced. The growing demand for GNSS services and the need to remain competitive in the arena are two main reasons that recently initiated the GPS modernization program, an ongoing, multibillion-dollar effort to upgrade the GPS space and control segments with new features to improve GPS performance (USNO, 2013b). A big part of program is dedicated to the design of new GPS signals with enhanced capabilities. Among others, the new signals will employ new modulation schemes, new structures, longer codes but also faster transmission rates, new data encoding, new navigation message formats and the possibility of dataless signals (Ziedan, 2006).

Specifically, it is planned to introduce three new signals designed for civilian use, L2C, L5, and L1C, while the legacy signal, L1 C/A, will continue broadcasting in the future (USNO, 2013b). L2C is designed specifically to meet commercial needs; when it is combined with L1 C/A in a dual-frequency receiver, L2C would enable higher positioning accuracy, enhanced reliability, and greater operating range. It is interesting to mention that the Commerce Department estimates L2C could generate $5.8 billion in economic productivity benefits through the year 2030 (Levenson, 2006). L5 is the third civilian GPS signal, designed to meet demanding requirements for safety-of-life transportation and other high-performance applications. It is broadcast in a radio band reserved exclusively for aviation safety services and features higher power, greater bandwidth, and an advanced signal design. L1C is the fourth civilian GPS signal, designed to enable interoperability between GPS and international satellite navigation systems. Originally, it was developed as a common civil signal for GPS and Galileo but satellite navigation providers of other systems, such as of China and India, are adopting L1C as a future standard for international interoperability. It is also mentioned that L1C will improve mobile GPS reception in cities and other challenging environments (USNO, 2013b).

In order to benefit from the new signals, users must upgrade their equipment. The new civil signals are phasing in incrementally as the Air Force launches new GPS satellites to replace older ones and most of the new signals will be of limited use until they are broadcast from 18 to 24 satellites. Based on a recent report published by United Nations (ICG, 2010), L2C, L5, and L1C civil signals are expected to be available to all GPS satellites by 2016, 2018, and 2021, accordingly. Moreover, according to (USNO, 2013b), there are no plans to privatize GPS thus civil GPS service will be provided free of direct user fees. In addition to the specific new features noted above, GPS modernization is introducing modern technologies throughout the space and control segments that will enhance overall performance. For example, legacy computers and communications systems are being replaced with a network-centric architecture, allowing more frequent and precise satellite commands that will improve accuracy for everyone (USNO, 2013b). Also, it is planned to include a new military signal, the M-code, in L1 and L2 frequencies (Navipedia, 2013, 16. May).

## 3.4 GLONASS

While U.S. was the country to first develop a GNSS, the landscape in the GNSS field has changed dramatically. More precisely, U.S. is not the only player as Soviet Union (later Russia) has also built its own GNSS, called Global Navigation Satellite System (GLONASS), whose development started already 1976 and which was fully operational by 1999. However, due to the collapse of Soviet Union and the lack of funding, the GLONASS orbital constellation was not maintained and as a result, the number of operational satellites significantly declined (Polischuk et al., 2002). With the advent of the 21st century and under the presidency of Vladimir Putin, the restoration of GLONASS system became one of the top priorities of the Russian government and by the end of 2011, GLONASS was fully operational.

GLONASS comprises 24 MEO satellites that are uniformly deployed in three roughly circular orbital planes at an inclination of 64.8 degrees to the equator and altitude of 19,100 km (RSS, 2013). Its ground segment consists of a system control center; a network of five telemetry, tracking and command centers; the central clock; three upload stations; two satellite laser ranging stations; and a network of four monitoring and measuring stations, distributed over the territory of the Russian Federation. Each GLONASS satellite transmits two types of navigation signals in L1 and L2 frequency bands: the standard positioning signal and the high accuracy positioning signal (ICG, 2010). It is worth mentioning that India is the only country to which Russia has agreed to give access to Glonass military-grade signals, which will enable the Indian military to greatly improve the accuracy of its land-, sea-, air and space-launched weapon systems (TheHindu, 2013, 21. October). Access to GLONASS civil signals is free and unlimited for both Russian and international users. GLONASS user segment is relatively small and mostly concentrated in Russia.

GLONASS modernization began with the launch of second generation of satellites, known as GLONASS-M, in 2003, while the following generation of satellites, GLONASS-K, has a service life of 10 years and enables greater interoperability with GPS, future Galileo and other GNSSs (Navipedia, 2012, 7. December). In March 2012, the new GLONASS Program for 2012–2020 was approved which foresees step-by-step performance improvement of all system components (Davidov & Revnivykh, 2012, 1. December). Particularly, it is estimated that by 2020, the GLONASS system in stand-alone mode will provide sub-meter accuracy for users with an open signal. The three major targets set for it:

- Maintain its full operational mode.
- Improve significantly its performance and service quality
- Provide conditions for worldwide use.

Despite the large progress in the GLONASS program, there have been some setbacks. For instance, according to a spokesman for the Russian Investigative Committee, very recently three senior managers were charged with embezzling $3.2 million allocated for Russia's GLONASS satellite navigation program (RIA, 2013, 4. September).

## 3.5 CNSS

As any GNSS is offered at the discretion of the operating entity, more and more governments are willing to gain political independence by developing their own augmentation system or GNSS. China, the world's second largest economy, is on its course to complete its Compass Navigation Satellite System (CNSS, in Chinese known as BeiDou-2) whose construction is steadily accelerating based on a "three-step" development strategy, following the general guideline of starting with regional services and then expanding to global services, first active positioning, and then passive positioning (Beidou, 2013, 17. May). Director of the China Satellite Navigation Office, Ran Chengqi, said that the general functionality and performance of the Compass would be "comparable" to the GPS system, but cheaper (ChinaDaily, 2012, 27. December).

On December 27, 2012, CNSS officially provided regional service, indicating that China has completed the second step of the system over a period of eight years and funding is assured through 2020 to complete and operate a full constellation (InsideGNSS, 2010). Specifically, according to Ran Chengqi, director of the China Satellite Navigation Office, China has already launched 16 navigation satellites and four test satellites and plans to launch 40 more over the next decade to advance the Beidou system. The space constellation consists of five GEO satellites and 30 non-GEO satellites (CSNO, 2012, 2. May). The GEO satellites are positioned at 58.75°E, 80°E, 110.5°E, 140°E and 160°E, respectively. The non-GEO satellites include 27 MEO satellites and three Inclined Geostationary Orbit (IGSO) satellites. The MEO satellites are operating in an orbit with an altitude of 21,500 km and an inclination of 55°, which are evenly distributed in three orbital planes. The IGSO satellites are operating in an orbit with an altitude of 36,000 km and an inclination of 55°, which are evenly distributed in three inclined geo-synchronous orbital planes.

The CNSS user segment consists of user terminals, which should be compatible with GPS, GLONASS, and Galileo. CNSS will offer two kinds of services: (1) an open service that will be free and open to users and (2) an authorized service which will offer more reliable positioning, velocity, timing and communications services as well as integrity information (Dong, Li, & Wu, 2007). The performance of the CNSS open service is expected to be comparable to that of GPS and Galileo OS while no commercial service such as Galileo CS is foreseen in CNSS.

## 3.6 Regional navigational satellite systems

Besides those navigation satellite systems which provide global coverage, there are also systems which are designed to serve only a specific region either on a stand-alone mode or to augment existing GNSSs with the purpose of improving positioning in this particular region. While this thesis focuses on GNSSs, for the sake of completeness, we also include in this section a brief overview of regional navigation satellite systems.

### 3.6.1 IRNSS

India has been also developing its own navigation satellite known as Indian Regional Navigation Satellite System (IRNSS). IRNSS is an independent regional navigation satellite system which is designed to provide position accuracy better than 10m over India and the region extending about 1500 km around India (ISRO, 2013). It will provide an accurate real time position, navigation and time services to users on a variety of platforms with 24x7 service availability under all weather conditions. The space segment of IRNSS consists of seven satellites; three satellites will be placed in the geostationary equatorial orbit (GEO) and two satellites each will be placed in the geosynchronous orbit (GSO). The first satellite was launched in July 2013 while a full constellation is expected by 2015. IRNSS will have two types of signals transmitted in L5 and S bands with center frequencies at 1176.45 MHz and 2492.028 MHz, respectively and will provide two types of services; a standard positioning service for civilian users and a restricted service for authorized users. The user segment consists of single and specially designed dual frequency receivers while the user receiver may receive other constellations in addition to IRNSS. Possible IRNSS applications include terrestrial, aerial and marine navigation, disaster management, vehicle tracking and fleet management, integration with mobile phones, precise timing, mapping and geodetic data capture, terrestrial navigation aid for hikers and travellers, and visual and voice navigation for drivers.

### 3.6.2 QZSS

In addition to Chinese, Japanese are also developing a satellite navigation system, named Quasi-Zenith Satellite System (QZSS). Unlike the previously described systems (i.e. GPS, GLONASS, Galileo and CNSS), QZSS is a regional navigation satellite system whose purpose is to augment existing GPS in order to enable positioning in areas where standalone GPS is not sufficient. Specifically, in locations without major obstructions, the position of the receiver can be easily and accurately determined using GPS signals. However, Japan has many mountainous and urban regions with many high-rise buildings where the required number of signals for accurate positioning cannot be received thus availability, i.e. the probability that one can use GPS SPS properly in a particular place, is limited (Tsujino, 2005). In particular, GPS signals are only available about 90% of the time in Japan, but satellite navigation will be possible 99.8% of the time with the QZSS satellites (Fujiwara, 2011, 5. September). QZSS consists of multiple quasi-zenith satellites that fly in the orbit passing through the near zenith over Japan and the signals have complete compatibility and interoperability with existing and future modernized GPS signals (Kogure & Yasuda, 2009). On March 2013, Japan's Cabinet Office announced the expansion of the Quasi-Zenith Satellite System from a three-satellite to four but ultimately the plan is to deploy seven QZSS satellites in the next decade (Clark, 2013, 4. April).

### 3.6.3 GAGAN

Like Japan, India has been also developing a regional satellite-based augmentation system known as GPS Aided Geo Augmented Navigation (GAGAN) with the purpose of using it as a low cost substitute for Instrument Landing System (ISP, 2013). GAGAN is jointly developed by Airports Authority of India and Indian Space Research Organization. India will launch during 2013 the first of its series of navigation satellites required to provide regional navigation service, independent of GPS (Balasubramanyan, 2013). GAGAN could be used in aviation sector and help in navigation over Indian airspace. Specifically, India plans to use the GAGAN system initially in 40 candidate airports in order to improve airport and air-space access in all-weather conditions while meeting environmental and obstacle clearance constraints. GAGAN would also enhance reliability and reduce delays by defining more precise terminal area procedures that feature parallel routes and environmentally optimized airspace corridors. For example, it has been estimated that GAGAN could offer 20% savings in fuel costs which represents an enormous opportunity for airlines (Airport-Technology, 2013). Other applications include defense services, security agencies, Railways, surface transport, shipping, telecom industry and personal users of position location based services.

## 3.7 Comparison of existing and emerging GNSSs

A GNSS is massive and complex architecture containing typically three segments, i.e. space, ground, and user segments, each of which consists of a large number of systems, subsystems and interfaces. A GNSS is characterized by many functional and technical features as well as implements multiple modes of operation, in a highly dynamic environment. Consequently, the complexity associated with the comparison of such systems is so high that typically, scientists, researchers, or experts focus only on one or few aspects. As a detailed comparison of the functionalities of current and emerging GNSS would be outside the scope of this thesis, in this section, we present a high level comparison of some of the key features present in the GNSSs described in the previous subsections (i.e. Galileo, GPS, GLONASS, and Compass) with emphasis on the provided services.

In terms of system architecture, the biggest difference among the four GNSSs is in their space segment. Specifically, each GNSS has not only a different number of operational satellites (in-use and spares) but also the configuration of the constellation differs greatly in terms of number of orbits, orbital inclination, distribution of satellites among the orbits, and altitude. For instance, the satellites of Galileo and Compass systems are located at a higher altitude than the GPS and GLONASS satellites. Moreover, because the inclination of the satellite orbits in GLONASS are higher than in other systems, it is more suitable for positioning in higher latitudes. Also, the technical characteristics (e.g. modulation scheme, frequency, data bit rate, etc.) of the transmitted navigation signals differ greatly among the four systems. In terms of services, all global systems are offering or plan to offer at least two types of services; a free-of-charge open access service for civilians with basic performance characteristics and a restricted service for military or governmental authorities with enhanced performance. Among the four GNSSs described earlier, future Galileo and modernized GPS systems promise additional civilian services. Specifically, Galileo will offer in total five distinctive services (including the search and rescue service under COSPAS – SARSAT program), two of which can be openly accessed, while in the modernized GPS three additional civil signals aimed at improving the performance for civilian users. Also, the GLONASS signals will be modernized but there are currently no plans on providing additional services. In terms of the systems' governance, GPS and GLONASS are operated by the military while Galileo and Compass are civil operated. Table 1 summarizes some of the key features of current and emerging GNSSs.

By year 2020 there will be in total four GNSSs, several regional satellite navigations systems, and more than 100 navigation satellites in the space. From the user point of view, the availability of more satellites can to lead to enhanced performance in terms of flexibility (i.e. more visible satellites at a given location), reliability (i.e., the more diverse the maintenance of the components of GNSS the less chance of overall system failure), faster positioning (i.e. more measurements in shorter time can lead to shorter observation periods without degrading accuracy), faster initialization (i.e. the time to first fix can be reduced), and higher positing accuracy (e.g. better correction of ionospheric errors with increasing number of signal frequencies) (PSU, 2013).

