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# Design of a sustainable electric vehicle sharing business model in the Brazilian context

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ABSTRACT

A product-service system (PSS) aims to improve the profitability and competitiveness of companies, generate superior value for customers, and contribute to sustainability. However, despite those benefits, manufacturing companies still find it difficult to structure their business models as PSS, especially regarding the design of sustainable business offers. Previous research on designing PSS business models has not integrated sustainability aspects and empirical evidence on how to design sustainable PSS business models remains limited, especially in contexts such as developing countries, where those offers have a great potential for sustainability improvements. Thus, this paper explores the practical design of a PSS business model for electric vehicle sharing in the Brazilian context, considering sustainable principles. An analysis of the challenges and opportunities of offering shared sustainable mobility in the Brazilian context is presented. The PSS business model is described considering an integrated approach focusing on the co-creation of value-in-use by the value network. The results aim to support practitioners in designing more sustainable PSS business models, generating superior value for the 'value network' of PSS and contributing toward expanding sustainable production and consumption knowledge.

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## 1. Introduction

Several studies (e.g., [1], [2], [3], [4]) have discussed how the success of a business is increasingly associated with understanding the challenges and opportunities the society's transition to sustainability. Many manufacturing companies have realized this trend and considered sustainability principles and practices in their strategies, operations, and innovations in products/services [2], transforming their strategy to create customer value [5]. However, it is still necessary to rethink the development of business models [1], [6].

In this context, many typical manufacturing companies gradually moved from selling products to offering product-service systems (PSS) [7], [8], [9]. A PSS is characterized as an integrated bundle of products and services to create customer utility and generate value and can be an approach to dematerializing products without loss of value [5], [10], [11]. The automotive industry, especially car manufacturers, increased service activities to reach a competitive advantage [12]. It is also noteworthy this strategic orientation toward services in other industries such as computing, music, and energy [11], [13].

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Recent studies [3], [14], [15] show that PSS solutions can have substantial positive effects on sustainability. However, many manufacturing companies still find it challenging to manage the transition from a product-centric business to a service-centric business [16], [17] incorporating sustainability aspects into the offer. Many failures in PSS implementation are due to the lack of operational practices and practical tools that can guide manufacturing companies in designing and implementing PSS business models [17], [18].

PSS business model concept has become highly relevant for manufacturing companies since it explains how the value is proposed, created, delivered, and captured [11]. In addition, it also allows companies identify opportunities for improvement and innovation in how they conduct their business [19]. Business models provide an opportunity to close the gap between knowledge about the effects of individual variables on company's performance and the need to learn how the relationships between these variables affect performance [20]. Therefore, there is a need to emphasize a business model structure that is connected to the PSS offering [21]. Moreover, research is needed to analyze the PSS business model challenges and how to overcome them [17], [22].

Several studies (e.g., [23], [24], [25], [26], [27], [28]) have analyzed PSS business model structures and their components for specific industry sectors. Nevertheless, most business models were not designed considering a sustainable perspective [11], [15], [26]. Research on how to design business models taking sustainability into account has been approached mostly from a circular economy perspective (e.g., [29]). Research on sustainable PSS business models have been looking at the sustainability potential of different archetypes (e.g., [14]), factors that contribute to the sustainability of a PSS (e.g., [30], [31]), and other aspects such as how to identify value uncaptured and then promote innovation towards a sustainable business model (e.g., [32]), with limited exploration on how to design a sustainable PSS. There has been limited research from both a theoretical and empirical perspective on how to translate the knowledge on business models into real solutions [33]. Therefore, there is a need to explore how to design a PSS from a sustainable perspective to overcome the challenges of PSS implementation.

Car-sharing systems are one of the most traditional examples of PSS in the B2C market [34]. Nevertheless, evidence of how vehicle-sharing systems are effectively implemented is still missing. This is even more relevant in developing countries, where local and contextual conditions interfere in implementing urban micro-mobility (e.g., sharing bicycles and electric scooters) in recent years [34]. PSS offerings in developing countries are particularly interesting given their potential to improve the sustainability scenario in those contexts. Recently, some companies, e.g., Volkswagen Brazil, have also implemented efforts toward providing access to product usage instead of transferring product ownership in Brazil [36], [37]. Moreover, transportation is responsible for high fossil fuel emissions in those countries, indicating a potential area for searching for more sustainable solutions [4].

As the goal of the study is to explore the embeddedness of sustainable aspects in the design of PSS business models and identify opportunities for improvement by also taking into account the perspective of the customers, a PSS offer with great sustainability potential was selected for analysis. Therefore, this study aims to describe the design of a PSS business model offer based on electric vehicle sharing from a sustainable perspective. By exploring the design of a sustainable PSS from an empirical perspective, the paper contributes to existing literature in different ways. First, the paper adds to existing knowledge by exploring the design of sustainable PSS business models in practice and shows how PSS offerings can have its sustainable potential enhanced through a collaborative perspective. The paper demonstrates the value of adopting collaborative approaches to designing sustainable PSS offerings and addresses how the components of a business model could be enhanced to overcome the challenges of implementing a sustainable PSS business model. Studies dealing with ways to overcome PSS business model implementation challenges and ways to improve its sustainability potential were not identified in existing literature. Second, the paper provides empirical evidence of the design of a sustainable PSS business model in practice, whereas previous studies have had mostly a theoretical focus. Additionally, the case under investigation is located in a developing country and is developed by a small company. Implementing sustainable PSS business models in developing economies has been considered as an opportunity, given the potential of these solutions for such contexts, and there have been calls for more investigation [28], [38].

