Development And Evaluation Of A Business Concept For The Galileo Based Time Synchronisation Services

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Abstract- Galileo is the European Union’s (EU) Global Navigation Satellite System (GNSS) providing accurate timing and positioning information. As GNSS timing and synchronisation is at the core of several critical infrastructures which currently rely on GPS in Europe, using Galileo for time synchronisation is a strategic objective for the EU. Therefore, a business concept for a Galileo based time synchronisation service was developed and evaluated. In this regard, firstly, a service concept for users requiring the accurate synchronisation of remote devices was proposed and assessed. Next, the business logic of the concept was developed and refined by implementing the business model canvas methodology. Finally, a cost-benefit analysis was conducted to determine the conditions under which the service could be financially sustainable. It was found that the proposed service might be both technically feasible and commercially viable. However, the number of service providers in the European market depends on pricing scheme as well as the market penetration rates.

Keywords Galileo, commercial service, time synchronisation, business model canvas, cost-benefit analysis

1. Introduction

This paper presents results of the “Robust European Global Satellite Navigation System (GNSS) Timing Service Project”, which aimed to, among others, develop and evaluate a business concept for time synchronisation services based on the precise time generated by Galileo.

Timing centres around the world maintain closely synchronised or coordinated time scales. Compared to “Greenwich Mean Time” (GMT), which is a name of the time zone, “Coordinated Universal Time” (UTC) is a time standard that is the basis for civil time and time zones worldwide. Various applications including power lines and grids, telecommunications, internet of things in consumer and industrial applications and financial transactions require a reliable and validated source of time synchronism. GNSS systems offer direct and accurate access to UTC as satellites are equipped with atomic clocks of the highest precision and long-term stability. Assuming that a sufficient number of satellites are visible, it is therefore possible to synchronise to these atomic clocks wirelessly from almost anywhere in the world [1].

Galileo is the European Union's (EU) GNSS providing accurate timing and positioning information. As opposed to its military controlled counterparts American GPS and Russian GLONASS, Galileo is specifically designed for civilian purposes. Currently serviced by 18 satellites in orbit, the fully deployed system will involve 24 satellites and 6 spare satellites in 2020 as well as the related ground infrastructure. With the “Declaration of Galileo Initial Services” on 15 December 2016, Galileo officially moved from a testing phase to the provision of three live services: i) open service, ii) public regulated service and iii) search and rescue service. When it reaches to the full operational capacity, Galileo will also offer a commercial service to its users worldwide [2].

The Galileo programme is owned and funded by the EU. The European Commission (EC) has the overall responsibility for the programme and manages the implementation of all activities. Two key objectives regarding the programme are accomplishing technological independence regarding other GNSS systems, and facilitating the development of new products and services based on satellite signals [2]. As GNSS timing and synchronisation is at the core of several critical infrastructures including telecoms, energy and finance which currently rely on GPS in Europe [3], using Galileo for time synchronisation is a strategic objective for the EU.

In this paper, a time synchronisation service concept based on the precise time generated by Galileo was proposed for users requiring the accurate synchronisation of remote devices. Next, since intrinsic value of an innovation remains latent until it is commercialised in some way [4], and the commercialisation as well as its success is shaped by a specific "business model" (BM) [4]–[6], a BM for the aforementioned service concept was systematically designed by using the "business model canvas" (BMC) methodology. Subsequently, a cost-benefit analysis (CBA) was conducted to determine the conditions under which the service concept based on the developed BM could be financially sustainable.

To this end the paper proceeds in the following fashion. In section two, consideration is given to the BM and CBA concepts and in particular to the BM definitions and ontologies including BMC approach. Thereupon, the methodology for the study is explained in section three. Section four describes the proposed service concept while section five provides the developed BM for the concept. In section six, the CBA is conducted. Finally, in section seven, some brief conclusions are given with respect to the study undertaken.

2. Theoretical Background

2.1. The BM Concept

According to [7], the term "BM" was firstly used in an article by Bellman et al. [8] while the first use in the title and abstract of an article was found by Jones [9]. The first definitions regarding the BM also emerged at the end of 1990s [10], especially with the emergence of the Internet and its extensive adoption for e-commerce [11]. Nevertheless, there is no unanimity concerning the definition of the BM [12]–[16], owing to two main reasons. Firstly, the BM concept is somewhat poorly understood, particularly as a research area [17]. Secondly, it draws from and integrates a number of disciplines [5], [16] including organisational design, strategy and entrepreneurship [16]**.** However, one commonality among the definitions is that the concept provides a holistic perspective on business activities by focusing on both the internal and external elements of a business [18]. For example, [19] states that the BM is a description of the value an organisation provides to different customers and the architecture of a company and its network of partners for generating, marketing and delivering this value and relationship capital to create profitable and sustainable revenue streams.

Two approaches in literature might be distinguished for defining the BM: static and transformational [11]. With static approach, a BM synthesises a way of creating value in a business [6], [20], [21], and assists describing how an organisation or business functions and generates revenues [11]. For example, [6] argues that a BM expresses the logic and provides evidences demonstrating how a business creates and delivers value to customers. Similarly, [21] states that a BM is "*the rationale of how an organisation creates, delivers and captures value*". On the other hand, the BM is considered as a concept or a tool to address change and concentrate on innovation, either in the organisation [22], [23], or in the BM itself [24], [25] with transformational approach. This perspective therefore insists that a sustainable BM is seldom found straightaway, but rather entails progressive improvements to create internal consistency and/or to adapt to its external environment.