However, with an increasing number of GNSSs, the concepts of compatibility and interoperability become increasingly relevant. In particular, the International Committee on Global Navigation Satellite Systems (ICG) forum has defined compatibility as the ability of global and regional navigation satellite systems and augmentations and the services they provide to be used separately or together without causing unacceptable interference and/or other harm to an individual system and/or service. In turn, interoperability refers to the ability of these systems to be used together to provide better capabilities at the user level than would be achieved by relying solely on the open signals of one system (OOSA, 2007). All in all, it is important to seek common understanding on appropriate methods to determine compatibility among all GNSS and it is desirable open signals and services to be interoperable to the maximum extent possible, in order to maximize benefit to all GNSS users (OOSA, 2008; OOSA, 2011).

Table 1 Comparison of existing and emerging GNSSs

| Features / GNSS | Type of operating entity | Coverage | Constellation size | Services | Key characteristics | Access |
|---|---|---|---|---|---|---|
| **Galileo** | Civil | Global | 27 MEO & 3 spares | Open Service | Standard performance comparable to GPS SPS | Open & Free |
| | | | | Safety-of-Life | Integrity, guaranteed enhanced performance | Open & Free |
| | | | | Commercial Service | Higher positioning accuracy than OS, authentication, service guarantee | Restricted & Fee-based |
| | | | | Public Regulated Service | Encrypted, resistant to jamming, high continuity | Restricted |
| **GPS** | Military | Global | 24 MEO & 4-6 spares | Standard Positioning Service (L1 C/A) | Standard PVT service | Open & Free |
| | | | | Precise Positioning Service | Encrypted, better performance than SPS | Restricted |
| | | | | L2C (& L1 C/A) | Faster signal acquisition, enhanced reliability, greater operating range | Open & Free |
| | | | | L5 | Improved accuracy and robustness (reserved exclusively for aviation safety services) | Restricted |
| | | | | L1C | Interoperability with other GNSSs, enhanced performance in cities and other challenging environments | Open & Free |
| | | | | M-code | Improved anti-jamming performance | Restricted |
| **GLONASS** | Military | Global | 21 MEO & 3 spares | Standard Precision | Standard PVT service | Open & Free |
| | | | | High Precision | Enhanced characteristics, better performance than SP | Restricted |
| **COMPASS** | Civil | Global | 5 GEO & 30 GSO | Open service | Standard PVT service | Open & Free |
| | | | | Authorized service | Encrypted, better performance than the open | Restricted |

# 4 GNSS BUSINESS MODELS

## 4.1 Business models for public infrastructures

The concept of a business model is widely used by both academics and practitioners; for instance, a search performed by the author in Google Scholar for the term "business model" in the abstract of articles returned 2430 results. Osterwalder, Pigneur & Tucci (2005) found that the term business model was first used in an article by Bellman & Clark (1957) while the first use in the title and abstract of an article was found in a piece by Jones (1960). Despite the abundance of publications referring to this term, there is no generally accepted definition of it, while according to Linder & Cantrell (2000) business models are relatively poorly understood, particularly as a research area. For instance, even though the first definitions of business models came into being at the end of the 1990s, the terms business model, business idea, business concept, revenue model, or economic model were, according to Magretta (2002) and Rentmeister & Klein (2003), frequently used as synonyms.

In 1995, Slywotzky referred to the business design (model) as the entire system for delivering utility to customers and earning a profit from that activity (Slywotzky, 1995). Dubosson-Torbay, Osterwalder & Pigneur (2002) defined business model as a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenues streams. Nowadays, the concept of business model has been established as a means to explicate how a company can create and capture value from implementing technological innovations (Chesbrough & Rosenbloom, 2002).

In this thesis, we argue that business models are not relevant only to companies but to any organization, public or private, for-profit or not-for-profit, who can create, deliver, and capture value. Therefore, governments can also have a business model since they create and manage public assets with the aim of maximizing gains and return these back to the citizens through further public investments. One way for governments to create value is to stimulate the economy by directly increasing their own expenditure, e.g. by the development of infrastructures.

Two pivotal aspects in the use of infrastructures as a means for value creation are (1) how to finance an infrastructure and (2) how to derive value from it. According to Wagenvoort, de Nicola & Kappeler (2010), infrastructures can be financed by private sources (e.g. a private utility company) and in this case both capital recovery and profits are expected. It can also be funded by a Public Private Partnership (PPP) but as it is noted in (Wagenvoort, de Nicola & Kappeler, 2010), in most PPPs, finance is entirely private and this why this scheme is classified under private sources (see figure 7).

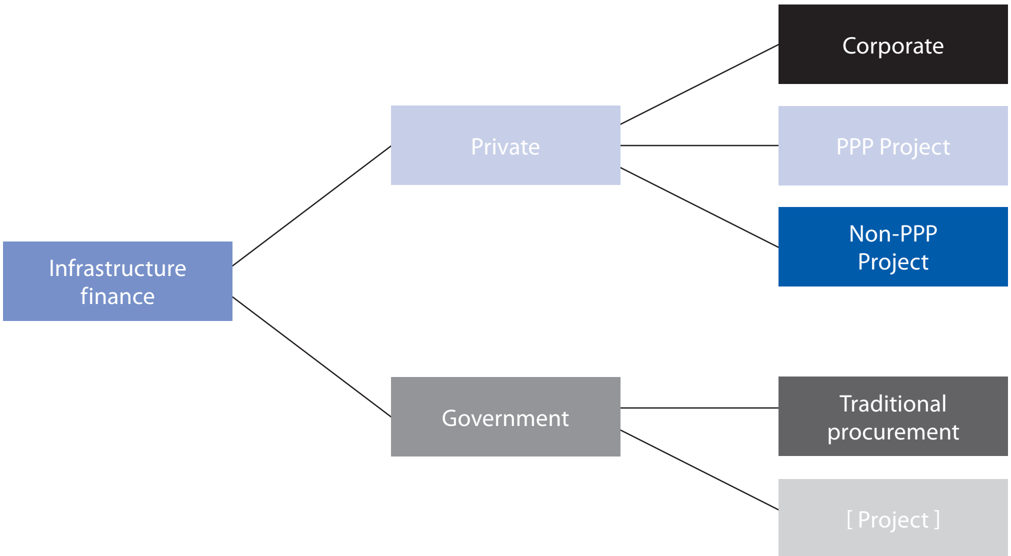


FIGURE 7 Composition of infrastructure finance (Wagenvoort, de Nicola & Kappeler, 2010)

Alternatively, infrastructures can be funded entirely by the public sector i.e. from state or regional budget. In this case, governments must seek appropriate mechanisms for creating value. Typical options include to (a) create a State Owned Corporation (SOC), i.e. a legal entity that is created by the government in order to partake in commercial activities on the government's behalf (e.g. in Finland, Fingrid is an example of such corporation who is responsible for operating of high-voltage power lines), (b) impose a specific tax for the infrastructure (e.g. road taxes), and (c) to treat the infrastructure development as an investment to lay the foundations of short- and long-term growth (Canning & Pedroni, 1999; Fedderke & Bogeti, 2006).

Beginning from the end of the 1980s many studies analyzing the relation between infrastructures endowment and economic development have been realized (Aschauer, 1989; Munnel, 1990; Coen, 2007). Cohen, Freiling & Robinson (2012), suggest that in U.S. economy and in short-run, a dollar spent on infrastructure construction produces roughly double the initial spending in ultimate economic output while in better economic times the return can be larger. For instance, one dollar spent on road construction is distributed to asphalt producers, laborers, providers of heavy construction equipment, etc. These respective recipients then spend money on purchasing inputs, which stimulates further indirect effects on the manufacturing sector, the retail sector, and various other businesses. In the end, one dollar spent in most sectors spreads through the whole economy, indirectly affecting other sectors, and generates greater than one dollar of ultimate economic impact. Cohen, Freiling & Robinson (2012) claim that over a twenty-year period generalized public investment can generate an accumulated $3.21 of economic activity per $1.00 spent, i.e. in the long run, money spent now can produce significant tax revenue returns to the government's budget.

As GNSSs are infrastructures, the above business model related questions (i.e. financing and value derivation) are crucial for them as well.

## 4.2 Galileo

In the beginning, EC had selected a 20-year PPP scheme for the deployment and operation of Galileo where the public sector (i.e., EC & ESA) would be responsible for the first two phases of the project (i.e., definition and development & IOV) and the PPP with a private Galileo concessionaire would be responsible for the other two phases (i.e., deployment and operation). As a dual- use system serving both governmental and mass-market applications, Galileo would be the first PPP ever to be undertaken at EU level and the rationale for the selection of such scheme was driven by the wish to optimize the procurement efficiency, minimize public sector's exposure to risks and to reduce total life-cycle costs by benefiting from private sector's management skills (Bertran & Vidal, 2005). However, in the spring of 2007, the E.U. Transport Commissioner Jacques Barrot claimed that only a publicly funded model could ensure Galileo became operational by 2012 (BBC, 2007, 16. May) and largely due to his efforts the PPP scheme was abandoned. The failure of the PPP funding model was due to several causes, among them the lack of a definite business case upon which companies could base their budget forecast and decide how much to invest, and also the lack of a single strong authority for the management of the program (Nardon, 2007). In result, Galileo has become a 100% publicly funded project.

Even though Galileo is funded from public budget, EU is considering the creation of a Galileo Operating Company (GOC), which can be considered as a state-owned corporation (see Section 4.1). GOC would be responsible for the operation of the system and the generation of revenues from CS. As such, Galileo is the only GNSS that intends to produce direct revenues and especially from the private sector (i.e. from service providers) in the form of payments for accessing CS. According to (EC, 2011), no revenues are expected before the completion of the Galileo constellation insofar as the performances of the initial services offered will not be in line with the expectations of potential users before full deployment of the infrastructures. However, any revenues generated by the operation of Galileo system shall be collected by the Union, paid to the Union budget and allocated to the program. If the income proves to be more than the one required to fund the program exploitation phases then any changes in the budget plan should be approved by the relevant authority (on the basis of a proposal from EC). Moreover, a revenue-sharing mechanism may be provided for in contracts concluded with private sector entities.

In addition to expecting direct revenues coming from CS, EC also focuses on Galileo as an investment into economic growth of the Union. And this is similar to the business models of the other three GNSSs. In terms of market opportunities, according to estimates produced in early 2000, Galileo had the potential to generate €100 billion of accumulated revenues for European companies in the global market for navigation applications in the period 2005-2030 and lead to the creation of as many as 100,000 high-tech jobs across Europe (Pietka & Urrutia, 2010).

The benefits will be directly derived from the growth of the downstream GNSS-based market (see figure 8 and related text for more details); for example, if more planes are equipped with Galileo receivers, additional revenues will be generated by the manufacturers of these receivers. Other direct benefits will results from the growth of the upstream market and technological spillover to other sectors; for example, instruments developed to evaluate and monitor the structural health of launchers or fuel tanks could be used in automotive, constructions, energy and utility companies). Finally, indirect benefits can be derived from the emergence of new applications; for example, safer transport models and more efficient emergency services due to Galileo technology will allow more lives to be saved.

In October 15, 2013, GSA published its third market report on future trends for the GNSS market (GSA, 2013b). According to the GSA Executive Director, Carlo des Dorides, the GNSS market is experiencing rapid development and, despite the recent economic slowdown, and the global installed base of GNSS devices has surpassed two billion units (Europa, 2013, 15. October). Based on this recent report, GNSS-enabled markets are forecast to grow to approximately €250 billion per annum by 2022 and the core revenues are expected to reach over €100 billion in the same time. In the EU-27, shipments of GNSS-enabled devices will grow from €218 million to more than €600 million per annum by 2022 while revenues are expected to more than double over the decade to €24 billion. The growing mobile LBS market, with EU unit (smartphones, tablets, digital cameras, laptops, fitness and people tracking devices) sales projected to reach almost 450 million units by 2017, remains the largest segment.

The GNSS consumer market in the road sector has significantly grown in the last six years with more than 60% per year of growth and prices declining. Within this segment, the EC is also investigating the field of Advanced Driver Assistance Systems (i.e. systems aimed at assisting the driver, examples include collision avoidance systems, intelligent speed adaptation, etc.) using integrity and authentication capabilities brought by Galileo, by coordinating the action for the establishment of a European certification body. Other applications segments are aviation, maritime transport, and precision agriculture.

GNSS represents a long-term growth industry partly due to the openness of end users to adopt new technologies and the availability of skilled human capital and entrepreneurial resources able to exploit the possibilities opened up by GNSS technology (Pietka & Urrutia, 2010). EU is the most important market for GNSS products and services after the United States. Galileo represents an investment in a general-purpose technology that will help to regenerate the European economy however, the regulation on the implementation and exploitation of the Galileo has not been adopted yet but it is currently under discussion at the level of the Budgetary Authority and is subject to the final decision on the content of the next multiannual financial framework (EC, 2013b). Nonetheless, based on the governance structure proposed by the Commission, the European GNSS Agency will become a major stakeholder in the exploitation phase of these programs (EC, 2011).

According to (EC, 2013a), the objective of the exploitation is to provide high quality services to satisfy users' needs and to take all measures for their widest and fastest adoption. An appropriate setting-up of the exploitation is critical to ensure the long term running of Galileo system as well as the maximization of the socio-economic benefits expected from the system. During the exploitation phase, which should start in 2014 with the provision of initial services, the Agency will progressively manage exploitation-related activities under a delegation agreement with the Commission. In addition, the Agency will ensure the coordination of all the tasks relating to the exploitation of Galileo such as maintenance, operations, service provision and the implementation of future system generations by taking into account also the changing operational needs and users' requirements.

