THE RELEVANCE OF SOLUTION-DEMAND NETWORKS IN THE CONTEXT OF FUNCTIONAL ECONOMY AND PRODUCT-SERVICE SYSTEMS: AUTOLIB CASE

A IMPORTÂNCIA DAS REDES DE SOLUÇÃO-DEMANDA NO CONTEXTO DA ECONOMIA DA FUNCIONALIDADE E DE SISTEMAS PRODUTO-SERVIÇO: CASO AUTOLIB

Manuela Gortz-Bonaldo [1]
Décio Estevão do Nascimento [2]
Frédéric Huet [3]

Abstract: *New economic proposals such as the Functional Economy and Product-Service Systems (PSS) present the challenge of cooperative integration in a multidisciplinary network of actors, each with their skills and interests. This study aims to analyze the role of solution-demand networks (S-DN) in the context of the Functional Economy and PSS. We adopted a qualitative approach by conducting a systematic literature review and content analysis for the proposal of a theoretical model. This model was then applied to the practical case of Autolib, a French car-sharing service and example of PSS. The results indicate that the role of solution-demand networks occurs in five distinct key points: (1) ownership; (2) complete solutions; (3) meeting needs; (4) heterogeneous network of stakeholders; and (5) sustainable development. The comprehension of these five key points can help us understand how the relationship between human and non-human actors takes place in the network.*
Keywords: *Functional Economy. Product-Service Systems. Autolib. Actor's Network. Actor-Network Theory. Car-sharing.*

Resumo: *Soluções de novas propostas econômicas como a Economia da Funcionalidade e Sistemas Produto-Serviço (SPS) apresentam o desafio da integração cooperativa em uma rede multidisciplinar de atores, cada um com suas habilidades e interesses. Este estudo tem por objetivo analisar o papel das redes de solução-demanda (RS-D) no contexto da Economia da Funcionalidade e de SPS. Adotou-se uma abordagem qualitativa conduzida por meio de revisão sistemática de literatura e análise de conteúdo para a proposta de um modelo teórico. Este modelo foi aplicado no caso de estudo Autolib, um serviço de car-sharing francês e exemplo de PSS. Os resultados indicam que o papel das redes de solução-demanda ocorre em cinco aspectos distintos: (1) posse; (2) soluções completas; (3) satisfação das necessidades; (4) rede heterogênea de stakeholders; e (5) desenvolvimento sustentável. A compreensão destes cinco aspectos contribui para entender como se dá o relacionamento entre atores humanos e não-humanos na rede.*
Palavras-chave: *Economia da Funcionalidade. Sistemas Produto-Serviço. Autolib. Rede de atores. Teoria Ator-Rede. Car-sharing.*

[1] Doutora e mestre em Tecnologia e Sociedade pela Universidade Federal do Paraná (UTFPR). Lattes: http://lattes.cnpq.br/1336056621257896. ORCID: https://orcid.org/0000-0001-6435-2441. E-mail: manuelagortz@alunos.utfpr.edu.br

[2] Doutor e mestre em Ciências do Homem e Tecnologia, pela Université de Technologie de Compiègne (UTC). Professor titular e pesquisador da Universidade Tecnológica Federal do Paraná (UTFPR). Lattes: http://lattes.cnpq.br/5009182371990039. ORCID: https://orcid.org/0000-0001-5902-6545. E-mail: decio@utfpr.edu.br

[3] Doutor em Ciências Econômicas pela Université de Technologie de Compiègne (UTC). Professor-pesquisador da Université de Technologie de Compiègne (UTC). Lattes: http://lattes.cnpq.br/0924271442037607. ORCID: https://orcid.org/0000-0002-4510-7093. E-mail: frederic.huet@utc.fr

Introduction

The last decades were characterized by the rising of new economic models that propose innovative production and consumption patterns, greatly in response to several problems generated by the industrial-based economy, such as exploitation of natural resources, pollution, and the rapid disposal of products (TERTRE, 2007). Among these new proposals, we can highlight the Functional Economy (STAHEL, 1997) and Product-Service Systems (GOEDKOOP *et al.,* 1999).

Functional Economy proposes a change in the sale of physical products by offering more complete solutions that meet consumers' needs by the delivery of functions and satisfaction (TERTRE, 2007; BUCLET, 2005; BISIAUX *et al.,* 2014). It emphasizes the use value and useful effects that a product, service or that the combination of them can offer (GIDEL; HUET; BISIAUX, 2016), relating to the idea of Product-Service Systems (PSS). PSS are systems of products, services, networks of actors and support infrastructure that seeks to satisfy consumer needs and remain competitive, with less impact compared to traditional models (MONT, 2002).

Functional Economy and PSS require the development of solutions in networks, co-constructed in a joint of heterogeneous elements (GIDEL; HUET; BISIAUX, 2016; CESCHIN, 2013; COOK, 2014), considering both human and non-human actors: producers, consumers, products, services. Thus, it is essential to understand the networks dynamic and articulation, relating to the principles of Actor-Network Theory (ANT) (CALLON, 1986; 1999). It is through and during these network interactions that it is possible to develop new solutions in solution-demand networks (S-DN). S-DN proposes that adapted solutions will emerge from interactions and through co-creation between different actors of the network, in a dynamic process of cooperation, seeking to identify and analyze how the dynamics and interaction take place between the actors of a network, each with their skills and knowledge (GORTZ, 2017).

However, these new co-created solutions demand greater integration between the different actors that are part of the network, each with their own interests. The major challenge in developing and maintaining these new proposals is in bringing all stakeholders together so that they cooperate towards a common goal.

We highlight the originality of this research in the joint approach of concepts of Functional Economy and PSS from the perspective of ANT. ANT is a theory that studies interactions between actors of a network, already explored in areas such as Architecture (FALLAN, 2008), Project Management (FLORICEL *et al*., 2014) and Design (MACHADO JUNIOR *et al.*, 2020) allowing us to extend its reach to other areas such as Economy and Sustainability. In addition, studying the Functional Economy from ANT's perspective can contribute with a new version of the functioning of markets and the relationship between the actors (CALLON; 1999).

