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EV Charging on Ferries and in Terminals—A Business Model Perspective

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Abstract: Ferry operators in Sweden provide transportation for tens of millions of people annually. As electric vehicles (EVs) are becoming more commonplace, ferries and ferry terminals seem like suitable places for providing charging services. However, high costs and low occupancy rates means that it is challenging to design profitable business models for charging services in general. This paper reports on a market review of the charging services that ferry operators in Sweden provide and a case study of suitable business model design elements for operators that intend to offer charging on board or in terminals. While only two of fifteen ferry operators offer EV charging on board, four more operators indicated that they were planning to provide such services in the near future. Nine operators offered charging in or close to ferry terminals. The results also indicate that business model design focuses primarily on safety, leading to higher costs for onboard charging due to hardware and staffing costs. Investments also tend to incorporate costs which are not specific to onboard charging but rather the general safety requirements associated with EVs. Finally, poor profitability makes future development dependent on managerial efforts to reduce costs and improve revenue as well as supportive policies such as investment subsidies.

Keywords: charging infrastructure; charging services; electric vehicle; business model; ferry operator

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1. Introduction

The electrification of the transport sector is dependent on accessible and appropriately designed charging infrastructure along national and international transport routes [1–3]. However, the rollout of charging infrastructure for electric vehicles (EV) has not met expectations due to lack of demand, technological challenges, and the difficulty of developing attractive business models [4–7]. A business model describes the purpose for being active on a market [8] and explains the resources and processes that must be managed to ensure the commercial success of charging services [9]. It is crucial for long-term competitiveness that the business model is linked to business strategy and the company's ability to effectively arrange and execute business processes [10]. The slow development of EV charging infrastructure indicates that it is difficult to find and implement business models which efficiently support the execution of long-term business strategies.

For charging infrastructure to expand in a profitable manner, it is necessary for managers to understand how business models for charging services function in specific market segments. While charging has historically been done primarily at home the increasing range of EVs means that longer journeys are becoming more feasible. Yet the availability of charging infrastructure is limited across significant swaths of the international transport network. For island nations and in areas with large bodies of water, ferry operators' ability to provide charging services on ferries and in terminals impacts the possibility to use EVs in cross-border trade and for long-distance travel. In Scandinavia, ferry operators began offering charging services early on. However, following a notable vehicle fire in 2010 on board the passenger ship M/S Pearl of Scandinavia, en route between Oslo and Copenhagen, ferry operators embargoed the practice of charging on board [11]. During the past decade, several developments have however revived the interest in providing charging services on board. The fire hazard of EVs has been evaluated and found to be less of a threat than feared, while routines for firefighting and fire prevention have been developed [12]. Electrification has become the main development scenario for a sustainable transport sector. Scandinavian ports are transitioning towards sustainability, increasing the potential for electrification [13,14], and some Scandinavian ferry operators have moved towards sustainable practices by investing in electrification and alternative fuels [15]. The number of ferries that offer charging on board appear limited, but both retro-fitting and orders of vessels with built-in charging capacity on board indicate that the market is about to expand. Furthermore, the growing proportion of EVs in the fleet increases the potential demand and, thus, the possibility of building profitable business models for charging services. In parallel with this development, companies have begun to offer charging services in terminal areas. Hence there is an increased interest in business models that enable the installation of charging infrastructure in the proximity of passenger ferries. While marketing strategies for charging infrastructure have been explored extensively [16], the profitability of charging infrastructure requires further research [7,17]. Additionally, the installation and use of chargers on board passenger ferries is a new and underdeveloped research topic. The purpose of this paper is thus to explore the potential for business models for charging on board and in terminals from the perspective of a ferry operator. By fulfilling the purpose, the paper identifies challenges related to business models for EV charging and potential strategies for actors active in this difficult market segment.

2. Materials and Methods

A literature review was conducted using Web of Science (WoS) and Scopus. The search terms for the literature review were as follows: Article title, Abstract, Keywords ((‘charging infrastructure’ OR ‘electric vehicle charging’) AND (‘business model’)) AND (onboard OR ferry OR ship OR vessel). Despite a considerable number of hits with the combination of charging infrastructure and business models (see Table 1), the added criteria generated zero papers. It is likely that separating the search term ‘electric vehicle charging’ into ‘electric vehicle’ and ‘charging’ would generate more results but that possibility was not pursued.