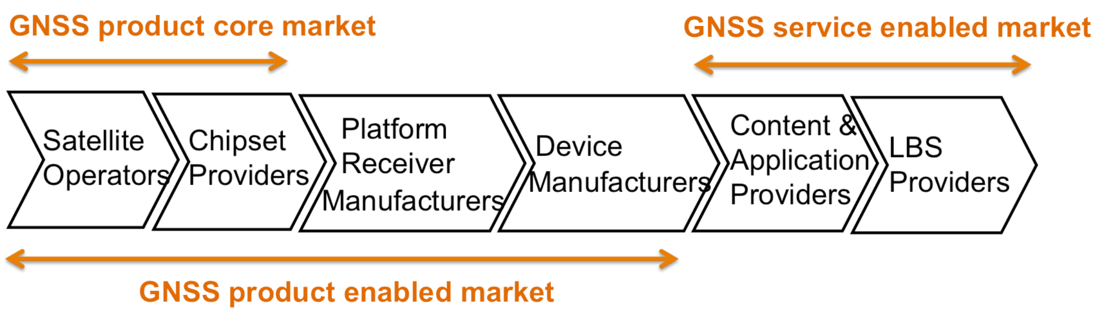

FIGURE 8 Galileo value chain (Dorides, 2009, 6. October)

Figure 8 provides an illustration of Galileo downstream value chain. In particular, the value chain includes the satellite and signal operators as well as the chipset providers (e.g. U-blox) both of which represent the GNSS product core market. In addition to the key stakeholders of the core market, the GNSS product enabled market includes platform receiver manufactures (e.g. ST Microelectronics, Texas Instrument) and device manufacturers (e.g. Garmin, Tomtom). In turn, the GNSS service enabled market consists of content and applications providers (e.g. Navteq, Teleatlas), as well as LBS providers (e.g. mobile network operators, assistant data providers, toll operators, etc.). Mobile LBSs have been recognized as the primary future market for Galileo in terms of the number of users and potential revenues (Ringert et al., 2006).

To foster the development of applications for individual handset and smartphones using Galileo, EC promotes Galileo-enabled chips and handsets through industrial cooperation with GNSS countries and with receiver manufacturers or through funding of R&D projects, e.g. under previous Framework Programs (FPs) and future Horizon2020 program, to reduce the cost of the receivers (Europa, 2013, 5. February). For instance, the FP7-funded project MUGGES aims to design and trial the deployment of a set of new innovative social location-aware mobile user-generated services using GNSS-based "Intelligent Tagging" (MUGGES, 2013). Another FP7-funed project, PERNASVIP, aims at developing a GNSS-based mobility service dedicated to visually disabled pedestrians in urban environment (PERNASVIP, 2013). Moreover, GNSS awareness raising will be promoted through an international Galileo Application forum, the establishment of a virtual information center and with a dedicated action towards SMEs. Synergies will also be sought with other programs such as those run by the European Investment Bank or the Technology Transfer Program from ESA, or with other initiatives such as GMES, GEOSS and telecommunication programs to enhance combined services (Europa, 2013, 2. September). In order to ensure the best return on investment on Galileo program, EC has created a detailed action plan on GNSS applications, including (a) certification, standardization and coordination activities, (b) information dissemination, information exchange, and awareness-raising campaigns, (c) regulatory measures, and (d) "horizontal" actions (EC, 2010).

## 4.3 GPS

All GPS program funding comes from general U.S. tax revenues (USNO, 2013c). The bulk of the program is budgeted through the DoD, which has primary responsibility for developing, acquiring, operating, sustaining, and modernizing GPS. Specifically, U.S. policy assigns the DoD responsibility for funding the extra costs associated with new, civilian GPS upgrades beyond the second and third civil signals. Agencies with unique requirements for GPS are responsible for funding them. The U.S. Congress provided over $1.2 billion to fund the core GPS program in Fiscal Year (FY) 2013, including both military and civil funding. The President's FY 2014 budget request includes nearly $1.3 billion for the GPS program; however, the program is defined differently than in prior years. More information about the funding of the GPS program can be found in (USNO, 2013c).

The commercial uses of GPS are diverse with applications across various industries. Some applications are simple, such as determining a position, whereas others are complex blends of GPS with communications and other technologies. The commercial GPS market has been forecast to reach a value of US$77.7 billion by 2018, primarily driven by restoration of growth fundamentals in logistics and transportation industry and subsequent expansion in commercial vehicle fleet with integrated navigational capabilities (De Angelis, 2012, 7. December). According to a study performed NDP Consulting Group in 2011 (Pham, 2011), the commercial adoption of GPS continues to grow at a high rate and is expected to annually create $122.4 billion in benefits and grow to directly affect more than 5.8 million jobs in the downstream commercial GPS-intensive industries. GPS equipment revenues in North America in the 2005-2010 time period averaged $33.5 billion per year and that commercial sales accounted for 25 percent of the total, while the consumer and military markets respectively made up 59 percent and 16 percent of the total. However, the revenues from GPS equipment sales and services represent only a small portion of the economic benefits of GPS to the U.S. economy. The study makes clear that its analysis is confined to the economic benefits of GPS technology to commercial GPS users and GPS manufacturers, mainly high precision GPS users, and the economic costs of GPS signal degradation to only those sectors. The report therefore does not capture the considerable benefits and costs to consumer users of GPS, other non-commercial users and military users. For instance, GPS manufacturers create employment, provide earnings, add value, and generate tax revenues for governments. Importantly, GPS technology improves productivity and produces cost-savings for end-users.

It is important to mention that although the GPS Standard Positioning Service was originally provided free of direct user charges with the purpose of stimulating the growth of commercial GPS applications and benefiting U.S. as well as the global community of users, in part, the "no-fee" approach was a technical necessity. According to a study performed by RAND Corporation in 1995 (Rand, 1995), this necessity would arise from the nature of GPS signals and the fact that enforcing payments would be difficult or impossible. This policy was also seen as a means of minimizing incentives for the entry of competitors, since it is difficult to compete against a free service. However, almost two decades after this study was made, the GNSS landscape has changed completely; GPS seems to compete with three other global systems which also offer free services but also an enhanced service, CS, which will be offered by Galileo with the purpose of generating direct revenues e.g. from the private sector.

## 4.4 GLONASS

Like GPS, the development of GLONASS has been funded from public budget. Civilian applications of GLONASS technology in Russian Federation produce substantial economic benefits (in excess of 1% of GDP) and enhance the safety and quality of life. Although, Russian industry has developed numerous types of GLONASS and GPS-GLONASS receivers and listed these for sale on the Russian Internet since the mid-1990s, the Russian press reported a lack of demand in early 2000 (Kaplan, 2005). As an attempt to promote GLONASS receivers, in July 2011, Russian Deputy Prime Minister Sergei Ivanov announced a plan to increase the customs duties on imported GPS-enabled devices not receiving GLONASS signals from 5% to 25%. However, almost one year after the announcement, the Eurasian Economic Commission rejected this plan on the basis that such action would contradict with the international obligations of Russia joining the World Trade Organization (WTO) (Toohey, 2012).

In order to provide strong support to GLONASS, several bodies have been created one of which is GLONASS Non-Commercial Partnership or Union (GlonassUnion, 2013a). It is a federal navigation network operator whose objectives are to support legislative development in the field of navigation activities, develop a common technology policy for navigation sector, unit the efforts and combining the resources of public and private sectors for development and adoption of navigation products and services that use GLONASS technology in Russia and abroad, and form a global ecosystem of developers and service and content providers that utilize GLONASS technology.

Another body is the GLONASS/GNSS Forum Association whose mission is to implement a comprehensive plan package for boosting development of GLONASS (AGGF, 2013). The Association unites more than 40 key Russian companies and coordinates organizations engaged in development, production and commercial use of GLONASS-based equipment and applications. It also analyses and selects GLONASS development priorities in Russia, participates in government policy-making in the field of GLONASS commercial use and cooperates with Russian and foreign partners to enhance the investment appeal, material and technical resources and scientific expertise of the Russian companies.

Russian regions account for a large part of GLONASS technology adoption efforts and this is evident in the a 2011 plan that was approved jointly by the Russian Federal Space Agency jointly with the Ministry of Regional Development, and National Navigation Services Provider (GlonassUnion, 2013b). Among others, it is planned to use the public-private partnership model for co-financing regional GLONASS technology implementation using federal, regional, and strategic private investor resources. It is also planned to build municipal transport systems. In fact, the Russian government has also decided that all vehicles transporting passengers, large volumes, or dangerous materials will be required to use GLONASS-supported navigators starting from July 2011 (EWDN, 2011, 15. March). One of the key elements in the 2011 plan was also the building a regional ground-based navigation information system called ERA-GLONASS which is the equivalent of the Emergency Response Service 1-1-2 in U.S. It will serve all roads in the country, and vehicles equipped with GLONASS/GPS navigation communication terminals (at the factory or a certified service center). In event of a traffic accident, the terminal will automatically collect data on its exact location, time, and severity, and transmit it with a high-priority alert to an ERA-GLONASS operator. Once verified, this information is passed on to the emergency response services. ERA-GLONASS will be free of charge and will be commissioned in December 2013 (GlonassUnion, 2013c).

It is worth noting that ERA-GLONASS system is considered also as the basis for rapid, large-scale advancement of GLONASS technology on world market for various reasons. First reason is because automobile transportation is a largest navigation market segment (more than 50%), where the window of opportunity is still open. Second, the national system, based on ERA-GLONASS is a platform for domestic market development, as well as the basis for integrating various government, regional, and industry sector systems: monitoring, road tolling, tachographs, and so on. Third, building systems on the basis of ERA-GLONASS solutions would allow the use of readily available, standardized, and mass-produced onboard equipment. Fourth, automobile transportation systems are highly comprehensive products: they include equipment (chipsets), solutions, services, and building the systems themselves. Fifth, building automobile transportation systems can be supplemented by deploying industry-sector navigation solutions (including high-precision solutions): civil engineering, road construction, agriculture, mineral extraction, and so on (GlonassUnion, 2013c)

## 4.5 Compass

Similar to GPS and Glonass, Compass is a publicly funded project. According to (ChinaDaily, 2012, 27. December), the total output of China's navigation service sector in 2012 topped $19.2 billion. China's government hopes that its language functionality will allow it to grab 70% to 80% of domestic market share away from GPS by 2020, and also allow Compass to gain traction in other Sinophone countries. The goal is to increase the navigation-related industry to over $65.4 billion, popularize Compass in both the national economy and the consumer market, and enhance the international effectiveness of the system. To achieve the goals, the plan lists major projects for the coming years, including creating a system of more than 30 satellites by 2020, creating core technologies in navigation chip production, and spreading the use of Compass products in key fields such as power, communications, banking and public security.

At present, positioning, navigation, timing, short message communications and other services provided by CNSS have been used in transportation, weather forecasting, marine fisheries, forest, surveying and mapping, emergency rescue and many other fields, which has been resulting in significant social and economic benefits. For instance, vehicle navigation terminals based on CNSS technology have already been put into experimental commercial use for mass production and more than 1000 terminals are currently in use in China (Beidou, 2013, 16. May). Moreover, the Ministry of Transport stipulated this year that all bus tour charters and vehicles carrying hazardous materials should install the Compass system. However, according to Hu Gang, vice-president of BDStar Navigation in Beijing, the system was not sold well in the mass market. He claimed that one of the major problems is the system's navigation chips, which are pricier than their overseas counterparts because they are larger and more expensive than similar chips made overseas. Moreover, according to Hu the higher cost of these chips also explains why the Compass system is largely used in military and industry applications and car navigation, which have lower requirements on chip size and power consumption (ChinaDaily, 2013, 11.10.2013).

It is also worth mentioning that China plans to invest another $810 million into Compass. According to ChinaDaily (2013, 2. May), the money will be used to build an industrial park that will house 30 to 50 companies focused on developing an ecosystem for Compass and will have an area especially for foreign companies and institutes to introduce their advanced concepts and technology. According to the article, the Chinese government not only would Compass to eventually dominate China's $19.2 billion navigation service sector, but also sees it as a way to make China's military less dependent on foreign technology. China would also like more companies from the Association of Southeast Asian Nations to participate in the research and development of applications for the country's GNSS, with the aim not only improve information infrastructure in the populous region but also increase the system's international competitiveness (GlobalTimes, 2013, 6. September).

# 5 DESCRIPTION OF PUBLICATIONS

This chapter describes the results of this thesis which are documented in two peer-reviewed publications as well as her contribution to each of these.

## 5.1 Description of publications

### 5.1.1 Publication [P1]

Publication [P1] is entitled as "Has the time to commercialize satellite navigation signals come?" and was published in the IEEE proceedings of 15$^{th}$ International Conference on Intelligence in Next Generation Networks (ICIN) on October 4-7, 2011. It studies the factors contributing to the willingness of service providers to adopt Galileo CS by conducting interviews with various key stakeholders, complemented by desk research (also known as secondary research).

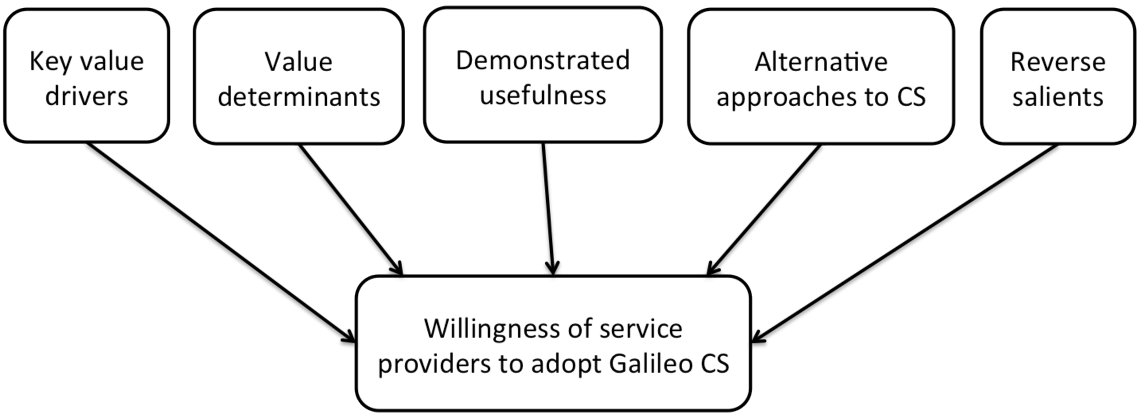


FIGURE 9 Factors contributing to the willingness of service providers to adopt Galileo CS

Based on the interview data, we identified five main factors affecting the willingness to adopt the Galileo CS; shown in figure 9 and described below.

