MESG

MESTRADO EM ENGENHARIA DE SERVIÇOS E GESTÃO

Service Design-for-X: a framework to evaluate sustainability performance of services

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Master Thesis

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In memory of Vera Lucia M. A. Sousa and Irene dos Santos Moura

Abstract

Society is becoming increasingly more concerned about environmental issues and efficient usage of natural resources. However, as companies struggle to prosper in an ever-changing and challenging business environment, the investments required to adapt their processes to a cleaner and more circular mentality might bring risks that many managers are not willing to take.

To address this challenge, many studies have been conducted recently to aid in the implementation of Circular Economy (CE) actions in companies. However, most of those studies are conducted in a product-oriented fashion, focusing on the application of circular business models in industries and supply chains, despite the current “servitization” tendency present in the business world. With that, there is still a gap regarding the assessment of CE actions on service-oriented business models.

To address this gap, this research developed the novel ServiceDfX (S-DfX) conceptual framework. The S-DfX framework is an adaptable method to assess the performance of services, in multiple dimensions. In this research, the steps to implement the framework were presented and the framework was tested, in a case study, for the evaluation of the circularity and sustainability dimensions of a service.

During the study, it was developed an innovative approach to assess the circularity performance of a system, by using the “Rs” of the 10R framework as macro-indicators and unfolding each “R” into consumption indicators. For the sustainability assessment, the dimension was decomposed into sub-dimensions, based on the three LCSA pillars. The assessment results were presented in individual tables and scorecards for better visualization, with alternative scenarios being proposed and assessed for the circularity dimension.

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1. EU – European Union
2. CE – Circular Economy
3. KPI – Key Performance Indicator
4. PSS – Product Service Systems
5. LeanDfX – Lean Design for X
6. MSM – Multi-layer Stream Mapping
7. LCSA – Life Cycle Sustainability Analysis
8. DSR – Design Science Research
9. S-DfX – Service Design for X
10. SLC – Service Life Cycle
11. UK – United Kingdom

1 Introduction

1.1 Project background

We live in an age where society is becoming increasingly more concerned about environmental issues and efficient usage of natural resources. Fuelled by the impacts observed around the globe, and its consequences on our lives, the urgency of those issues have been acknowledged at the highest governmental level. Most notably, it can be mentioned the action plan formulated originally by the European Union (EU) in 2015 and revised in 2019, aimed at diminishing the impacts caused by the traditional economic model through the adoption of actions from the Circular Economy (CE).

As regarded by the EU in 2015, economic actors, such as business and consumers, are vital in enabling the transition from the linear to the circular economy. However, as companies struggle to prosper in an ever-changing and challenging business environment, the investments required to adapt their processes to a circular mentality might bring risks that many managers are not willing to take, especially in a market already shaken due to the current COVID-19 pandemic.

To ease such concerns, many studies have been conducted recently to show the lasting advantages of applying CE actions in business. According to the Ellen MacArthur Foundation (2020), the CE not only addresses the negative impacts of the unsustainable linear economy, but more importantly it represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and social benefits. As such, contrary to management fears, investment in CE can be an effective and tangible pathway towards a prosperous recovery. Still, most studies covering the implementation of CE are conducted in a product-oriented fashion, focusing on the application of circular business models in industries and supply chains, despite the current “servitization” tendency present in the business-world that is well aligned in the Industry 4.0 paradigm. With that, there is still a gap in the literature regarding the assessment of CE actions on service-oriented business models.

To fill this gap, this research developed, at first, a new conceptual framework to assess the performance of services, in multiple dimensions. More specifically, in the proposed case study, this framework aims at evaluating services circularity and sustainability, while specifying the appropriate Key Performance Indicators (KPI).

1.2 Problem Description

Despite the mentioned interest in the circular economy model and the fact that more companies are adopting a service-centric approach, there is still a lack of supporting methodologies and real-life applications to demonstrate how service-oriented companies can implement circular-economy business models (Heyes *et al*., 2018) and therefore evaluate their performance.

Urbinati, Chiaroni, and Chiesa (2017) concludes that that all the circular economy principles refer to products, as they assume the key unit of analysis is the product itself. Consequently, service-oriented companies that adopt circular business models need to rely on frequently inaccurate methods of assessing the performance of their services, which may drive to misleading results.

Furthermore, studies frequently present services, and product-service systems (PSS) as a way towards circularity and as a mean to improve environmental sustainability. However, as indicated by Kjaer, Pigosso, McAloone, and Birkved (2018), PSS are not necessarily environmentally benign compared to conventional systems and it is still necessary to evaluate the system's performance to verify if a real environmental improvement was achieved. As an example, there have been noticed that the growing demand for food delivery services has resulted in an alarming increase in waste due to the disposal of primary and secondary packages (Accorsi, Cascini, Cholette, Manzini, & Mora, 2014). In accordance with that, Jia et al. (2018) estimated that 1.68 million tons of food delivery packaging waste was generated in 2016 in China, which needed 58.89 GWh of electricity for processing, and emitted 73.89 Gt of CO2 equivalent (CO2e) emissions. The situation is even further aggravated by the current COVID-19 pandemic, with the increased demand for food delivery services due to lock-downs and reduced social contacts.

Therefore, as there was not found any specific method in the literature regarding the performance assessment of services, that also covers the scope of CE and Life Cycle Engineering mind-set, this study aims to develop a conceptual framework to guide service-oriented companies in assessing the performance of their services throughout the phases of the service lifecycle.

1.3 Research Questions

To reach the main objective of developing a conceptual framework to assess the performance of services in an agnostic and multidimensional perspective, the present research addressed the following research questions:

1. How to deal with the inherent complexity of services, in order develop an adaptable assessment framework?
2. How to address, in a holistic and quantitatively way, the multi-dimensional performance assessment of services?
3. How to integrate and measure the service performance for the dimensions of sustainability and circular economy?

These research questions provided the key objectives for the thesis project. As secondary objectives, this research aims to develop an implementation roadmap and the creation of hierarchical scorecards, to facilitate the performance assessment.

1.4 Study and Project Development at INEGI

This project was conducted at INEGI, a non-profit institute dedicated to developing projects in the fields of research, scientific and technological consulting, and innovation on Mechanical Engineering and Industrial Engineering. This study took, as basis, the background of performance assessment methodologies created at the institute, namely the Lean Design-for-X (LeanDfX) framework, devoted to multi-dimensional product assessment (Baptista, Peixoto, Ferreira & Pereira, 2018) and the Multi-Layer Stream Mapping (MSM), devoted towards system efficiency assessment (Lourenço, Pereira, Barbosa & Baptista, 2016).

1.5 Report outline

This study is organized following the structure presented in Figure 1, below.

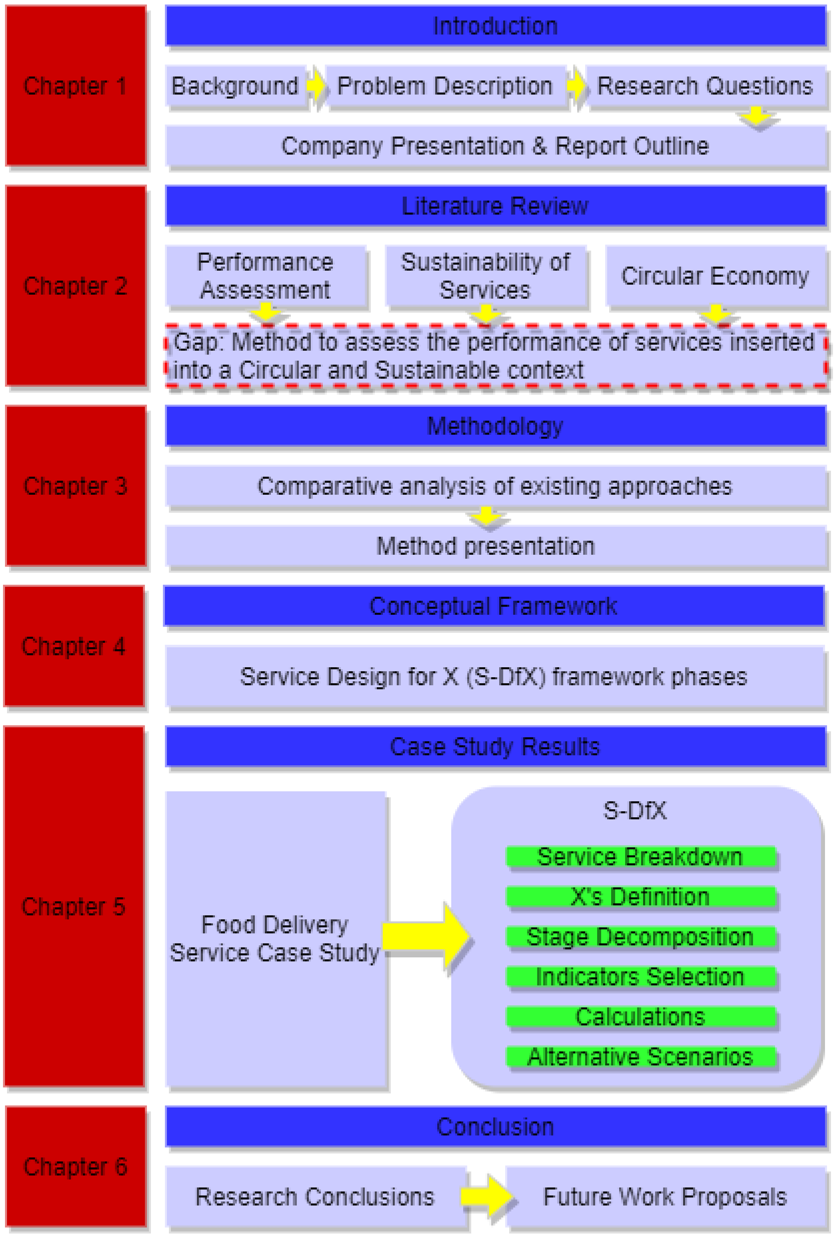


Figure 1 - Report Outline

2 Literature Review

This chapter will cover the main topics necessary for the development of the study, serving as a theorical support for the concepts presented in the following chapters. The chapter will begin with an analysis of the dimensions and methods usually considered by researchers when assessing the performance of services. Next, the two performance dimensions highlighted will be presented, starting with the concept of sustainability, and the main indicators used when studying it, followed by the circular economy concept, and its importance for services. Finally, the identified gaps in the literature will be highlighted.

