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**DOI:**
10.1109/DCOSS.2019.00086

**Document Version**
Accepted author manuscript

# Towards Systematic Specification of Non-Functional Requirements for Sharing Economy Services

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***Abstract*—Sharing Economy (SE) systems use technologies to provide individuals with information that enables the optimization of resources through the mutualization of excess capacity in goods and services; thus, SE systems contribute to the re-use phase of the Circular Economy. In this paper, we assess existing SE services and identify their weaknesses in areas that are not technically connected to their core functionality, but are essential in creating trust: information security, personal data protection and economic incentives. We then propose to take a systematic approach to non-functional requirements specification, where a well-defined, structured approach would pay immediate dividends. As existing frameworks are not holistic and have several shortcomings, we set forward a research agenda, both for ourselves and the community, aiming at systematizing the specification of non-functional requirements for SE services in a *top-down-top* manner.**

***Index Terms*—Sharing Economy, Security, Privacy, Data Protection, Trust, Economic Incentives, Requirements Specification**

## I. Introduction

Circular Economy (CE) represents a novel paradigm shift that promotes a sustainable and environmentally-friendly future, in which our society moves away from the traditional *linear* economy (*produce-use-dispose*) and adopts the more sustainable *circular* economy that facilities maximum reuse of resources and goods, then recycle and regenerate new goods, while keeping the waste at minimum levels (*design-reuse-recycle-regenerate-redesign*) [1], [2]. CE covers the entire aspect of our everyday life, from using renewable energy sources, reusing our goods and assets as much as possible, to sharing them with others while they are not used by us. The latter is known as Sharing Economy (SE) – a special (sub)case of the CE. The SE focuses on maximizing the utilization of assets and goods by multiple people, i.e., it advocates and incentivizes collaborative rather than individual consumption of goods [3]. Figure 1 illustrates the relation between CE and SE.

SE systems use emerging information and communication technologies (ICT) to provide individuals with information that enables the optimization of resources through the mutualization of excess capacity in goods and services. There are many examples of successful and well-regarded services following the SE model: Uber, Airbnb, Zipcar, TaskRabbit and the original, eBay, are some of the household names. Uber ($120 billion) and AirBnB ($31 billion), the two flagship companies, attained astronomic valuations in late 2018. This is remarkable concerning the mechanics of these businesses: essentially matching demand and supply (for a fee) in well-defined areas of daily life, e.g., transportation or temporary housing.

Another example of an SE service that has been gaining attention is vehicle sharing systems - the worldwide number of users of vehicle sharing services has grown by 170% from 2012 to 2014, reaching 5 million in total [4], and is expected to reach 26 million by 2021 [5]. Several companies (including Volvo, BMW, Toyota and Apple) have already invested in such SE services. Furthermore, the energy sector has also been undergoing substantial transformation with the realization of the smart grid vision [6]. Peer-to-peer electricity markets where users trade their excess electricity directly with each other are redefining the way electricity is generated, delivered and consumed [7].

All these innovative SE services have been made possible by advancements in ICT. These advancements allow users (and/or companies) to connect to, collect and analyze data from, share their assets and goods with, and deliver services to others. A prominent example is Internet of Things (IoT) devices (and their sensors) which allow remote access, monitoring and control of virtually everything connected to the Internet, ranging from houses, cars, fridges, TVs, bicycles, watches to even dolls. Advancements in computing power and parallelism allow technologies such as Artificial Intelligence (AI) and Machine Learning (ML) to be used for efficient analysis of all the available data collected from these IoT devices and for automatic decision making. In addition, smart contracts could provide the means to digitally facilitate, verify, and/or enforce the negotiation of contractual (and possibly legally binding) agreements between users [8].