Owing to the lack of definitional clarity, alternative conceptualizations of BMs also exist resulting in a variety of ontologies and BM representations. Representations in literature can be collected under two research streams. The first research stream comprises a graphical flow perspective of the BM and, thus, the process of value exchange in a business [26]–[29]. A prominent example for this stream is the e3-Value method [26], [27]. The second research stream involves a textual representation of constitutive characteristics of BMs [12], [15], [30]. With this focus, BMs render a system-level holistic overview and emphasise the business logic of an organisation [15]. The most prominent example for this stream is "Business Model Ontology" (BMO) [12], [21], which identifies the BM with regards to four main business areas and associated nine "building blocks", as given below:

- *Customers*: customer segments, customer relationships and distribution channels
- *Offering*: value proposition
- *Infrastructure*: key activities, key resources and key partners
- *Finances:* revenue streams and cost structures

These nine BM building blocks can be captured in a single diagram called "the Business Model Canvas" or BMC, as demonstrated in Figure 1. The BMC, which was developed by [21], is an evolution from the BMO [12]. The BMC can be described as a summary of activities an organisation needs to perform to deliver value to their customers, partners, and stakeholders. It is used regularly in practical contexts and recognised as one of the most well-known tools for systematically developing and improving BMs [31]. For example, the BMC was used in "European field operational test on safe, intelligent and sustainable road operation project" [32] to develop a BM for cooperative intelligent transportation system services.

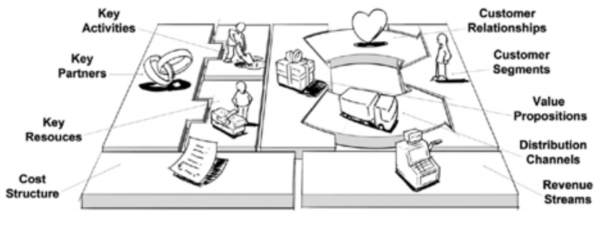

Fig. 1. Business model canvas [21]

2.2. CBA

A successful policy necessitates making investment decisions based on objective and verifiable methods. Economic analysis is frequently used for this purpose. It allows determining whether a specific option is cost-effective (justification/feasibility) and which option yields the greatest overall benefits. CBA is the most widely used ex-ante microeconomic evaluation tool for assessing the welfare benefits of different policy decisions [33] as well as the wider impacts of a policy [33], [34] in order to support the decision making regarding efficient allocation of resources [33], [35].

In the European Context, the Article 18 (thematic concentration) of Regulation (EU) No 1303/2013 states that Member States should focus the European Union (EU) support on actions which bring the highest added value concerning the Europe 2020 priorities of smart, sustainable, and inclusive growth. In this regard, the CBA provides fundamental support in evaluating the contribution of the projects to the realisation of Europe 2020 targets [36].

CBA is based on the Kaldor–Hicks compensation principle of "monetising negative externalities" or "internalising external costs" [33]. According to this principle, an outcome is found more efficient if those that are made better off could in theory compensate those that are made worse off. It has less stringent criteria compared to Pareto efficiency principle which requires making every party involved better off (or at least no worse off). Therefore, it provides an integral overview of the estimated costs and benefits of alternative plans and transforms them as much as possible into monetary terms for comparison [33], [37]. Although there are different approaches for conducting CBA such as the "European Commission´s Guide to CBA of Investment Projects" [36], at the core of the different CBA approaches remain the identification and quantification of total costs and benefits for comparing different options.

3. Methodology

The development and evaluation of a Galileo based synchronisation service concept involved a number of steps, as discussed below.

Development of a service concept: The initial points for developing a business came from the technical and strategical aspects: designing a time synchronisation service concept based on the "Galileo Precise Time Facility" (PTF) as time determination capabilities are inherent to GNSS systems, and it is significant to facilitate the independence from GPS and foster the dissemination of common standardised time and synchronisation services across Europe. The intention was developing a concept which is based not only on the signal in space to calculate the time of each single node and the synchronisation among the nodes as a time difference, but also distributing directly clock corrections parameters with respect to a common reference. To achieve this aim, relevant reference sources and transfer methods for time and frequency were explored. A market analysis study was also conducted to identify and describe different user segments for synchronisation services. Next, a value chain analysis was conducted to analyse and define key actors necessary to introduce synchronisation services. Then, design requirements for a robust service satisfying different user segments were explored. After that, three different service concepts were developed and evaluated based on a number of criteria, including the following: the active role of the synchronisation service provider (SSP), applicability of robustness concepts, the role of the Galileo infrastructure, estimated size of the targeted audience (service users), feasibility of the concept and estimated costs of the service. The evaluation results led to the selection of a final concept. Finally, semi-structured in-depth interviews, which are the most widely used interviewing format for qualitative research [38], were conducted with both potential users and service providers to verify the developed concept. This type of interview was chosen as it is a useful tool for enabling comparison of views of respondents from different backgrounds [39].