It is important to mention that despite being used in similar contexts by many researchers, sustainability and circularity are distinct concepts. According to Geissdoerfer, Savaget, Bocken, and Hultink (2017), sustainability and circularity have different origins, objectives and targets, with one clearly emphasizing financial advantages for companies, while the other aims at benefiting the environment, economy and society at large. Therefore, for the present study, sustainability and circularity will be considered distinct concepts and shall be addressed separately in the next steps.

2.1 Service Performance Assessment

With the rising concern on environmental issues, the political and social pressures are impacting companies, making them increase their focus on attaining sustainable and circular economic models, which minimize resource consumption (Kazancoglu, Kazancoglu, & Sagnak, 2018). However, as the transition from a linear to a circular economic model takes place, service managers started to feel the need of effective methods to measure both the performance of their services and the environmental efficiency of their processes. That need sparked the interest of researchers and became the topic of many recent studies such as (Baptista et al., 2018), (Ekener et al., 2018) and (Kazancoglu, Kazancoglu & Sagnak, 2018).

Despite being of utmost importance to measure, service performance has proven to be a difficult concept to grasp (Brady & Cronin Jr, 2001) mostly due to the high diversity and complexity of services, making it difficult to standardize a single method applicable to assess the performance of services from distinct fields. However, to correctly draw conclusions about issues, such as how their service compares with that of their competitors and whether performance has improved over time, service managers require precise measures of the service performance and its efficiency (Finn, 2007). Moreover, since the improvement of the processes are dependant of an effective performance assessment, if the service is measured with greater precision, the firm will earn higher profits (Finn, 2007). Therefore, it is crucial to distinguish between the planned performance and the real performance of the service delivery, to be able to take the right measures for optimizing the service organization (Meier et al., 2013).

Many dimensions have been used throughout the years to assess the performance of a service, ranging from service quality and customer satisfaction to profitability and market share. As presented in studies, such of Yang and Chan (2010), Meier et al. (2013) and Brady and Cronin Jr (2001), the existing methods to assess the service performance in multiple dimensions were developed mainly focusing on aspects of the service quality and customer experience dimensions. With that, two dimensions that are viewed as of utmost importance in a product-oriented approach, but that are still rarely addressed in a service-oriented fashion, are sustainability and circularity. Therefore, those two dimensions will be presented in further detail and are the ones chosen to be assessed in the framework testing, further ahead. That decided, it is still necessary to select a method to assess the performance of services.

Recently, the Multi-layer Stream Mapping (MSM) and Lean Design-for-X (L-DfX) approaches emerged as suitable methods for the performance assessment of complex systems and to support the decision-making process. The MSM framework was developed for multi-domain analysis in an original manner to assess the overall performance of a system while evaluating the productivity and efficiency of resource utilization as well as evaluate the costs related to missuses and inefficiencies (Lourenço, Pereira, Barbosa, & Baptista, 2016).

The MSM approach relates to Lean Principles, with a clear definition between value-adding and nonvalue-adding time and waste components during a service provision, and focus on continuous improvement (Baptista, Lourenço, Silva, Estrela, & Peças, 2018). The MSM also assesses the overall performance, considering the efficiency of each process parameters while considering material and information flows inherent to the production system (Lourenço et al., 2016). As such, one of the cornerstones of the methodology involves the systematic nondimensionalization of the process parameters that characterize the production system, allowing consecutive aggregation of the efficiency ratios along the production system and the display of results in MSM dashboards (Baptista et al., 2018). Furthermore, the MSM framework can be used to identify which processing units are the least / most efficient, within an overall efficiency assessment of a multi-domain complex system analysis, enabling the analysis of “where” and “how much” a processing unit or a production system can improve its performance (Lourenço et al., 2016).

Also developed for multi-domain analysis, the L-DfX framework combines Lean Principles with Design-for-X concepts. According to Atilano et al. (2019), the framework deploys a systematic approach towards effectiveness design goals assessment while focusing in decreasing waste resources within the product, broadly covering many phases of product/service design and its life cycle. The phases and tools to applying both MSM and L-DfX approaches are lightly distinct and are described in further detail by Lourenço et al. (2016) and Baptista et al. (2018), respectively. However, the following stages shall be incorporated in this study and will be used as a base to develop the proposed framework: identification of the system’s boundaries, processing units and variables, selection of ‘X’ domains, definition of the relevant KPI to each processing unit and analysis of the results.

2.2 Sustainability of Services

The development of sustainable products and services is one of the major challenges currently faced by businesses, fuelled by the increasing pressure of diminishing the impact companies have on the environment. To answer that challenge, sustainable service development initiatives have been evolving to support companies in adopting a more sustainable approach (D. Maxwell & van der Vorst, 2003). However, despite receiving increasingly more attention of researchers in the last decades, the environmental component is not the sole factor when measuring the sustainability of a business. To assess the sustainability performance of products or services over the whole life cycle, there should be implemented a complementary approach to assess the environmental, economic and social aspects of the product or service (Traverso, Finkbeiner, Jørgensen, & Schneider, 2012). As such, multiple methods were developed to assess sustainability focusing on those three aspects. One of these methods is the

Life Cycle Sustainability Analysis (LCSA), an evaluation procedure that measures performance with regard to environment, economy, and society (Traverso et al., 2012). This method not only ensures that all aspects of sustainability are tuned and checked against each other, but also guarantees consideration of the impact of a product throughout its lifespan (T. Li, Roskilly, & Wang, 2018).

As a tool that combines three different components, applications of LCSA commonly deliver three separate outcomes, presented side-by-side, although a final integration of the results may also support the user's analysis (Ekener, Hansson, Larsson, & Peck, 2018). The main goal of LCSA studies is the comparison of alternative scenarios, with secondary objectives being to obtain a "picture" of the sustainability performance of the system under analysis and identify opportunities to improve (Alejandrino, Mercante, & Bovea, 2021). In agreement with that, Visentin et al. (2020) indicates that LCSA should be used as a decision support tool that assists organizations achieve their goals, focusing the analysis on the three pillars of sustainable development. Furthermore, the interest in the area has been growing exponentially, which can be explained by the efforts of the scientific community in developing methods aimed at making LCSA more practical and standardized, meaning that further applications may yet be developed Visentin et al. (2020).

Despite the increasing amount of research conducted on LCSA, more research is still required as there exist a necessity to obtain a consistent basis for future LCSA case studies (Alejandrino et al., 2021). In fact, there is still a lack of commonly accepted indicators for the economic and social analyses, unlike the environmental analysis, that possess a greater consensus in the determination of indicators (Visentin et al., 2020).

Visentin et al. (2020) presents the main environmental, economic, and social indicators used in LCSA analyses, indicating that the choice of impact categories and indicators are usually made by the analysts themselves (Visentin et al., 2020) and therefore depend on the type of system under study. Figure 2 displays the mentioned indicators, which will serve as a basis for the selection of KPIs suitable to the services under analysis in this thesis.

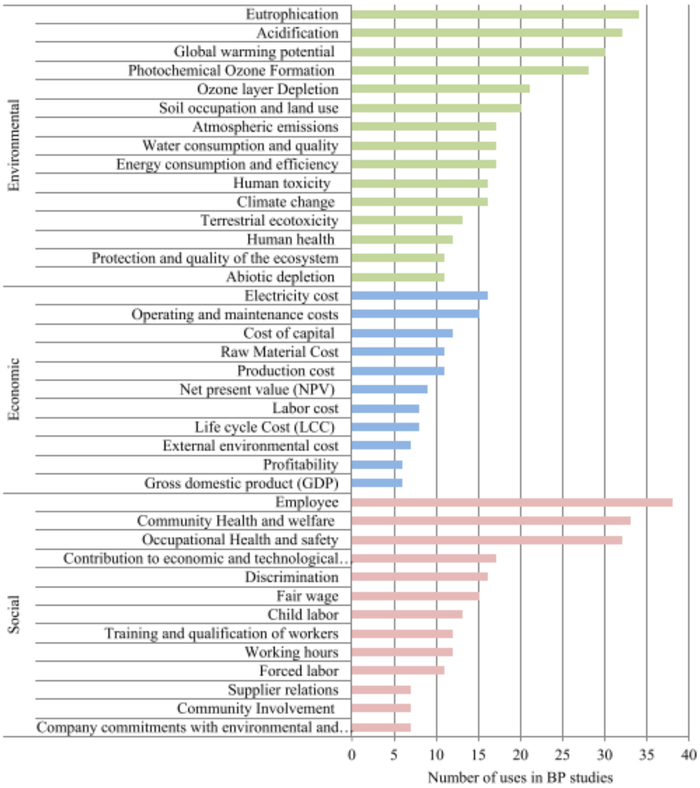


Figure 2 - Indicators most used in the Bibliographic Portfolio. Source: Extracted from Visentin, Trentin, Braun, and Thomé (2020)

Lastly, one important misconception that needs to be addressed is the notion that services, and Product/Service-Systems are naturally more environmentally benign than products. Despite being frequently proposed in studies as a manner to improve environmental sustainability and attain a Circular Business Model, services should not be viewed as a cleaner alternative by default, without any evaluation. That is especially evident, for example, in the online delivery service, where packaging waste brings a heavy impact on the environment. For example, according to Accorsi et al. (2014), the evolution of food purchasing behaviours has resulted in an alarming increase of both primary and secondary packaging waste. Deliveries also generate significant environmental problems as each order usually requires multiple packaging materials, and while many of those materials can be recycled, most packaging waste end up destined for landfilling or incineration (Duan, Song, Qu, Dong, & Xu, 2019). Therefore, to support decision-making during PSS design and implementation or when optimising existing systems, it is necessary to evaluate the environmental performance of service systems to determine under which circumstances it leads to real environmental improvements (Kjaer et al., 2018).