A typical SE service usually requires the involvement of a number of users (a priori unknown to each other), as well as the collection of a considerable amount of (mostly personal and potentially sensitive) user data by the SE service provider in order to support various services and be flexible in providing (personalized) services to users. This, of course, results in

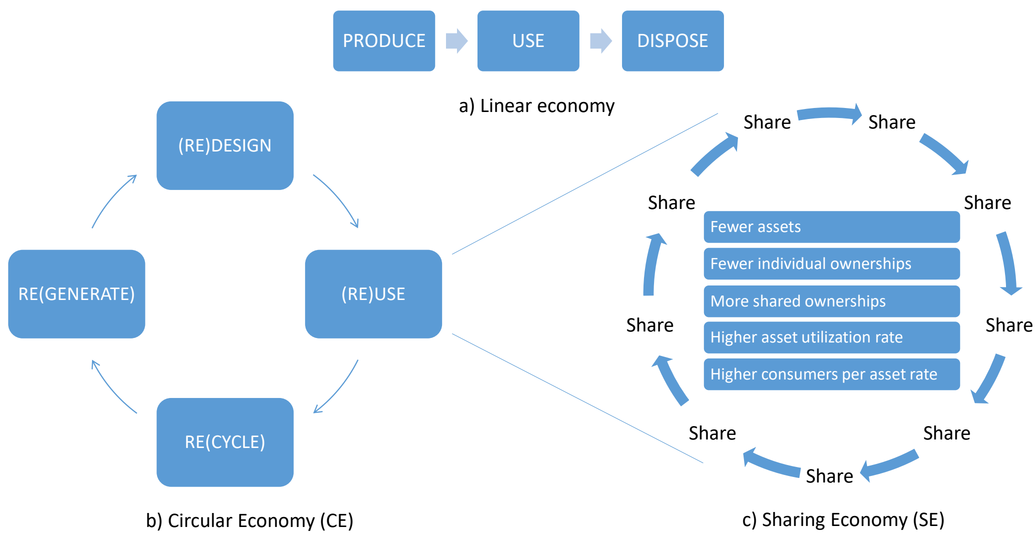


Fig. 1. Relation between different types of economy models: a) Linear Economy, b) Circular Economy and c) Sharing Economy.

the emergence of a complex SE ecosystem, with many SE services available to users. Intuitively, the more flexible the SE services are, the more attractive they become for users, thus contributing more towards the main goal of SE (CE) – to have a sustainable and environmentally-friendly future through the efficient re-use of assets.

Inevitably, higher service flexibility comes with more personal data being collected, processed, analyzed, stored and shared by various SE service providers, raising concerns about how to (i) provide high levels of trust and accountability in such complex SE systems, (ii) protect the privacy of the users of these SE systems, and (iii) design and integrate appropriate and fair economic incentives to encourage users to proactively engage with SE systems. To address these concerns, one should design SE systems in such a way that, in addition to the functional requirements needed to provide the core functionality with the high quality surely expected by the users, the crucial non-functional aspects, i.e., information security and privacy requirements, data protection regulation compliance and appropriate economic incentives, are also taken care of. Unfortunately, there exists no established unified framework for non-functional requirements specification, let alone one specifically tailored for SE systems.

Our contributions in this paper are two-fold: (i) we highlight the lack of a systematic approach to non-functional requirements specification for SE services and justify the need for such, and (ii) we take the first steps towards building a unified framework, while also providing some future research directions for the community.

The remainder of this paper is organized as follows. Section II reviews several types of SE services and emerging ICTs and identifies common features of SE services. Section III analyzes the challenges of SE services in terms of security, privacy and economic incentives; and highlights the lack of a systematic approach for non-functional requirements specification. Section IV describes the limitations of existing frameworks. Section V takes the first steps towards building a unified framework for non-functional requirements specification. Finally, Section VI concludes the paper.

## II. Sharing Economy Services and Emerging ICTs

This section gives an overview of the types of SE services available (see Fig. 2) and the emerging ICTs, before attempting to identify and extract the common features of the SE services.

### A. *Sharing Economy Services*

*1) Accommodation/space share:* This type of SE services allows users to temporary rent out (partially) their properties and spaces. In terms of accommodation, this ranges from renting out entire properties, holiday homes, spare bedrooms, couches in the living room to garages. Probably, the most well-known companies offering this type of SE services are Airbnb and Couchsurfing. Space-related SE services predominantly focus on renting out spare parking and office space. Other examples include services for renting out space in the garden used for camping or for growing vegetables.