The remainder of the paper is organized into five other sections. The next section presents the literature background on PSS business model challenges, sustainable aspects of an electric vehicle-sharing business model, and sustainable value network. After that, the third section describes the research design of this study. Then, the findings of the analysis of the

challenges and opportunities identified to improve the designed business model are presented in the fourth section. This is followed by a discussion of the results, pointing out the business model challenges, and the sustainable aspects considered in the business model design in the fifth section. Finally, the theoretical and practical implications of the study are described, as well as its limitations, and suggestions for future research.

## 2. Literature background

### 2.1 PSS business model challenges

Business model thinking helps create more sustainable competitive advantage to companies and to align strategic, operational, and economic decisions [39], [40]. Therefore, when planning to implement a PSS, each company needs to structure its business model based on its core competences and resources. However, designing a PSS business model is a challenging process, and requires the involvement of a multidisciplinary team and the development of critical capabilities [41].

A recent meta-analysis on PSS risks and potential [42] shows that strategies of sharing and servitization were associated with high improvement potential and failure risks. Moro et al. [34] explored the internal and external barriers of PSS based on an analysis of twenty literature review papers. The high investment required to implement a PSS and the risks are the most prominent economic barriers stated by the previous cited authors.

According to Besch [43], consumers make decisions based primarily on price, implying that a PSS will only be successful if it is cheaper than the product purchase. In this sense, PSS-based offers are often perceived by the end-user as more expensive compared to purchasing products, because even with a lower initial investment, users generally do not consider the total cost of ownership, including use, maintenance, repairs, and disposal costs [44].

When dealing with new business models, it is easier for small companies to make the necessary changes during the solution development compared to large companies [45]. Moreover, although servitization makes customer relations a strategic necessity in large companies, engineers with high-value technology are unlikely to be interested in relatively small service contracts [46]. In this context, Teece [47] highlights that established companies may be reluctant to implement innovative business models if they cannibalize existing sales and profits or disrupt other essential business relationships. However, to achieve critical mass for small companies is a challenge and a prerequisite for market development. Therefore, it requires the involvement of several different actors, and at this stage, even competing companies can act in partnership to achieve the common goal [48].

Kamal et al. [8] emphasize the need to understand the value of servitization for manufacturing companies regarding resource consumption and impact on company competitiveness to assess flexibility limits and improve corporate agility and resilience. Moreover, the literature (e.g., [49], [50]) indicates that servitization and digitization bring better results if explored together. Nevertheless, even if companies recognized, for instance, the need to adopt a "big data strategy", it is still poorly understood how they can do it in practice [51].

### 2.2 Sustainable aspects of an electric vehicle sharing business model

There are some drivers that support the use of sharing models: the global economic crisis and the evolution of a lifestyle based on digital technology, concerns about environmental issues, and the consequent desire to consume sustainably [48]. Thus, the emotional component and seeking status can become allies. Electric vehicle users are generally willing to accept the challenge of novelty. Since the main benefit of the electric car is linked to the environmental impact, it is interesting for the company to work on defining a sustainable value proposition according to the benefits expected by potential customers, differentiating its offers from competitors.

Today is also relevant the concept of circular economy. Its focus is the transition from linear and unsustainable systems to circular systems, developing new business models to support this transition [52]. In this sense, PSS is frequently pointed out as a facilitator of new business models for the circular economy, potentially triggering and improving the circularity resources of supply chains [53]. PSS can be also considered a circular business model, i.e., value creation is based on economic value after using the product to produce new offers [54]. Therefore, PSS business models can be a way to ease the transition to the circular economy. Pallaro et al. [34] stated that sustainability issues related to vehicle end-of-life (EoL) management are rarely considered when developing a PSS. In this context, the focus on demonstrating environmental benefits, combined with the electric vehicle's cost reduction, may facilitate the

adhesion of customers and partners, aiming to attract new stakeholders to increase the 'value network' of the PSS. Furthermore, cases that presented difficulties and major disadvantages perceived in the study by Annarelli et al. [18] were those not designed to allow reuse and/or recycling.

### 2.3 Sustainable value network

The global economy is increasingly digital, networked, and knowledge-based, requiring companies to reconsider their business models constantly and, if necessary, modify them to adapt to changing conditions [20]. Kamal et al. [8] point out that manufacturing companies from emerging economies often cannot offer integrated services to products and thus connect with service providers in a collaborative network. In this sense, it is highlighted that large companies, e.g., car manufacturers, can become investors or even suppliers. The more a PSS business model involves manufacturers, owners, and users, the greater the potential for creating sustainable value [14].

For example, most car-sharing systems in Europe have partnerships with other providers. 'Flinkster,' Germany's largest car-sharing provider, with a diverse fleet of vehicles, ranging from popular small cars to vans, maintains partnerships with more than 20 suppliers [55]. Thus, it is highlighted that in PSS business models, partnerships with competitors can often be interesting for the business's longevity and for taking advantage of the structure, technology, and/or platform that the focal company has.