2.3 Circular Economy (CE)

In recent years, citizens worldwide were confronted, by the media and governmental agencies, about environmental-related issues and fast depletion of the planet’s resources. There is a growing recognition that the current linear model of our economy is unsustainable and, therefore, a sustainable way of conducting business and generating wealth must be attained (Sarja, Onkila, & Mäkelä, 2021). In this context, the Circular Economy (CE) concept was born, adopting as a starting point the reuse of products and materials and the conservation of natural resources (Reike et al., 2018).

Emphasizing minimal resource consumption and environmental protection (Kazancoglu et al., 2018), CE is a sustainable development strategy aiming to improve the efficiency of materials and energy usage (Su, Heshmati, Geng, & Yu, 2013). Therefore, in a CE, the linear flow of "resources - products - waste", typical of traditional business models of companies, is replaced by the new pattern "resources - products - waste - renewable resources" (Urbinati et al., 2017). This new system has attracted attention from major global companies due to the financial and environmental benefits (Lewandowski, 2016), and therefore is currently a field of interest of many researchers and is a topic addressed in many different scientific papers. However, the CE concept should not be considered only by global companies, as micro-sized companies also have the capacity to take initial steps towards the CE (Heyes, Sharmina, Mendoza, Gallego-Schmid, & Azapagic, 2018).

According to Sarja et al. (2021), transition to the CE is favoured due to its attractiveness for business potential and possibility to decrease costs. CE strives for economic and environmental value creation in every part of the system (van Boerdonk et al., 2021) and uses the reduction of resources as the leading principle within a circular economy system (Su et al., 2013). The discourse of potential benefits accelerating CE transition was labelled a win-win perspective on environmental and economic gains, offering business models, new ways to utilize resources, enhance brand reputation and offer access to new markets and opportunities (Sarja et al., 2021). Thus, circular business models can enable economically viable ways to continually reuse products and materials, using renewable resources where possible and introducing economic incentives for slowing resource loops and potentially reducing the total need for physical goods (Bocken, de Pauw, Bakker, & van der Grinten, 2016). It creates economic and environmental values for both the consumers and firms (van Boerdonk et al., 2021). However, according to Kirchherr, Reike, and Hekkert (2017), the current definition of CE considers the main goal to be economic prosperity and environmental quality, whereas the business models are rarely outlined as enablers of the CE.

Bocken et al. (2016) presents some innovation strategies usually adopted to incorporate elements from circular economy into a business model, such as delivering access and performance rather than ownership, and encouraging sufficiency through delivering long-lasting products and then supporting the customer with high level of services. According to these authors, to transform the economy from linear to circular, business model and design strategies will need to go hand in hand. Despite that, Urbinati et al. (2017) reaches the conclusion that all the circular economy principles refers to products, as they assume the key unit of analysis is the product itself. However, according to Heyes et al. (2018), the service sector has the potential to play an instrumental role in the shift towards circular economy since its strategic position between manufacturers and end-users means that it can influence the way in which customers use the products.

Furthermore, over the last decades, a paradigm shift has emerged, moving away from selling just products towards more "servitization". This change in thinking assumes that business value is not necessarily just associated with the production and distribution of tangible products, but rather with the use and functionality that the products offer (van Boerdonk et al., 2021). Aligned with that, offering services rather than products is seen as one of the key recommendations for the CE (Heyes et al., 2018). One such way is through the adoption of Product/Service-Systems, that turns the business model into a functional model, where customers pay for the use of products and not for their possession (Urbinati et al., 2017). Thus shifting to a usage focus in service provision may bring opportunities for building fully circular business models, with no change in product design, but rather in how the user interact with existing products (Heyes et al., 2018).

On another perspective, the focus of CE, embedded in the original concept, has gradually been shifted from narrow waste recycling to broad efficiency-oriented control during the closed-loop flows of materials at all stages of production, distribution and consumption (Su et al., 2013). With that, to ensure an appropriate efficiency control, the service managers require a selection of the set of indicators to assess the CE actions. However, different implementation levels of the CE and different characteristics of companies, sectors or regions require different assessment indicators (Su et al., 2013). Therefore, the high complexity of services may bring challenges to the attempt of standardizing a single method to assess the CE performance of services.

A possible solution to this challenge is presented in Reike, Vermeulen, and Witjes (2018). In this study, ten categories in which to organize business options regarding circularity are identified. Called the “10R”, this categorization provides a better visualization of the desired aspects to be achieved and allows the user to better understand the role of actions taken towards CE. Building on this new concept, Kirchherr and Piscicelli (2019) further expands the understanding of the 10R by dividing them into three categories and hierarchically listing them in terms of their circularity, as seen in Figure 3. The first three “Rs” are deemed by the authors as the most circular of the 10R’s and are viewed as ideal strategies for the CE. The next five Rs are deemed as an extension of the lifespan of the product and range from good to intermediary strategies in terms of circularity, and the last two Rs are deemed as strategies of the linear economy and viewed as only a manner to attain some return from the materials and avoid waste being sent to landfill.

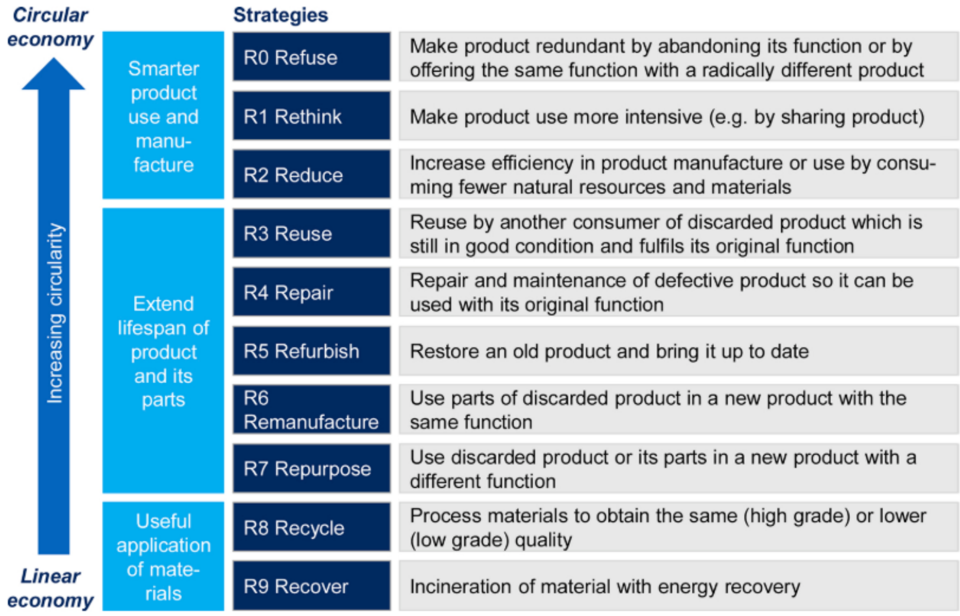


Figure 3 - 10R of Circular Economy. Source: Extracted from Kirchherr and Piscicelli (2019), p. 8.

Upon deeper analysis, it can be concluded that the 10R themselves are suitable to be used as indicators of the circular performance of a system. The increasing scale of circularity presented by Kirchherr and Piscicelli (2019) can also be adapted as a differentiator when assessing different types of circular actions. With that, the 10R framework can be used as a basis for the circularity assessment of a service.

2.4 Identified GAP

From the presented topics it can be concluded that there is a gap in the literature regarding a method to assess the performance of services in the sustainable and circular dimensions, partially due to the notion that services are naturally less harmful to the environment than products. Regarding the sustainable aspect, the social and financial pillars are receiving less focus on studies due to the renewed interest of researchers in the environmental pillar. That is especially evident when considering the lack of commonly accepted indicators for the economic and social analyses. Lastly, there is still a lack of methods to assess the circularity performance of services, as the CE principles are seemingly focused on products. To answer that, the 10R framework may be used as a basis when assessing the circular performance of services.

3 Methodology

3.1 Comparative analysis of existing approaches and reasons for the choice of adopted approach

According to J. A. Maxwell (2009), works on research design often understand “design” in two ways. Some take design in a fixed manner, with standard arrangements and methods that have their own coherence and logic and some other models, such as qualitative research, that lacks any elaborate typologies. According to the author, other models present design as a logical progression of stages or tasks, from problem formulation to the generation of conclusions or theories, that are needed for the planning or development of a study. Such models usually resemble a flowchart, with a clear starting point and a specified order for doing the tasks. Even though some versions are circular or iterative, all those models are linear since they are made up of one-directional sequences of steps for conducting the activities or components of a research.

Among the methodologies typically used in the field of engineering, one that stands out for the proposed objective of the present study is the Design Science Research (DSR). According to Hevner et al. (2004), the DSR mainly addresses research through the building and evaluation of artifacts intended to solve identified organizational problems, highly focusing on the utility of such artifacts. Table 1, presented below, presents the guidelines proposed by the mentioned authors as a guide to conduct good DSRs.