**Key value drivers**

We explicitly asked interviewees to respond to the value they would perceive from the three key value drivers that Galileo CS would provide. Regarding higher positioning accuracy, interviewees propose that this is especially imperative for Business-to-Business (B2B) applications that are safety- or security-critical, and less important for Business-to-Customer (B2C) applications that are non-critical. Some of the interviewees considered positioning accuracy "addictive" and thus the higher the better. Others emphasized that for certain applications, positioning accuracy is not the bottleneck, while real-time positioning is, as illustrated by this quote: "It is a matter of instant satisfaction".

Signal authentication was regarded as a necessary feature for B2B applications and particularly for safety- and business-critical applications in which business or lives depend on GNSS signals. For such niche markets, signal authentication was perceived as the most distinguishing key value driver. On the other hand, for mass market (consumer) applications which are not safety-critical, the possibility to authenticate the signal would bring little if no benefits at all.

Interviewees were most skeptical about the key value driver of service guarantee. While most of them were attracted to the concept of someone being liable for the service offered, some interviewees from the business sector were concerned about the scope and the cost of such guarantees. They feared that in conditions where positioning performance is heavily degraded, such as in extreme weather conditions, during solar storms, or in densely built areas, guarantees would not protect them against such cases, unless they would pay a very high price.

**Other value determinants**

Besides the key value drivers, interviewees proposed several other factors that would positively influence their decision to adopt Galileo CS. The European control of CS platform was considered of strategic importance to gain political independence from the military-controlled GPS. The availability of such commercial service was also regarded as an enabler for new services and applications or as a way to improve existing service offerings. Road tolling was an example of enabled services that was quoted the most. The main principle is that road users are charged based on how much they drive and this information is obtained by employing GNSS receivers that are built into the vehicles. An interviewee from a space agency emphasized that using GNSS for collecting road usage fees is especially advantageous over terrestrial-only or terrestrially supported solutions because it is easier to maintain, update or upgrade. Also, the same interviewee mentioned that a GNSS-based road tolling system would offer certain economic advantages for example, lower investment and maintenance cost than supporting terrestrial infrastructures, such as augmentation systems. In this example of enabled services, an environmental benefit was also recognized in the form of minimizing the traffic disturbance by e.g. reducing the number of the stops a car has to make. The advantage of choosing CS over alternative GNSS-based solutions was identified in the concepts of fraud prevention and reliability, i.e. the probability that a system will perform its intended function satisfactorily or without failure for a specified length of time (Kececioglu, 1991).

Along with road tolling, the following services or applications were mentioned that could benefit from CS platform: tracking of valuable/dangerous goods, land/offshore construction, air traffic management, car parking and sharing, rail track and road lane sensitivity, inland and harbor shipping, maintenance of road infrastructure, fleet management, underground cable positioning, machine control, security services, financial transactions, logistics, agricultural activities, etc. We notice that the value determinants of reliability and safety that were mentioned in connection with the road tolling application were also considered crucial in other applications. As safety is a measure of confidence that the service will not cause accidents, it was found necessary in safety-critical applications, such as in transportation of people or dangerous goods. Reliability was found extremely necessary in financially or security sensitive applications such as bank transactions. Lower outage probability due to better management of the system was also mentioned. Finally, the package of the three key value drivers of CS was seen as strong differentiator over existing services and therefore, could be used as a selling point.

**Demonstrate usefulness**

Besides the key value drivers and the value determinants, an ability to demonstrate the usefulness of CS platform was also found to have a positive influence on the willingness to adopt it. As one interviewee from a space agency said, "At the beginning, the governments would probably be the ones to initially sign up for Galileo CS. This will be also a way to show to other potential customers that such service when deployed, works well; if governments invest in using CS, then this can be a positive sign to the rest".

**Alternative approaches to Galileo CS**

The existence of alternative approaches to CS platform was quoted by almost all interviewees. Specifically, the alternative approaches include accepting the risks and choosing an inferior technology or considering a technology that could provide similar benefits as CS does. The most commonly quoted alternative platform was GPS since this has been the default GNSS in use for the last two decades and its widespread adoption has turned it into a utility. GLONASS was also mentioned as an alternative satellite-based platform. Besides these two systems, the future Galileo OS was also regarded as a strong competitor to CS. OS is intended for mass-market applications and is accessible to any user equipped with a Galileo receiver. However, OS does not offer integrity information and the determination of the quality of the signals will be left entirely to the users. This is also the case with the GPS and GLONASS standard positioning services and even with the future L2C GPS signal (described in Section 3.1.3) which is intended for commercial applications. The main reason why interviewees are in favor of these alternatives is because they are all offered free-of-charge and even if their offerings are much less than of CS, they are willing to compromise.

**Reverse salients**

A negative contribution to the willingness to adopt Galileo CS platform is represented in the concept of reverse salients. Literally, a reverse salient is the inverse of a salient, which depicts the forward protrusion along an object's profile or "a line of battle" (Hughes, 1987). Hence, reverse salients are the backward projections along such continuous lines. In this paper and throughout this thesis, we use this term to describe the system characteristics or the system environment conditions that have a negative impact in the adoption of it.

Some of the main factors identified are trust in GPS continuous operation which undermines the value of service guarantee and the accuracy saturation for certain applications (i.e. higher positioning accuracy is not needed or does not bring any benefit) which in turn, undermines the value of higher positioning accuracy. Also, the imperative need of terrestrial infrastructure for security purposes weakens the value determinant of lower cost than terrestrially-only solutions. The higher cost of CS receivers and the existence of earlier investments also act as opposite forces to the adoption of CS. As one interviewee from a space agency said, "Users employing existing systems won't switch to a new system before they get the return of their investment in the system they use. They will be conservative".

Interviewees were also asked whether they foresee any risks associated with the adoption of CS. The risks mentioned were the possibility CS is not realized or it does not to work as promised or expected. Financial risks are also inherently present. Moreover, some interviewees emphasized their lack of trust in the EU decision making processes, due to e.g. the continuous delays of the program. This may impel service providers to choose an alternative solution from which it would be hard to switch to CS, when it will be available. One interviewee also expressed his belief that Galileo services should be offered for free since Galileo has been a publicly funded program. Finally, being accustomed of using GNSS signals for free was also found as a reverse salient in the willingness to adopt CS.

### 5.1.2 Publication [P2]

Publication [P2] is entitled as "Impact of Galileo commercial service on location-based service providers: business model analysis and policy implications" and was published in the Journal of Location Based Services in December 2012. It extends the work performed in [P1] by synthesizing the related work in business models and discussing the policy implications of Galileo CS. The main contribution of [P2] is raising awareness, among relevant stakeholders, on and bringing insight in how a new technology like Galileo CS may impact the business models of LBS providers across different domains, as well as make recommendations for the future.

Specifically, it was evident that Galileo CS will impact the business models of LBS providers for specific target groups and services only: Galileo CS will mainly add value for business users (e.g. fleet managers and logistics providers) and governments (e.g. road pricing). It was also clear that in order to ensure a competitive positive influence, CS design has to address at least the disadvantages of the existing solutions, such as higher cost (for example, due to the use of proprietary technology), inflexibility and lack of reliability and security.

Overall, we found that LBS providers are reluctant to make any serious preparations for adopting the technology, as they indicate there are too many uncertainties. As Galileo CS will only be available by 2020, various yet unknown technological alternatives may emerge in the meantime. The legal, financial and technical conditions that the EU will impose on using the CS signal as well as the liability chain to support the service guarantee are yet to be defined. LBS providers may adopt a wait-and-see strategy, but on the other hand they could also be more assertive to get a, perhaps temporary, competitive advantage over other LBS providers. A core issue has been whether and when to make end-users aware of the existing and future issues about the security, accuracy and reliability issues that pertain best- effort GPS signal.

As a message for policy makers on Galileo, this article pointed out that the viability of Galileo CS and the possibility to create revenues for its operators should not at all be taken for granted as it is highly uncertain whether LBS providers would adopt CS. This is in line with the recent observations made by the officials in the EU itself (Simon, 2011). To convince LBS providers to adopt Galileo CS, building up trust will be crucial, as interviewed LBS providers were skeptical on the reliability of the offering and EU decision-making processes in general. Providing clarity regarding conditions, contract terms and liability models is crucial to create trust among LBS providers. Another approach to build up trust and reputation may be to get government institutions to adopt the Galileo CS system early on, for example for road tolling applications. One suggestion would be to intensify attempts to involve a broad range of LBS providers and users more intensively in Galileo-related R&D programs of the European Commission and the European Space Agency. LBS providers may find themselves forced to adopt Galileo CS once their competitors start to adopt it. In other words, once a critical mass of LBS providers has adopted Galileo CS, others will have no choice but to adopt it simply to remain competitive. The institution operating Galileo CS may thus try to achieve a critical mass quickly, for example, by applying progressive pricing schemes, in which early adopters get discounts just to get them on board early on.

## 5.2 Author's contribution

The work that led to publications [P1] and [P2] was done during a three-month research visit, between November 2010 and January 2011, at TUDelft, The Netherlands. All the work presented in this thesis has been performed in collaboration with Asst. Prof. Mark de Reuver (TUDelft) and Adj. Prof. Dr. Elena-Simona Lohan (Dept. of Communications Engineering, Tampere University of Technology).

The author of this thesis is the main contributor to [P1] and has greatly contributed to [P2]. Some of the ideas have originated from the discussions with Mark de Reuver and Simona Lohan. Therefore, the author's contribution cannot be completely separated from the contribution of the co-authors. More precisely, in [P1], the author carried out the interviews, performed the qualitative data analysis and wrote most of the article content. [P2] extends the work of the authors' work in [P1]. A large part of this publication was written by the author of this thesis who also acted as the corresponding author during the review and publication processes, even though she is not listed as the first author in the article's author list.

We notice that both of the above publications (i.e. [P1] and [P2]) have been included in this thesis with the permission of their corresponding publisher as well as of the two co-authors, Mark de Reuver and Simona Lohan.

# 6 CONCLUSIONS AND FURTHER RESEARCH

An ever-increasing number of people are using location-based services (LBSs) or applications. This has essentially increased humanity's dependency on positioning information. Apart from the societal, political or privacy issues arising from such dependency there is a growing demand for (a) better positioning performance, especially under poor signal conditions, (b) authentication capability in security and financially critical applications to prevent malicious attacks such as spoofing, as well as (c) service guarantee. These needs have brought GNSS in the center of attention in the circles of both academics and practitioners, since it has been the default positioning technology with global coverage. Specifically, the Galileo Commercial Service is envisaged to meet all above-mentioned needs in exchange for charging a fee to access it. While the materialization of CS could revolutionize the way location information is currently used, it is still highly uncertain whether LBS providers are willing to pay for accessing CS signals. Motivated by the lack of research in this area, this thesis studied the factors contributing to the willingness of service providers to adopt the future Galileo Commercial Service by conducting interviews with various key stakeholders, complemented by secondary research.

Based on the analysis on the interview data, we found that the factors contributing to the willingness of service providers to adopt CS are the (1) key value drivers, i.e. higher positioning accuracy, signal authentication and service guarantee, (2) other value determinants such as novel applications enabled and reliability, (3) demonstrated usefulness, (4) approaches alternative to Galileo CS and (5) reverse salients. Among these factors, demonstrated usefulness and value determinants have clearly a positive impact. On the other hand, reverse salients, such as those associated with service cost and lack of trust in EU decision making, as well as the existence of competing platforms, that are currently inferior but may in the future deliver similar functionality (such as the modernized GPS), negatively affect also the willingness to adopt CS.

In overall, it appears that LBS providers are reluctant to make any serious preparations for adopting this technology, as they indicate there are too many uncertainties. As Galileo CS will only be available by 2020, various yet unknown technological alternatives may emerge in the meantime, which could affect the relative advantage of CS over them. In particular, the issue of relative advantage has a pivotal role in the adoption of innovation (Tornatzky & Klein, 1982; Teng, Grover, & Güttler, 2002). The legal, financial and technical conditions that the EU will impose on using the CS signal as well as the liability chain to support the service guarantee are yet to be defined. In order to increase the chances of CS adoption, we suggest the following actions:

- Clarify the value proposition of Galileo CS as uncertainty about the benefits of a new service could significantly slow down its uptake and raise awareness of it early-on
- Focusing attention on getting governments on board to create trust and reputation for the platform as regulatory environment and governmental institutions could create a powerful effect on CS adoption (e.g. via the ability of a government to "sponsor" it with network effects) or
- Focusing on LBS providers directly by applying e.g. progressive pricing schemes or choosing non-discriminatory pricing schemes.

The message we would like to relay to policy makers on Galileo is that the viability of Galileo CS and the possibility to create revenues for its operators should not at all be taken for granted. However, as in any study that analyses the business impact of a future technology, the results should be interpreted with care. Specifically, as Galileo CS will be launched in about seven years from now, various alternative technologies may emerge that might achieve similar positioning accuracy, signal authentication and reliability. On the other hand, also future events like issues with GPS concerning outages, hacking, spoofing, wars and other unforeseen problems may provide the rationale for adopting Galileo CS. Although the technical specifications of Galileo CS still have to be worked out in detail, our results do pave the way for discussion on the merits of going beyond best-effort GNSS signals by increasing accuracy, security and reliability.