*2) Mobility share:* This type of services allows users to rent means that would provide them with mobility, i.e., help them move from point A to point B. There are several varieties of mobility sharing, ranging from renting (i) only a vehicle such as car (e.g., Turo), van, scooter, bike, and skateboard, (ii) a ride where the user determines the starting point and time as well as the destination of the ride (e.g., Uber), to (iii) user joining a ride with a predefined route and time (e.g., BlaBlaCar).

*3) Food share:* This type of SE services allows users to share their food (meals) with others. Some services focus on delivering the (excess) food from individuals and/or restaurants to users, whereas others focus on providing more unique user experience where individuals can host users and share a meal (e.g., dinner) with them.

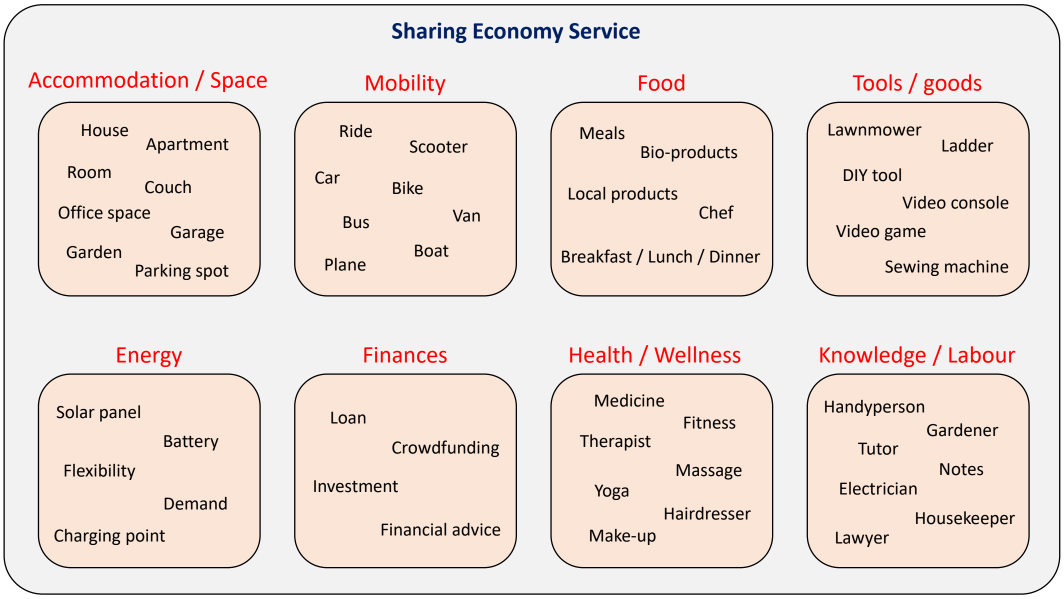


Fig. 2. Sharing economy (types) of services.

*4) Everyday tools/goods share:* This type of SE services allows users to borrow from each other everyday tools, goods and equipment such as home gadgets, game consoles, DIY tools, gardening tools, BBQ and books.

*5) Energy share:* This type of SE services allows users to trade their excess electricity (generated, for example, from their solar panels) directly with other users (instead of trading with their suppliers) as well as trade their flexibility (i.e., ability to shift their consumption patterns) to suppliers and/or grid operators. The most popular services are peer-to-peer electricity trading as well as offering demand response to third party electricity aggregators.

*6) Finance share:* This type of SE services allows users to lend money to others or invest in others' loans and start-up companies. Borrowers can get lower interest rates compared to borrowing directly from banks or lending institutions, and lenders could get better return on their money.

*7) Health/wellness share:* This type of SE services allows users to borrow medicine from each other as well as connect with relevant certified professionals, such as beauticians, dietitians and personal fitness trainers, to get personalized advice.

*8) Knowledge/labour share:* These types of SE services connect users with (mostly local) experts and professionals, ranging from handypeople, mechanics, gardeners, babysitters, to lawyers, tutors and freelancers.