Table 1 - DSR Guidelines (adapted from Hevner et al., 2004)

Guideline	Description
Guideline 1: Design as an Artifact	DSR must produce a viable artifact in the form of a construct, model, method or an instantiation.
Guideline 2: Problem Relevance	The objective of DSR is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective DSR must provide clear and verifiable contributions in the areas of design artifact, design foundations and/or design methodologies.
Guideline 5: Research Rigor	DSR relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	DSR must be presented effectively both to technology-oriented as well as management-oriented audiences.

According to Hevner et al. (2004), one issue that must be addressed in DSR is differentiating routine design from design research. Routine design applies existing knowledge to organizational problems, so no contribution is made to the existing knowledge base. DSR on the other hand, tackles important and unsolved problems in unique or efficient ways. In other words, results derived from DSR become best practices, as they are codified in the knowledge base, bringing real contribution to future studies.

Another manner of categorizing the different types of researches is presented by Zikmund (2008). In this classification, usually applied in business research, the methodologies are classified based on technique or purpose as follows:

- Exploratory: conducted to clarify ambiguous situations or discover potential opportunities. It is not intended to provide conclusive evidence to determine a particular course of action. Usually, this type of research is performed when there is little knowledge regarding a topic and is meant to be a first step, conducted with the expectation that additional research will provide more conclusive evidence.
- Descriptive: conducted to describe characteristics or the state of objects, people, organizations or environments. It is usually performed when the researcher has a firm grasp of the situation being studied and directs the study toward specific issues.
- Causal: seeks to identify cause-and-effect relationships between variables or events. Often may take long periods of time to be conducted.

In addition to this way of categorizing the research, Creswell (2009) presents a very popular classification approach:

- Qualitative research: is meant for exploring and understanding the meaning of individual or groups, usually through interpretations of data collected. The study is usually presented with a flexible structure. Typical strategies of inquiry are case studies and ethnographies.
- Quantitative research: is meant for testing objective theories by examining the relationship among variables, which can be measured usually using statistical procedures. Typical strategies of inquiry include experimental designs and surveys.
- Mixed methods research: is an approach that combines both qualitative and quantitative forms. It involves philosophical assumptions and attempt to make use of both kinds of data to develop more robust results. Typical strategies are sequential and concurrent inquiries.

With all the above considered, the present study uses a Design Science Research methodology as the foundation upon which the research method will be developed, applying a qualitative research strategy of a case study.

3.2 Method used in the project.

As previously mentioned, the methodology used as a base for the development of the study is the DSR. Thus, the present research will follow the guidelines, presented in Table 1, to conduct the development of the study. In addition to that, the present work will go through four phases to better align the development of the study with the expected results established for the project. Those phases are listed below with a brief description of the expected work performed in each one of them:

1) **State of Art research**: it was conducted an assortment of existing standards and relevant assessment models as well as analysis of case studies performed in service companies with circular business models.
2) **Specification & Design**: it was designed a conceptual framework to assess service performance in multiple dimensions, specification of objective KPIs to measure the service performance in each dimension and creation of hierarchical scorecards.
3) **Testing & Validation**: the framework was tested through its application in a case study, highlighting the steps needed to effectively use the framework.
4) **Conclusion**: the testing results were analysed, and conclusions were drawn regarding the effectiveness of the framework. Lastly, future steps were proposed to advance the research knowledge in the field.

4 Conceptual Framework

The novel ServiceDfX or just S-DfX framework was developed inspired upon the existing INEGI's Lean Design-for-X (LeanDfX) framework. As the LeanDfX was developed for an industrial environment, with a product-centric approach, multiple changes had to be performed to adapt the framework to the service context. The S-DfX framework is recommended for the performance assessment of services, in multiple dimensions "X", throughout the stages of the Service Life Cycle (SLC). The S-DfX is structured in 6 main phases that constitute the bulk of the approach and that the user should address to effectively use the framework.

- Phase 1 – Service Break Down

Break down the service into the stages of the Service Life Cycle (SLC), for instance as defined by Mahut et al. (2016), and presented in Figure 4: Service Definition, Service Design, Service Implementation, Service Delivery and Service Decommission. The user may select one or more stages that he/she wishes to analyze and then should assess each one individually.

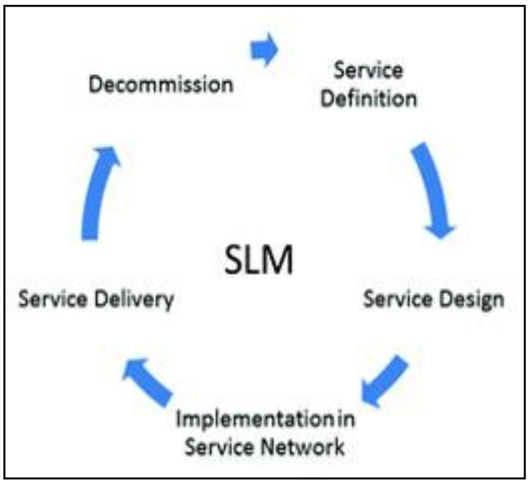


Figure 4 - Service Life Cycle. Source: Adapted from Mahut, et al. (2016)

- Phase 2 – X's Dimensions Definition

Define the X dimensions in which to measure each stage of the SLC, based on the user's requirements (i.e.: service quality, sustainability, circularity, maintenance, etc.). In this phase, the user must have a clear understanding of the dimensions he/she wishes to assess in the project. As each stage of the SLC is individually analyzed, the user has the flexibility to select different dimensions for each stage, if needed.

- Phase 3 – Stage Decomposition

Decompose each stage of the service into an organizational structure best suited to its particularities. In this phase, it is intended to diminish the service system complexity by dividing it into smaller sections that are easier to analyze. Furthermore, by decomposing the service, it will be easier to visualize troublesome sections, in later phases, and improve them.

As the user should be experienced in the service under study, he/she will be the most suited to select the best type of organizational structure to deal with the complexity inherent to the service. Some suggested organizational structures include modules, hierarchical and operational structures, service encounters and Value Stream Mapping.

- Phase 4 – Selection of Indicators

Select the indicators, or Key Performance Indicators (KPI), best suited to assess the performance of each organizational unit associated with each phase of the SLC for the chosen dimension “X”. As each type of service has its particularities, a standard set of indicators may fail to capture the characteristics of different services, thus there is no set of indicators in the literature that is applicable to every type of service. With that, similarly as in phase 3, the user will be the most suited to identify the most relevant indicators for the project’s goals.

- Phase 5 – Parameters and Calculations

Identify the targeted values and achieved values for each one of the selected indicators. The calculation needed is dependant of the type and the objective desired for that indicator (i.e.: minimize consumption, maximize production, meet a targeted value, etc.)

Use the target values (T) and achieved values (A) to calculate the performance of each indicator for each organizational unit and the overall performance of each unit, in order to create dimensionless ratios (percentages) for effectiveness (S) and efficiency (Y), when applicable. Equations 1 and 2 presents examples for a KPI with the objective to meet a minimum target value.

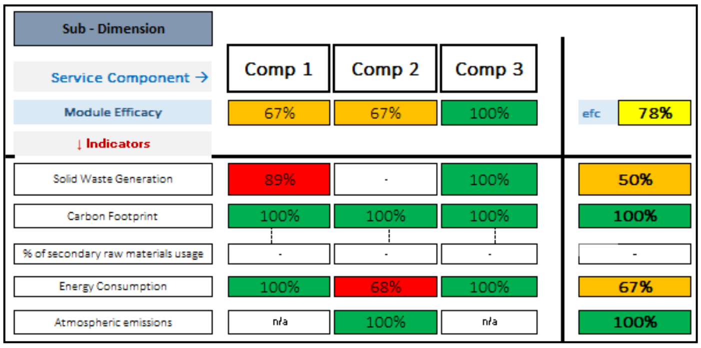
$$(1)\quad \begin{cases} T = 100\ tons \\ A = 83\ tons \end{cases} \rightarrow \begin{cases} S = 0 \ \ (requirement\ not\ met) \\ \\ Y = \dfrac{83}{100}(\%) = \ 83\% \end{cases}$$

$$(2)\quad \begin{cases} T = 100\ tons \\ A = 105\ tons \end{cases} \rightarrow \begin{cases} S = 1 \ \ (requirement\ met) \\ \\ Y = \dfrac{100}{105}(\%) = \ 95\% \end{cases}$$

The overall efficacy (OS) and overall efficiency (OY) of each unit is then calculated by the simple average of the KPIs (see Equation 3).

$$(3)\quad \begin{cases} OS = \dfrac{1+0}{2}\ (\%) = 50\% \\[2ex] OY = \dfrac{95+83}{2}(\%) = \ 89\% \end{cases}$$

To visually aid in the analysis, the results are presented in scorecards with colors associated with their performance, as presented in Figure 5. Additional tools, such as charts or diagrams, may also be employed to further aid in the presentation of results.