Development and adjustment of a BM: The business logic of the developed concept was developed and refined by implementing the BMC methodology [21]. The BMC methodology was chosen as it is used regularly in practical contexts, and its visual and simple-to-use structure aligns with design thinking and managing as designing [40]. By adapting the BMC methodology, the BM was described as an abstract illustration describing various elements and their relationships with each other to elucidate how the SSP generates and captures value [12], [14]. To develop the BM, the technical concept was translated into the language of benefits (value proposition) for various potential customers (customer segments). The other areas of the BMC were then developed based on these areas as they determine the logic of shaping the whole BM [21]. The developed BM was then communicated and refined at the workshop at the "European Frequency and Time Forum (EFTF) Conference" by conducting semi-structured in-depth interviews with external stakeholders.

Assessment of the financial sustainability: A CBA was conducted to determine the conditions under which the service concept based on the developed BM could be financially sustainable. For identifying, estimating and analysing the costs and benefits regarding the service, two key analyses were used for the CBA: i) demand and ii) financial. As the commercial service is expected to be provided when the Galileo programme reaches to full operational capacity in 2020 [2], the service was assumed to be available in 2020 (year 1). Besides, the forecasts regarding aforementioned analyses covered 15 years of time horizon (2020-2035) by considering the EC-proposed reference periods [41].

4. Galileo Time Synchronisation Service Concept

The developed and verified service concept is demonstrated in Figure 2. It is based on the existing functionality of Galileo system and it relies on existing infrastructures for data exchange. As can be seen, all users and the time scale reference organisation are assumed to be equipped with a GNSS timing receiver for the time transfer measurements. The market analysis study revealed that the user related to time synchronisation depend heavily on the applications. A good overview of applications requiring time synchronization can be found in [1], [3]. Moreover, the key performance indicator (KPI) for segmenting the users might be selected in a number of ways, including accuracy, stability, availability, and robustness. The absolute accuracy was selected as the KPI since user requirements for accuracy can be estimated in a relatively straightforward manner.

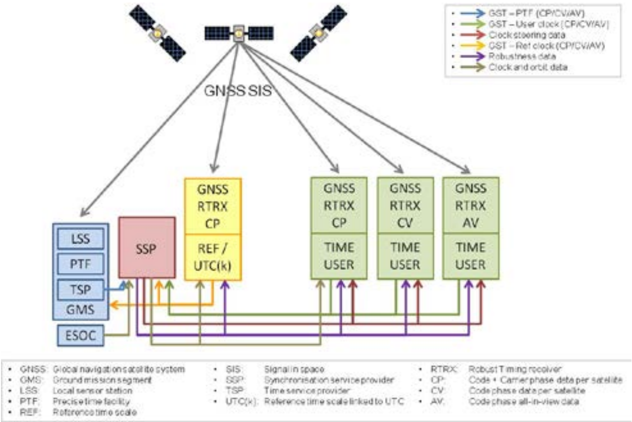

Fig. 2. Time Synchronisation Service Concept

The concept offers three different levels of accuracy (and price), depending on the hardware and time transfer technique, as given below.

- GNSS all-in-view [42]: low-cost simple receiver which is the least accurate
- GNSS common view (code only): more expensive receiver providing more accurate synchronisation
- GNSS precise point positioning (PPP) carrier phase: The most expensive receiver providing the best accuracy

The service concept is flexible since the accuracy of the service and the requirements on the hardware can be tailored to the user's needs. Time synchronisation from the millisecond range to the nanosecond range can be achieved. This makes the concept suitable for a wide range of applications.

The SSP has an active role for the provision of synchronisation services as the SSP collects data from time users and reference laboratory. Assuming that the reference laboratory is equipped with high quality atomic clock and a GNSS receiver capable of receiving both code phase and carrier phase data at multiple frequencies, the SSP will have sufficient reference data for the types of time transfer mentioned above. After gathering the data, the SSP processes the data into clock differences between the user and the reference laboratory. Finally, the SSP sends clock steering parameters back to the user. The SSP might be the same organisation as the reference laboratory or another separate entity. However, the reference laboratory is likely to be a UTC(k) laboratory. The data among SSP, reference laboratory and users is exchanged via Ethernet.

5. Development of a BM

Based on the proposed service concept, a BM for the SSP was systematically designed by using the BMC methodology, as described in the following sub-sections.

5.1. Customer Segments

Customers are the vital part of any business. In order to better satisfy customers, they might be divided into distinct groups or segments with similar requirements, characteristics or behaviours [21]. As discussed before, the absolute accuracy was selected as the KPI. The market analysis study disclosed that three different customer segments for the service concept might be distinguished by considering different performance requirements in terms of time synchronisation service accuracy: milliseconds (ms), microseconds (µs) and nanoseconds (ns).

ms-level time synchronisation accuracy is required for general time stamping applications such as for government bodies (e.g., organisations providing cryptographic time-stamping of legal or financial documents) and some economic transactions. This level of accuracy is also required for synchronising clocks on church towers, railway stations, public buildings, home computers, mobile phones, and tablets.