Table 1. Search terms and results.

Search Terms	Scopus	WoS
((‘charging infrastructure’ OR ‘electric vehicle charging’) AND (‘business model’))	126	22
((‘charging infrastructure’ OR ‘electric vehicle charging’) AND (‘business model’)) AND (onboard OR ferry OR ship OR vessel)	0	0
((‘charging infrastructure’ OR ‘electric vehicle charging’) AND (onboard OR ferry OR ship OR vessel)	48	8
Duplicates removed	15	
Screening elimination	161	
Final selection	28	

The ‘business model’ criterium was removed to identify technological aspects related to charging on board; from those papers, it was thought that aspects related to the business model could be identified. However, in the additional papers, little or no information was found regarding business models for charging infrastructure. Hence, many papers were eliminated in the screening process due to them only mentioning the business model and instead mainly dealing with other topics such as technology, charging behaviour or consumer perceptions. The final review relied primarily on literature dealing with business models designed for onshore charging infrastructure. An internet search using Google was also executed with identical search terms to find supplementary grey literature in the form of reports, news items and blog posts. The final selection of papers and grey literature are presented in the literature review.

2.1. Data Collection

Data were collected (see Table 2) through a web-based review of the charging services linked to passenger ferries in Sweden and through meetings and interviews with industry actors. The study of the Swedish market was conducted by examining offers for charging in terminals and on ferries available on company websites. When needed additional information was obtained via email. Interviews were conducted with one ferry operator and with representatives from three suppliers of charging infrastructure solutions (Marine Charging Point, Chargenode and Hitachi Energy). The interviews dealt with hardware configurations, investment practices, safety issues and business models. In addition, the author participated in a yearlong case study of an international ferry operator's work to design onboard and terminal charging infrastructure. The case study was conducted to better understand a ferry operator's perspectives on the decisions behind investments and business modelling for charging services. The case study involved ten meetings, lasting one to two hours, during which different aspects of business models for charging services were discussed. The workshops were attended by a manager and multiple staff tasked with specific issues such as operations or safety. Furthermore, a final evaluation was conducted with senior managers during which the outcome of the case study was discussed.

Table 2. Observations and method used.

Method of Data Collection	Number of Observations	Type of Respondents
Homepage reviews	15	Ferry operators
Email inquiries	11	Ferry operators
Workshops with the case company	10	Ferry operator
Interviews	4	Equipment manufacturers (3), Ferry operator (1)

2.2. Analysis

The business model canvas was used to structure both the output of the literature review and the results. The business model canvas conceptualises how different assumptions and decisions affect aspects of a business [18] and has been used to portray and evaluate business models for charging infrastructure [19] and shipping [20]. The canvas divides the business model into four sections (offering, customer, infrastructure and financial viability) which, in turn, consist of nine parts (value offering, customer segments, customer relationship, channels, key activities, key resources, key partners, cost structure and revenue streams) [18].

3. Literature Review

Operators of charging infrastructure require attractive business models in order to establish and maintain an accessible and reliable charging network [7,9]. Operators face technological and business model–related choices that influence both the complexity of the solution and the size of the investment [6]. Business models for charging infrastructure contain components that can be combined to fit the local conditions, and identical services can be provided through different business models [21]. Choices regarding technology and business models are thus interconnected. For example, the integration of the EV into the energy system through vehicle-to-grid (V2G) technology is valuable for both the vehicle owner and other actors in the grid due to the potential for systems services [9]. While development enables alternative business models, it also tends to increase complexity. Pioneering solutions such as induction and battery replacement have historically been associated with ventures such as Better Place that exhibited poor commercial performance [7]. Due to technological and business model-related obstacles, such alternatives are not expected to play any major role in future charging infrastructure [22,23].

While there has been no single, clearly defined business model for charging infrastructure [17], studies of specific markets have identified the potential for combinations of business models to support market growth. In the UK, three main business models have been identified for charging infrastructure [24]: (i) a publicly funded business model where the public sector covers some or all of the costs that private actors incur when setting up stations; (ii) a utility-based model where network operators and energy companies set up charging stations and use a tariff-based payment model in which electricity carries the cost of investments; and (iii) an integrated business model where specialists such as vehicle manufacturers, energy companies and charging station hardware manufacturers independently or collaboratively establish stations for selected customer segments. Four key success factors have been identified for the UK market [24]: (i) local demand, (ii) access to power, (iii) the location of the charging station and (iv) the degree of occupancy. Furthermore, since business models and technology develop over time, charging operators must have a strategic perspective regarding the service and pay attention to market developments [24].