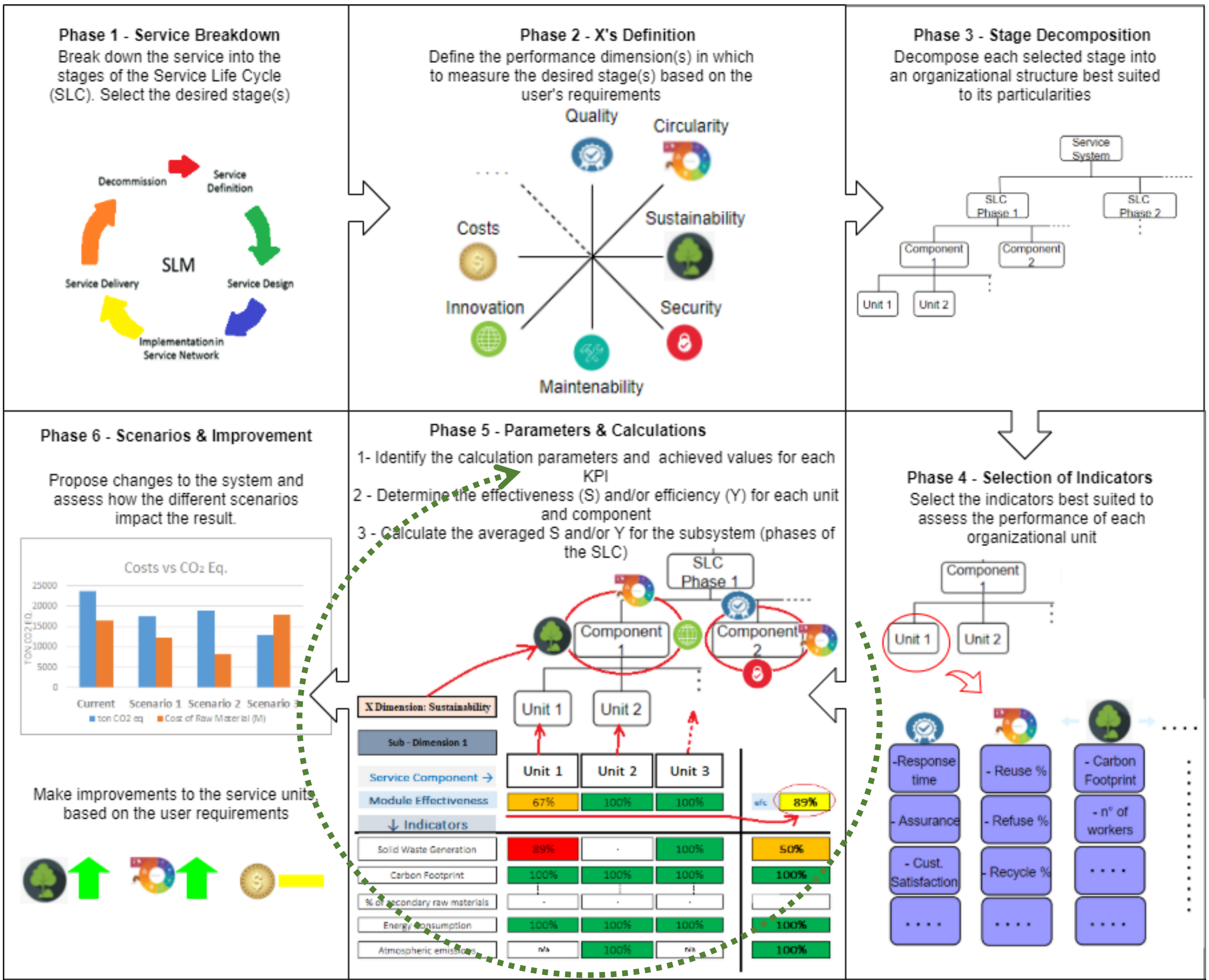
Sub - Dimension					
Service Component →	Comp 1	Comp 2	Comp 3		
Module Efficacy	67%	67%	100%	efc	78%
↓ Indicators					
Solid Waste Generation	89%	-	100%		50%
Carbon Footprint	100%	100%	100%		100%
% of secondary raw materials usage	-	-	-		-
Energy Consumption	100%	68%	100%		67%
Atmospheric emissions	n/a	100%	n/a		100%

Figure 5 - Efficacy Scorecard

- Phase 6 – Alternative Scenarios & Improvement

Propose changes to the service system and assess how the different scenarios impact the results, comparing the current system with the proposed scenarios. Make improvements to the service units that achieved unsatisfying results. As this phase revolves on performing corrective measures to the service system, it is recommended a thorough analysis to ensure an alignment between the project's goals and the company's objectives.

Figure 6 presents a summary of the main concepts of the ServiceDfX framework.



SUMMARY:

- The S-DfX framework was developed based on INEGI's L-DfX tool, to assess the performance of services, in multiple dimensions, throughout the phases of the Service Life Cycle (SLC), helping users to compare alternative scenarios and improve the system;
  The S-DfX uses simple mathematical calculations and integrates multiple visual management tools, such as scorecards, to facilitate the user analysis;

NOTES:

- The user should be experienced in the service under analysis, to best select the appropriate organizational structure and KPIs;
- Not all performance dimensions are applicable to every phase of the SLC;
- The user should assess the phases of the SLC separately as different phases may have different organizational structures.

Figure 6 - ServiceDfX Framework Summary

5 Case Study Results

The case study was conducted for a food delivery service, based on public data acquired in multiple websites and articles for Deliveroo's activities in the UK between 2018 and 2019, and data on consumer's behaviour in the UK, presented in Appendix A. As seen in chapter two, food delivery services carry a heavy environmental impact, especially due to the packaging used in the deliveries, which reinforces the necessity of a method to assess its environmental performance. According to Li, Mirosa, and Bremer (2020), the industry of online food deliveries requires highly efficient delivery services and has provided job opportunities for many people across a range of types of employment. Furthermore, this service system is of high importance currently, as the lockdown caused by the COVID-19 pandemic has made the number of deliveries increase in the last years, making stakeholders in the food delivery sector take action to diminish their massive carbon footprint (Li et al., 2020).

It was decided to use Deliveroo's data for this case study because of its corporate culture committed towards sustainability and respect for the environment (Galati, Crescimanno, Vrontis, & Siggia, 2020). Some actions have already been taken by the company to diminish its environmental impact and increase circularity. These actions include the addition of an option, in their app, to give customers the choice of not receiving cutlery with their order and receiving the food in returnable, and reusable, containers.

In this case study, the framework was applied for the sustainability and circularity dimensions of the Service Delivery phase of the SLC. After assessing the performance of both dimensions, through a set of KPIs, alternative measures were proposed to assess how they would impact the performance on different scenarios. As not all required data is available for the public, some estimations were required.

Service Breakdown

In this study the chosen stage of the SLC is the Service Delivery. This stage covers all the activities performed by the service provider from the moment the service is requested by the customer to the moment the service is concluded. Although the discard of food packaging by the customer is technically not a part of the Service Delivery, it is a very important factor to take into consideration in this type of service and, therefore, was included in the analysis.

X's Dimensions Definition

The "X" dimensions selected to be assessed in this study were sustainability and circularity. Despite being generally used as synonyms in studies, both terms have different goals, approaches and origins, as presented in section 2, and therefore were analysed separately. As seen in the literature review, sustainability is the combination of three main pillars, namely environmental, social and economic sustainability. Therefore, the sustainability analysis was divided into three sub-dimensions, each one assessing the service performance of one of the pillars for the service delivery stage.

Stage Decomposition

Considering the environmental sub-dimension and the circularity dimension, the food delivery service was decomposed into three components: food packaging, cutlery/utensils and transportation. This way of decomposing the service allowed an individual assessment of the components and provided a clear view of which components caused more environmental impacts. Specifically for the circularity dimension, the food packaging component was further decomposed into the most common types of food ordered in the UK, i.e. Chinese, Indian, Pizza and others (Lock, 2020) (see Figure 7). Since the type of packaging vary for each type of food, this second decomposition makes sense as actions taken by the delivery companies, to become more circular, may not affect all types of packaging simultaneously. Lastly, the available social and economic data were not detailed enough to require a decomposition of the service, therefore the social and economic indicators were used to assess the entirety of the service for both sub-dimensions. This may not be the case for every type of service, as some of them may require separated economic and/or social structures.

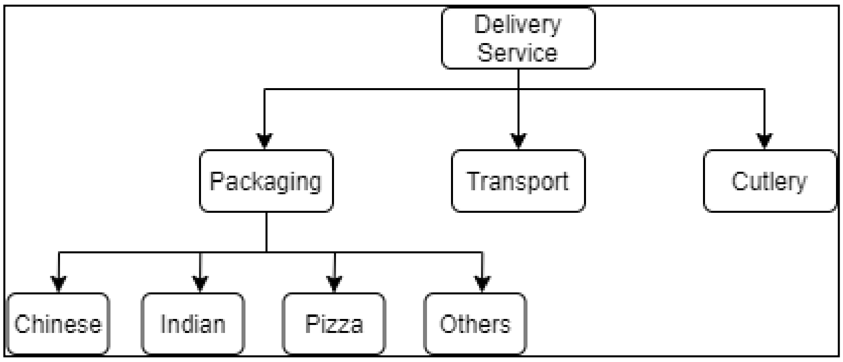


Figure 7 - Delivery Service Components

Selection of Indicators

As mentioned in section 2, Visentin et al. (2020) presented a list of the most used indicators in researches about sustainability. However, as the list was formulated taking into consideration studies performed both on industries and services, not all the indicators are applicable to the service environment. Therefore, this list was analyzed and the indicators were selected taking into consideration the characteristics of the service under study. The resulting KPIs are those presented in Table 2.

Table 2 - Selected Indicators

Social Indicators	Direct Employment	Worker's Satisfaction	Qualification of Workers
	Total Employment	Inclusiveness	Commitment with Environment
	Community Involvement	Occupational Health / Safety	
Economic Indicators	Operational Costs	Revenue	Profit
	External Environmental Cost	Electricity Cost	Cost of Capital
	Cost of Raw Materials	Labor Cost	Market Share

Environmental Indicators	Solid Waste Generation	Carbon Footprint	Energy Consumption
	Atmospheric Emissions	% of secondary raw materials usage	

As for the circularity dimension, the "10R" proposed by Reike et al. (2018) were used as macro KPIs to assess the impact of each "R" in the waste generation, resource consumption, and carbon footprint of the service. As seen in chapter 2, the top "R's" have larger circular impact on the environment, and thus will have a higher weight when calculating the circular performance of the service.