Moreover, electric car-sharing business model could be aligned with the concept of distributed energy – i.e., the generation of electricity in distribution networks or on the customer side of the network [56], integrating the generation and use of energy, aiming at sustainable mobility, at a local level. Developing local networks enhances PSS's sustainable potential with local priorities [57]. The development of co-creation mechanisms that facilitate the development of capabilities, reduce the adverse effects of servitization, and improve product development appear as relevant research topics [8]. Developing servitized business-to-business (B2B) business models may be necessary, for example, between actors in the 'value network' of a PSS business model, for component supply, maintenance, or operation. Furthermore, the combination of PSS and digital technologies enables a stronger relationship among the actors of automotive network [58]. This could be even better if there is a geographic proximity between technology companies and product manufacturers [59].

## 3. Research design

Problem solving in the context of sustainability has been described as complex, ill-structured or even "wicked", and in need of cooperation across disciplines [60]. Therefore, a 'transdisciplinary 2' approach was adopted to provide interactions among academic and non-academics [60]. Figure 1 shows the steps for the design and analysis of the PSS business model under investigation, followed by a description of the five steps, presented next.

Business model frameworks support the understanding of the differences and similarities in how companies create and deliver value [19]. Thus, adopting a business model design framework provides companies with the necessary tool to successfully leverage, coordinate, and align the critical ele-

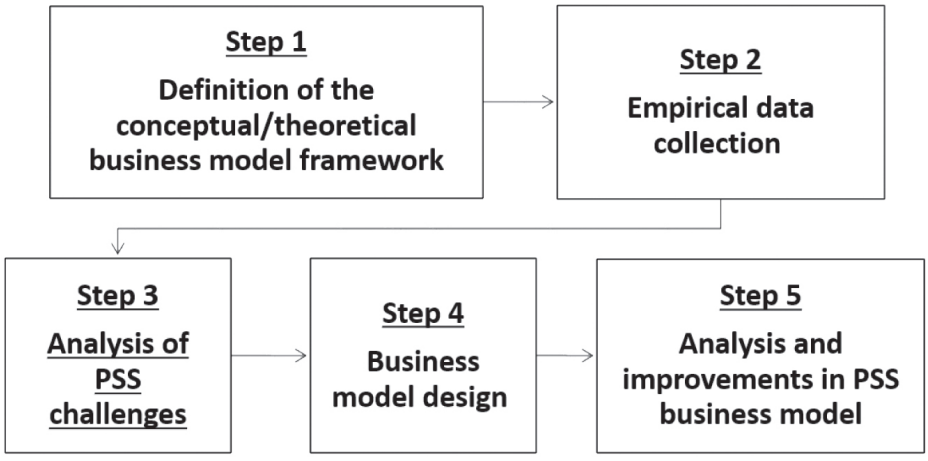


**Figure 1.** Research design steps

ments necessary to create, deliver and capture value [61]. Several business model frameworks have been used and proposed in the literature to represent a PSS business model (e.g., [38], [40], [41], [62]). In this study, a business model framework was employed to support the design of the PSS under analysis. The framework proposed by Moro et al. [41] was selected, as it covers sustainable aspects of a PSS business model, which has not been addressed by the majority of previous frameworks, and covers sustainable opportunities to improve the components of the business model. The framework was developed following five stages: (i) value proposition, (ii) configuration, (iii) delivery, (iv) capture, and (v) value network. Figure 2 summarizes the adopted framework to support the design of the PSS business model, including the main stages and components. In this work, components mean parts of a system that are sources of differentiation of business models [63].

A research protocol was developed and a list of variables to be explored was defined based on previous literature reviews as recommended (e.g., [64]). A semi-structured questionnaire was developed for conducting interviews with those involved in the PSS offering, covering the challenges and the components of the business model under investigation (further details in Appendix A). A pilot study on a bike-sharing system [41] was conducted to test the protocol and research procedures.

Five interviews were initially conducted with the company's founder and business partners (e.g., from a partner university and local associations) to identify the characteristics of the electric vehicle, the difficulties they are facing in its development, and their business plans. The interviews were recorded and transcribed for further analysis. Excerpts from the transcripts were considered to manually code potential findings. Short phrases and words were used when coding the data to identify themes and relationships [65]. The codes used were related to the stages and components of the PSS business model framework (Figure 2). Interview coding, cross-interview analysis, and fact-checking (e.g., competitors' analysis) in consultation with other sources were performed subsequently. The interviewees were informed upfront about the anonymity and confidentiality of the information provided. Besides the interviews, direct observations (e.g., of the developed prototype and results of the tests performed) and analysis of secondary sources (e.g., company leaflets, websites from the company and its partners, internal documents such as MS Power Point presentations, reports related to the PSS development process, and product testing) were performed to gather additional data. Data obtained from all these sources (i.e., semi-structured interviews, participant observation, and internal documents) were triangulated to identify dominant patterns in the information. All data collected was grouped accordingly with the business model's stages and components (Figure 2) for further analysis.