Based on this context, this study aims to analyze the role of solution-demand networks in the context of the Functional Economy and PSS. The research examines Autolib as a case study, supported on secondary data collection. Autolib was a French electric car-sharing service which operated from December 2011 until July 2018. We conducted a systematic literature review and content analysis to propose a theoretical model, which was then applied to the practical case of Autolib, an example of PSS.

Theoretical Background

Functional Economy and Product-Service Systems (PSS)

The expression Functional Economy emerged in 1986 with authors Walter Stahel and Orio Giarini (BUCLET, 2005). It focuses on the transition from an industrial economy, oriented to the production and sale of material goods, to a new consumption model focused on services and functions, where products are only a means of providing functions and satisfaction (BUCLET, 2005; STAHEL, 1997). This model involves the transition to an immaterial economy, which considers intangible resources such as trust between the actors and the new competencies involved (TERTRE, 2007), as well as providing consumers with access to use value, involving the proposition of sets of goods and services (HUET; CHOPLIN, 2012).

For Goedkoop *et al.* (1999), Product-Service Systems (PSS) are a marketable set of pro-

ducts and services that, when offered together, can fully satisfy users' needs. Thus, we can relate PSS with the concept of Functional Economy, since the user pays for the experience of using the solution or function of a product, and not for its possession (MOATI; RANVIER; SURY, 2006). PSS can also be characterized as a design strategy to supply functions by combining products and services that allow the reduction of consumption of material resources, aiming for a more sustainable society.

The design of PSS experiences can fill the absence of ownership; therefore, it is crucial to design personally meaningful and positive experiences to satisfy the functional and emotional needs of consumers (DEMYTTENAERE; DEWIT; JACOBY, 2016). In the development of new solutions for the Functional Economy and PSS, authors such as Tertre (2007), Buclet (2005), and Bakker *et al*. (2014) highlight the importance of also including emotional issues, symbolic and immaterial dimensions, besides meeting functional requirements only.

Regarding a product's property, PSS can be classified in three types: (i) product-oriented, (ii) use-oriented, and (iii) results-oriented (TUKKER, 2004). In a product-oriented PSS, ownership remains with the consumer, but the provider sells additional services; in a use-oriented PSS, the property remains with the provider, and the usage rights are sold to the consumer; in a results-oriented PSS, product functions are sold, which directly meet consumer demands. Car-sharing systems are considered one of the leading examples of use-oriented PSS, since the ownership of a car is replaced by a service that provides access to mobility for the customer, while the provider owns the vehicle (GIDEL; HUET; BISIAUX, 2016). These systems offer the availability of a car when needed, and are usually paid by use, allowing the user to have their mobility needs answered through the service and the products that support and allow this access, which is developed and made available by a network of partners or stakeholders (SALAZAR; LELAH; BRISSAUD, 2015).

One of the goals of the Functional Economy and PSS solutions is to offer complete solutions so that users have their usage needs met when using the complete system. Therefore, it is vital to consider the total user experience journey and include related elements such as insurance, fuel, and maintenance. These are elements that the user would probably have to search separately when purchasing a product, but the PSS provides all in the same service. This idea is related to the concept of "bouquets" by Moati, Ranvier, and Sury (2006), which define it as a commercial offer of a set of products or services which are complementary in producing useful effects.

Although some authors consider that the environmental dimension of the Functional Economy and PSS solutions are more a consequence than a prerequisite (BISIAUX *et al*., 2014), many proposals allow improvements in environmental, social, and economic terms. Considering environment issues, these new solutions can present rebound effects, when the costs for maintaining a product in a PSS are higher than the current selling of the product (SCHNEIDER, 2003). However, other environmental features can contribute to reducing the sale of individual products to make the product available through a service, to be used by several users in a shared way. Regarding the development of the local economy, as the systems demand complete solutions, they require different suppliers with specific skills, which mobilize different segments of the economy and can contribute to the generation of new jobs and opportunities. Likewise, it allows valuing local suppliers to meet the demand in which the PSS is being offered, strengthening the territory and the relationship between stakeholders (VEZZOLI; KOHTALA; SRINIVASAN, 2014).

For Vezzoli, Kohtala and Srinivasan (2014), designing PSS that meet satisfaction needs should consider the existence of socioeconomic stakeholders (with their skills and capabilities) and the interaction that occurs between them (partnerships and interactions). It involves, therefore, understanding who the best partners are and how to place these interactions, in which all stakeholders should be involved (KOTNAROVSKY *et al*., 2013). We went from the sale of a product or service to the sale of a co-projected solution, which goes beyond a single exchange logic, giving rise to a logic of co-production in situation (HUET; CHOPLIN, 2012).

Ceschin (2013) considers essential building a heterogeneous network of actors with scientific, social, economic, political, and cultural links. For Cook (2014), PSS comprises products, services, human and non-human actors (artifacts), capable of incorporating their me-

anings and values beyond functionality. This finding relates to the concepts of the Actor-Network Theory, in which authors like Callon (1986; 1999), Latour (1994; 2005), and Law (1992) consider this heterogeneous network of actors constituted by human and non-human agents. The interactions between actors occur through translation and negotiation processes, allowing the creation of solutions through cooperation, which considers issues of local economy and territory (SALAZAR; LELAH; BRISSAUD, 2015).

Actor-Network Theory

The Actor-Network Theory (ANT) emerged from sociological studies of science in the 1980s, in works by authors such as Callon (1986), Latour (1994; 2005), and Law (1992). Law (1992) states that the Actor-Network Theory is a set of theoretical and empirical writings that treat social relations as network effects. What makes the theory so distinctive is that it considers networks as materially heterogeneous, in which agents, texts, devices, and architectures are essential to social networks and therefore, should be analyzed under the same terms. For this author, the focus of ANT approach is the concern with how actors and organizations mobilize, juxtapose, and maintain the parts of which they are formed (LAW, 1992). The ANT as a whole is complex and encompasses many elements, so we selected some considered most relevant according to these research goals.