What follows is a categorisation of the research and the grey literature on business models for charging infrastructure using the four areas presented in the business model canvas. Due to space constraints, the areas 'offering' and 'customer' have been consolidated.

3.1. Offering and Customer

EV charging by consumers is assumed to take place primarily at home, and the need for expanding the charging infrastructure is thus associated with range anxiety [9,25]. There is a hierarchy of needs in terms of consumer charging preferences, with home charging being the most common preference, followed by charging at the workplace and then at public charging stations [26]. Since demand for charging infrastructure is considered to have a high price elasticity, business models that enable users to easily identify price differences will struggle to compete with home charging [9]. To make charging away from home attractive it is thus important to link charging with other values or services. Key value aspects include simplicity and environmental friendliness [19], and charging infrastructure operators may attempt to differentiate their offerings based on quantitative and qualitative aspects linked to convenience, reliability and cost [24].

As the number of EVs and the vehicle range have increased, the potential for charging services has improved. Nevertheless, availability is a key concern when designing business models for charging infrastructure. There are three categories of access directed to consumers [9]: private, semi-public (restricted access) and public access. The three variants are linked to different requirements for the design of the charging service, such as the ability to handle payment systems or exchange information with other systems in real time, and the type of access thus impact which type of offering and customer the operator may target [9].

Due to differences in climate, charging network characteristics, the composition of the EV fleet in terms of battery capacity, typical driving patterns and drivers' propensity to use fast chargers, consumers' driving habits and attitudes towards services such as fast charging differ between countries [27]. For example, in Northern Europe (i.e., in Norway), charging times vary throughout the year, with the longest average charging (25.3 min) taking place in January and the shortest (19.1 min) in September [27]. Furthermore, due to a habit of driving longer distances, Swedish motorists charge for an extended time and use fast charging to a greater extent than drivers in countries such as Germany [27]. This indicates that ferry operators might see differences in charging behaviour between Swedish customers and customers from the European continent.

3.2. Infrastructure

Several actors play a role in the establishment of EV charging infrastructure, yet the exact arrangement varies between countries and markets [17]. Operators need to decide which activities and resources to handle internally and identify which actors can produce services or components with the desired quality and price. Due to their monopolist status, local grid owners influence both access to power and the cost of installation [28]. When establishing large-scale systems, the transmission system operator (TSO) may play an important role to ensure access to power and the TSO may also compensate the operator for services provided by connected vehicles [28]. The electricity supplier is essential to minimise cost and ensure that specifications regarding the origin or environmental impact of electricity are met [28]. If the operator does not own the property where the charging infrastructure is installed, the property owner will also play an important role in designing and operating sustainable transport solutions [28,29]. It is possible that actors such as vehicle manufacturers or owners of other charging networks may act as intermediaries between the customer and the operator [28]. Other significant actors such as suppliers of charging infrastructure solutions, original equipment manufacturers (OEM) and local contractors provide the charging operator with hardware and services [17]. Technological solutions may enable the switching of roles, or introduction of new players, in the constellation of actors that provide a charging service. For example, the installation of solar cells enables an operator to sell electricity via the grid, ensures a green profile and may provide access to alternative financing [30]. Collective ownership of a charging station may also decrease risk exposure and cost while increasing the number of potential users [31]. Actors may also change responsibilities for the charging service, taking responsibility for parts or as exemplified by Tesla's Supercharger network, all of the service content [21,23].

For those doing long-distance journeys to ports, the location of the charging infrastructure will impact the viability of heavy-duty EVs [32]. There are considerable differences in hardware requirements when providing charging to consumer vehicles versus heavy EVs [33]. For a heavy electric vehicle with a 1000 kWh battery, charging takes 20 h using a level 3 charger with >25 kW output [34]. Raising the power output to reduce charging time puts additional pressure on the grid and requires technological solutions which increases costs. The charging of heavy vehicles may also pose additional challenges, such as providing access and power during irregular hours in order to meet demand [35]. Hence, the charging of heavy-duty EVs appear unattractive on ferries but possible in terminals with access to power.