Based on the collected data, a preliminary representation of the company's PSS business model was developed using the selected conceptual framework shown in Figure 2. The company's director evaluated the initial version of the business model representation through a face-to-face meeting. The business

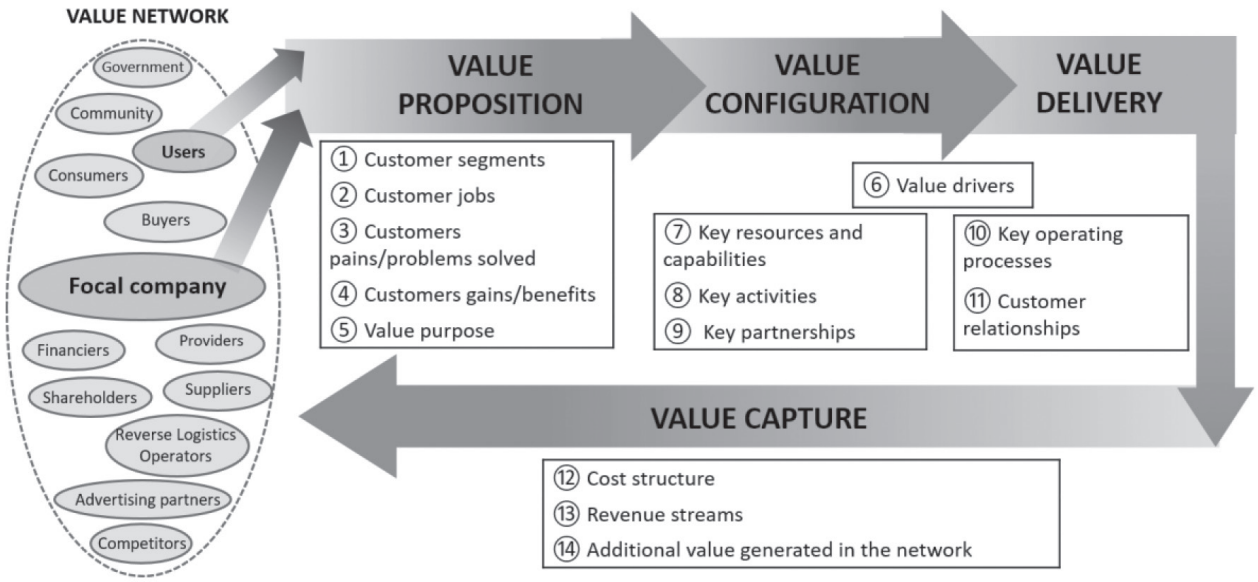


**Figure 2.** PSS business model framework [41]

model analysis focuses on the challenges identified by the company in the initial interview and their perceptions captured during the other interviews, taking into account the conceptual framework developed. Internal and external challenges from the design and implementation of PSS business models were revealed by interviewees (Appendix A).

After defining the business model's main challenges, possible opportunities to address the weaknesses and to improve the sustainability potential of the solution were identified based on previous literature analysis. Further discussions with the company's director (e.g., about the PSS value drivers) to improve the PSS business model were also performed. A workshop was conducted to present and discuss some opportunities, such as those related to circular economy implementation. Some aspects discussed were considered in the improved PSS business model presented in this work. Moreover, a representation of the exchanges among the actors involved in the PSS value network was developed later on.

## 4. Results

The unit of analysis is a small technology company located in the South of Brazil. KERS Electric Vehicles has been developing a PSS business model for its three-wheeled electric vehicle. The business model is related to the provision of micro-mobility on a shared basis and represents a trend in the automotive sector. Sharing-based business models have great potential to contribute toward environmental sustainability [4]. The business model's main differential is using a smaller (two passengers) electric vehicle with low production cost. Figure 3 shows a prototype of the three-wheel electric vehicle. The vehicle is in the development and testing phases by the focal company.

### 4.1. Analysis of the PSS business model challenges

Table 1 presents the relationship between the found business model challenges and opportunities to designing a more sustainable business model. The challenges were identified in the initial interviews and other data sources analysis. The opportunities were based on previous literature.

### 4.2. The designed PSS business model

The chosen conceptual framework was used to represent the designed PSS business model in a simplified way, presenting the essential characteristics to understand the operation of the business, value architecture, and PSS components. Figure 4 shows the final representation of the three-wheel electric vehicle sharing business model developed using the conceptual structure presented in Figure 2.

As shown in Figure 4, the business model is based on sustainable mobility technology that provides a reduction in environmental and noise pollution. In addition, the vehicle is small – up to two people, thus minimizing material and energy consumption. From the perspective of sustainability, especially in the social sphere, it is essential that the business model also generates value for various stakeholders beyond the focal company. A value network refers to a system of stakeholders and partners collaborating to support a standard business model [11]. The value network could be helpful when a new PSS is being developed to identify key stakeholders and visualize critical relationships. Therefore, Figure 5 shows the relationships and types of exchanges between the actors of the sharing business model value network based on the focal company (KERS Electric Vehicles).