### *B. Emerging ICTs*

Recently, several (new) ICTs/paradigms have attracted the attention not only of academics, but also of the industry. The IoT paradigm - connecting everything to the Internet - is already (becoming) a reality. There are already a vast number of *IoT devices* (with multiple sensors) operating in our everyday lives, hence collecting and sending data to various service providers. Typically, these devices have limited computational capabilities, thus they send their data to the *cloud environment* for analysis. The amount of data collected and available can be so vast that companies may even struggle to process it by themselves, hence usually being 'forced' to use the services of third-party companies specialized in data analytics. This paradigm is known as the *big data*, which can facilitate learning new insights from the data. This is possible now due to the advanced AI (ML) techniques such as *deep learning* that could find relations and patterns in extremely complex data sets, using only unsupervised learning.

Furthermore, *distributed ledger* (e.g., Blockchain) have also gained enormous attention in the last few years due to their sought after properties such as verifiability, decentralization and transparency. When coupled with *smart contracts*, they become even a more powerful technology that can facilitate an automated and enforceable 'contract' agreements between users.

*Secure distributed computing* is another technology that starts making the headlines due to its promise to overcome the main limitation of centralized systems - the single point of failure. Although fully homomorphic crypto systems are not fully practical yet due to being computationally 'slow', somewhat (semi) homomorphic crypto systems are already being deployed in practise. In addition, Multiparty Computation (MPC) technology overcomes the limitation of the fully homomorphic crypto systems by offering relatively 'fast' computations at the expense of high communication overheads.

### *C. Common Features of SE Service Providers*

Since the SE services have similar objectives - to connect users (unknown to each other) in order to maximize the use of certain assets and goods, most of the SE service providers share similar features. A non-exhaustive list of common features of SE service providers is given below.

- *Centralized digital platforms*: Most of the SE services providers use centralized digital platforms to provide their customers with bespoke services and user experience.
- *IoT devices*: The majority of the service providers rely on various types of IoT devices to collect vast amounts of (personal) data of users.
- *Artificial intelligent and machine learning algorithms*: Companies deploy advanced AI/ML algorithms to analyze the collected data and obtain in-depth insights into the habits and behaviour of their customers.
- *User-centric/-friendly interface*: Most of the SE service providers make sure that their user interfaces are designed in such a way that their services are easy to engage with and simple to use.
- *New technology-friendly*: Companies providing SE services are open to explore, test and adopt emerging new technologies in their business models in order to increase their market share.

## III. Challenges in Sharing Economy

This section analyzes some of the main challenges of SE systems: (i) trust, accountability and transparency, (ii) information security and privacy, (iii) data protection compliance and (iv) fair economic incentives.

### A. Trust, Accountability and Transparency

*Trust* is the single most important enabler of the SE. Eloquently defined as "confident relationship with the unknown", trust is the new oil of collaborative consumption. A user of an SE service needs to trust the business proposition, the platform matching supply and demand (if any) and often the other users of the service. Given that SE services (i) are powered by information technology, (ii) deal with massive amounts of personal data thereby falling within the scope of data protection laws, and (iii) have multiple interacting stakeholders with diverging economic interests, *trust relationships are created and maintained via an ensemble of technological, legal and economic mechanisms*. Note that *trust* is also closely interrelated with *accountability* (to guarantee that misbehaviour is punished) and *transparency* (to guarantee fair and non-discriminatory treatment of users). The efficiency of these means relies on the science of (i) information security and data privacy, (ii) law and (iii) economic mechanism design, respectively.