3.3. Economic Viability

Differences in investment and operating costs between normal and fast charging make it necessary to adapt both hardware and business model for the specific charging scenario [17,36]. In a review from the UK covering 2015–2017, the difference in cost between a slow wall charger and the fastest type of charger was as high as 30 times, necessitating careful consideration of how much power is needed [37]. Component shortages and high demand during the pandemic have further affected prices globally [38]. It is suggested that businesses that invest in normal and semi-fast charging should utilise alternative revenue streams to support their business model, while those that operate fast chargers should instead focus on securing access to power while guaranteeing an attractive price to customers [24].

Cost modelling for charging infrastructure indicates that the utilisation rate is crucial for achieving profitability. It is, therefore, important to have access to a large group of potential users or plan the location of the charging station to match driving patterns [39].

Construction costs for fast chargers encompass the design and preparation, the station itself, the delivery and installation and upgrades to the local grid [36]. Operating costs include electricity, space, administration, maintenance and services linked to unforeseen events [36]. The operator should also account for the equipment's residual value, appropriate discount rate, forecast inflation, possible occupancy rates, and forecast revenues based on price models and pricing [36]. It is possible to identify important risk factors such as the number of EVs in the vehicle fleet or the proportion of vehicles expected to use the specific charging service [36]. While hardware and labour constitute a significant part of the cost of setting up a charging network, soft costs (i.e., alternative costs, marketing and permit processes) are considered the most problematic for operators. Soft costs often result in delays in establishing the infrastructure, yet they are also likely to be easier to address than other costs [40]. The operator may reduce costs by [40]: procuring strategically and at scale; installing hardware during construction; assessing locations carefully and considering how conduits can be run efficiently; reviewing the costs and needs linked to data management and communication; focusing on standardised solutions; working proactively in the permitting process; and linking business risks to business and pricing model elements. Hence, if a port terminal or a ferry is being electrified and the grid capacity is improved, an investment in charging infrastructure can be added to both lower the total cost and potentially enable alternative revenue flows by providing services linked to load management through peak shaving and energy storage [41–43].

To convert customer value into cash flows, the business model must focus on the values that are most important for customers, i.e. convenience, reliability and cost [24]. The International Council on Clean Transportation (ICCT) lists four general offerings for charging infrastructure business models [21]: (i) a basic model that offers electricity with a price premium in comparison with what can be obtained for home charging, (ii) an alternative cost model that accounts for the cost-per-kilometre of traditional fuels (and is thus especially appropriate in markets that have fossil fuel taxes), (iii) a perspective that views charging as an opportunity to prompt customers to spend both more time and money at the charging station and (iv) a plan to utilise advertising revenue to subsidized or pay for the charging service. Considering that sales on board may generate 30–55% of total revenues for cruise ferries and 20–30% for ro-pax [44], additional sales and ad revenues may contribute to the profitability of charging services.

Since profits arise mainly from the price margin on electricity and cost-reducing subsidies, price and capacity are the two central factors for operators to decide on [45]. Pricing and payment models are thus central to the profitability of charging services [17]. Pricing can be designed to incentivise behaviour that is in line with the operator's needs [45]. The customer's desire for simplicity and flexibility in payment systems may however increase complexity for the charging operator [37]. Swedish property owners utilize four main approaches to consumer-oriented pricing [46]: (i) free charging, (ii) standardized cost including electricity, (iii) pay per hour and (iv) pay per kWh. A third party can also offer the service. Thus, a parking area could be rented out to a charging operator that makes the necessary investments and who oversees arrangements with customers and the network owner [46].

In the long run factors that are beyond the control of the charging operator may greatly impact the profitability of charging services. Regulatory change, consumer trends and technological progress, both in terms of vehicles and charging infrastructure, affect profitability and render future market developments difficult to predict [45]. However, establishing charging infrastructure stimulates a positive feedback loop of increased electrification and market growth [47].

4. Results

The Swedish passenger ferry market is part of the Scandinavian and Baltic markets. Swedish members of the passenger ferry organisation, which represent 95% of all ferry traffic to and from Sweden, transport up to 25 million people per year to and from Sweden [48]. To gain an understanding of the Swedish market and the potential business models, an inventory was made of the offers available in the parts of the Scandinavian and Baltic markets that intersect with the Swedish market. Table 3 lists the offerings in terms of prices and charging possibilities in the terminal and on board as of January 2022.