**Figure 3.** Prototype of the three-wheel electric vehicle

**Table 1.** Relation between challenges and opportunities in the business model

| Internal challenges | Stage* | Opportunities identified |
|---|---|---|
| Resistance to change by stakeholders | PRO | Aligning the interests of consumers and the company [66] and developing a "sustainable value network" |
| | CON | Introduce services to reduce the perceived risk of new technology or facilitate access to the benefits of an established technology [46] |
| | NET | Value creation for the local community (e.g., by local employment) [67] |
| Need for high initial investment | PRO | Integrating sustainability information into their reporting cycle [11] |
| | NET | Explore the sharing economy and collaborative consumption as an opportunity to favor the acceptance of solutions [44] |
| | DEL | Include additional functionalities [68] |
| | CON | Reducing waste generation through prevention, reduction, recycling, and reuse [11] |
| Need for new skills | CON | Delegate specific tasks to third parties and focus on core competencies [69] |
| | CON | Develop highly compatible products [70] |
| | DEL | Explore IoT-enabled solutions focusing on preventive maintenance, optimizing maintenance operations, increasing product safety, reduce operating costs and collecting information to improve the solution development [71] |
| Difficulty evaluating how to charge for solutions | CAP | Personalized offers and participatory projects to facilitate direct and long-term contact with customers [72] |
| | CAP | Adjust prices dynamically based on remaining available capacity [73] |
| Need for a dense network of suppliers adept at the business model | NET | Include actors that will directly or indirectly affect the system where the PSS will be inserted to create more favourable conditions for the adoption and further dissemination of the PSS [74] |
| **External challenges** | **Stage*** | **Opportunities identified** |
| Low environmental awareness of users | PRO | Perform socio-technical experiments with potential consumers [75] |
| Resistance to consumption without ownership | PRO | Involve users at the time of design and/or production, or just as a source of information [76] |
| | NET | Explore the market potential for innovations through easy access to expensive products [66] |
| Consumer adapting to new types of offers | PRO | Consider aspects of human needs as well as the social processes involved in consumerism [77] |
| Lack of legislation to encourage the use of cleaner vehicles | DEL | Perform real-time analysis using Internet of Things technology to avoid failures, save energy or reduce emissions [71] |
| | DEL | Use smart, connected functionality to monitor usage data to improve customer operations and reduce reporting costs [78] |
| The difficulty of cultural acceptance | CAP | Promote continued customer interaction during PSS delivery operations, including co-creation [39] |
| Lack of engagement of municipalities to plan urban mobility | NET | Develop close and lasting partnerships with key customers [79] |

*Note:* * PRO: Value proposition; CON: Value configuration; DEL: Value delivery; CAP: Value capture; NET: Value network.