The contributions of a research study can be, according to Hevner et al. (2004), defined by two constituents. The first constituent is the contribution to the archival knowledge base for further research and practice. The second constituent is the applicability of the study results to a business need in an appropriate environment, i.e., how the study aids in solving relevant problems. Based on the above discussion, it becomes clear that this thesis contributes to both. In particular, this thesis contributes to the knowledge base by advancing our understanding about the factors influencing the adoption of Galileo Commercial Service by LBS providers. The importance of such knowledge lies in the fact that up to now, access to satellite navigation signals has been either granted free of charge (e.g. GPS and GLONASS open signals) or restricted to military use (e.g. GPS and GLONASS high precision signals), while CS represents that first attempt of a GNSS operator to charge for accessing satellite navigation signals in exchange for improved performance. Even though this thesis focused on Galileo CS, its results are relevant for any type of GNSS service that offers premium-priced characteristics like improvements in accuracy, security and reliability. Furthermore, this thesis provides recommendations to relevant stakeholders, such as LBS providers, the Galileo operating company, managers and policy makers, by analyzing their business needs and other relevant implications. Thus, this thesis's contribution has also a practical side.

The findings of the thesis also have implications for future research. Specifically future research could explore innovative business models that do not burden rising deficits and maximally stimulate the private sector. These are crucial requirements especially during recessions and difficult economic time periods such as the current one. Further research would also benefit from a wider scale survey of end user perceptions about CS but this should take place later, when the technical aspects of CS as well as the general service offering have been well-defined.

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# PUBLICATIONS

**Publication P1**

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# Has the Time to Commercialize Satellite Navigation Signals Come?

## Business model viability of a Galileo Commercial Service platform

Danai Skournetou, Elena-Simona Lohan
Dept. of Communications Engineering
Tampere University of Technology
Tampere, Finland
Danai.Skournetou@tut.fi
Elena-Simona.Lohan@tut.fi

Mark de Reuver
Faculty of Technology, Policy and Management
Delft University of Technology
Delft, Netherlands
G.A.deReuver@tudelft.nl

***Abstract*—While mobile location based service providers today still depend on the US military controlled GPS system, the European Union is looking to reduce this dependency by launching its own global navigation satellite system, Galileo, which will be fully operational around 2020. Besides the free-of-charge basic signal, a Commercial Service (CS) will be offered at a premium-rate to service providers to provide higher positioning accuracy, signal authentication and service guarantee. However, it is still highly uncertain whether location-based service providers are willing to pay for accessing CS signals. Motivated by the lack of research in this area, this paper analyzes the viability of CS by conducting various interviews with key stakeholders, complemented by desk research. The results indicate that the willingness to adopt CS platform is questionable. It depends greatly on the type of applications of interest, as well as on the existing and future alternative solutions.**

***Keywords- Galileo, Commercial Service; positioning platfrom;***

### I. INTRODUCTION

In today's European mobile market, Location Based Services (LBSs) are omnipresent both in the consumer and in the professional market. The business of European LBS providers largely depends on the Global Positioning System (GPS). Not only is GPS operated under the discretion of the US military, but it also only gives best effort guarantees on accuracy and availability. Fortunately, the European Union is preparing the launch of its own Global Navigation Satellite System (GNSS) platform, Galileo, which is expected to reach full operational capability around 2020 [1].

Galileo will provide basic, free-access signals called Open Service (OS), which may yield better performance in certain environments due to the improved signal characteristics. Still, accuracy will not be a major improvement compared to GPS. Because of this and given that LBS providers increasingly rely on positioning information, the European Union proposes to offer a premium-rate version of Galileo called Galileo Commercial Service (CS). This premium-rate service will enable (1) higher positioning accuracy and (2) signal authentication. The latter is regarded as a security measure against malicious attacks in the form of intentional misguiding (commonly known as spoofing). In addition, it is envisaged that the CS will offer (3) service guarantee [1].

The business case behind the launch of Galileo assumed that part of the investments would be recouped by having service providers pay for the enhanced CS [1]. In other words, CS signals will only be available to service providers who purchase a license to do so from the future Galileo Operating Company (GOC). However, as yet, it is still highly unclear whether LBS providers are in fact interested to pay for accessing CS signals. As far as we are aware, there is no academic research on the business model viability of Galileo CS, which is surprising given (i) the dependence of LBS providers on reliable and accurate positioning information; and (ii) the considerable amount of tax-payers money which has been invested in the Galileo system in the assumption that the CS business model would recoup part of that investment.

Despite the growing academic attention for platform-based business models, there is still considerable ambiguity as to what should be defined as being a platform [12]. In the traditional sense, Galileo CS is not an ICT platform, as applications are not physically running on top of it [12]. On the other hand, Galileo CS does provide generic elements that can be used in a range of location-based services, thus meeting the broader definition from Gawer & Cusumano [3]. In addition, there are elements of two-sidedness, given that not only service providers should adopt Galileo CS but also end-users need devices that are equipped with Galileo chips. We can also foresee platform competition in the future marketplace between GPS, Galileo and Galileo CS [11]. Given these considerations, Galileo CS can be conceptualized as a phenomenon that is at the boundaries of the platform concept, and thus it would be interesting to study how decisions to adopt it by service providers are in line with predictions from platform theory.

Motivated by the lack of research in this area, this paper analyzes the business model viability of Galileo commercial platform. We focus on the service provider willingness to pay for the Galileo CS signal, as this is a conditio sine qua non to have any viable business model for the platform. We analyze how the willingness to pay depends on the key value drivers proposed by Galileo CS, competing platforms like GPS and risks associated with adopting the platform. To study this issue, we conducted 14 semi-structured, in-depth interviews with key stakeholders as well as analyzed secondary data through desk research.

The remainder of this manuscript is organized as follows: Section II describes the method and Section III discusses the results. Section IV draws conclusions and outlines future research directions.

## II. Research Method

Interviews are particularly useful for getting the story behind a participant's experiences as the interviewer can pursue in-depth information around the topic [4]. We conducted 14 semi-structured, in-depth interviews with people who are directly or indirectly involved in the GNSS arena and who represent private or public sectors. More precisely, we interviewed two representatives from EU Commission, four from European space agencies, six from location based service providers and two from research organizations. Typical job descriptions of interviewees include Chief Executive Officer, market monitoring officer, business consultant, project manager or academics.

In the beginning of each interview, we briefly described the Galileo system and the five services that are envisaged to provide. Then, we focused on one of the five services, the CS. We presented the business model idea (i.e., the future Galileo operator will sell the rights to access CS signals to the service providers who will offer CS-enabled services to their customers) and the three key CS features. We also emphasized that very little information about CS is at public's disposal and the technical or business characteristics are yet to be published. We asked the interviewees in what types of services or applications does each of the three key features of CS play an important role and which features are important for professional and non-professional applications. We also asked the interviewees whether they are aware of any alternatives to CS features and if yes, which ones. Finally, we asked the interviewees to identify risks associated with the adoption of CS platform, if any.

The interviewees were allowed to make sidesteps and elaborations and their responses were taped in order to facilitate the transcription process. After the transcriptions were made, we submitted them to the interviewees in order reduce errors and clarify possible misunderstandings. We analyzed the transcripts using Atlas.ti (version 6.2) which is one of the most frequently used software for structuring the qualitative analysis of interview material [6]. The use of a software tool in analyzing qualitative data can reduce analysis time, make procedures more systematic and explicit, and permit flexibility and revision in analysis procedure [5].

An important step in the process of data analysis is the identification and annotation of the various concepts, known as coding. While analyzing the interview transcripts, we focused on the key concepts such as positioning accuracy, signal authentication and service guarantee. However, to prevent premature closure we kept an open mind to explanatory factors beyond the conceptual model and coded them as well, as recommended in [7][8]. After completion of the coding stage, we merged codes referring to similar concepts and removed others that were not considered essential. In order to ensure the applicability of the merging actions, we looked at the quotations attached to each of the codes and checked whether the merged code does indeed describe all the quotations. When the final code list was formed, we identified logical connections between codes and the nature of their relationship. Using one of the Atlas functions, we generated a network of codes which is a visual illustration of the various concepts encountered during the interviews and their interconnections. In order to facilitate the data analysis, we identified categories of codes with common characteristics and grouped them into code families. This structuring not only improves the visual quality of the network by reducing the complexity but also introduces a hierarchy which can serve as a guidance model. Besides network views, we used interesting quotes to support to illustrate the findings.

## III. Results And Discussion

This section presents the results in a top-down approach. We start by identifying the generic factors that were found to contribute to the root concept of this study, the willingness to adopt CS platform. Then, we analyze each factor separately by tracing its connection to other concepts or examples. As the generated code network is very large, the limited space in this paper only permits displaying the higher-level relationships; those relationships omitted are described in text.

Based on the interview data, we identify five main factors affecting the willingness to adopt the Galileo CS, which are illustrated in Figure 1. The two numbers enclosed in curly brackets appearing on the right side of each code indicate the code frequency and the code density, respectively. The former is defined as the number of quotations to which the code is applied and the latter as the number of links to other codes.

### *A. Key value drivers*

We explicitly asked interviewees to respond to the value they would perceive from the three key value drivers that Galileo CS would provide, see Figure 2. Considering the number of quotations, it appears that higher positioning accuracy is the most relevant key value driver, while signal authentication and service guarantee are less crucial.

#### *1) Higher positioning accuracy*

Regarding higher positioning accuracy, interviewees propose that this is especially imperative for Business-to-Business (B2B) applications that are safety- or security-critical, and less important for Business-to-Customer (B2C) applications that are non-critical. Some of the interviewees considered positioning accuracy 'addictive' and thus the higher the better. Others emphasized that for certain applications, positioning accuracy is not the bottleneck, while real-time positioning is, as illustrated by this quote: "*It is a matter of instant satisfaction*".

#### *2) Signal authentication*

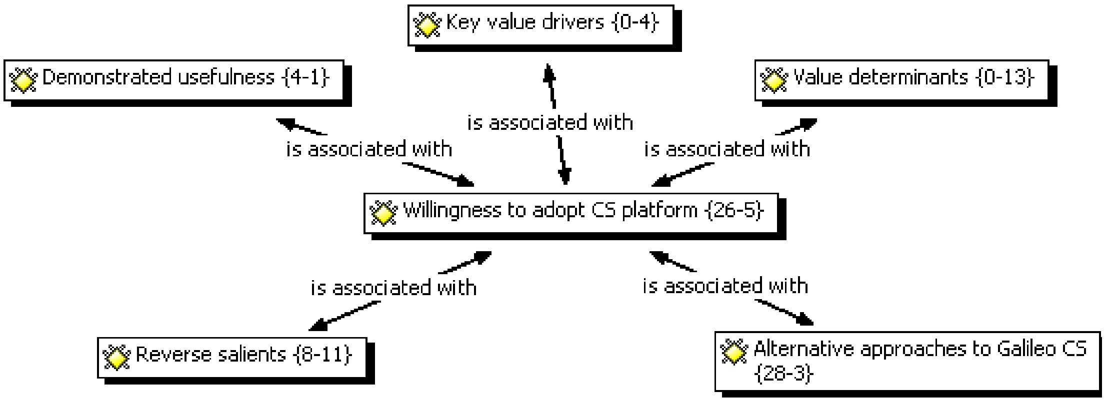


Figure 1. Factors affecting willingness to adopt Galileo CS platform.

Signal authentication was regarded as a necessary feature for B2B applications and particularly for safety- and business-critical applications in which business or lives depend on GNSS signals. For such niche markets, signal authentication was perceived as the most distinguishing key value driver. On the other hand, for mass market (consumer) applications which are not safety-critical, the possibility to authenticate the signal would bring little if no benefits at all.

*3) Service guarantee*

Interviewees were most skeptical about key value driver service guarantee. While most of them were attracted to the concept of someone being liable for the service offered, some interviewees from the business world were concerned about the scope and the cost of such guarantees. They feared that in conditions where positioning performance is heavily degraded, such as in extreme weather conditions, during solar storms or in densely built areas, guarantees wouldn't protect them against such cases, unless they would pay a very high price.

### B. *Other value determinants*

Besides the key value drivers, interviewees proposed several other factors that positively influence their decision to adopt CS, see Figure 3. The European control of CS platform was considered of strategic importance to gain political independence from the military-controlled GPS. The availability of such commercial platform was also regarded as an enabler for new services and applications or as a way to improve existing service offerings. Road tolling was an example of enabled services that was quoted the most. The main principle is that road users are charged based on how much they drive and this information is obtained by employing GNSS receivers that are built into the vehicles. An interviewee coming from a space agency emphasized that using GNSS for collecting road usage fees is especially advantageous over terrestrial-only or terrestrially supported solutions because it is easier to maintain, update or upgrade. Also, the same interviewee mentioned that a GNSS-based road tolling system would offer certain economic advantages for example, lower investment and maintenance cost than supporting terrestrial infrastructures, such as augmentation systems. Also, an environmental benefit was recognized by minimizing the traffic disturbance (for example, by reducing the number of the stops a car has to make). The advantage of choosing CS over alternative GNSS-based solutions was identified in the concepts of reliability and fraud prevention. The former is a measure of confidence that service provides accurate positioning and the latter has is more of a societal benefit.

Along with road tolling, the following services or applications were mentioned that could benefit from CS platform: tracking of valuable/dangerous goods, land/offshore construction, air traffic management, car parking and sharing, rail track and road lane sensitivity, inland and harbor shipping, maintenance of road infrastructure, fleet management, underground cable positioning, machine control, security services, financial transactions, logistics, agricultural activities, etc. We notice that the value determinants of reliability and safety that were mentioned in connection with the road tolling application were also considered crucial in other applications. As safety is a measure of confidence that the service will not cause accidents, it was found necessary in safety-critical applications, such as in transportation of people or dangerous goods. Reliability was found extremely necessary in financially or security sensitive applications such as bank transactions. Lower outage probability due to better management of the system was also mentioned. Finally, the package of the three key value drivers of CS was seen as strong differentiator over existing services and therefore, could be used as a selling point.