Table 3. Ferry operators' charging services.

Operator	Vessel Type(s)	Example Routes	Charging in Terminal	Charging on Board
DFDS	Ro-Pax	Karlshamn–Klaipeda, Köpenhamn–Oslo	Offered in a small number of terminals.	Not available but under development.
Finnlines	Ro-Pax	Travemünde-Malmö, Kapellskär-Naantali	Two stations in Travemünde and one in Helsinki.	Not available.
Fjordline	Ro-Pax, High-speed ferry	Hirtshals-Langesund, Hirtshals-Bergen, Sandefjord-Strömstad	Offered in Hirtshals in collaboration with Bee Charging Solutions.	Available on Fjord FSTR. Price €13.
ForSea	Road ferry	Helsingborg-Helsingör	Five fast chargers are offered in the port of Helsingör in collaboration with Bee Charging Solutions.	Not available.
Färjerederiet	Road ferry	Short routes mainly around Stockholm and Gothenburg	Not available but is under development in a handful of locations.	Not available.
Molslinjen	High-speed ferry, Ro-Pax	Ystad-Bornholm	Not available.	High speed ferries: Express & Max—Ystad-Rönne. Price €13.30.
Polferries	Ro-Pax	Gdańsk—Nynäshamn, Ystad- Świnoujście,	Not available.	Not available.
Rederi AB Gotland	High-speed ferry, Ro-Pax	Visby-Nynäshamn/Oskarshamn	Offered in collaboration with Bee Charging Solutions, €0.50 per kWh, in Nynäshamn and Oskarshamn.	Installed in M/S Visborg but not in use.
Scandlines	Ro-Pax	Rödby-Puttgarden, Gedser-Rostock	Fast chargers in Puttgarden and Rostock in collaboration with E.ON. Free of charge.	Not available.
Stena Line	Ro-Pax	Göteborg-Fredrikshamn/Kiel, Halmstad-Grenaa, Karlskrona-Gdynia	Offered in specific terminals in the Irish sea but not in Scandinavia.	Not available.
Tallink Silja	RORO/RO-Pax	Stockholm-Tallinn/Helsinki/Åbo/Åland	Offered in Tallinn, semi-fast charging €0.15 per kWh, fast charging €0.18 per kWh.	Installed in Megastar but not in use.
TT-Line	RORO	Trelleborg-Travemünde/Świnoujście	Not available.	Not available but planned for Green Ships.
Unity Line	RORO/RO-Pax	Trelleborg/Ystad-Świnoujście	Not available.	Not available.
Wasaline	RO-Pax	Umeå-Vaasa	Not available.	Not available.
Viking Line	RO-Pax	Stockholm-Helsinki/Åbo/Åland	Offered in Stockholm in collaboration with Stockholm City.	Not available.

Note that in instances where charging is offered in collaboration, the ferry operator does not own the charging infrastructure. Furthermore, while a ferry operator may not offer charging inside their terminal, it is possible that public charging locations exist close to the terminal.

A total of fifteen ferry operators were included in the review. Nine operators offered charging either in or close to the terminal. Some ferry operators offered charging at several destinations or collaborated with specific infrastructure providers. For example, Destination Gotland offered charging at the ferry terminal in both Nynäshamn and Oskarshamn. Thus, a ferry operator that collaborates with charging infrastructure operators provides benefits for customers that have access to or are accustomed to those networks. The stations in Puttgarden and Rostock had fast-charging capacity (43 kW AC or 50 kW DC), which was installed with support from the EU project GREAT.

While only two ferry operators (Bornholmslinjen and Fjordline) offered onboard charging, two operators had vessels with installed stations that were not in operation

(Rederiet AB Gotland and Tallink Silja), and another two planned to offer the service in the near future (DFDS and TT-Line). It is noteworthy that the Swedish Transport Agency has issued a guideline for the charging of EVs on board ferries that, among other things, bans experimental vehicles from charging [12].