Callon (1999) ponders that it is the network interaction between different actors that shapes the actors themselves and their motivations. During interactions, actors interact with each other, make decisions, and act according to their interests, in constant negotiation processes, when facing conflicts of interest with the actions of other actors. What is more important is the network links, more than the actors themselves, and that this network interaction is unstable and dynamic. The concepts of the Actor-Network Theory contribute to a practical perspective, suggesting that projects are fragile organizations that depend on a constant and collective translation process to align the actors' interests with and within the project (FLORICEL *et al*., 2014), considering both human and non-human actors (LATOUR, 2005; LAW, 1992).

Fallan (2008) introduces a relation of the architecture field with ANT, in which co-production is essential. It is not just about building, but about coproducing architecture, both in nature and culture (FALLAN, 2008). From the moment it is considered a social co-production, architecture is no longer only the work of architects. Architects are essential actors in the architecture production network, but they are just a group among many, as also the work of engineers, contractors, consultants, bricklayers, carpenters, electricians, politicians, planners, and users (FALLAN, 2008).

This understanding can be extended to the Design field. Henze, Mulder and Stappers (2013) consider that increasing complexity in the development of Product-Service Systems goes along with the concept of complex heterogeneous networks. The success of new strategies of Functional Economy and PSS depends on the network of interrelations between different actors involved and their actions. This view can be complemented by Callon's (1986) proposition that the ability of some actors to obtain other actors (whether human beings, institutions, or natural entities) to obey them depends on a complex network of interrelations in which society and nature are intertwined. Hence, it is necessary to cover the complete life cycle of a PSS development process, starting with understanding the users' needs in generating product service propositions, where the process is an accumulation of translations and transformations (HENZE; MULDER; STAPPERS, 2013), which can result in solution-demand networks.

Solution-demand networks (S-DN)

To Callon (1999), one of the main points of ANT is that it assumes a radical indeterminacy of the actor. He points out that it is the network interaction of different actors that configures the actors and their motivations, in a dynamic process that requires constant negotiations. Actors in networks make decisions and act according to their interests, in constant interactions and discussions, as they face conflicts of interest with the actions of other actors. However, these actions can neither be predicted nor predetermined; the future remains un-

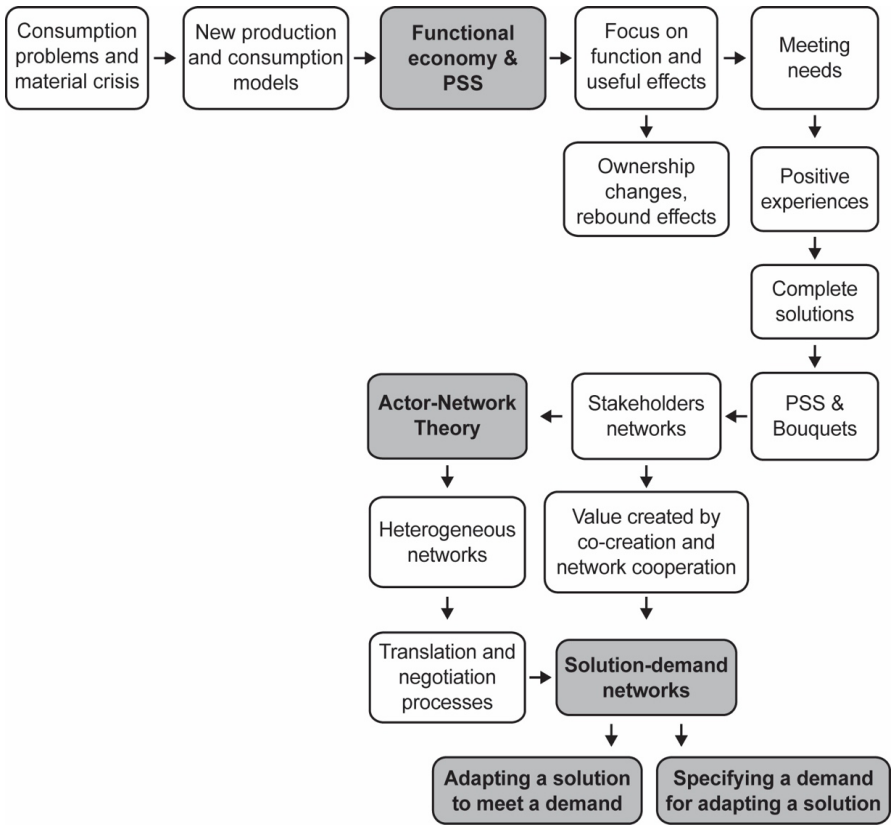
defined, being modified, and constructed as network relationships take place (CALLON, 1999).

These aspects of Actor-Network Theory can be related to the Functional Economy proposal since it proposes a rupture with the presupposition of pre-existing needs so that initially, it is not possible to identify the needs for the value of use of the consumers (GIDEL; HUET; BISIAUX, 2016). In the Functional Economy, the consumers, as actors, do not know what use value they need, and producers/suppliers cannot impose the answer to this need. Also, exchanging the sale of a product for a service that offers its functionality is an essential element in the complex network of actors involved since they are the bridge between the solution developed by the producers-sellers, and the use function that is delivered and used by consumers (CESCHIN, 2013; GOEDKOOP et al., 1999).