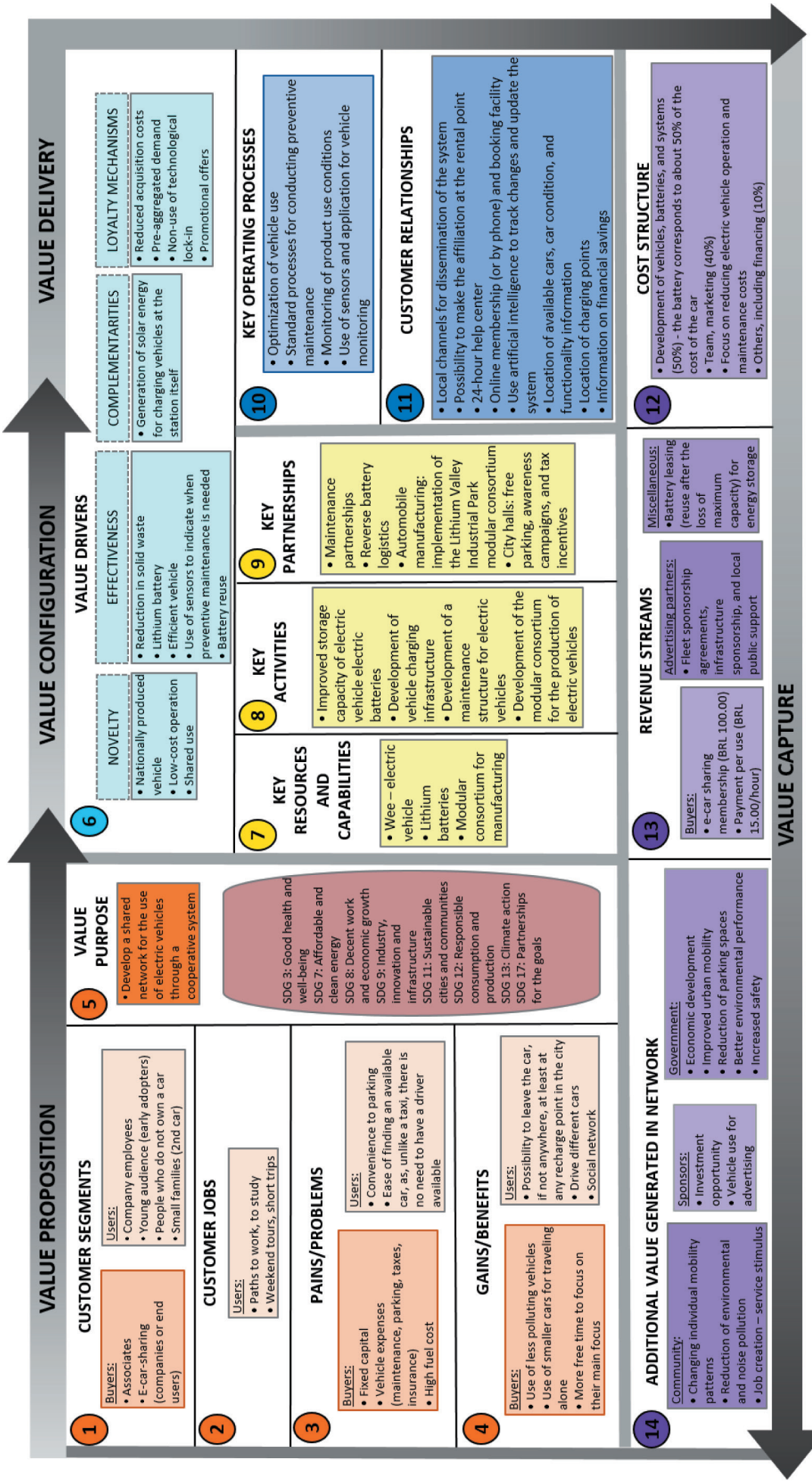


**Figure 4.** Representation of the three-wheel electric vehicle sharing business model

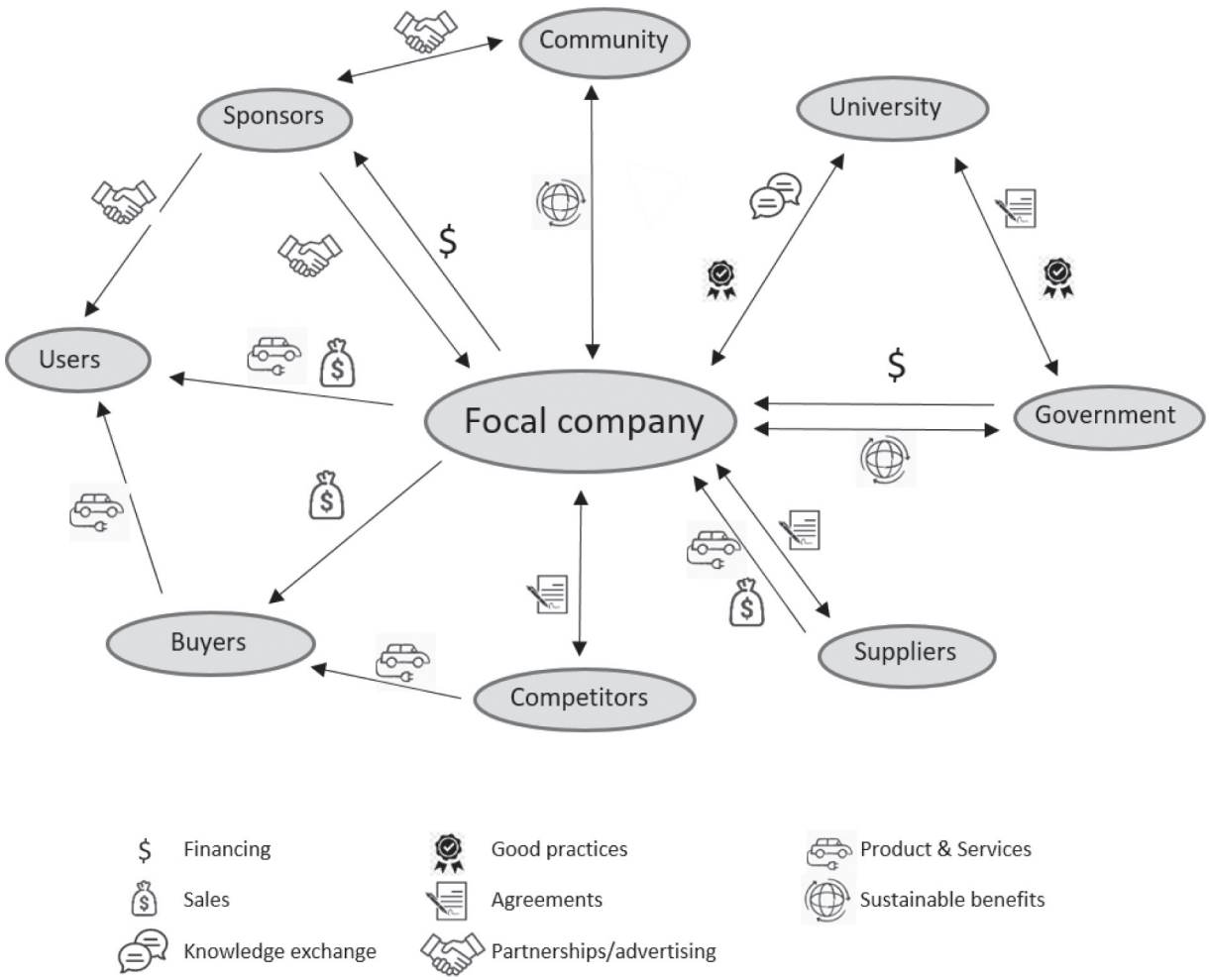


**Figure 5.** Three-wheel electric vehicle business model value network exchanges

Next section discusses the main findings presented regarding the challenges identified by the company and the development of a 'sustainable value network'.

## 5. Discussion

The high investment required to implement the business model is one of the main challenges highlighted by the director, and it was also cited as a significant challenge by previous studies (e.g., [43], [80]). Therefore, revenue sources are critical in sharing business model design. Thus, a key insight into sharing business models is that prices must be dynamically adjusted based on available capacity, with fewer remaining vehicles translating into higher prices [73]. Another opportunity to increase the system usage is to offer cheaper travel to places with fewer vehicles available - to adjust the vehicles distribution during the day.