Parameters and Calculations

With the indicators for each dimension selected, this step required an extensive research to attain the necessary data to calculate the performance of each KPI. Tables 3, 4 and 5 presents the available social, economic, and environmental data, as well as the parameter in which each KPI will be compared with, for the sustainability dimension. Similarly, Table 6 presents the acquired data for the circularity dimension, displaying the measures that are taken by Deliveroo to diminish its environmental impact, and its equivalent "R". Though not all the required data was available to public, it was decided to keep the "blank" indicator in the tables, to reinforce that a full assessment would require that information, as well as any other deemed necessary by the users. The source of the used data, the assumptions in which some estimations were made, and the calculations conducted are detailed in Appendix A to C.

Table 3 - Social Indicators and data

KPIs	Parameter	Value	Goal
Direct Employment	Number of Uber Eats drivers in the UK	50000	45000
Total Employment	-	58000	-
Community Involvement	-	-	-
Average wages (per hour)	Average wage compared with Uber Eats	£ 12,00	£ 15,00
Worker's satisfaction	Indeed rating, compared with Uber Eats	3,4	3,7
Occupational Health/safety	-	-	-
Inclusiveness	Percentage of female employees	7	40
Qualification of workers	-	-	-
Commitment with environment	-	-	-

Table 4 - Economic Indicators

KPIs	Parameter	Value	Goal
Revenue (M)	Last value plus 30%	£ 476,00	£ 360,00
Operational Costs (M)	Best of last 3 values	£ 349,00	£ 106,00
Profit (M)	Last value plus 30%	-£ 232,00	-£ 129,00
Market Share	Last value plus 5%	18%	17%
Electricity Cost	-	-	-
Cost of Capital	-	-	-
Raw Material Cost (M)	-	£ 16,50	-

Labor Cost (M)	Labor cost for targeted number of drivers	£ 468,00	£ 421,20
External Environmental Cost	-	-	-

Table 5 - Environmental Indicators

KPIs	Packaging		Transport		Cutlery		Total
	Value	Goal	Value	Goal	Value	Goal	
Solid Waste generation (tons)	10978,5	10440	-	-	21,2	212	10999,7
Carbon Footprint (ton of CO2 eq)	6566,2	9966,2	5988,6	29882	44,0	440	12598,8
% of secondary raw materials usage	-	-	-	-	-	-	-
Energy Consumption (KWh)	$6{,}59 \times 10^6$	$6{,}26 \times 10^6$	$3{,}77 \times 10^6$	28×10^6	743,13	7431	1×10^7
Atmospheric emissions (ton of CO2)	n/a	n/a	4822,2	21222	n/a	n/a	4822,2

Table 6 - Circularity Measures

R's	Service Component	Measure	Impact	Source
R0	Cutlery / Utensils	In 2018, it was launched an option for users to ask for disposable cutlery, instead of sending it by default.	90% reduction of cutlery	Spencer (2018)
R1	Transport	It is estimated that drivers carry at least 2 orders per delivery.	50% reduction of trips	Rkaina (2017)
	Packaging	The company offers kraft paper salad bowls, paper straws, boxes, and other biodegradable packaging.	Reduction of ~3400 ton of CO2 eq per year	Poulter (2018)
R2	Transport	Deliveroo is a company that highly encourages deliveries by bikes and electric mobility.	Estimated reduction of 80% in emissions	Galati et al. (2020) and Reid (2018)
R3	Packaging	Washing and reuse of cutlery and packaging by users of online food delivery services in Australia. Here it is assumed that users in the UK have similar behavior.	33% reduction in waste generated	Arunan and Crawford (2021)
	Cutlery / Utensils		36% reduction in waste generated	
R8	Packaging	Recycling of discarded plastic packaging and cutlery in the UK	64% reduction in waste sent to landfill	Hill et al. (2018)
	Cutlery / Utensils			
R9	Packaging	Incineration of plastic packaging and cutlery in the UK	17% reduction of waste sent to landfill	Hill et al. (2018)
	Cutlery / Utensils			

As can be noted, the components that are mainly responsible for the environmental impact of the service are the packaging and transport. In comparison, the cutlery component is responsible for around 0,3% of the total carbon footprint of the service, while the packaging and transport are responsible for 52,2% and 47,5% respectively. As such, the cutlery component shall not be the priority when proposing actions to improve the service.

To visually aid in the assessment, the S-DfX framework encourages the use of scorecards and charts to present the results. To illustrate the results, Figure 8 presents the elaborated scorecard for the economic sub-dimension example, while Figure 9 presents the scorecard for the waste reduction of the circularity dimension. It is worth to mention that each macro-indicator "R" in the circularity dimension may have an individual scorecard, as exemplified in Figure 10, to better assist in the impact analysis that each action taken have on the overall result. To present a "cleaner" scorecard, it is advisable to display only the cards that are applicable to the service. However, it was decided to maintain the cards with a blank indicator in the presented scorecards to reinforce the necessity of those indicators in a complete assessment.

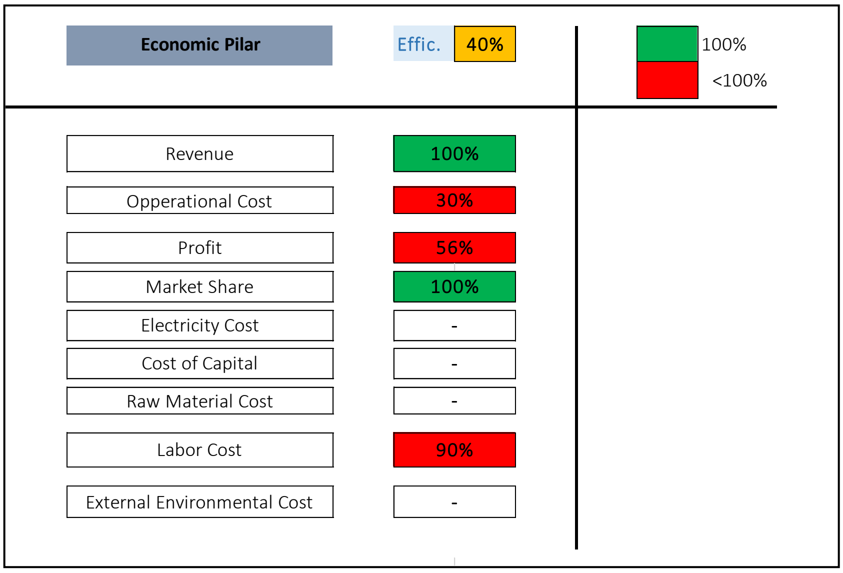


Figure 8 - Economic Pilar Efficacy Scorecard

		Packaging	Transport	Cutlery
100 - 80%; 79 - 60%; 59 - 40%; < 40%	Service Modules →	30%	58%	64%
Smarter Product use and manufacture	R0 Refuse	-	-	90%
	R1 Rethink	-	50%	-
	R2 Reduce	-	80%	-
Extend lifespan of product and its parts	R3 Reuse	33%	-	36%
	R4 Repair	-	-	-
	R5 Refurbish	-	-	-
	R6 Remanufacture	-	n/a	-
	R7 Repurpose	-	n/a	-
Useful application of materials	R8 Recycle	64%	-	64%
	R9 Recover	17%	-	17%

Figure 9 - 10R Scorecard for the Current Scenario

The calculation of the efficacy indicators, for the sustainability dimension, was done by dividing the achieved value by the target value and then multiplying the result by 100 to display it in a percentage fashion (see Equation 1). Indicators that reached or surpassed the target value received the green mark and were fixed in the 100% value, while the rest was marked red. The total efficacy for each one of the sustainable sub-dimensions was then calculated by dividing the number of indicators that reached the target value by the total number of non-blank indicators (see Equation 3).

For the circularity calculation, it was first estimated how much material/fuel and energy the service would require without the company performing a given action, for example how much fuel or energy the service would consume if none of the drivers used e-scooters or bicycles and carried only one order per delivery. Then, it was calculated the percentage of material/fuel and energy being saved by the actions performed in each R, starting from R0. Each subsequent R has, as its initial value, the remainder value from the preceding R (see Equations 4 and 5).

$$(4)\ For\ R1 \begin{cases} R0 = 0\ L \\ Total = 7{,}11\ x\ 10^6\ L\ - R0 =\ 7{,}11\ x\ 10^6\ L \\ R1 = 3{,}55\ x\ 10^6\ L \end{cases} \rightarrow R1_{Efficiency} = \frac{Total}{R1}(\%) = 50\%$$

$$(5)\ For\ R2 \begin{cases} Total = 7{,}11\ x\ 10^6\ L - R1 =\ 3{,}55\ x\ 10^6\ L \\ R2 = 2{,}8\ x\ 10^6\ L \end{cases} \rightarrow R2_{Efficiency} = \frac{Total}{R2}(\%) = 80\%$$

Lastly, for the calculation of the circularity performance of each service component, it was assigned a weight to each R that decreases in value based on its position in the circularity matrix, starting with R0 receiving a weight of 10, and ending with R9 receiving a weight of 1. It was then conducted a weighted average with the active R's and the result was multiplied by the percentage of resource that was saved in total (TS) (see Equation 6). It is important to note that in a complete assessment, with full access to the service data, instead of a "blank" indicator the user must insert the value 0% for the Rs in which no action is performed, to reach an accurate result.