The success of new Functional Economy and PSS strategies depends on the network of interrelations between different stakeholders (actors) and their actions. What the Functional Economy proposes and is in line with the concepts of the ANT (CALLON, 1999), is that adapted solutions will emerge from the interactions within the network between the different actors, in a dynamic process of cooperation, constituting solution-demand networks. Solution-demand networks can thus be defined as heterogeneous networks, formed by different actors (producers, designers, and engineers, suppliers, traders, consumers, products, public and private services...) which, through translation, negotiation, and cooperation processes, are articulated around a common goal, by adapting a possible solution to meet a demand, or by the specification of a possible demand for adaptation of a solution (GORTZ, 2017).

To summarize this section, Figure 1 illustrates a synthesis of the concepts discussed and the relation between them.

Figure 1. Conceptual alignment of the theoretical basis.



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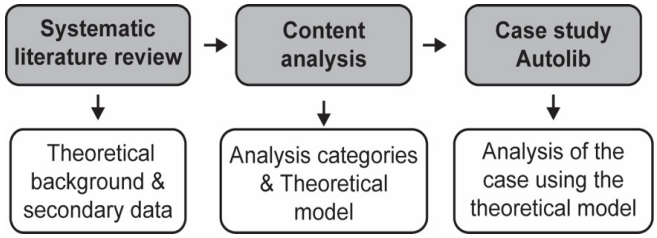
Next, we describe the procedures adopted to conduct this study.

Methods

This study was conducted using a qualitative approach. The methodology applied (see Figure 2) consisted of three steps: (1) systematic literature review for an initial survey of scientifically indexed publications to identify the theoretical background; (2) next, for secondary data analysis, we used the categorical and thematic analysis based on the content analysis method, to propose a theoretical model; (3) this model was then applied to analyze the practical case of Autolib and verify it as a solution-demand network in PSS.

Figure 2. Sequence of methodological procedures adopted for developing the study.



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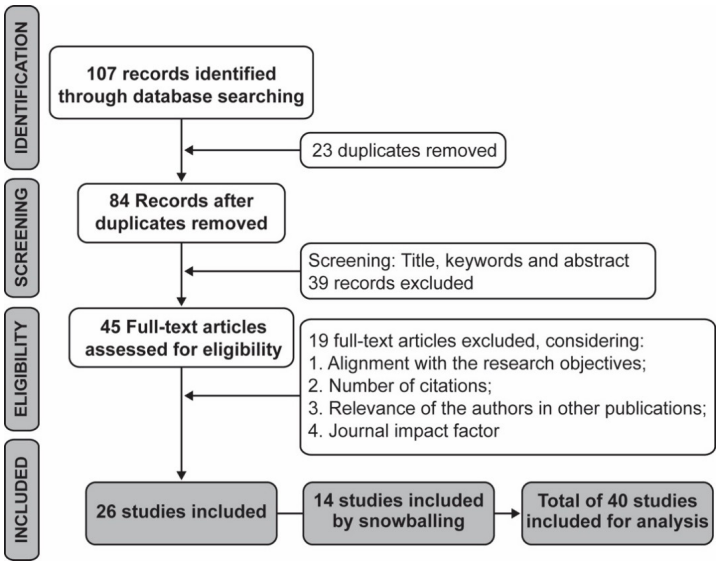
Systematic literature review

The bibliographic survey was carried out based on a systematic literature review, suggested by Denyer and Tranfield (2009) and Geraldi, Maylor e Williams (2011). We conducted a preliminary bibliographic survey in May 2017, with the keywords *Functional Economy*, *Product-Service Systems*, *Actor-Network Theory*, and its combinations. We selected these terms by performing keyword adherence tests. The research was carried at the international databases of Science Direct, Scopus, and Web of Science, for their relevance to the research's topic. The survey raised publications within the last five years. Figure 3 illustrates the process of collecting, screening, and selecting documents, since the 107 first records identified through database searching until the definition of the 40 studies included for analysis.

Figure 3. Filtering process applied to the systematic literature review.



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Next, we performed the secondary data analysis by applying the method of Content Analysis.

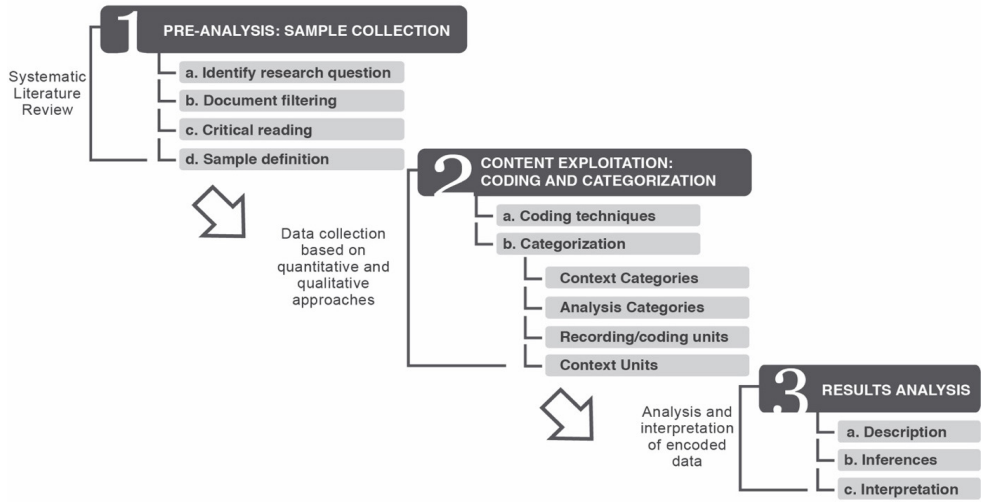
Content Analysis

The analysis techniques adopted in this study were based on the categorical and thematic analysis, based on the Content Analysis method and the contributions from Krippendorff (2004) and Bardin (2011). Content analysis is a research technique for making replicable and valid inferences from texts to the contexts of their use, considered one of the most important research techniques in the social sciences (KRIPPENDORFF, 2004).