Charging in terminal areas was offered in collaboration with infrastructure operators who handle payment systems and thus affect possible business model configurations. At terminals, three price models were identified: (i) charging per kWh, (ii) free of charge and (iii) network provider's model (e.g., Bee Charging Solution's model). Prices per kWh varied between €0.15 and €0.50 depending on the location and the type of charge. Bee Charging Solutions (later merged with Grön Kontakt to form the company Mer Sweden AB) relied on two different types of charging subscriptions during the winter of 2021: Bee Flexible, with no monthly fee but €0.30 per kWh for AC charging and €0.50 per kWh for DC charging, and Bee Around, which provided free charging for a fixed monthly fee of €38.80.

Charging on board was priced with a fixed fee (Bornholm line €13.30; Fjord line €13). Selected parts of the marketing from the two ferry operators are presented in Table 4.

Table 4. Ferry operators' marketing message for onboard charging.

Ferry Operator	Marketing Message
Bornholm line	'Bring your electric car. Charge the batteries during the trip. On the BORNHOLM LINE, it is now even easier to take the electric car on the ferry. On board the BORNHOLMSLINJEN fast ferries, you can charge the electric car's batteries. There are two charging stations on the Ystad route, and these are available as an option when booking tickets according to the "first come, first served" principle. We support and have cables on board for TYPE2 connectors.' [49]
Fjord line	'Charge your car during the crossing. If you have an electric car, you can use the Fjord FSTR to drive ashore with a fully charged battery. On board the Fjord FSTR, we have charging stations available that can be used for a small additional charge. 16 type 2 charges up to 22 kWh. You must bring your own cable. You can choose this option during the booking process.' [50]

4.1. Business Models for Charging in Terminals and on Ferries

Figure 1 delineates aspects identified in the study that are considered decisive for business models for charging in terminals or on ferries.

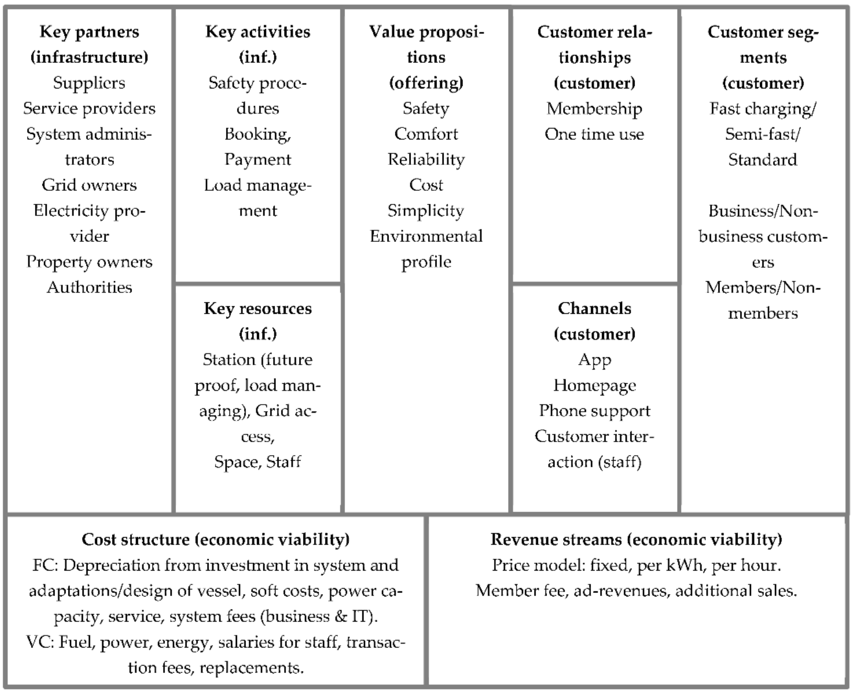

Figure 1. Key business model aspects of on board and in-terminal charging.

4.2. Offering and Customer

Charging services were expected to become part of the basic set of services provided by ferry operators. The respondents thus thought that it was important to evaluate which customer segments expect access to charging services now and in the future so as to design services that create value over time. Customer segmentation was based on three categories: charging technology (standard, semi- and fast charging); business vs. consumer; membership in for example the company's customer club and charging networks (member/non-member). Similarly, the customer relationship differs based on whether the customer is a member or if it is a one-time user of the charging service. Customer communication to and from the ferry or charging infrastructure operator occurs mainly through apps. Other communication channels include homepages, phone support and direct interaction with staff.