$$(6)\quad Circularity = \left(\frac{(10 * R0 + 9 * R1 + 8 * R2 + \cdots + 1 * R10)}{\sum R_{active}} \; x \; (TS) \right) (\%)$$

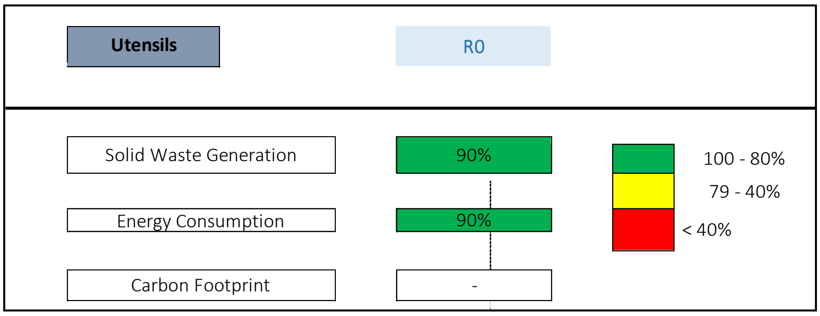


Figure 10 - Refuse scorecard for cutlery / utensils

Finally, Figures 11 and 12 present the individual estimated contribution that each "R" has in diminishing the amount of waste that is sent to landfill ("leakage from the close loop" and circularity concept), for the packaging and cutlery components. The complete list of scorecards and charts for the current scenario are presented in Appendix D to F.

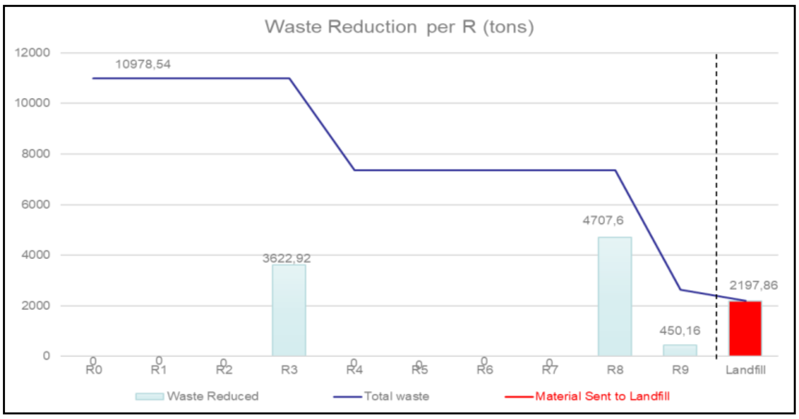


Figure 11 - Reduced waste generated for packaging

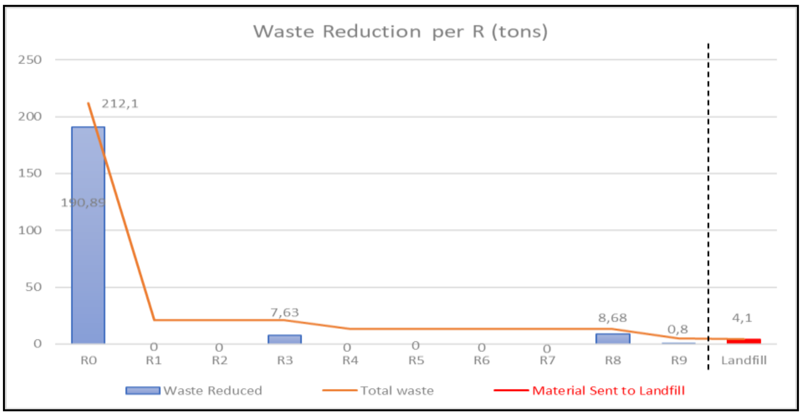


Figure 12 - Reduced waste generated for cutlery

Alternative Scenarios and Improvement

In this section, actions were proposed to diminish the environmental impact of the service and increase its circularity. While packaging plays an integral role in protecting and distributing products, it's one of the biggest sources of waste and adds no value for the final consumer (Accorsi et al., 2014). Therefore, the focus of the first two propositions was to deal with packaging waste in the top half of the 10R hierarchy. In addition to that, the transport component incurs the second biggest carbon footprint of the service system and therefore is the focus of the third proposition. For the cutlery component however, no additional action will be proposed, as Deliveroo has already made great progress in diminishing its waste. With that, the following three measures were proposed for the alternative scenarios:

1. A biodegradable greaseproof paper, bellow the pizza, with straps. In this proposition, the pizza will be delivered on a greaseproof paper that will keep grease from soaking the pizza box. Furthermore, the paper will have side straps that allows the client to easily lift the pizza from its box and onto a plate or platter. In this manner, the client will have the option to receive only the pizza

and the driver will be able to take back the empty and untainted box to the restaurant, or other dropping location, instead of returning with an empty backpack.

2. One initiative already developed by Deliveroo, the barePack option allows the users to request reusable containers for their orders, not applicable to pizza deliveries, by depositing a fee that will be fully refunded when returning the box with containers to any of the restaurants in the network (Deliveroo, 2020). As mentioned, this initiative was developed, and is already under implementation, by Deliveroo. However, there is no public data regarding its efficacy. Therefore, this idea was tested using data from 2018 to verify the results that the initiative may bring.
3. A campaign to further encourage the use of bikes, instead of cars, for the deliveries. Despite the performed estimation that only 20% of Deliveroo's drivers use cars in the UK, this result should be further improved to reach a CE.

After the application of those measures, it was then calculated the results for the sustainability and circularity dimensions of the service for three scenarios: an optimistic view, where 75% of the users adopted the proposed measures, an intermediary view, with 50% adoption rate, and a pessimistic view, where only 25% of the users adopted the measures. Then the results were used to develop scorecards and transcribed into charts, to enable a better comparison. As can be seen in Figures 13 and 14, the proposed actions enabled a clear improvement in the packaging waste that ends up in landfill, even when considering a pessimistic scenario. However, when diving into deeper analysis, as exemplified in Figures 15 and 16, we can see that the biggest contributor to this improvement is the second proposition rather than the first one. In fact, we can see that the first proposition results in an improvement of only 7% to the packaging indicators in an optimistic scenario while the second results in an improvement of 24% even in a pessimistic scenario. This result makes sense because, although both measures target the packaging component, the first proposition only affects the pizza packaging, while the second affects the remaining sub-components. Thus, this result reinforces the importance of suitably breaking down the service for a better component assessment.

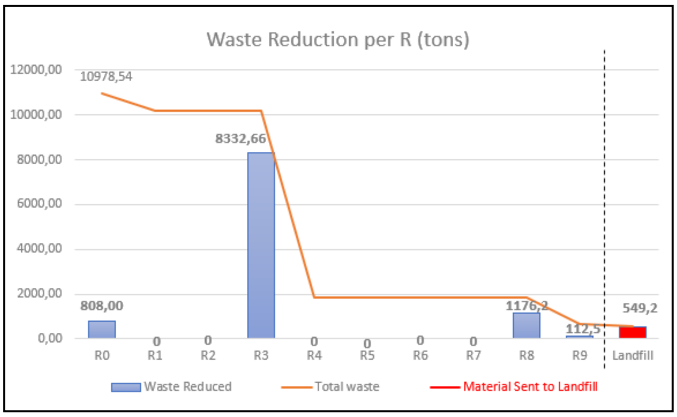


Figure 13 - Waste Reduction per R (optimistic)

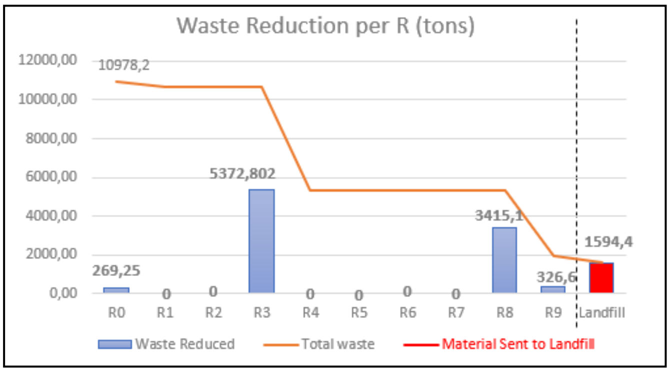


Figure 14 - Waste reduction per R (pessimistic scenario)

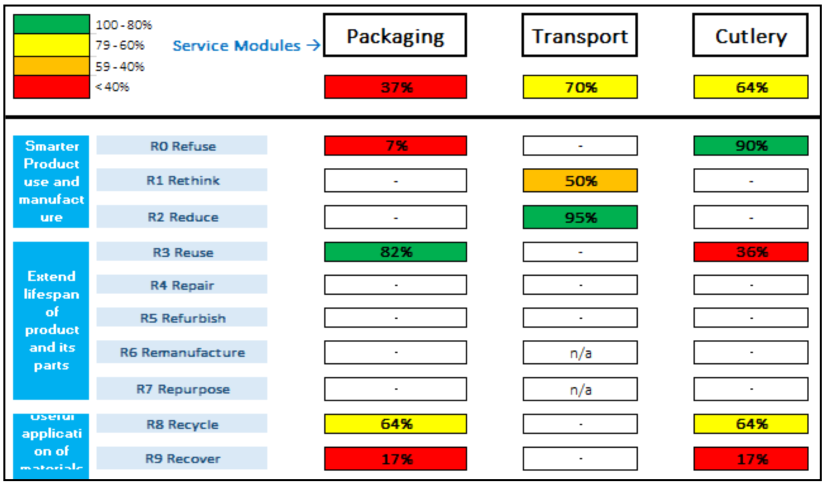
R0 Refuse					
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficiency	0%	0%	75%	0%	R0
Solid Waste Generation	0%	0%	75%	0%	7%
Energy Consumption	0%	0%	75%	0%	7%
Carbon Footprint	0%	0%	75%	0%	7%

Figure 15 - Refuse scorecard for first proposition (optimistic scenario)

R3 Reuse					
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficiency	25%	25%	0%	25%	R3
Solid Waste Generation	25%	25%	0%	25%	24%
Energy Consumption	25%	25%	0%	25%	24%
Carbon Footprint	25%	25%	0%	25%	24%

Figure 16 - Reuse scorecard for second proposition (pessimistic scenario)

Lastly, Figure 17 presents the scorecard for the circularity performance to the optimistic scenario while Figure 18 shows the evolution of material costs and the carbon footprint of the service, per year, through the different scenarios studied. It is appropriate to note that the circular index for the packaging component did not improve much with the proposed actions. That behavior is explained by the R0 indicator, that have the highest weight, going from a blank value to a 7% value. In other words, it was from not being considered in the calculations to receiving a very bad result. Intuitively, that should not happen in an assessment with full access to data, as a 7% action in the R0 indicator is better than no action performed in R0. For that reason, it is reinforced that in a complete assessment, the user should not use blank values, to avoid such inconsistencies. The complete list of scorecards and charts are presented in Appendix G to M.