Although content analysis is predominantly qualitative in terms of results, it is an empirical and mixed method involving quantitative and qualitative procedures. Quantitative procedures mostly consider the frequency of some aspects in the content, while the qualitative approach observes the presence or absence of a characteristic or set of elements in a message fragment (KRIPPENDORFF, 2004).

As a technique, content analysis involves specialized procedures (BARDIN, 2011), which can be detailed in three phases: (1) pre-analysis; (2) content exploitation (coding and categorization), and (3) results analysis and interpretation (see Figure 4).

Figure 4. Content analysis phases.



Source: developed by the authors (2021).

The first phase of pre-analysis consists of the sample collection and organization. In this study, it consisted of document gathering and critical reading to define the sample of secondary data. These procedures were conducted during the Systematic Literature Review.

The second phase of content exploitation, is characterized by coding techniques that allowed us to categorize the content considering four groups:

- **Context Categories:** encompass the content as a whole, since they are broader and directly related to the research objectives;
- **Analysis Categories:** subdivision of context categories into smaller parts to allow analysis;
- **Recording/coding units**: words that explain the analysis categories and that can be identified by quantitative (frequency and recurrence) and qualitative criteria;
- **Context Units:** phrase or fragment that explains the registration units, limiting the information considered in the description of recording units.

In this study, the process of categorization for these four groups was conducted based on quantitative and qualitative criteria. First, the context categories were defined based on

the keywords of this research, as they are broader, contain smaller subdivisions, and represent their context.

Next, to identify the analysis categories, the recording, and context units, we conducted a quantitative and qualitative procedures for the 40 selected studies. The quantitative procedure was carried out by determining the five most frequent words present in each article, thus identifying the most cited words in all articles.

Next, we carried out a qualitative procedure based on reading the documents, considering expressions in common between different texts, which did not necessarily appear in the word frequency. Subsequently, the words and expressions resulting from the quantitative and qualitative surveys, within each category of context, were grouped, considering frequency, recurrence, associations, and equivalences.

After this grouping, we set out to define the recording units and analysis categories. We made several groupings and exclusions of the identified words, considering that the final categories come from the progressive regrouping of categories with a weaker generality (BARDIN, 2011). Table 1 presents the final analysis categories, which consists of the proposition of the theoretical model.

Table 1. Proposition of the final analysis categories and theoretical model.

Contex t categories	Analysis categories	Recording/ coding units	Context units
S-DN in PSS	Ownership	User or Provider	Regarding ownership, PSS can be product-oriented, use-oriented, or result-oriented, which determines whether is the user or the provider that holds the product's property (TUKKER, 2004).
		Rebound effects	The costs for maintaining a product in a PSS are higher than the current selling of the product by unexpected side effects (SCHNEIDER, 2003).
	Complete solutions	PSS and Bouquets	A bouquet is a commercial offer of a set of products and services, complementary in offering a particular function, and complete solution to the situation of use (HUET; CHOPLIN, 2012).
		Experience	Set of effects caused by the interaction between a user and a product, which includes the degree to which all the senses are satisfied, the meanings that are attributed to the product and the feelings and emotions aroused (HEKKERT, 2006).
	Meeting needs (satisfaction)	Functional and Emotional	Creating experiences has the possibility to fill the absence of ownership, so it is important to design personally meaningful and positive experiences, designed to satisfy the functional and emotional needs of consumers (DEMYTTENAERE; DEWIT; JACOBY, 2016).
		Use value	Identify and emphasize the design functions of a product (material goods or services) that satisfy users and provide their use value (MONT, 2002).
	Heterogeneous Network of Stakeholders (actors)	Providers, companies	All the actors that form the stakeholder network that offer and maintain the PSS.
		Customer, user	All the actors that that will use the PSS.
		Devices	Equipment and devices are essential for the interaction between the actors in the network to occur (CALLON, 1999)
		Cooperation, co-production and interaction	It is the network interaction of different actors that configures the actors and their motivations, in a dynamic process that requires constant negotiations. During interactions, the actors interact with each other, make decisions and act according to their interests, in constant processes of interactions, negotiations and discussions, since they face conflicts of interest with the actions of other actors (CALLON, 1999).
	Sustainable development	Local Economy Development	Actions to improve the local and regional economy.
		Valorization of the Territory and social aspects	Concerns with the territory, perceived as a multisectoral and multi-functional place for the meeting of several actors, centered on shared use value strategies
		Environmental aspects	PSS are design strategies for sustainability, which aim to integrate a system of products, services and communication based on new forms of organization and reconfiguration of the roles of consumers and other stakeholders, sustainable medium and long-term objectives (VEZZOLI; KOHTALA; SRINIVASAN, 2014).

Source: developed by the authors (2021).

At last, the third phase of content analysis corresponds to the analysis of the results, performing the processes of description, inferences, and data interpretation. In this study, we applied the theoretical model in Autolib's practical case, to analyze the role of a solution-demand network in the context of the Functional Economy.

Autolib Case Study

Autolib was a proposal of Functional Economy for the B2C market (the company serves the final consumer), consisting of providing shared electric cars through a paid service. The car-sharing system was developed to initially meet the city of Paris, by offering innovation in urban travel and transforming the experience in cities, besides increasing mobility by reducing the use of private vehicles and providing only one type of car to reduce environmental impact (BISIAUX, 2015).

Dijk, Orsato and Kemp (2013) point out that the idea was to reduce the number of cars parked on the streets, ease traffic jam, and reduce pollution. The project of the French company BlueSolutions, belonging to the Bolloré Group, launched in Paris in December 2011 and complemented the city's bike-sharing system called Vélib, which operated since 2007 (DIJK; ORSATO; KEMP, 2013). The vehicle was called the Bluecar, a compact electric silver car that held up to four people (ROE, 2017). Designed by Studio Pininfarina and developed by the Bolloré group, the Bluecars were equipped with a maintenance-free battery, an onboard computer connected to the operations center, and Michelin tires. The project was a car with low environmental impact that met the needs of mobility within the city (BISIAUX, 2015).