It is noteworthy that several financing mechanisms encourage new business models and enable improved local energy for industrial manufacturers seeking to save on utility bills and achieve sustainability goals [81]. Therefore, such mechanisms can be used as opportunities to facilitate the development and implementation of the PSS. The business model analysis reinforces the need for continuous business model realignment over time, as demonstrated in other contexts (e.g., B2B - [82]).

The analyzed company has already a mindset focused on sustainable innovation purposes, so this was perceived that this scenario facilitated the development of the sharing business model considering a sustainable perspective. Nevertheless, for small companies, achieving critical mass is a challenge and a prerequisite for market development. This requires the involvement of several different actors, and at this stage, even competing companies can act in partnership to achieve the common goal [48]. Thus, the company should develop long-term education and

awareness programs to expand the knowledge of the sustainable benefits of its proposed business model.

It is also relevant that the system has complementarities with other systems that offer different products, such as bicycles, scooters, etc. Thus, the company's competitors can also be partners, aiming at consolidating the PSS supply network and thus making its use more viable. In this sense, another challenge is the need to engage a value network for the PSS, which involves different actors of the PSS business model. For this, the digitalization of processes necessary to deliver value through the PSS are being considered by developing partnerships with the local university to develop smart technologies to support the system (e.g., sensors to vehicle monitoring, preventive maintenance, and use conditions verification).

Some of the business model's internal challenges pointed out by the director are related to the PSS value proposition. In general, consumers make decisions based primarily on price, implying that a PSS will only be successful if it is cheaper than the product purchase [43]. In this sense, PSS-based offers are often perceived by the end-user as more expensive compared to purchasing products, because even with a lower initial investment, users generally do not consider the total cost of ownership, including use, maintenance, repairs, and disposal costs [44]. Thus, the company should develop long-term education and awareness programs to expand the knowledge of the sustainable benefits of its proposed business model.

As illustrated in Figure 4, partnerships and agreements with large suppliers are necessary to generate the PSS scale. Kamal et al. [8] highlighted that manufacturing companies from emerging economies often cannot offer integrated services to products and thus connect with service providers in a collaborative network. In this sense, it is highlighted that large companies, e.g., car manufacturers, can become investors or even suppliers. The more a PSS business model involves manufacturers, owners, and users, the greater the potential for creating sustainable value [14]. This PSS was developed to be connected to other similar systems since, in the case of sharing, it is important all systems to communicate to increase the number of vehicles available to customers. Thus, in PSS business models, partnerships with competitors can often be interesting for the business's longevity and for taking advantage of the structure, technology, and/or platform that the focal company has. Besides, the geographic proximity between technology companies and product manufacturers in a specific geographic area increases competitiveness [59] and thus favours the development of innovations such as PSS, which demand integration between products and services. In this context, if different solutions are offered on a single platform, it is easier for the customer to use the electric vehicle sharing.

Moreover, the PSS business model designed is aligned with the concept of distributed energy and the company has a partnership with a local university to develop the technology. The co-creation of mechanisms that facilitate the development of capabilities reduce the adverse effects of servitization, and improve product development appear as relevant research topics [8]. Developing servitized B2B business models may be necessary, for example, between actors in the 'value network' of a PSS business model, for component supply, maintenance, or operation.

The company director recognized that PSS value drivers could be a great tool to easily visualize the business model's value, which can help them explore the solution's benefits. Those opportunities related to the product's life cycle, e.g., reuse, remanufacturing, and recycling, could enhance the system's effectiveness. In the developed business model, only the use of the battery is optimized due to its high costs. In this case, the vehicle batteries could, later on regular use, store energy. Generally, when PSS is associated with advanced technology and allows for more significant savings in resources (e.g., electricity, fuel, etc.), there is a greater chance of acceptance, which can contribute to the solution's success. Integration with power generation systems can be used as a 'value driver' of 'complementarities' aimed at the system's financial viability and representing a competitive advantage in the face of high fuel costs. In this sense, partnerships are crucial in maintaining the business model's sustainability, especially with operators in the electricity sector.

As shown in the business model 'value configuration,' battery longevity is a significant benefit, as the battery life cycle is optimized because of its high costs (more than half the cost of the vehicle). So, the batteries are used in the car until they have a good energy density to allow good autonomy of the vehicle. After regular use, the batteries are reused for energy storage (in fixed stations), generating additional revenue for the business model. Moreover, an exciting feature of the PSS business model related to 'complementarities' as a source of value creation is the integration with power generation systems, ensuring the system's financial viability and representing a competitive advantage for the high fuel costs.

### 5.1. Theoretical implications

Innovative business models such as PSS in start-ups is little explored in PSS studies, as most of them analyse large companies (e.g., [51], [58]). The business model design approach used by a sustainable start-up presented here was valuable, given its intrinsic characteristics of agility and quick reversal of scenarios. Moreover, the framework used is based on the challenges faced by the companies that are designing a PSS and opportunities to overcome them. In this sense, it is a practical and transdisciplinary tool.