µs-level time synchronisation accuracy is necessary for time stamping applications such as for telecommunication networks, electric power grids, company computer networks, time stamping authorities, stock exchanges, electronic trading, digital video broadcasting companies and services. Future Smart Grids or energy networks will also require µs-level time synchronisation accuracy to meet e.g., digital sub-station standards (IEC61850), and to allow flexible incorporation of renewable energy sources.

ns-level time synchronisation accuracy is needed for time stamping or frequency distribution/comparison applications, including for scientific users, universities, radio astronomy centres and observatories, best accredited calibration laboratories, and metrology institutes and timing laboratories in developing countries. While current requirements from telecommunication networks and electric power grids are at the µs-level, it is estimated that the requirements for these applications will be tightened to the ns-level in the near future. Future applications of ns-level timing may also include forms of passive-radar, ground-based navigation systems or distributed measurement/control systems.

5.2. Value Proposition

Value proposition describes products and/or services creating value for a specific customer segment. It is located in the centre of the BMC to highlight its significance [21]. The main value proposition for the service was defined as the provision of accurate and traceable time synchronisation to the end user**.**

In the market, the choice of users concerning the synchronisation service depends on the requirements of their applications, including the following: accuracy and availability of the service, metrological traceability to a national or international standard, legal traceability/auditability in accordance with legislations, and costs of equipment, infrastructure, and service.

The accuracy and cost of the service depend on the type of receivers and transfer techniques. Although low-cost time synchronisation services exist in the market such as GNSS time scales, predictions of UTC disseminated by GNSS, and time over Internet using the “network time protocol” (NTP), they are typically not acceptable when either metrological or legal traceability is required. To demonstrate traceability to a recognised time reference, the assistance of a SSP is required. In that context, to satisfy the needs of aforementioned customer segments, three different transfer techniques and hardware were proposed for the service concept, as given below.

- *ms-level time synchronisation accuracy*: GNSS all-in-view; low-cost simple receiver
- *µs-level time synchronisation accuracy*: GNSS common view; more expensive receiver
- *ns-level time synchronisation accuracy:* GNSS PPP carrier phase; the most expensive receiver

In terms of traceability, the service aims to provide turn-key solution for customers in different market segments that have a desire to comply with either technical recommendations or requirements including ITU-T 8272 (Primary Reference Time Clocks) or ITU-T G8272.1 (Enhanced Primary Reference Time Clocks) in the telecom sector, IEC61850 (digital substation standard) in the energy sector, MIFID-2 (Markets in Financial Instruments Directive-2)/RTS-25 regulations in the financial sector as well as ITU-R TF.1876 (Trusted time source for Time Stamp Authority) for e-commerce or legal time-stamping. A good overview of time synchronisation standards can be found in [1], [43]**.** In short, the service provides specialised and not commonly available know-how for time & frequency to the customers. Thus, customers do not need to invest heavily in this area in order to meet regulations/requirements/recommendations.

5.3. Key Activities

Key activities are the most significant internal or external activities that an organisation needs to perform in order to operate successfully. Key activities are strongly related with the key resources and value propositions areas in the BMC [21]. For the service concept, all users and the time scale reference organisation are assumed to be equipped with a GNSS timing receiver for the time transfer measurements. Based on this assumption, key activities for the SPP involve collecting data from time users and reference laboratory, processing the data into clock differences between the user and the reference laboratory, and providing clock steering corrections back to the user.

5.4. Key Partners

Partnerships with other organisations or individuals might support significant activities in a BM. In fact, only a few organisations own all the resources or perform all the activities described by their BMs. Instead, they extend their own capabilities by relying on other organisations to acquire particular resources or perform certain activities [21]. In this regard, the SSP was also designed to be an interface between users and some partners, as given below:

- *Reference station:* It is an organisation, institute or a laboratory maintaining an accurate and stable time scale realisation that will be the source to which the clocks of time users will be synchronised. Examples might be UTC(k) laboratories, the Galileo PTF, calibration laboratories, or other commercial companies owning atomic clocks.
- *National Metrology Institutes (NMIs) and Timing Laboratories:* The legal time in the most European countries is based on UTC(k) and legislated to be derived from the respective national institute or timing laboratory. Those organisations also collaborate with commercial SSPs to find the best approach for UTC dissemination via the Galileo system. NMIs are the most likely candidate for providing a reference station in the service concept.
- *The European Space Agency (ESA):* The agency operates the Galileo PTF, which is the ground reference time system for Galileo, generating “Galileo System Time”. The core task of the facility is the navigation, and it is needed for Galileo spacecraft orbit determination and time synchronisation.
- *The European GNSS Agency:* The agency is responsible for the European GNSS Service Centre providing the single interface between the Galileo system and the users of the “Galileo Open Service” as well as the “Galileo Commercial Service”. While the agency can be a valuable partner (for example in delivering precise orbit and clock information), it is not necessary.

5.5. Key Resources

Key resources are the crucial assets required to implement the BM. They might involve human, financial, material as well as other tangible and intangible resources. Key resources might also be classified as external and internal [21].