Autolib's car-sharing system was launched as a public-private partnership between the Bolloré Group and the City of Paris. By engaging actors who were not used to collaborate before, public actors had to adapt their organizations to meet the new challenges of a car-sharing system and develop new skills (TERRIEN *et al.*, 2016). Thus, Autolib caused a rupture in existing public and private organizational structures by establishing new connections and creating a hybrid organization, Autolib'Métropole, linking public and private sectors (TERRIEN *et al.*, 2016). However, when considering the integration of Autolib with the operating public transport system, despite being integrated with the Vélib bike-sharing system, the idea remained centered on the car as a dominant means of transport, with no compatibility with other means of transport (HILDERMEIER; VILLAREAL, 2014).

Autolib's service closed its activities on July 31, 2018, because of the high maintenance costs that made the service unfeasible (LAGADIC; VERLOES; LOUVET, 2019), as well as the increasing complaints of users about the smell, lack of cleaning and maintenance, and the number of depredated vehicles (HENLEY, 2014). Although the service was discontinued, it is still internationally renowned as one of the best examples of an electric car-sharing scheme and pioneering in the public electric car-sharing service (DODMAN, 2018).

Results

In order to identify the role of a solution-demand network in a PSS, we conducted the analysis by comparing the five analysis categories defined by the theoretical model with the practical case of Autolib. Next, we describe the findings for each analysis categories and its respective recording units.

Ownership

Regarding the "Ownership" analysis category, we identified Autolib as a use-oriented PSS, where ownership remains with the service provider, and usage rights are passed on to the consumer, who is the temporary owner while driving the vehicle (TUKKER, 2004). In this way, Autolib is a model that proposes temporary ownership, offering the primary function of mobility through a shared car (SALAZAR; LELAH; BRISSAUD, 2015), without entailing the everyday concerns of owning a vehicle, such as fuel costs, finding parking spaces, maintenance, and re-

pair. In Autolib, these responsibilities are transferred to the provider and maintainer of the service (VERVAEKE; CALABRESE, 2015). Besides, as a pay-as-you-go system, Autolib allows access to individuals who previously could not afford to purchase a car, by offering access to mobility at lower costs compared to the purchase of a private car (VEZZOLI; KOHTALA; SRINIVASAN, 2014). This can be noticed since Autolib attracted young users who often could not afford to own a vehicle and found an opportunity in shared-use models (HENLEY, 2014).

Considering the "User or Provider" recording unit, we can highlight the concepts exposed by Law (1992), that social relations are understood as network effects, and by Callon (1999), who considers that it is the network interaction between different actors that shapes the actors themselves and their motivations. In this sense, although the user-provider relationship is one of the most noticeable, we must consider all actors involved in this materially heterogeneous network, which allowed the delivery of Autolib's service to users as a PSS by using a shared electric car.

Regarding the "Rebound Effects" registration unit, we can recall Callon's (1999) argument that one of the main points of ANT is that it assumes a radical indeterminacy of the actor, not based on any stable theory of actors. Actors in networks make decisions and act according to their interests, in constant processes of interactions, negotiations, and discussions, as they face conflicts of interest with the actions of other actors. However, these actions can neither be predicted nor predetermined, being modified and constructed as dynamic network relationships take place (CALLON, 1999). Thus, although Autolib predicted possible damage and sought to anticipate issues by positioning tax officials responsible for reporting the vehicle's conditions, it was not possible to predict the actions of all the actors in the network, and even some actors that were not considered being part of the network. The reported cases of vandalism, or of homeless people that managed to breach the Bluecars' security lock and used the vehicles to sleep (DODMAN, 2018) demonstrate the complexity of a network and how challenging it can be to foresee and prevent issues.

Complete solutions

Concerning the analysis category "Complete Solutions," although Autolib's project was to articulate with Vélib, the bike-sharing system already at use (DIJK; ORSATO; KEMP, 2013), we consider that Autolib's offer could be total if it was integrated with other means of urban transport, such as subways and buses (HILDERMEIER; VILLAREAL, 2014). Thus, we ponder that Autolib could have expanded the solution offered and the network of actors involved, since PSS are understood as integrated systems of products, services, and stakeholders, referring both to the system of products and services delivered to the consumer, as to regarding the system of actors who produce and deliver this set (CESCHIN, 2013).

Considering the "PSS and Bouquets" registration units, we consider Autolib as a use-oriented PSS, as it aimed to offer the function of mobility within the city. In this sense, although Bluecars had a speed limited to 130km/h, Autolib sought to meet the specific demand in urban transport situation (HUET; CHOPLIN, 2012). To do so, the company was responsible for maintenance and repairs, offered emergency service channels, and a 24-hour monitoring system (VERVAEKE; CALABRESE, 2015).

Regarding experience, Autolib could be considered similar to most car-sharing offerings, with some advantages: being able to use the service on the same day of subscription and pre-booking parking spaces for the return of the vehicle (ROE, 2017).

As we already pointed out, the success of new Functional Economy and PSS strategies depends on the dynamic network relations between different stakeholders (actors) and their actions. In this way, we can say that the network interaction between different actors can generate adapted and complete solutions, through the processes of exchange and cooperation, in the solution-demand networks. In some cases, the solution is tailored to meet a demand. In others, the identification of a possible demand requires the construction and adaptation of a solution (GORTZ, 2017).

In the case of Autolib, we understand that an existing solution, such as battery technology and electric car, has been adapted to meet a demand for urban mobility, improving the

experience in the city. Although the electric car solution already existed before Autolib, the service offered a differentiated and adapted solution for not requiring the purchase of the vehicle. Before Autolib, most of the proposals of electric cars were for private use, through acquisition. Moreover, car-sharing services, although not new, have so far offered conventional vehicles, and Autolib was one of the first car-sharing companies to offer electric vehicles (DODMAN, 2018). Thus, in Autolib, the solution was adapted to make it more complete by assembling the electric car and offering it in a complete PSS of car-sharing, allowing the use of cleaner cars and improving urban mobility experience.