### B. Information Security and Privacy

*Technical information security and data privacy* have a crucial role in SE services. There are many security and privacy aspects of SE services. First, in scenarios where users share their own assets, such as vehicles or properties, cyber-physical security is of utmost importance. For instance, if an unauthorised user obtains access to another user's property or vehicle, substantial financial damages for the latter may incur. Second, SE services use platforms for their operations, and the platform itself should be secure and transparent in its mechanisms. Most platforms run on public cloud infrastructure, inheriting its security issues. Also, if the platform handles payments it usually utilizes a third-party financial provider to process transactions, thereby being vulnerable to attacks on the financial provider. For example, in a breach of security 57 million Uber customers' and drivers' information were compromised [9]. Third, SE service providers collect vast amount of user sensitive data [10]; a by-product of the immense amount of data generated by users and transferred to these providers. This changes completely the adversarial model currently used – only the users and the outsiders are seen as threat, but not the providers. Nowadays, SE service providers are also seen as a threat considering the amount of user data they collect. For example, vehicle sharing service providers collect personal data such as user and vehicle identity, vehicle location, user preferences, rental time, duration, pickup location, and when, where and with whom someone is sharing a vehicle [11]. SE service providers can even attempt to infer additional sensitive information about users from the data they already hold on them – such as racial and religious beliefs [12] or their health-related information, by identifying users who regularly visit specific hospitals [11].

### C. Data Protection

Owing to the massive amounts of personal data handled, compliance with *data protection law* plays a central role for SE services. Note that, multiple user data sets can be acquired and *fused* by a single data broker such as Cambridge Analytica [13] and Palantir [14]. Such big data-silos can contain rich information about individuals' everyday lives and habits. That enables profiling and micro-targeting of users such as in political elections. The General Data Protection Regulation (GDPR) [15], that became applicable as of May 2018, reinforces the earlier European framework by creating more stringent requirements for data controllers and processors. As the data processed by SE services is often related to an identified or identifiable person, and the SE providers either are established within the European Union, or their activities relate to the offering of services to persons who are in the European Union, the GDPR is applicable. Therefore, the SE service providers, as the legally responsible entity (controller), have to comply with the requirements of the GDPR and especially have to safeguard data subjects' rights. For instance, the GDPR establishes the protection of individuals against automated-decision making, profiling and discriminatory practices based on profiling.

Compliance with these rules must be transparent for the individual. For example, art. 13 and 14 of the GDPR provide that the data subject must be informed about the existence of automated decision making or profiling, and should receive "meaningful information about the logic involved, as well as the significance and the envisaged consequences of such processing for the data subject."[1] Furthermore, the data subject

[1] art. 13 (g), art. 14 (g) GDPR. Which article applies depends on whether the personal data was obtained directly from the data subject, or indirectly from another source.

has the right to object against profiling (art. 21 GDPR) and has the right not to be subject to automated decisions or profiling if it would produce a legal effect for the data subject (art. 22 GDPR). This right, however, does not apply if the profiling is either authorized by Union or Member State law, or necessary for concluding a contract between the data subject and the controller, or if the data subject gives explicit consent. For the last two cases the GDPR specially reiterates the obligation for the controller to implement suitable measures to safeguard the data subject's rights and freedoms (which includes that not only the right to data protection, but also other rights such as the right to privacy, needs to be taken into account), and that the data subject has the right to obtain human intervention from the controller. The human intervention should help to express the point of view of the data subject and provide a possibility to contest the decision. The application of the GDPR is monitored by supervisory authorities, and in case a lack of compliance becomes known it can result in burdensome fines from the supervisory authority. Furthermore, in case an infringement of the Regulation results in damage (material or non-material), the person who suffered the damage could get compensation from the SE provider.

### D. Fair Economic Incentives

As SE services are built on the principle of involving multiple stakeholders with their own incentives, proper *economic mechanism design* is essential for their success. Broadly defined, economic mechanism design can be seen as a type of inverse game theory: while the desired outcome of a multi-party decision problem is given, the incentives and game mechanisms that take the system under study there need to be systematically engineered [16]. Lately, proper incentives have been shown to make or break successful and efficient systems such as secure computer networks [17], online social networks [18] and even legal frameworks (see art. 83 GDPR on monetary penalties – an incentive for compliance [19]).

Most SE services operate as two-sided (or multi-sided) markets, providing the means (a platform) to match service providers (supply) and customers (demand) [20]. Two-sided markets, if operating efficiently, have the potential to amplify and transfer the network effects from each side to the other. Hence, in addition to the inherent benefits of utilizing ICT, demand side economies of scale (more customers attracting more providers and vice versa) can boost transaction density, revenues and the value of the platform. In order to operate such an SE service efficiently, incentives for all three stakeholder types should align well [21]. In such environments, there are two key issues that are universal in distributed systems in general, specifically in the SE sector: fairness and efficiency.