The synchronisation service depends on the Galileo technical infrastructure as well as time information provided by key partners. One significant external resource is the information gathered from a reference station as it is crucial for synchronising the users´ clocks. The reference station necessitates at least a time scale realisation based on an atomic clock, a GNSS timing receiver with antenna, a computer for data acquisition with Ethernet connectivity. A typical reference facility would also include at least 2 cesium clocks or hydrogen masers and 2 multi-GNSS constellation, multi-frequency timing receivers. A minimum facility includes at least one rubidium clock, one single-GNSS constellation and single-frequency timing receiver.

Relevant internal resources for the SSP are given below:

- *Local sensor station:* The station obtains the GNSS time data.
- *Human resources:* The operators of the SSP need to have experiences in atomic clock steering

algorithms and they need to be able to interpret GNSS time data.

- *Material resources:* The SSP requires computer servers with Ethernet connectivity. These computers collect GNSS timing data measured by the reference laboratory and users and calculate the difference between the reference clock and the user clock.

5.6. Cost Structures

Cost structures describe all relevant costs incurred to operate a BM such as creating and delivering value, maintaining, generating revenue, etc. While two different BM cost structures that are cost-driven (minimising costs) and value-driven (focussing on value creation) might be recognised, numerous BMs fall in between these two extremes [21]. Related costs for the service include terminal side costs (e.g., cost to equip all new devices with required E-GNSS capabilities including GNSS hardware and/or software requirements), infrastructure costs (specific hardware and software for time synchronisation) as well as costs for SSPs and their operations (equipment, interfaces, staff, and communication links).

5.7. Revenue Streams

The revenue stream comprises the rationality of how to gain profit with the BM. This involves revenue and pricing models for each customer segment, thereby attempting to find a reasonable balance for the exchange. Some of the ways to generate revenue streams could be assets sale, usage fee, subscription fees, lending/renting/leasing, licensing, brokerage fees and advertising. For each revenue stream, different pricing mechanisms might be identified [21].

The market analysis study revealed that users buy their own equipment and use time from freely available time sources such as GNSS or NTP. Some customers also pay for time delivery by "precision time protocol" (PTP) service or periodic "time service bulletin". Current PTP servers typically include a GNSS receiver, and costs range approximately 2000-6000€ or more for high-end models that include rubidium clocks. These units typically do not require a recurring subscription, and firmware/software updates are provided for free for the lifetime of the equipment. Moreover, customers pay subscription fees on a monthly or yearly basis.

A similar approach was developed for the service concept. It was proposed that the customers will pay for the use of dedicated equipment as well as the delivery of accurate and reliable time. Besides, the service will be provided on a subscription-basis (monthly and yearly), where customer Ethernet/Internet connected user-terminals (GNSS-receiver or computer at user premises) will be identified cryptographically and allowed access only when the subscription is paid. The price will be contingent upon the required accuracy and volume. Equipment for subscribing to the service will be either sold directly or leased to the customer. Since GNSS-antenna installations typically need to be made by trained personnel, and antennas need to be installed in suitable locations, this will be sold as a service together with the equipment. Correspondingly, the service requires periodic GNSS receiver calibrations, which will be made by trained personnel for a certain fee.

5.8. Distribution Channels

A distribution channel might be described as a value proposition delivery method for customers. It is recognised as one of the key elements for achieving customer satisfaction. According to [21], distribution channels encompass five distinct phases: "awareness, evaluation, purchase, delivery and after sales". A distribution channel might involve one or more of these phases, and it can be either direct (i.e., in-house sales force or a website) or indirect (e.g., retail stores). Against this background, the distribution channel of the service is described below:

- *Awareness* for the service will be created through conferences, publications, and one-on-one conversations.
- *Evaluation* assisting customers to understand the offered value and benefits regarding the service will be made through a service demonstrator.
- *Purchase* will be provided through a service subscription on monthly/yearly basis. The service might be provided by current PTP-server manufacturers who could package the required software into their products and sell it on a subscription basis.
- *Delivery* of the service will be achieved by installing the dedicated equipment at the user's premises and setting up a GNSS antenna if it is not available. The service also requires the GNSS signals-in-space as one delivery channel and an Ethernet/Internet connection as an additional communications/delivery channel.
- *After sales*, periodic evaluations will be conducted with customers.

5.9. Customer Relationships

Customer relationships are formed between an organisation and its customers. They are motivated by several factors such as customer retention and new customer acquisition. Six types of customer relationships can be recognised: personal assistance, dedicated personal assistance, self-service, automated services, communities and co-creation [21]. For the service concept, customer relationships were characterised as "automated" as the data transfer is achieved over Ethernet. However, GNSS-antenna installations and periodic GNSS receiver calibrations by trained personnel can be defined as dedicated personal assistance.

6. Evaluation and Adjustment of the Developed BM

Based on the above discussed aspects of the BMC and the service concept, the BM for the time synchronisation service was developed, as illustrated in Table 1. As can be seen, key BM mechanics and interactions between elements were highlighted with arrows. The different colours in the canvas also represent different customer segments. As discussed before, three different value propositions were aimed to be delivered to three customer segments by considering their different synchronisation accuracy requirements.