Meeting needs (satisfaction)

In relation to the analysis category of "Meeting needs (satisfaction)", we consider that Autolib proposed an innovative solution when offering the use of electric cars as a service without requiring the acquisition and consumer's high investment. As Henze, Mulder and Stappers (2013) point out, it is necessary to cover the complete life cycle of a PSS development process, starting with understanding the users' needs in generating product service propositions, where the process is an accumulation of translations and transformations, and the ability of some actors to obtain other actors to obey them depends on a complex interrelations network in which society and nature are intertwined (CALLON, 1986). Thus, it is essential to understand the user's true need, which in Autolib's case was a demand for mobility in the city, not for a car.

We reckon that Autolib had the potential to satisfy both the functional and emotional needs of users by offering a mobility alternative within the city, combined with comfort, ease, and safety. As Vezzoli, Kohtala and Srinivasan (2014) point out, the PSS design process should broaden its approach, not only on functional issues but on satisfaction as well, shifting the focus from a product to a broader system that satisfies a specific demand. Moreover, because there were own stations for picking up and returning vehicles, a significant concern and inconvenience of drivers in large cities were mitigated, in addition to the fact that the vehicle could be returned in a different station from withdrawal (BISIAUX, 2015; ROE, 2017). Thus, it was a proposal of satisfaction of mobility needs and transportation by offering services and products that support and allow this access (SALAZAR; LELAH; BRISSAUD, 2015).

Other aspects such as easy access, use, and direction, functional, efficient and pleasant design, search for less expensive solutions, contribute to emphasize the use value and the useful effects (GIDEL; HUET; BISIAUX, 2016; HUET; CHOPLIN, 2012) of a car-sharing system such as Autolib, constituting a PSS that worked and provided added value to the product life cycle (VERVAEKE; CALABRESE, 2015).

Heterogeneous network of stakeholders (actors)

Regarding the "Heterogeneous network of stakeholders (actors)" analysis category, to develop and implement of Autolib it was necessary to create partnerships and interactions by different actors, each with competences, resources, and interests (DIJK; ORSATO; KEMP, 2013). In this way, Autolib was a project that depended on a constant and collective translation process to align the actors' interests with and within the project (Floricel *et al*., 2014), considering both human and non-human actors (LATOUR, 2005; LAW, 1992). The trajectory that led to this electric car-sharing system was the result of 20 years of research and various alliances between companies (VERVAEKE; CALABRESE, 2015), hiring people with complementary skills from outside the group (TERRIEN *et al*., 2016).

Autolib's network consisted of both human and non-human actors ("Providers and companies; Customer and user; Devices" recording units). We can identify that Autolib's solution came about through the interaction between different actors and moments: (i) the success of the bike-sharing system; (ii) the development of LMP batteries that allowed the introduction of appropriate technology; (iii) the involvement of different sectors and companies, which allowed adapted solutions to be generated by interactions between different actors within the ne-

twork in a dynamic process of cooperation, thus constituting solution-demand networks. Thus, Autolib enabled the proposal of a solution-demand network (GORTZ, 2017), since Autolib's idea conception, to the verification of economic viability by the development of efficient batteries for the demand, the partnership with different producers, until the acceptance of the users to adhere to the model.

Moreover, considering the "Cooperation, co-production and interaction" recording unit, we consider that Autolib has unleashed innovative and collaborative standards. This can be identified by the way established automakers have collaborated with municipal administrations to develop new business models around shared cars and electric cars (HILDERMEIER; VILLAREAL, 2014).

Sustainable development

Regarding the "Sustainable Development" analysis category, we consider Autolib's model was aligned with the sustainable principles of the Functional Economy and PSS proposals. In economic terms, Autolib encouraged the creation of new jobs, by the demands of maintenance, and as the model expanded to more cities, more local jobs were created. Also, it contributed to regional economic growth by demanding skills from different partners and contributing to the local economy development (VERVAEKE; CALABRESE, 2015; DIJK; ORSATO; KEMP, 2013; TERRIEN *et al*., 2016). Despite not being integrated with the urban transport system as a whole (HILDERMEIER; VILLAREAL, 2014), Autolib allowed the creation of a public-private partnership, bringing benefits to the private companies and also to the city of Paris (VERVAEKE; CALABRESE, 2015; TERRIEN *et al*., 2016).

We understand that Autolib was also a proposal that sought to value the territory, while seeking to reduce the impact of cars in cities, reducing the number of vehicles in circulation and the amount of urban area intended for parking spaces. According to Drut (2015), collective consumption is a fundamental characteristic of an efficient transportation system, considering that the satisfaction of individual needs affects collective needs, for reasons such as congestion and disputes for the use of parking spaces (DRUT, 2015). To do so, Autolib proposed to contribute to better planning and use of urban space (ROE, 2017).

Regarding social aspects, in addition to providing more employment opportunities for the local population, Autolib's proposal covered the opportunity to access a vehicle, at low cost, especially for the younger public, which is often unwilling to purchase a vehicle, not only because of high initial investment but also because of maintenance, fuel and parking expenses (HENLEY, 2014).

Regarding environmental aspects, Goedkoop *et al*. (1999) consider that car-sharing systems can have as positive effects the reduction of the number of cars needed to meet the demands of mobility, which also implies the reduction of areas destined for parking and reduction of the number of cars to be produced, maintained and available. Autolib also aimed to contribute to the reduction of atmospheric pollution and carbon emissions, as well as noise pollution in large cities (BISIAUX, 2015). Also, in the Bluecars design, development, and production, critical environmental issues were considered, such as (i) the use of materials with less risk of depredation, (ii) use of metal's own color to avoid painting, and (iii) development of components with extended durability.