On the other side, this study approaches the design of PSS business models taking sustainability into consideration into the design process and from a collaborative perspective, which has not been considered by previous research. Another important consideration is that this work describes the exchanges of the PSS value network (Figure 5). This tool could also be useful for PSS developers to understand better their business models and the partnerships that they need. The representation of the business model value network also allows the integration of the social perspectives of the PSS, focusing on the design of a business model and enabling the generation of superior value for the stakeholders involved. Therefore, it could be useful for other studies and approaches related to the design of more sustainable PSS solutions.

### 5.2. Practical implications

The necessary characteristics of the business model were verified by identifying practical challenges to structuring PSS business models and to design this business model considering the Brazilian context. It is also noteworthy that several actions have been conducted to develop smarter and more sustainable cities at the local level. Thus, PSS business models such as the analyzed represent essential contributions to improving micro-mobility. The spread of the mobile internet and information and communication technology in urban sustainability planning makes it possible to combine electric vehicles with energy-efficient buildings and smart service networks to create distributed and responsive energy systems [48]. Moreover, it is important to take advantage of digitization to facilitate the implementation and operation processes of PSS business models [49], [50], [58].

The developed business model representation gives managers greater clarity on essential aspects of their business model, enables analysis and identification of opportunities to generate superior value, and thus allows better communication of value to their internal and external stakeholders. Thus, the companies' managers were receptive to applying the PSS business model framework to design their business models. This development may also help verify the viability of the PSS business model (e.g., by investors, partners, etc.).

Considering the current trends to increase the flexibility of modern production systems, the wide dissemination of production knowledge, and a better-educated workforce, it is essential to assume that the possibility of producing final products closer to consumption surpasses the traditional concept of manufacturing, whereby economies of scale dominate decision-making [6]. Trust among actors is another critical factor, as the actors need to share information [4]. Therefore, it is essential to align the interests of the different stakeholders in the value network to collaboratively design and deliver a value proposition that meets the customers' needs.

## 6. Concluding remarks

This study provides empirical evidence of the design of an electric vehicle-sharing business model considering its sustainable aspects. During the business model development, exchanging information with PSS developers made it possible to analyze the challenges and opportunities and their practical adequacy. The challenges faced were in alignment with previously identified in the literature, and the opportunities identified aimed to develop a more sustainable PSS for the value network involved. Studies dealing with ways to overcome PSS business model implementation challenges and exploring the sustainability potential was not identified previously.

A further contribution is related to the case under investigation - located in a developing country and developed by a small company – a context not commonly explored in PSS business model studies. The business model designed is related to mobility and may contribute to smarter and more sustainable cities. Considering that research on PSS mostly investigates the European context of developed countries, it is appropriate to consider its suitability to the Brazilian context in order to achieve business model success and widespread. Thus, the findings of this study are relevant, especially by considering problems related to urban mobility faced in developing countries like Brazil, which stand out as priorities for economic and social development in the coming years. In this sense, the development of various initiatives movements (e.g., the 'United Nations Agenda 2030' and

a 'National Program of Strategies for Sustainable Smart Cities') emphasizes the practical importance of the subject, which emerges as opportunities for future studies.

The 'value proposition' of the PSS business model was focused in providing a value-in-use experience, enabling long-term customer relationships. The social and economic dimensions of sustainability were integrated from the design of the business model, aiming to increase the value generated by the 'value network' of the PSS. Considering the sustainable aspects of a PSS since its business model design stage could enhance the value generated by the solution to its clients and other stakeholders.

### 6.1 Limitations and future research opportunities

This study analysed a unique small and sustainable-based company, which might limit the generalisability of the findings regarding the design of sustainable car sharing offers. However, the single case allowed demonstrating the benefits of using a framework for business model design from a collaborative point of view and taking into account sustainability aspects in terms of improving the sustainable potential of the solutions and value creation and capture for the stakeholders. Comparative investigations with larger companies and other vehicle sharing schemes can be a further direction for research, as empirical research comparing sustainable PSS offers from different perspectives is still limited. Moreover, new studies applying the conceptual framework used in this research can also be conducted in product manufacturing companies (e.g., automobiles or bicycles) moving towards servitized business models. The analysis of the challenges for the business model design can be used by stakeholders involved in the development of PSS business models, aiming at more significant value generation for the PSS. Additionally, the perspective of value co-creation is also little addressed in existing literature. Thus, the study of strategies to facilitate the integration of the PSS' value network' emerges as another opportunity for future work (e.g., using a modular strategy or co-creation processes with several stakeholders).

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## **APPENDIX A** – Challenges identified in the initial interview

| | |
|---|---|
| **Organizational**<br>In your perception, what are the main organizational barriers to offering PSS business models? | • High investment in intellectual and technological capital<br>• Build a chain of suppliers who believe in its viability – stakeholders |
| **Customers**<br>In your perception, what are the main barriers regarding the acceptance of PSS by customers? | • Identify and have access to the customer who can consume the product |
| **Contextual**<br>In your perception, what are the main contextual barriers to adopting PSS business models? Examples: laws, regulations, culture. | • Form the market for the use of sharing systems, as there is still no established culture for the use<br>• Lack of legislation to encourage the use of cleaner cars<br>• Dependence on decisions by municipalities to plan and execute the urban mobility policy<br>• Bureaucracy in the country to start and maintain a business |