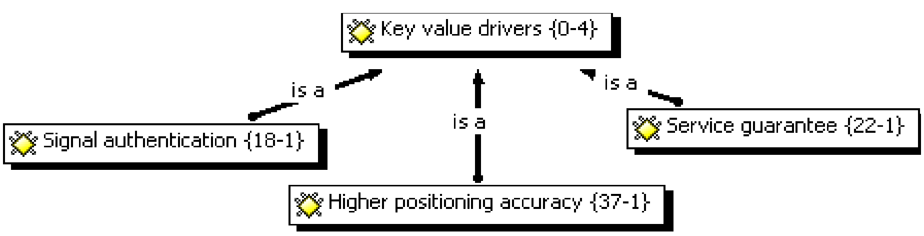


Figure 2. Alternative approaches to Galileo CS platform.

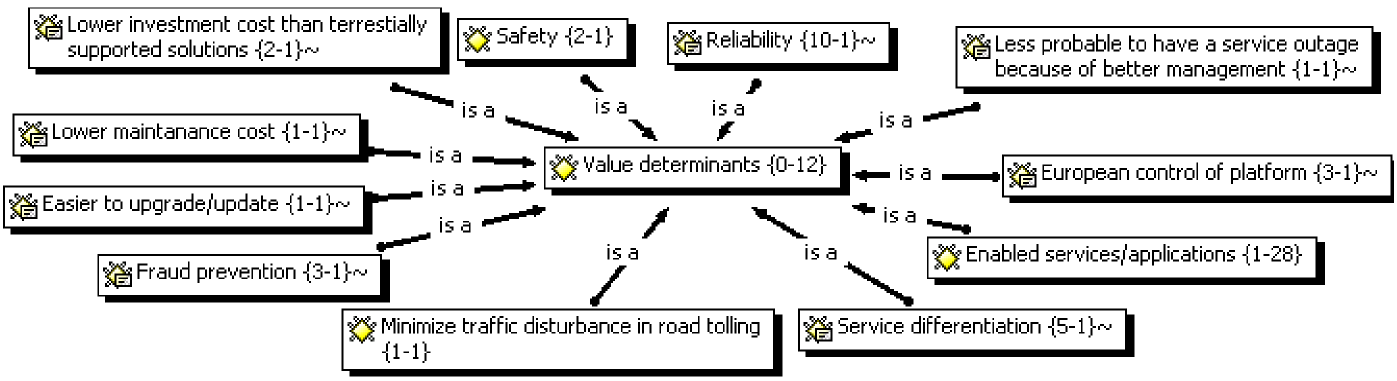


Figure 3. Value determinants of the willingness to adopt CS platform.

*C. Demonstrated usefulness.*

Besides the key value drivers and the value determinants, an ability to demonstrate the usefulness of CS platform was also found to have a positive influence on the willingness to adopt it. As one interviewee from a space agency said, "*At the beginning, the governments would probably be the ones to initially sign up for Galileo CS. This will be also a way to show to other potential customers that such service when deployed, works well; if governments invest in using CS, then this can be a positive sign to the rest.*"

*D. Alternative approaches to Galileo CS*

The existence of alternative approaches to CS platform was quoted by almost all interviewees. As Figure 4 shows, the alternative approaches include accepting the risks and choosing an inferior technology or considering a technology that could provide similar benefits as CS does. The most commonly quoted alternative platform was GPS since this has been the default GNSS in use for the last two decades and its widespread adoption has turned it into a utility. The Russian GLObal NAvigation Satellite System (GLONASS) was also mentioned as an alternative satellite-based platform. GLONASS was fully operational by 1995 but the collapse of Soviet Union significantly delayed the system's continuous operation. Nowadays, the system is operational and GLONASS signals are being used for positioning. Besides the existing GPS and GLONASS system, the future Galileo OS was also regarded as a strong competitor to CS. OS is intended for mass-market applications and is accessible to any user equipped with a receiver, with no authorization required. OS does not offer integrity information and the determination of the quality of the signals will be left entirely to the users, as in the case of the GPS and GLONASS standard positioning service [1]. The main reason why interviewees are in favor of these alternatives is because they are all offered free-of-charge and even if their offerings are much less than of CS, they are willing to compromise.

Besides inferior positioning technologies, interviewees also pointed out various specialized solutions that have already been developed to assure higher positioning accuracy and signal authentication. Among the technologies designed to provide higher positioning accuracy, space-based or ground-based augmentation systems are the most commonly used. An augmentation system consists of a network of earth stations whose exact location is known with great precision. These stations compute their location based on GPS signals and transmit the difference between the computed position and the true one to the users. Then, the user receiver incorporates this difference in the position calculation procedure in order to remove certain error. In that way, higher positioning accuracy is achieved. This method, known also as differential service, was the one quoted the most by the interviewees. Examples of such systems are the U.S. Wide Area Augmentation System (WAAS) and the European Geostationary Navigation Overlay Service (EGNOS). In addition, other methods for achieving higher positioning accuracy are Inertial Navigation System (INS), Real Time Kinematic (RTK) and Precise Point Positioning (PPP) technologies. Regarding alternative technologies for authenticating signals, most interviewees were not aware of any. Nonetheless, two alternative methods were mentioned. The first one was mentioned by an academic and it utilizes existing encrypted signals, such as the GPS military signal or the future Galileo Public Regulated Service (PRS) signals, in order to authenticate unencrypted signals transmitted from the same satellites. The second method is to introduce as much redundancy of reference signals as possible in order to minimize the possibility of intentional misguidance. This method was mentioned by two interviewees who work in a company that provides professional services. Nonetheless, this method is not a direct alternative since it cannot solve the problems related to simulated GNSS signals; instead, it is a way to mitigate the risks associated with unencrypted signals. Apart from the individuals methods for increasing positioning accuracy and authenticating the signal, there were no other methods or services mentioned that would offer all three distinguishing features of the CS. All in all, in applications where higher positioning accuracy is the main or only requirement, the competition among different technologies would be higher simply because there are many options available. In this case, economic solutions will appeal more to price-sensitive customers. In applications where security is very crucial, there are very few alternatives and CS can be a competitive solution due to its higher flexibility. In applications, where liability is necessary, CS would be the only option. Besides the alternatives to individual value drivers, the combined offering of higher positioning accuracy, signal authentication and service guarantee has a vantage point, only

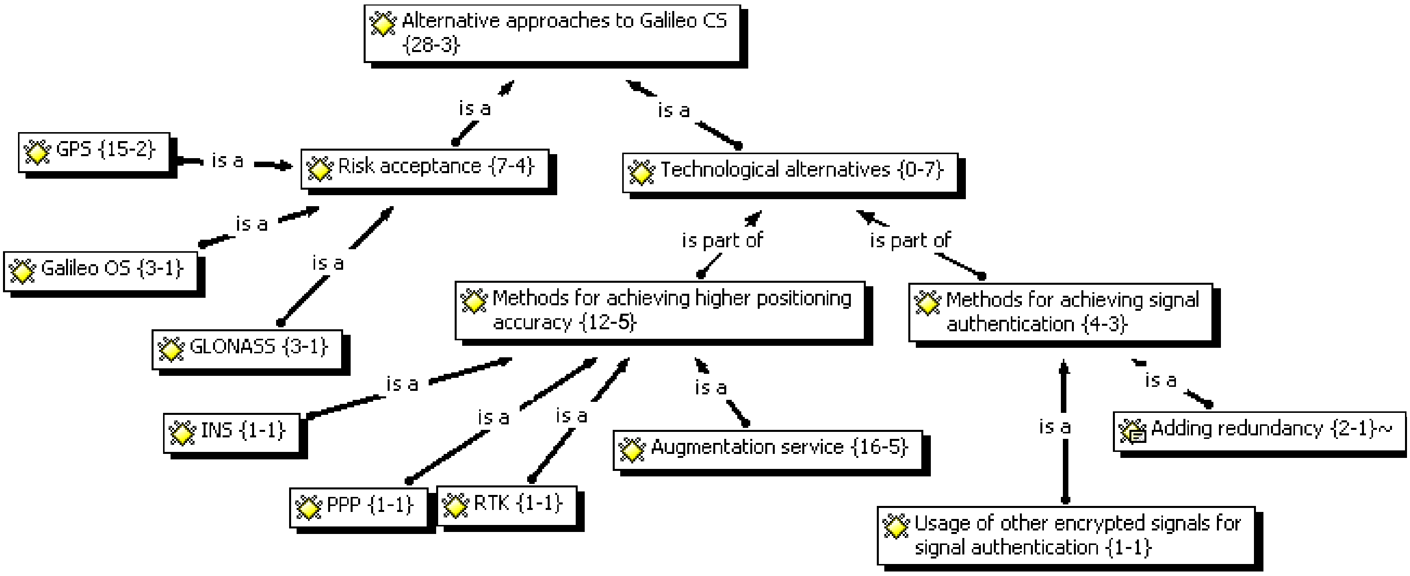


Figure 4. Alternative approaches to Galileo CS platform.

as long as there are applications which would benefit from such mix.

### *E. Reverse salients.*

A negative contribution to the willingness to adopt CS platform is represented in the concept of reverse salients. Literally, a reverse salient is the inverse of a salient, which depicts the forward protrusion along an object's profile or "a line of battle" [9]. Hence, reverse salients are the backward projections along such continuous lines. In this paper, we use this term to describe the system characteristics or the system environment conditions that have a negative impact in the adoption of it. Some of the main factors identified are trust in GPS continuous operation which undermines the value of service guarantee and the accuracy saturation for certain applications (i.e. higher positioning accuracy is not needed or does not bring any benefit) which undermines the value of higher positioning accuracy. Also, the imperative need of terrestrial infrastructure for security purposes weakens the value determinant of lower cost than terrestrially-only solutions. The higher cost of CS receivers and the existence of earlier investments also act as opposite forces to the adoption. As one interviewee from a space agency said, "*Users employing existing systems won't switch to a new system before they get the return of their investment in the system they use. They will be conservative*". Interviewees were also asked whether they foresee any risks associated with the adoption of CS. The risks mentioned were the possibility CS is not realized or it does not to work as promised or expected. Financial risks are also inherently present. Some interviewees also emphasized their lack of trust in the EU decision making process, due to the continuous delays of the program. This may impel service providers to choose an alternative solution from which it would be hard to switch to CS, when it will be available. One interviewee also expressed his belief that Galileo services should be offered for free since Galileo has been a publicly funded program. Finally, being accustomed of using GNSS signals for free was also found as a reverse salient in the willingness to adopt CS.

## IV. Discussion and Conclusions

In order to answer the main research question, whether Galileo CS platform is viable, we need to determine the nature of the influence of the five main factors contributing to the willingness to adopt CS. Demonstrated usefulness and value determinants have clearly a positive impact. On the other hand, reverse salients and the existence of competing platforms that are currently inferior but may in the future deliver similar functionality negatively affect the willingness to adopt CS.

While interpreting the value perceived from CS, the professional markets and mass-market should be distinguished, according to the interview results. If CS is meant to serve professional markets, higher positioning accuracy and signal authentication are not anymore unique value drivers due to the existence of alternative solutions, such as differential services, whose advantages are straightforward: they are already available to the market, businesses have customized them to their needs and users are familiar with them. In order to ensure a competitive positive influence, CS design has at least to address the disadvantages of the existing solutions, such as higher cost (for example, due to the use of proprietary technology), inflexibility and lack of reliability and security. According to some interviewees, certain existing solutions breathe no trust to their customers or offer no liability. For these, service guarantee is an admittedly unique differentiator; however, interviewees found its definition and scope ambiguous. Therefore, the provision of service guarantee requires a clear definition of the "liability chain" and its apportionment to each actor in the value chain [10].

If CS was to serve the mass-market, higher positioning accuracy would be a clear differentiator since there are no alternative technologies developed to address this particular market. Signal authentication may at first seem an unnecessary feature for mass-market applications. However, as the dependence on positioning information increases, and the number of people relying on it is higher, the consequences of a malicious attack are also higher. As one interviewee said, at the

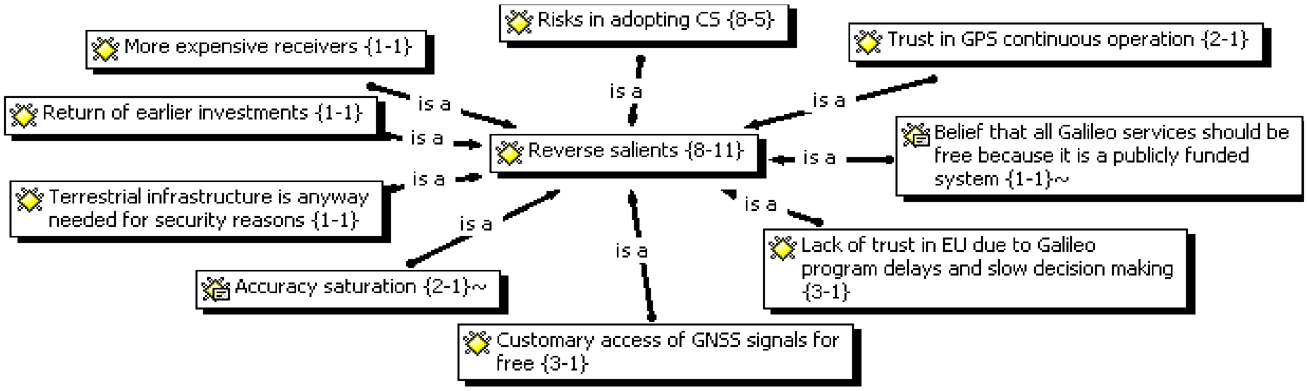


Figure 5. Reverse salients in the willingness to adopt CS platform.

early years of Internet, there were no network-spreading viruses to implicate the users' security. As more and more people started using the Internet, such viruses started being developed and security was jeopardized or breached. All in all, the viability of Galileo CS platform and the possibility to crate revenues for its operators shall not be taken for granted. Instead, the results presented in this paper indicate the willingness to adopt CS is rather questionable and depends on a number of different factors some of whose positive or negative influence is determined by the type of market targeted. Considering the high investment figures and the increasing size of the LBS market, we believe that these issues should gain a closer attention of EU policy makers.