Analysis synthesis

As pondered by Callon (1999), during the network interactions, actors interact with each other, make decisions and act according to their interests, in constant negotiation processes, when facing conflicts of interest with the actions of other actors. Thus, we consider that in Autolib's network, the relationship between human actors worked well until a moment. As soon as some actors began not to see more advantages, such as the city of Paris that wanted to leave the partnership, even with the negotiation actions of the other actors, it was not possible to maintain the network.

We can also ponder that the network dynamic was not enough to go beyond conflicting

relationships among certain stakeholders. If there were attempts to strengthen and approach the links and attachments with other transport operators and even between the relation of provider and users, there could be a chance of keeping the relationship between public institutions and the Bolloré group. This shows the relevance of network relationships among the different stakeholders involved and that we cannot take any actor for granted.

Therefore, although Autolib's activities were closed in July 2018, we consider that it was a good example of future solutions of PSS within the urban context. Autolib's case reinforces the importance of regarding beyond technical and functional issues, and consider the relationship between different stakeholders involved, which can contribute to the success or failure of a PSS solution. We summarized the analysis findings in Table 2, which demonstrates how the five analysis categories proposed by the theoretical model were identified in Autolib's PSS model.

Table 2. Theoretical model applied to Autolib's case.

Analysis categories	**Recording units**	**Application on the Autolib case**
Ownership	User or Provider	The user was the temporary owner while driving the car, but the permanent ownership was of the company that provides the service (use-oriented PSS).
	Rebound effects	There were employees at the stations to supervise and prevent the vehicles from being depredated. There were records of cases of vandalism. When the user bumped the car, he/she should pay a fee, and if it was recurring (3x), the account was suspended.
Complete solutions	PSS and Bouquets	User oriented PSS model: the service was offered to the user through the Bluecar (product), which provided the function of meeting the demand and mobility needs in the city.
	Experience	Similar to car-sharing offers, with the proposition to improve the experience in cities. Issues to be improved (interface and usability.
Meeting needs (satisfaction)	Functional and Emotional	Functional: Meets transportation and mobility needs. Emotional: Offers comfort, practicality, security.
	Use value	Mobility offer as use value.
Heterogeneous Network of Stakeholders (actors)	Providers, companies	Partnership between several suppliers: tires, battery, monitoring system, design, production, public-private partnership.
	Customer, user	Anyone with a driver's license, document and credit card can use the system.
	Devices	The car itself, 24h monitoring system, computer, GPS.
	Cooperation, co-production, and interaction	Development of the offer together with different suppliers, each with its own competencies and interests. Constant interaction between partners for enhancements.

Sustainable development	Local Economy Development	New jobs created, and partnerships with several companies to offer the service as a whole. Regional economic growth.
	Valorization of the Territory and social aspects	Concern in reducing impacts caused by vehicles in the city. Proposition to complement other means of transport, such as bike-sharing (Vélib), but lacks greater integration with other means, such as subways, buses.
	Environmental aspects	Proposal to reduce atmospheric and noise pollution, reduce carbon emissions and fuel consumption. Components with longer durability.

Source: developed by the authors (2021).

Therefore, after conducting the analysis, we observe that the role of solution-demand networks in PSS solution occurs in five distinct key points, which must be considered with their respective characteristics. The comprehension of these five elements contributes to understanding how to improve the relationship between actors, (both human and non-human). Thus, interactions could be more collaborative, cooperative, and contribute to the continuity and maintenance of the PSS solution-demand network.

Conclusion

This study aimed to analyze the role of solution-demand networks in the context of the Functional Economy. By conducting a systematic literature review and content analysis, we proposed a theoretical model which was applied to the case of Autolib. We observed that the role of solution-demand networks in PSS solution occurs in five distinct key points: (1) Ownership; (2) Complete solutions; (3) Meeting needs (satisfaction); (4) Heterogeneous Network of Stakeholders (actors); and (5) Sustainable development.

We consider that Autolib functioned as a solution-demand network during its shaping and operation period, by adapting an existing solution (the electric vehicle) to a specific demand (access to mobility and not the purchase of a car). However, the closure of the Autolib service can also be associated with the dismantling of this solution-demand network initially formed. As the service grew, the number of users registered on the platform increased, but the number of vehicles made available did not increase in the same proportion, which caused the dissatisfaction of many customers. In addition, the lack of vehicle's maintenance resulted in dirty and damaged cars. With the growing dissatisfaction and complaints about the service's quality the city of Paris decided to end its public-private partnership, which also affected the group that operated the service. Thus, the solution offered by Autolib was no longer seen as an economically viable solution to meet the demand for mobility in the urban context.

We emphasize the relevance of the role of all actors involved that enabled the creation and implementation of the system. Through processes of translation and interactions, Autolib was made possible, and also implemented to improve city experience. However, networks are also dynamic and depend on the commitment and motivation of all involved actors, whether human or non-human. Even with competent actors with different abilities, the network may not be established and continue, for the different interests of the actors, which may change. That is why it is essential to carry out constant analyzes to understand the working of the networks.

We understand that the use of secondary data only was a limitation to this study, and therefore we suggest the continuity of this research by conducting surveys also with primary data. This study can also be expanded to other examples of PSS, in order to apply the theoretical model and analyze SD-N on other practical cases.

Therefore, the comprehension of the five key points in a solution-demand network can help us understand how to improve the interaction among stakeholders, so that it is more collaborative, cooperative, and benefiting to all actors involved. These five key points should be considered when designing new PSS solutions, or used as a way to analyze and improve already working PSS. How these five aspects are present (or not) in an PSS solution can help us to understand how the relationship between stakeholders takes place, in addition to contributing to the diagnosis of what needs to be changed or improved, to ensure its continuity and avoid that the network is dissolved.

Acknowledgments

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes--Brasil), the institution that contributed with part of the authors of this paper, contributing to the evolution of this research.

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Recebido em 29 de maio de 2020.
Aceito em 25 de agosto de 2021.