Based on the marketing material and the interviews, customers are believed to value safety, comfort, reliability, cost, simplicity and environmental friendliness. Bornholmslinjen and Fjordline marketed their services through simplicity and convenience as leading customer values. The elimination of pre-departure and post-arrival charging saves time for the customer, and offering the customer an additional opportunity to charge their vehicle while the vehicle is not accessible reduces the customer's range anxiety. It is possible to generate convenience by offering prioritised boarding, potentially prompting customers to stay on site for longer and thus increasing sales in stores and restaurants. Respondents believed that staff should connect and disconnect the vehicles, which is convenient for customers and prevents mistakes during charging, reducing stress and creating an impression of safety.

When charging in a terminal, the environmental impact is determined by the energy mix, while charging on board uses electricity from the ship's engines or energy storage. Respondents thus thought it to be important to explain and demonstrate the environmental value of charging on board to customers. In this context, the vessel's fuel mix and engine efficiency are crucial to the emission profile associated with charging. The potential use of biofuels and electric power from hybrid systems have been identified as ways to improve the environmental impact. Simultaneously, Swedish ferry operators are expected to gradually switch to wholly electric propulsion. This will result in the environmental impact of charging being determined by the energy mix found in the grid that is used to charge the ferry. Hence, the exact environmental impact may vary depending on the port of departure.

4.3. Infrastructure

Due to the severe implications of fire, safety emerges as a main concern in the design of on board charging services. The safety-first perspective requires fire safety assessments of the area where the EV is parked. It also requires assessment of the potential for damage to equipment while driving, as well as when connecting or disconnecting cables. When staff manages the charging, it minimises the chance that damaged or non-standard equipment is used, as well as the risk of damage to equipment. The particularities of EV fires indicate that parking areas, bulkheads, fire extinguishing systems and fire drills may require upgrading. The safety perspective is thus highly relevant to key resources and activities. Hence, to minimize risks it is most attractive to keep vehicles connected throughout the journey and use load management between cars since this eliminates the need for moving cables. By employing load management between stations, it is also possible to keep the total power output and hardware costs down. Other key activities include booking and payment. The design of these systems can improve customer confidence in the service and ensure the charging service is competitive. Systems must however be capable of communicating with other online services that customers access.

Key resources include a future-proof charging system with load management capacities, access to power (either on board or through the grid), suitable space for parking and staff with proper training (both in the specific systems and in customer interaction).

Key partners include suppliers of hardware and services, system administrators (i.e., operators of charging networks), grid owners, electricity providers, owners of property or ships, and authorities. These actors may influence the business model during the planning, installation and operations stages.

4.4. Economic Viability

The respondents stated that it was difficult to achieve profitability both in the case of on board and in terminal charging. The main reason for this was the high cost of hardware and a low occupancy rate. Revenue streams are derived directly and indirectly from the charging services. The direct revenue streams are determined by the price model, which consists of payments for the service (a fixed fee for charging, a fee per kWh charged and/or a fee per hour at the station). Whatever the model, the occupancy rate is crucial for profitability, and it is therefore important to consider which price model is suitable in each specific case by exploring how it will impact occupancy. Indirect revenue streams include membership fees linked to the charging service, ad revenues and additional sales. For ferry operators additional sales are particularly important as a projected revenue stream.

The design of both terminals and vessels differs considerably between locations. Hence, the cost profile for charging infrastructure will be project dependent. However, despite the need to upgrade onboard equipment from a safety perspective, it was not thought to be considerably more expensive to retrofit charging stations on ferries compared to incorporating them during the design phase. Furthermore, governmental support programs for investments in charging infrastructure was thought to be an effective way to improve the business case.

The fixed costs (FC) include the cost for charging station hardware, adaptations/design of property or vessel for technological or safety reasons, possible rent for the space, soft costs such as the cost of marketing and permits, fees for access to power, service and maintenance fees, and system fees (payment and information systems). The charging station is the largest cost and due to the considerable investment, the cost structure is in turn dominated by fixed costs. It was observed that there is a tendency to add costs associated with EV fire safety to the investment cost for charging stations and this was thought to make it unnecessary difficult for investments in charging hardware.

The variable costs (VC) include the cost of having properly trained staff (it is considered variable since this staff will do other things if there are no EVs to serve), transaction costs for payment systems, the cost of energy (fuel or electricity) and, in terminals, the cost of power based on the contract design with grid owners. In certain scenarios the cost of energy is subsidised through tax exemptions.