Providers care about their monetary revenues; this implies a fair share of exposure in crowdsourced systems translating into equal income opportunities. Furthermore, owing to the two-sided network effects, if the SE system is fair, more providers and hence more customers will join, resulting in less idle time and more steady demand. Furthermore, as most SE services utilize some kind of review mechanism, providers' incentives include delivering good service in order to get favorable ratings, and get selected by customers in the future. For customers, receiving adequate service for a reasonable cost is the foremost objective. Customers should also care about a fair (to providers) SE system, as a fair matching mechanism ensures that many providers join and stay in the system. This in turn means a higher availability of the service in case of peak demand (such as national holidays for accommodation or Saturday night for ride-hailing services). Additionally, as SE services can be much more flexible than their centralized counterparts, customers might be willing to receive worse service (e.g., wait longer for a car) if given the right monetary incentives (e.g., discount fare). These type of micro-incentive strategies show potential in keeping the whole service running efficiently and in a balanced manner [22]. Platforms themselves need to attract both providers and customers. The larger the pool on either side, the more resilient the SE service is to societal or economic effects. It could already be seen that societal movements such as #DeleteUber can cause more than just a temporary dip in demand [23].

As far as efficiency, in most SE applications there are natural limits on the extent to which the resources can be shared [24]. In ride-hailing, each vehicle has a fixed capacity for passengers, accommodations have a fixed size, and so on. Therefore, participants have to be organized in groups of limited size so that individual resources are shared near-optimally. From the economic mechanism design perspective, a straightforward goal would be to allocate users into sharing groups that extract the maximum amount of overall utility; corresponding to the socially optimal allocation. In a distributed SE environment, such computation is impractical to carry out centrally: information on individual preferences is scarce and a central authority may not even exist (or has only a limited power, e.g. setting incentives). Therefore, game-theoretical investigations into a revenue-distribution mechanism inducing a near-optimal, self-organizing group allocation are needed. Early theoretical work [24] in this area proves that welfare distribution based on the Shapley value [25] shows promise; however, embedding such theoretical results into an actual SE application is far from trivial.

### E. Lack of a Unified Framework

The above examples show that these fields, i.e., information security and privacy, data protection and fair economic incentives, should be systematically considered during the SE system design phase. If used in a structured manner, these fields should provide system designers with essential *non-functional requirements* for SE systems. Although all current such systems provide us with the core functionality, which is usually a platform that helps people match demand and supply of various assets and goods, they either neglect such non-functional requirements or treat them in an ad hoc manner. This lackadaisical approach may result in failing services, legal problems, decreased revenues and disappointed users.

## IV. Limitations of Exiting Approaches

Regarding non-functional requirements analysis, there are several methodologies for system analysis and design [26], [27]. However, they are domain-specific and heterogeneous in their focus. For example, system engineering methodologies, e.g., secure software design lifecycle [28], do not take into account methodologies for privacy threat analysis and elicitation of requirements such as LINDDUN [29]. LINDDUN considers the legal requirements for data protection and privacy, such as GDPR [15] and ePrivacy (Directive 2002/58/EC [30]), only as a high-level policy requirement but not as a technical one. Existing domain-specific frameworks for system protection (e.g., for smart metering systems [31]) have only focus on the security and privacy challenges from a technological perspective. Existing work on economic mechanism design is highly theoretical and considers general system models [16]; therefore it is a non-trivial task to apply it to a real-world SE system. Most importantly, aligning all the analysis and compilation of requirements from technical information security and privacy, data protection law and incentive mechanism design perspective to a single methodology is a challenging task which has not been undertaken yet.