However, since a suitable and sustainable BM is seldom found straightaway, but rather entails progressive improvements [6], [11], the developed BM was communicated, evaluated and further improved by conducting semi-structured in-depth (that is qualitative/informal conversational/guided) interviews with the external stakeholders at the workshop at the EFTF Conference in 2017. The interviewees were defined and chosen intentionally by the project partners. The interviews were conducted based on an interview guide (Table 2), which was developed by considering the previously discussed building blocks of the BMC.

The interview results revealed that there might be limited business opportunities for the lowest performance level of synchronisation since it is provided by NTP which is widely and freely available over the public internet. However, the higher levels of synchronisation offer sufficient added value to create suitable business opportunities. Accordingly, this customer segment and the related value proposition were removed from the BM.

7. CBA for the Developed BM

After developing and evaluating the business logic of the service concept, a CBA was conducted to assess the cost and benefit components of the service provision as well as to determine the conditions under which the service could be financially sustainable, as discussed in the following sub-sections.

7.1. Demand Analysis

Demand analysis recognises the necessity for an investment by evaluating existing and future demand. Several qualitative and quantitative techniques such as multiple regression models, trend extrapolations, Delphi method and expert interviews can be used for this purpose. The decision regarding the most suitable technique depends on several factors including the nature of the good or service, characteristics of the market and reliability of the available data [36].

Table 1. The developed preliminary BM for the time synchronisation service

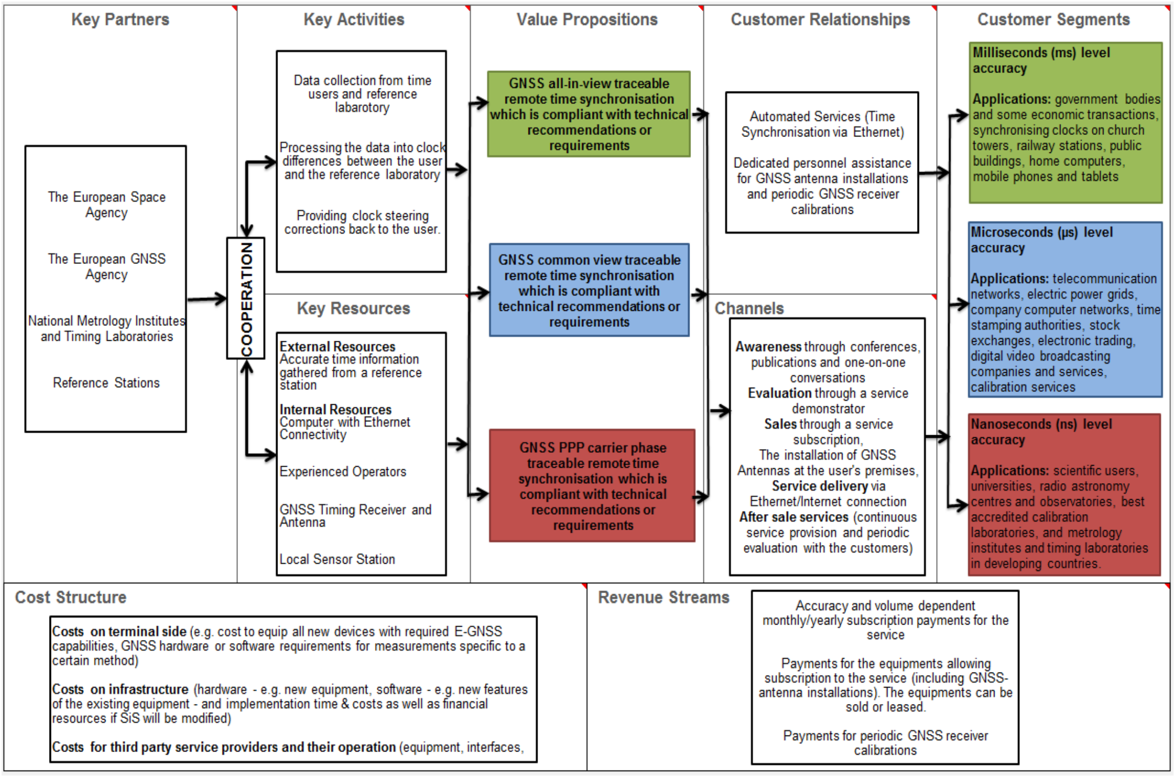

Table 2. Interview guide

Business Model Elements	Questions
Customer Segments	Who are the most important customers for the synchronisation service?
Value proposition	What are the most important existing and emerging requirements of the customers in the time synchronisation market?
Distribution Channels	How can we reach to different customers?
	Through which channels do different customers want to be reached?
Customer Relationships	What type of relationships do different customers expect us to establish and maintain with them?
Revenue Streams	How much do the customers currently pay for a similar service?
	Would the customers prefer purchasing a service based on a monthly or yearly subscription fee?
Key Resources	What kind of key resources are required for delivering the synchronisation service?
Key Partners	Who might be the key partners for delivering the synchronisation service?
	Which key activities can they perform?
Cost structure	What are the most important costs inherent in such a service?