5. Discussion

The results indicate that even in the case of onboard charging it is difficult to ensure profitability. Due to the high investment cost, financial support from public sources may have a considerable positive impact on profitability. Yet, reliance on subsidies constitutes a risk. For example, charging on board occurs with certain tax advantages due to fuel subsidies, but this may change in the future. Thus, an assessment must be made of the possible effects that such changes may engender and the probability that change will occur during the life of the investment. Focus for operators should thus be on the investment practices and business model aspects that they control. For example, if investments in onshore power supply (OPS) or other high-capacity electric systems are made in the terminal area, the sharing of that grid infrastructure with a charging infrastructure could lower the total cost of investment. However, the effects of the pandemic on travel patterns, rapid technological development, ongoing component shortages and high energy prices result in considerable uncertainty regarding the suitability of different business models. It is therefore suggested that all the strategies presented to reduce investment and operating costs should be evaluated and, if possible, implemented. Similarly, occupancy rate needs to be boosted and associated revenue flows explored. Furthermore, the growing share of EV means that regulators need to consider what type of policies that will support a swift and cost-efficient deployment of charging infrastructure in ports and on board.

As soon as similar services are offered, the risk arises that they will cannibalise each other. In the case of charging infrastructure, there is a risk of cannibalisation between charging in terminal and on board. In addition, it is possible that charging in terminal is subject to cannibalisation by nearby charging services. To avoid cannibalisation, the operator may differentiate services so that they target different customer segments and create customer value with minimal overlap. The product portfolio, therefore, requires strategic management to ensure that the investment is utilised to the maximum. Similarly, it is important to consider the future development of the charging infrastructure. Since charging infrastructure is still in a build-up phase, there is uncertainty surrounding the location of potential stations. It is likely that fast chargers will appear along the most important traffic corridors [21,51] rendering it vital to assess placement to minimise potential competition. In addition, if the terminal is located in an area with restricted access to electric power, it is possible that this will create a bottleneck which negatively affects the possibility of establishing and offering charging services in a profitable way. The availability of electric power and the competition for customers thus make it necessary to inventory grid capacity as well as already available and possible future charging services offered in the vicinity.

Although various safety measures for EVs appear to be associated with general investments in onboard charging, those costs should not automatically be included in the investment evaluation. The number of EVs that use ferries will increase whether charging services are offered or not. Thus, some safety-enhancing investments will likely be needed even if charging hardware is not installed. Since a budget for charging infrastructure should only be burdened with costs derived from that specific decision, costs for safety-related investments in surrounding areas not linked to the charging infrastructure should be excluded from the investment decision. The same line of reasoning applies to the installation of charging infrastructure in a terminal. It would for example be unreasonable to burden investment in charging infrastructure with costs associated with the installation of OPS.

6. Conclusions

This paper reports on a market survey and a case study regarding charging business models for ferry operators in the Swedish ferry market. Only two out of fifteen ferry operators offered on board charging, while four operators either considered or had installed charging equipment but did not currently operate it. Nine of the ferry operators offered charging in or near ferry terminals. The presence of charging infrastructure in the vicinity of ferry terminals and onboard ferries improves accessibility to charging infrastructure and may positively impact range anxiety, further supporting electrification. Through interviews and a series of workshops, characteristics and prerequisites for business models for onboard and terminal charging were identified. The content of the business model was structured and presented using the business model canvas. The results highlight the importance of safety when choosing and designing technological and business model elements for charging services. The results also indicate the potential for cannibalisation between services which in turn stresses the importance of customer segmentation. The study confirms that profitability is a challenge when evaluating charging infrastructure both on ferries and in terminals. It is, therefore, vital for operators to make use of cost-reducing and revenue increasing strategies. Nevertheless, on board charging is considered a future necessity for ferry operators that aim to attract customers among the growing number of EV owners.

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Abbreviations

EV	electric vehicle
EU	European Union
FC	fixed costs
ICCT	International Council on Clean Transportation
kW	kilowatt
kWh	kilowatt-hour
OEM	original equipment manufacturers
OPS	onshore power supply
ROPAX	onshore power supply
RORO	roll-on, roll-off
TSO	transmission system operator
UK	United Kingdom
VAT	value-added tax
VC	variable costs
V2G	vehicle-to-grid
WoS	Web of Science

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