Existing solutions for SE services have only tackled partially some of the challenges mentioned in the previous section. In the vehicle sharing service domain, for example, Dmitrienko and Plappert [32] designed a secure free-floating vehicle sharing system. However, their system contains a centralized fully-trusted SE provider that collects and stores all the information exchanged within the system. Symeonidis et al. [33] performed security and privacy analysis of such systems and designed a solution for secure and privacy-friendly vehicle access provision [34]. Akash et al. [35] proposed a solution for the booking and payments functionality of a car sharing system using smart contracts. Similarly, in the energy sharing domain, use case specific (but still generic) security and privacy analyses have been performed [36], [37] as well as concrete privacy-friendly solutions for different functionalities have proposed [38]–[41]. However, none of these solutions (i) cover the entire asset/goods sharing life-cycle, (ii) are fully GDPR-compliant (even though they are privacy-preserving from a technological perspective) and (iii) provide fair mechanisms based on proper incentive-based economics analysis. The H2020 project Ps2Share has studied participation, privacy and power in the SE [42]. Though valuable as a reference, this project had a clear economic policy focus and did not adopt a system design mindset.

## V. Unified Framework for Non-functional Requirements Specification

This section sets the first steps towards building a unified framework for non-functional requirements specifications for SE services. In building this framework, we propose to take a *top-down-top* approach, i.e., start with a generalized initial framework, apply it to a concrete SE service, and then generalize the results to a wide range of SE services. More specifically, we propose the following steps.

- Step 1: *Develop an initial methodology for non-functional requirements specification, focusing on security and privacy, data protection law and economic incentives*
  One should identify and systematize selected non-functional requirements covering a broad range of SE services through carefully selected use cases from the market and the corresponding literature. The focus should be on per-domain best practices and their interplay following the recommended *security-by-design, privacy-by-design, legal compliance and economic incentive-based mechanism design* frameworks. The systematization yields a preliminary (but extendable) methodology for the non-functional requirement analysis of SE services.
- Step 2: *Design a secure, incentive-compatible and data protection compliant SE service*
  One should validate the initial methodology by applying it to a proof-of-concept SE service, for example for vehicle sharing. The goal should be to design and implement a concrete solution that satisfies the requirements defined, but still retains its core functionality. In the design process, one should aim at combining various advanced technologies such as distributed ledgers, smart contracts and multiparty computation in order to offer technical guarantees for satisfying all the identified non-functional requirements. System designers should pay special attention to (i) offering accountability, conditional privacy and data protection, and forensic evidence provision, (ii) being compliant under the GDPR and the upcoming new ePrivacy regulation, and (iii) designing proper economic incentives for all stakeholders. In addition, the designer should also create a list of all the non-functional requirements devised in this step as well as a catalog of the existing solutions for satisfying those requirements.
- Step 3: *Generalize the results from applying the initial framework to a concrete SE service*
  One should take the devised lists of requirements and existing solutions and generalize them such that they are valid for all (or at least the majority of SE services). Ideally, the devised requirements should be applicable to each SE service. In case this is not possible, SE services should be grouped based on the nature of their business model. This grouping should allow designers to provide these groups specific sector-tailored sets of requirements as well as candidate solutions.

## VI. Conclusions

Sharing Economy services are already mainstream. However, if such services are to contribute to the greater goal of Circular Economy, a systematic approach to the elicitation and specification of their requirements are needed. Specifically, this paper advocates for a systematic approach to non-functional (yet crucial) requirements specification for SE services. We highlighted the lack of such an approach focusing on three differing but intertwined branches of requirements stemming from technical information security and privacy, data protection regulation and economic incentive design. We showed the shortcomings of existing (partial) requirements specification frameworks, and set forward a research agenda based on the *top-down-top* approach, i.e., start analyzing a wide range of SE services with the aim to capture all common features and devise an initial framework; apply the initial framework to a concrete SE service to obtain tangible results for this specific service; and then generalize the results so that they are applicable in every SE scenario.

## Acknowledgment

This work was supported in part by the Research Council KU Leuven: C16/15/058 and by the Flemish Government through FWO SBO project SNIPPET S007619N. Mustafa A. Mustafa was supported by the Dame Kathleen Ollerenshaw Fellowship awarded by The University of Manchester.

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