For the project, experiences of the project partners were used as it is a new service concept and there is no previously available demand data. The resulting prognoses were then consulted with experts for a reality check of the initial assumptions. To support forecasting the demand, market analysis study [3] was used. The market analysis study revealed two main trends affecting the GNSS time synchronisation market: i) emerging technologies and their time synchronisation requirements such as Small Cells and 5G for the telecommunications sector, and smart grid development for the energy sector; ii) industry mandates for highly accurate and traceable network time such as MiFID-2.

Some assumptions were also considered to assist demand forecasting, as given below:

- The market demand was forecast based on the number of installed receivers.
- Only Europe was considered for the service. The demand in different countries in Europe was assumed to be directly related with the size of the country in terms of population.
- The demand for customer segment 2 was expected to be between 20 and 50 installed receivers for small countries (in terms of population) such as Finland, and approximately 200 for big countries such as France. This estimate was based on the consultation with power-grid operators in Europe. The demand for customer segment 3 was expected to be between 5 and 30 depending on the size of a country. This was based on an estimate of the number of governmental, industrial and scientific organisations requiring ns-level synchronisation.
- The demand for the receivers in Europe was estimated to reach to peak in 2030 and remain steady during the rest of the considered time horizon owing to the market analysis study results.
- At the beginning of the market entry, a market penetration of approximately 1% was estimated for the SSP. It was also assumed that in 2035, a 10% of the market share can be captured. Consequently, the market penetration rates which are expected to follow a sigmoid curve were determined, as shown in Table 3.

Table 3. Market penetration rates for the service

Year	*Penetration Rates (%)*
2020	1,5
2021	1,71
2022	1,96
2023	2,23
2024	2,54
2025	2,9
2026	3,31
2027	3,77
2028	4,29
2029	4,87
2030	5,54
2031	6,29
2032	7,13
2033	8,08
2034	9,14
2035	10,32

Based on above mentioned criteria, the total market size for two customer segments as well as the demand for the service was forecast, as demonstrated in Table 4 and Table 5 respectively.

Table 4. Market size in Europe

Market Size in Europe based on the number of installed receivers (forecast)																
User Segment	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*2031*	*2032*	*2033*	*2034*	*2035*
µs level accuracy	1792	1803,2	1820	1848	1904	1960	2044	2184	2324	2464	2660	2660	2660	2660	2660	2660
ns level accuracy	314	324,8	336	350	369,6	392	420	462	504	546	588	588	588	588	588	588

Table 5. Demand for the service in Europe

Demand for service providers based on the number of installed receivers (forecast)																
User Segment	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*2031*	*2032*	*2033*	*2034*	*2035*
µs level accuracy	27	31	36	41	48	57	68	82	100	120	147	167	190	215	243	275
ns level accuracy	5	6	7	8	9	11	14	17	22	27	33	37	42	48	54	61

Table 6. Number of customers for the service in Europe

Number of customers for each market segment (forecast)																
User Segment	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*2031*	*2032*	*2033*	*2034*	*2035*
µs level accuracy	14	15	18	21	24	28	34	41	50	60	74	84	95	107	122	137
ns level accuracy	5	6	7	8	9	11	14	17	22	27	33	37	42	48	54	61

For forecasting the number of customers, the following requirements were considered:

- ns-level accuracy synchronisation requires 1 receiver per customer, as further synchronisation to other receivers is typically performed by the customer himself.
- µs-level accuracy synchronisation assumes approximately 2 installed receivers for each customer. In this case, synchronisation is performed by the SSP.

Based upon these requirements, the number of customers for each customer segment was forecast, as illustrated in Table 6.

7.2. Financial Analysis

A financial analysis for the BM was conducted to calculate its financial performance indicators. The first step during the financial analysis was evaluating the amount of total costs and breaking them down over the years. Generally, costs involve investment, and operating and maintenance (O&M) costs. Investment costs can also be analysed under two headings: i) initial investment including the capital costs of all the fixed assets and non-fixed; and ii) replacement costs covering the costs occurring during the reference period to replace short-life equipment. For estimating and calculating these costs, experiences of the project members as well as the sectoral data from experts were considered.

As discussed in section 4.6, costs for the service can be examined in three categories: i) terminal side costs ii) infrastructure costs and iii) costs for SSPs. However, for CBA, only costs for SSPs were considered, as demonstrated in Table 7. This assumes that the user terminal side equipment is either purchased or owned by the user of the service or that the terminal side equipment cost is negligible in the overall CBA.

Table 7. Relevant costs for the service provider

	Cost Categories	*Costs (€)*
Initial Investment	High level atomic clock (optional)	100.000
	Receivers (2)	40.000
	Computer Systems	20.000
	Setting up the room for systems	75.000
O&M	Fiber internet connection from 2 different vendors (per annum (p.a))	25.000
	Energy costs (p.a)	5.000
	Time link with the fiber (p.a)	6.000
	Labour costs (p.a)	240.000

Some of the costs in Table 7 such as costs for atomic clock are only applicable to the new service providers as existing providers already possess them. Besides, it was considered as optional since a service provider with a time link with the fibre does not require an atomic clock. It was thought that a majority of the service providers will consider having time link with the fibre instead of an atomic clock to reduce costs. In terms of replacement costs, it was expected that computer systems and receivers need to be replaced every ten years.