Conceptually, the findings in this case of Galileo CS can be related back to concepts of platforms and platform competition. We find that especially the value that service providers perceive from the platform influences their decision to adopt it, while this is moderated both by the type of services they offer and the target group for the services. In addition, interviewees pointed to the need to demonstrate the usefulness of the platform in government applications, thus stipulating the importance of creating a ′buzz′ in the marketplace [5]. Strikingly, concerns about two-sided markets and critical mass of end-users that adopt Galileo-enabled devices were not mentioned as a reverse salient in the interviews. Apparently, getting the other side of the market on board is not a crucial issue in this case. The case of Galileo CS does illustrate issues of platform competition, especially as they might be fueled by uncertainty about future technological developments.

This paper mainly focused on the willingness to pay for Galileo CS, which is a first condition to build any viable business model. Follow-up research should aim to design a more detailed business model for the platform. While doing so, the specific services and target groups that benefit most from the key value drivers, as identified in this paper, should be the focal points. However, we do point out that designing and testing such business model is challenging considering that the platform will be launched in ten years time from now. Especially given the rapid technological developments to achieve similar positioning accuracy, signal authentication and service guarantee, a scenario approach would be relevant to stress-test the resulting business model.

## V. AKNOWLEDGMENT

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# Impact of Galileo commercial service on location-based service providers: business model analysis and policy implications

Mark de Reuver[a], Danai Skournetou[b]* and Elena-Simona Lohan[c]

[a]*Faculty of Technology, Policy and Management, Technology University of Delft, Delft 2600 GA, The Netherlands;* [b]*bgator Ltd, Hermiankatu 6–8, FI-33720 Tampere, Finland;* [c]*Department of Communications Engineering, Tampere University of Technology, PO Box 553, Tampere FI-33101, Finland*

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Today's mobile location-based services (LBSs) largely depend on a free-of-charge, best-effort positioning technology, called global positioning system, which is controlled by the US military. The European alternative Galileo will not only offer a similar best-effort system by 2020, but also a premium-rate service known as Galileo commercial service (CS). Galileo CS is planned to provide higher positioning accuracy, improved security due to signal authentication and service guarantee. While the technology behind Galileo is often studied, the impact of Galileo CS on the LBS marketplace is rarely discussed. In this article, we fill this gap by analysing how improved accuracy, authentication and service guarantee may impact the business models of LBS providers. We do so by interviewing service providers, policy makers and industry experts on what new services would be enabled; technological alternatives that may emerge in the coming years; and organisational and financial issues that service providers face when adopting such a premium-priced positioning signal. We find that a more accurate, secure and reliable global navigation satellite system signal enables a range of new LBSs, although several alternative technologies are emerging that may make Galileo CS obsolete before it is even launched. To convince the LBS providers to adopt Galileo CS, the institution operating Galileo should get governments on board early on for building trust and should consider progressive pricing schemes. Still, service providers are sceptical about adopting Galileo CS, and the hope to recoup any investments in Galileo may thus be in vain.

**Keywords:** Galileo; location-based services; business models; satellite technologies; GPS



## 1. Introduction

Location-based services (LBSs) are omnipresent, both in the consumer (e.g. navigation services like TomTom) and business market (e.g. fleet management and tracking of dangerous goods). The business of LBS providers largely depends on the global positioning system (GPS), which employs two signals; one free-of-charge signal meant for civilian use and one used by the US military and its allies. Not only is GPS operated under the discretion of the US military, but it also gives only the

*Corresponding author. Email: danai.skournetou@bgator.com

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best-effort guarantees on the accuracy and the availability of the civil signal. The European Union is preparing the launch of its own global navigation satellite system (GNSS) platform, Galileo, which is expected to be fully operational around 2020 (European GNSS Agency 2011).

Galileo will provide basic, free-access signals called open service (OS), which is expected to provide at least comparable performance to the civil GPS signal. In addition, the European Union plans to offer a premium-rate service based on Galileo called Galileo commercial service (CS; European GNSS Agency 2011). The CS signal will occupy the E6 band (1260–1300 MHz) of the radio navigation satellite services frequency band and it consists of two channels: the data channel E6B and the pilot channel E6C. The carrier frequency of E6 signal is at 1278.75 MHz and the receiver reference bandwidth is 40.920 MHz (the corresponding bandwidth of the free GPS signal is 2 MHz). The modulation used is the binary phase shift keying scheme, while the symbol and data rates are 1000 symbols/s and 500 bits/s, respectively. CS will provide several advantages compared to Galileo OS and GPS. First, CS will enable higher positioning accuracy and second, the use of CS will involve an authentication mechanism with which the signal's origin will be authenticated in order to avoid spoofing (i.e. generation of a GNSS like signal with the help of a signal generator to 'confuse' the GNSS receivers and cause erroneous positioning calculation). It is expected that a range code encryption type of authentication (similar to the one used in the military GPS signal) will be used (Barreca 2010). Third, CS will offer service guarantee in order to enhance safety. From a legal point of view, the notion of service guarantee is relying on mechanisms to prevent, inform (offline), alert (online) or compensate failure, disruption, or low performance (Feng 2003).

While the technical implementation of these three advantages of Galileo CS are still under discussion, it does raise the question as to what the added value would be of a GNSS offering better accuracy, authentication and service guarantee than the free GPS signal. While the technological details of Galileo are often discussed in academic work, the business implications for the (mobile) telecommunications sector have not been studied by academics or popular press. We argue that the business impact of Galileo CS is highly relevant, given the sheer size of the LBSs market in the (mobile) telecommunications sector as well as the increased dependence of consumers and business on LBSs for their everyday activities. As far as we are aware, there is only a handful of reports, mainly from consultancies, that give a prediction on the business viability of Galileo CS; for example, a recent study from Helios emphasised that achieving all four objectives (i.e. stimulate the wider GNSS market, deliver a public service, generate commercial revenues and ensure fairness to all) set by EC for CS, equally, in an existing market with competing service providers and products is an extremely difficult task. Moreover, only in the context of a new emerging market and innovative service concept the CS will be able to deliver substantial revenues and user benefits without being overly constrained by issues of fairness (Sage and Mitchell 2010). Motivated by the lack of research in this area, this article analyses how Galileo CS may impact the business models of typical LBS providers. We will structure the discussion along different business model domains (Bouwman *et al*. 2008), including the service domain (i.e. what new services would be enabled by Galileo CS?); technology domain (i.e. what are the merits of Galileo CS compared to emerging technology alternatives); and Organisation/finance domain (i.e. what are organisational issues and financial risks that LBS providers face when adopting Galileo CS). We focus explicitly on Galileo CS, and treat the free-of-charge, best-effort version of Galileo as one of the alternative technologies. To do so, we conducted 14 semi-structured, in-depth interviews with policy makers, service providers and industry experts in 2011.

The main contribution of the article is to raise awareness on and bring insight in how a new technology like Galileo CS may impact the business models of LBS providers. As a secondary contribution, we reflect on whether it is realistic to expect that service providers would be willing to pay for Galileo CS. The latter is crucial for policy makers but also the general public given that large investments are being made in Galileo hoping that they would partly be recouped using the premium-priced signal (European GNSS Agency 2011). While the article focuses on Galileo CS, its results are relevant for any type of GNSS service that offers premium-priced traits like accuracy, security and reliability improvements.

The remainder of this article is organised as follows: Section 2 provides a concise overview of related work on business models for information and communication technology enabled services, focusing on mobile context-aware services. Section 3 describes the method and Section 4 provides the results. Section 5 discusses the results and draws conclusions.



## 2. Related work on business models for LBSs

The concept of business models has been established as a means to explicate how companies can create and capture value from implementing technological innovations (Chesbrough and Rosenbloom 2002). While business models were initially often used in a loose and narrative manner (Magretta 2002), in the recent years, several detailed frameworks have appeared in the literature that provide the key components and variables that comprise business models (Gordijn and Akkermans 2001, Osterwalder and Pigneur 2002, Bouwman *et al*. 2008, Ballon 2009).

Business models have especially gained attention in the domain of mobile telecommunications and mobile Internet services, which is not surprising given the evolving industry structure and technological landscape. Li and Whalley (2002) were very early to discuss the changing role of operators due to vertical disintegration and the subsequent impact on business models in the sector. Recently, the increasing role of device manufacturers and application stores has steered debate on how business models are changing (de Reuver *et al*. 2011, Holzer and Ondrus 2011). Another reason why business models are often discussed in the mobile services domain is due to the struggle of service providers to come up with value-adding and viable mobile services.

With regard to business models for context-aware services, Hegering *et al*. (2004) argue that a non-trivial context-aware service can only be realised by moving beyond the boundaries of single organisations. They advance several management challenges that are specifically relevant when providing context-aware services, such as configuration of the context value chain, error management, accounting, performance (quality of context) and security. Killstrom (2007) suggest four generic business models for context-aware mobile services, i.e. an advertising-based model built around contextual advertising, a mobile extension model that extends the existing business of a company towards the mobile domain, a technology-based model that leverages new context-aware applications and a contextualised content delivery model that delivers content based on user context. All these generic business models are generally complex, as they require the participation of partners providing context as well as content and/or partners from advertising. Bormann *et al*. (2007) discuss business models for local mobile services that enable SMEs in different segments (e.g. health, tourism, publishing and maintenance) to offer their local mobile services via a mobile network infrastructure, while Pawar *et al*. (2008) discuss a business model for context-aware services for mobile virtual communities that exploit the potential of social interaction and context-related information to offer personalised services.

Compared to other business model frameworks (e.g. Gordijn and Akkermans 2001, Osterwalder and Pigneur 2002, Ballon 2009), the framework from Bouwman *et al*. (2008) explicitly includes technology issues that enable a service offering as well as the organisational relationships between multiple actors in the ecosystem. As these elements are core for the present research question, we adopt their framework and define a business model as the way a company intends to create and capture value (Bouwman *et al*. 2008). In their conceptualisation, business models cover four domains: service domain, a description of the value proposition (added value of a service offering) and the market segment at which the offering is aimed; technological domain: a description of the technical functionality required to realise the service offering; organisational domain: a description of the structure of the multi-actor value network required to create and distribute the service offering and to describe the focal firm's position within the value network; and financial domain: a description of the way a value network intends to generate revenues from a particular service offering and of the way risks, investments and revenues are divided among the various actors in a value network. In the context of mobile context-aware services, de Reuver and Haaker (2009) have illustrated the relevance of the above four business model domains for analysing the impact of context-aware technologies in the marketplace. We will, therefore, structure the discussion on the impact of Galileo CS on business models along these four business model domains.



## 3. Research method

Interviews are particularly useful for getting the story behind a participant's experiences as the interviewer can pursue in-depth information around the topic. To determine the number of interviewees, we used the saturation principle (Miles and Hubermann 1994), i.e. we stopped interviewing additional persons if no additional insight was gained. Based thereon, we conducted 14 semi-structured, in-depth interviews with people in the GNSS and LBSs domain, during the spring of 2011. More precisely, we interviewed two representatives from EU Commission, four from European space agencies, six from LBS providers and two from research organisations. Typical job descriptions of interviewees include chief executive officer, market monitoring officer, business consultant and project manager or academics.

In the beginning of each interview, we briefly described the Galileo system. Then, we explained that Galileo CS would be offered at a premium-rate to LBS providers in exchange for improved accuracy, signal authentication and service guarantee. Regarding the service domain of the business model, we asked the interviewees how accuracy, signal authentication and service guarantee would impact their services, and how this would differ across service categories and target groups. Regarding the technology domain, we asked the interviewees whether they are aware of any alternatives to CS features and if yes, which ones. Regarding the organisation and finance domain, we asked the interviewees to identify organisational and financial risks associated with the adoption of CS platform, if any.

The interviewees were allowed to make sidesteps and elaborations and their responses were taped in order to facilitate the transcription process. After the transcriptions were made, we submitted them to the interviewees in order to reduce errors and clarify possible misunderstandings. We analysed the transcripts using Atlas.ti (version 6.2) which is one of the most frequently used software for structuring the qualitative analysis of interview material. The use of a software tool in analysing qualitative data can reduce analysis time, make procedures more systematic and explicit and permit flexibility and revision in analysis procedure (Tesch 1989).

An important step in the process of data analysis is the identification and annotation of the various concepts, known as coding. While analysing the interview transcripts, we focused on the key concepts such as positioning accuracy, signal authentication and service guarantee. However, to prevent premature closure we kept an open mind to explanatory factors beyond the conceptual model and coded them as well (Miles and Huberman 1994). After completion of the coding stage, we merged codes referring to similar concepts and removed others that were not considered essential. In order to ensure the applicability of the merging actions, we looked at the quotations attached to each of the codes and checked whether the merged code does indeed describe all the quotations. When the final code list was formed, we identified logical connections between codes and the nature of their relationship. Using one of the Atlas functions, we generated a network of codes, which is a visual illustration of the various concepts encountered during the interviews and their interconnections. In order to facilitate the data analysis, we identified categories of codes with common characteristics and grouped them into code families. This structuring not only improves the visual quality of the network by reducing the complexity but also introduces a hierarchy, which can serve as a guidance model.

## 4. Results

This section describes the results of the interview analysis by focusing on the impact on services, value propositions and target groups; alternative technologies for Galileo CS; and organisational and financial issues that LBS providers face when adopting Galileo CS. The description of the results is based on the code network, from which views were created to focus on specific business model domains. Where relevant, we provide such views on the code network to illustrate the discussion.

## 4.1. *Service domain: new services, target groups and value propositions*

First, we explore how higher positioning accuracy, signal authentication and service guarantee would change the services and value proposition that LBS providers can offer to their users.

### 4.1.1. *Higher positioning accuracy*

The improvements regarding positioning accuracy were mentioned the most in all interviews (37 times in total). Positioning accuracy is especially an issue in urban areas due to line-of-sight constraints and attenuation. Regarding higher positioning accuracy, interviewees propose that this is especially imperative for business-to-business (B2B) applications that are safety- or security-critical, and less important for business-to-customer applications that are non-critical. Some of the interviewees considered positioning accuracy 'addictive' and thus, the higher the better. Others emphasised that for certain applications, positioning accuracy is not the bottleneck, while real-time positioning is, as illustrated by this quote: 'It is a matter of instant satisfaction'.

### 4.1.2. *Signal authentication*

Signal authentication was regarded as a necessary feature for B2B applications and particularly for safety- and business-critical applications in which business and even lives depend on GNSS signals. For such niche markets, signal authentication was perceived as the most distinguishing key value driver. On the other hand, for mass-market (consumer) applications, the possibility to authenticate the signal would bring little if no benefits at all.

### 4.1.3. *Service guarantee*

Interviewees were most sceptical about key value driver service guarantee. While most of them were attracted to the concept of someone being liable for the service offered, some interviewees from the business world were concerned about the scope and the cost of such guarantees. They feared that in conditions where positioning performance is heavily degraded, such as in extreme weather conditions, during solar storms or in densely built areas, guarantees would not protect anyone against such cases, unless they would pay a very high price. A core issue here is the high level of trust that LBS providers we interviewed have in the continuous operation of GPS, which makes them sceptical as to whether the service guarantee would provide added value for the end-users.

### 4.1.4. *New services enabled by Galileo CS*

The availability of CS was regarded as an enabler for new services and applications or as a way to improve existing service offerings. Road tolling was an example of enabled services that was quoted the most. The main principle is that road users are charged based on how much they drive and this information is obtained by employing GNSS receivers that are built into the vehicles. An interviewee coming from a space agency emphasised that using GNSS for collecting road usage fees is especially advantageous over terrestrial-only or terrestrially supported solutions because it is easier to maintain, update and upgrade. Especially, the proposed reliability and fraud prevention due to signal authentication would make CS more suitable than other GNSS-based services.

Other services that could benefit from CS platform are tracking of valuable/dangerous goods, land/offshore construction, car parking and sharing, rail track and road lane sensitivity, inland and harbour shipping, maintenance of road infrastructure, fleet management, underground cable positioning, machine control, security services, financial transactions, logistics, agricultural activities, etc. Again, especially, reliability and security were the most mentioned regarding these services. Security was found necessary in safety-critical applications, such as in transportation of people or dangerous goods. Reliability was found extremely necessary in financially or security sensitive applications such as bank transactions. Interviewees also expected the CS service to suffer from less outage due to better management of the system, which is partly driven by the service guarantees.



### 4.2. *Technological alternatives to Galileo CS*

Almost all interviewees pointed to various (emerging) alternative technologies for Galileo CS. As Figure 1 shows, alternatives include not only inferior technologies (indicated with the code *risk acceptance* in Figure 1) but also alternative technologies that could provide similar benefits as CS does (*technological alternatives*).

The most commonly quoted alternative technology was GPS since this has been the default GNSS in use for the past two decades and its widespread adoption has turned it into a utility. The Russian GLObal NAvigation Satellite System (GLONASS) was also mentioned as an alternative satellite-based platform. GLONASS was fully operational by 1995 but the collapse of Soviet Union

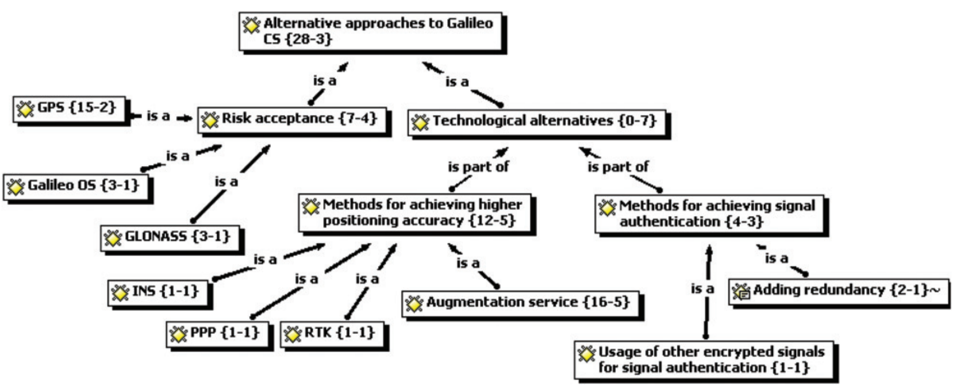


Figure 1. Alternative approaches to Galileo CS platform (number in brackets indicates the number of times mentioned in the interviewees and the number of interrelated codes, respectively).

significantly delayed the system's continuous operation. Nowadays, the system is operational and GLONASS signals are being used for positioning. Besides the existing GPS and GLONASS system, the future Galileo OS was also regarded as a strong competitor to CS. OS is intended for mass-market applications and is accessible to any user equipped with a receiver, with no authorisation required. OS does not offer integrity information and the determination of the quality of the signals will be left entirely to the users, as in the case of the GPS and GLONASS standard positioning service. The main reason why interviewees are in favour of these alternatives is because they are all offered free of charge and even if their offerings are much less than CS, they are willing to compromise and accept the risks.

Besides inferior positioning technologies, interviewees also pointed out various specialised solutions that have already been developed to assure higher positioning accuracy and signal authentication. Among the technologies designed to provide higher positioning accuracy, space-based or ground-based augmentation systems are the most commonly mentioned. An augmentation system consists of a network of earth stations whose exact location is known with great precision. These stations compute their location based on GPS signals and transmit the difference between the computed position and the true one to the users. Then, the user receiver incorporates this difference in the position calculation procedure in order to remove certain error. In that way, higher positioning accuracy is achieved. This method, known also as differential service, was the one quoted the most by the interviewees. Examples of such systems are the US Wide Area Augmentation System and the European Geostationary Navigation Overlay Service. Other methods for achieving higher positioning accuracy are

- Inertial navigation system (INS) – a technique in which measurements provided by accelerometers and gyroscopes are used to track the position and orientation of an object relative to a known starting point, orientation and velocity. INSs are used for the navigation of aircrafts, tactical and strategic missiles, ships, etc. (Woodman 2007).
- Real-time kinematic (RTK) – a *differential GNSS* technique which provides high-positioning performance in the vicinity of a base station. RTK utilises carrier measurements and the transmission of corrections from the base station, whose location is known to the rover receiver, thus the main errors that drive the stand-alone positioning are cancelled out (Hofmann-Wellenhof *et al*. 2003).
- Precise point positioning (PPP) – it requires the availability of precise reference satellite orbit and clock products in real time using a network of GNSS reference stations distributed worldwide. Combining the precise satellite positions and clocks with a dual-frequency GNSS receiver, PPP is able to provide position solutions at centimetre to decimetre level (Laínez Samper *et al*. 2011).
- Receiver autonomous integrity monitoring – a technique that provides integrity using redundant satellites (i.e. beyond the minimum required to estimate the user position) to protect the user against large navigation errors.

Regarding alternative technologies for authenticating signals, two alternative methods were mentioned. The first one utilises existing encrypted signals, such as the GPS military signal or the future Galileo public regulated service signals, in order to authenticate unencrypted signals transmitted from the same satellites. The second method is to introduce as much redundancy of reference signals as possible in order to minimise the possibility of intentional misguidance. The latter method is not a direct alternative since it cannot solve the problems related to simulated GNSS signals; instead, it is a way to mitigate the risks associated with unencrypted signals. Apart from the individual methods for increasing positioning accuracy and authenticating the signal, there were no other methods or services mentioned that would offer all three distinguishing features of CS.

All in all, for services where higher positioning accuracy is the main or only requirement, Galileo CS can be replaced by various technologies that are possibly more cost efficient. In applications where security is very crucial, there are very few alternatives to Galileo CS. In applications, where liability is necessary, the service guarantee from Galileo CS would be the only option. Besides the alternatives to individual value drivers, the combined offering of higher positioning accuracy, signal authentication and service guarantee has a vantage point.

### 4.3. *Organisational and financial issues*

Galileo CS will introduce a number of organisational and financial issues that limit the benefits of the technology for the business model, according to our interviewees. We provide an overview here (Figure 2).

Interviewees were asked whether they foresee any risks associated with the adoption of CS. The risks mentioned were the possibility CS has not realised or it does not work as promised or expected. Some interviewees also emphasised their lack of trust in the EU decision-making process, due to the continuous delays of the Galileo programme. This may impel service providers to choose an alternative solution from which it would be hard to switch to CS, when it will be available. Finally, being accustomed to using GNSS signals for free was also found as a reverse salient in the willingness to adopt CS.

Financial risks are also inherently present. The higher cost of CS receivers and the existence of earlier investments would make the business model of LBS providers less attractive. As one interviewee from a space agency said, ‘Users employing existing systems won’t switch to a new system before they get the return of their investment in the system they use. They will be conservative’. One interviewee also

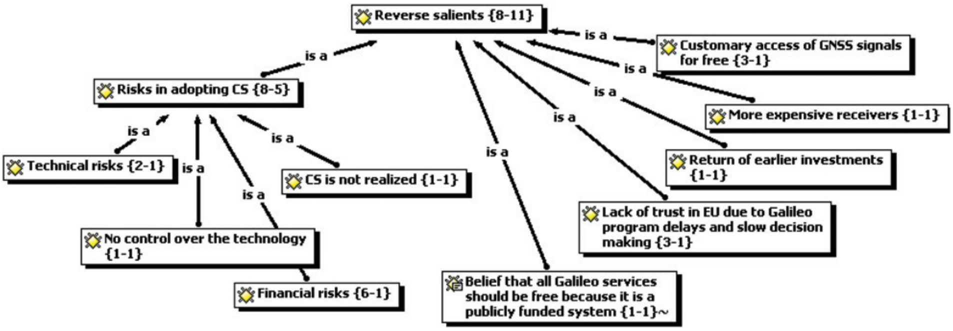


Figure 2. Organisational and financial issues that lead to reverse salients.

expressed his belief that Galileo services should be offered for free since Galileo has been a publicly funded programme.

## 5. Discussion and conclusions

Based on the interview analysis, it is evident that Galileo CS will impact the business models of LBS providers for specific target groups and services only: Galileo CS will mainly add value for business users (e.g. fleet managers and logistics providers) and governments (e.g. road pricing). Still, if CS is meant to serve professional markets, various technological alternatives are available such as differential services, with straightforward advantages: they are already available to the market, businesses have customised them to their needs and users are familiar with them. Based on the interviewees, it is clear that in order to ensure a competitive positive influence, CS design has to address at least the disadvantages of the existing solutions, such as higher cost (for example, due to the use of proprietary technology), inflexibility and lack of reliability and security. Service guarantee is an admittedly unique differentiator according to the interviewees; however, the concept of service guarantee is still ill defined, especially regarding governance, legal and accountability aspects.

If CS was to serve the consumer market, higher positioning accuracy would be a clear differentiator since there are no alternative technologies to address this particular market. Signal authentication seems an unnecessary feature for mass-market applications, although increased dependency on LBSs will increase the consequences of a malicious attack.

Overall, we find that LBS providers are reluctant to make any serious preparations for adopting the technology, as they indicate there are too many uncertainties. As Galileo CS will only be available by 2020, various yet unknown technological alternatives may emerge in the meantime. The legal, financial and technical conditions that the EU will impose on using the CS signal as well as the liability chain to support the service guarantee are yet to be defined. LBS providers may adopt a wait-and-see strategy, but on the other hand they could also be more assertive to get a (perhaps temporary) competitive advantage over other LBS providers. A core issue is whether and when to make end-users aware of the existing and future issues about the security, accuracy and reliability issues that pertain best-effort GPS signal.

As a message for policy makers on Galileo, we point out that the viability of Galileo CS and the possibility to create revenues for its operators should not at all be taken for granted. This is in line with the recent observations made by the officials in the EU itself (Simon 2011). Instead, our findings show that it is highly uncertain whether LBS providers will benefit from Galileo CS. To convince LBS providers to adopt Galileo CS, building up trust will be crucial, as interviewed LBS providers were sceptical on the reliability of the offering and EU decision-making processes in general. Providing clarity regarding conditions, contract terms and liability models is crucial to create trust among LBS providers. Another approach to build up trust and reputation may be to get government institutions to adopt the Galileo CS system early on, for example for road tolling applications. One suggestion would be to intensify attempts to involve a broad range of LBS providers and users more intensively in Galileo-related R&D programmes of the European Commission and the European Space Agency. LBS providers may find themselves forced to adopt Galileo CS once their competitors start to adopt it. In other words, once a critical mass of LBS providers has adopted Galileo CS, others will have no choice but to adopt it simply to remain competitive. The institution operating Galileo CS may thus try to achieve a critical mass quickly, for example, by applying progressive pricing schemes, in which early adopters get discounts just to get them on board early on.

As in any paper that analyses the business impact of a future technology, the results should be interpreted with care. As Galileo CS will be launched in about 10 years from now, various alternative technologies may emerge that might achieve similar positioning accuracy, signal authentication and reliability. However, also future events like issues with GPS concerning outages, hacking, spoofing, wars and other unforeseen problems may change the rationale for adopting Galileo CS. Although the technical specifications of Galileo CS still have to be worked out in detail, our results do pave the way for discussion on the merits of going beyond best-effort GNSS signals by increasing accuracy, security and reliability.



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