The second step in financial analysis was the calculation of the revenues. To calculate the revenues, firstly a pricing scheme for the service was determined, as given in Table 8. To facilitate the forecasting, only price for yearly subscription was used although monthly subscription is also intended to be provided for the service. Moreover, to accelerate the market penetration, one-time start-up fee was not considered, and fees were kept lower than the market average during 2020-2025 periods and approximately at market average during the rest of the forecasting period. The yearly subscription fee includes technical support, equipment replacement, assembly, testing, and calibration of the system as well as the cost of shipping the system to the subscriber´s site. It was presumed that the price of the GNSS receivers will remain unchanged during the 2020-2035 periods.

Table 8. Pricing scheme for the service

Market Segments	Pricing Scheme for 2020-2025		Pricing Scheme for 2026-2035	
	Fees	Amount (€)	Fees	Amount (€)
µs level accuracy	One-time start-up fee	-	One-time start-up fee	-
	Yearly subscription fee	7700	Yearly subscription fee	10000
	Fee for the equipments allowing service subscription	12500	Fee for the equipments allowing service subscription	12500
	Fee for periodic GNSS receiver calibrations (every 2 years)	750	Fee for periodic GNSS receiver calibrations (every 2 years)	750
ns level accuracy	One-time start-up fee	-	One-time start-up fee	-
	Yearly subscription fee	11000	Yearly subscription fee	15000
	Fee for the equipments allowing service subscription	25000	Fee for the equipments allowing service subscription	25000
	Fee for periodic GNSS receiver calibrations (every 2 years)	750	Fee for periodic GNSS receiver calibrations (every 2 years)	1000

Table 9. FNPV(C) and FRR(C) of the service concept

Inflows and Outflows	NPV (4%)	2020	2021	2022	2023	2024	2025	2026	2027	2035
Investment Cost	-135000	-135000	0	0	0	0	0	0	0	0
Revenues	9729063	155100	292140	231350	270700	301800	354600	572500	698750	2285000
O&M Costs	-3216033	-276000	-276000	-276000	-276000	-276000	-276000	-276000	-276000	-276000
Replacement Costs	-40533	0	0	0	0	0	0	0	0	0
Cash-flow		-255900	-239760	-284410	-289710	-263910	-185310	111190	533940	10625190
FNPV(C)	6337497									
FRR(C)	36.5									

Table 10. Number of providers and financial sustainability

Inflows and Outflows	*1 Provider*	*2 Provider*	*3 Providers*
Investment Cost	-135000	-270000	-405000
Revenues	9729063	9729063	9729063
O&M Costs	-3216033	-6432066	-9648099
Replacement Costs	-40533	-81066	-121599
FNPV(C)	**6337497**	**2945931**	**-445635**

Determination of costs and revenues enabled the assessment of the service concept´s profitability. The adopted financial analysis methodology was the "Discounted Cash Flow (DCF)" method, in compliance with section III of Commission Delegated Regulation No 480/2014 [41]. A 4% "Financial Discount Rate" (FDR) was adopted to calculate the present value of the future cash flows, as suggested by Article 19 of the aforementioned regulation.

To measure the project´s profitability, financial net present value – FNPV(C) - and financial rate of return – FRR(C) - on investment indicators were used. Table 9 illustrates the calculation results for one SSP serving the whole European market whereas Table 10 demonstrates the calculation results for up to three SSPs that serve to the same market. As can be seen, the results indicate that the carrying capacity of the European market for SSPs is two, based on aforementioned assumptions and criteria. Above this limit, it seems that the service will not be financially sustainable.

8. Conclusions

GNSS is commonly used for timing and synchronisation of critical networks. As European critical infrastructures currently rely on GPS for time synchronisation, using Galileo for time synchronisation is a strategic objective for the EU. In that context, a business concept for a Galileo based time synchronisation service was developed and evaluated. Key outcomes for the study include:

- A technically feasible service concept was developed and assessed. The proposed concept is based on the existing functionality of Galileo system and it relies on existing infrastructures for data exchange. Moreover, the concept is flexible as the accuracy of the service and the requirements on the hardware can be tailored to the users´ needs. This makes the concept suitable for several applications.

- The business logic of the concept was systematically developed and refined by implementing the BMC methodology. The developed BM was then evaluated by conducting interviews with experts. The BMC methodology facilitated the BM development and evaluation processes as its visual and straightforward structure aligns with design thinking and managing as designing. While three different value propositions were designed for three customer segments, the interview results disclosed that there might be limited business opportunities for the ms-level time synchronisation accuracy. Therefore, this customer segment and corresponding value proposition were not considered in the final version of the BM. However, as BMs are also subject to innovation, the developed BM should not be considered as a permanent given model.
- A CBA was conducted to determine the conditions under which the service could be financially sustainable. It was found that when market penetration rates of the service are low (1,5% at the market entry (2020) and 10,3% at the end of the forecasting period (2035)), the European market can be profitable for two SSPs even if the pricing scheme is kept lower than the market average. However, to enable several SSPs in the European market, the pricing scheme needs to be kept at least similar to the market average and higher market penetration rates need to be achieved.

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