	Service Modules →	Packaging	Transport	Cutlery
100 - 80% 79 - 60% 59 - 40% <40%		37%	70%	64%
Smarter Product use and manufacture	R0 Refuse	7%	-	90%
	R1 Rethink	-	50%	-
	R2 Reduce	-	95%	-
Extend lifespan of product and its parts	R3 Reuse	82%	-	36%
	R4 Repair	-	-	-
	R5 Refurbish	-	-	-
	R6 Remanufacture	-	n/a	-
	R7 Repurpose	-	n/a	-
applicati on of	R8 Recycle	64%	-	64%
	R9 Recover	17%	-	17%

Figure 17 - Circularity Scorecard (Optimistic Scenario)

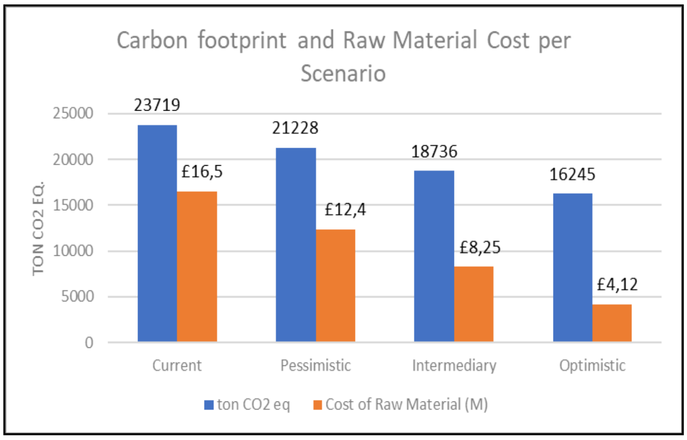


Figure 18 - Evolution of material costs and the carbon footprint

As a last step of the framework, the analyst of the system shall take measures to incorporate the most efficient actions proposed into the service system. This project, however, has a limitation regarding the application of the proposed actions into Deliveroo's system. Therefore, no improvement actions were performed for the service system. However, it is important to note that the improvement step should not be overlooked, as it is of crucial importance to attain continuous improvement.

6 Conclusion and future research

This research had as its main goal the development of the novel ServiceDfX or S-DfX framework for the performance assessment of services in multiple dimensions and phases of the Service Life Cycle, while seeking to answer the proposed research questions. The focus for its demonstration were the dimensions of Sustainability and Circularity. During the literature review and formulation of the framework, it became clear that the inherent complexity of services makes it impracticable to develop a single standard method and set of indicators (or KPIs) to assess the performance of services from different sectors and industries. As such, to deal with service complexity, the S-DfX framework has the adaptability to allow the user to select the most appropriate organizational structure and KPI's to the service under study. That decision is based on the knowledge that the user will be the most suited to handle the characteristics of the service system, as he/she should be an experienced professional or researcher on that specific field and economic sector.

Considering the studies conducted on sustainability and circularity in a service-oriented approach, this research aimed at analysing different forms in which a service system can be assessed for its performance in both dimensions, and then testing it with the S-DfX framework in a real based data for a case study.

Besides the S-DfX framework, the research also developed an inovative approach to assess the circularity of the service, by using the 10Rs as macro-indicators of the circular performance and unfolding each "R" into consumption indicators. For the sustainability assessment, the dimension was decomposed into sub-dimensions, based on the LCSA pillars, and the results were presented in three individual tables and scorecards for better visualization. Despite the lack of vast public data, the study was successful in testing the applicability of the framework to assess the sustainability and circularity for the delivery phase of a food delivery service (UK based Deliveroo company). As the online food delivery service is a segment that brings a heavy impact on the environment, the decision to test the framework in this service system is well motivated.

This research aimed to make a contribution to the DSR literature by adressing the identified gap regarding the performance assessment of different services in multiple dimensions. This aim was reached through the production of the S-DfX framework and its implementation roadmap, that may be used to guide future researchers in using it. The testing of the framework in a case study and publication of the results will also provide benefits to the field, as they will be available to the academic community. As the current servitization tendency intensifies, the relevance of adressing this research for the business segment is reafirmed and, as the research was developed with support of INEGI, the business community may also benefit from the results in future projects.

This research had some limitations regarding the access to Deliveroo's data for the case study and access to the "user point of view", namely to validate the selected organizational structure and indicators inputs for the service evaluation. Those limitations were nonnetheless dimminished through an extensive literature research, and justified aproximations which don't affect the demonstration and testing of the new designed framework and concepts.

Finaly, to ensure the applicability of the method, it is recommended future research using the S-DfX in different types of services, different phases of the Service Life Cycle, and for multiple performance dimension, conducted by users experienced in the service under study and with vast access to data (paving the way to a link towards data-analytics studies with the framework). Furthermore, the application of the new approach to measuring circularity performance based on the 10R framework, with original scorecards (inspired by MSM framework), should be further tested and improved, both in services, product development and manufacturing, to verify its applicability in different areas of knowledge.

The new S-DfX can also be studied for its complementary integration with LeanDfX, providing a joint product-service performance assessment methodology.

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APPENDIX A: Source of used data

Data	Source
Direct employment; Total Employment; Revenue; Profit; Average Wages; % of female employees.	Iqbal (2021)
Deliveroo Market Share in the UK in 2018	Curry (2021)
Number of food deliveries made by Deliveroo in the UK (2019)	Deliveroo - 2021 Q1 Trading update
Estimation on the carbon footprint per type of food delivery	(Arunan & Crawford, 2021)
Estimation of electricity consumption to treat waste	(Accorsi et al., 2014)
Deliveroo’s production of greaseproof paper for pizzas	Upton (2019)
barePack Initiative	Deliveroo (2020)
Most popular cars among delivery drivers in the UK	Harrison (2020)
Emission factor in the UK in 2018	Hill et al. (2018)
Carbon footprint of processing polypropylene plastic (for cutlery)	(Carlton, Taniura, Wen, & Knechtle, 2015)
UK’s most ordered type of food delivery	Lock (2020)
Fuel efficiency, energy efficiency and emissions of the cars most used for deliveries and e-scooters	Wattson (n.d.), MotorK Italia (2021), Prez (2020) and Alex (n.d.)

APPENDIX B: Assumptions used for the calculations

Assumptions
Each driver carries at least 2 different orders per delivery.
The average distance travelled by a driver per delivery is roughly 4 km in the city
The reuse behavior of packaging/cutlery for the UK citizens is similar to those in Australia
The transport choice of the drivers is 20% of drivers use electric cars, 50% use e-scooters and e-bikes and 30% use bicycles for the deliveries
For the electric cars, the proportion is 40% drive a Yaris, 35% a Prius and 25% a Golf
The drivers of electric cars drive 50% of the distance with fuel and 50% in electric mode
The barePack initiative will not affect the 33% package reuse behavior of the regular non-returnable containers

APPENDIX C: Calculations for the current scenario

Type of food	Container	kg of CO2 equivalent per order	Packaging weight (g)	Price per container
Chinese	Plastic container + bag	0,16	280	£ 0,37
Indian	Plastic container + paper bag + cling film	0,18	120	£ 0,25
Pizza	Cardboard box	0,2	153	£ 0,24
Others	Various (paper bag and box, plastic straw, etc.)	0,21	200	£ 0,30

Estimated Number of Orders in 2019	Average Orders per delivery	Average Distance per Delivery	Total Distance in 2019
5416419485	2	4 km	108000000

Most ordered type of food in the UK	%	n° of Orders	Carbon Footprint (tons of CO2)	Packaging Waste Generated (tons)
Chinese	35%	18.957.468	3.033,19	5.308,09
Indian	24%	12.999.406	2.339,89	1.559,92
Pizza	13%	7.041.345	1.408,27	1.077,32
Others	28%	15.165.974	3.184,85	3.033,19
Total			9.966,21	10.978,54

Cutlery Weight	CO2 to process plastic	CO2 to extract and transport	Total cutlery pairs required	Total Carbon Footprint	Reduction thanks to R0
4,5 g	76 kg CO2 / ton	2 kg CO2 / kg	47.122.849	440,22 ton of CO2	44,02 ton of CO2

Transport	Fuel	Fuel spent	Energy	Electricity	Emissions/km	Emissions

(2019)	Efficiency	(L)	Efficiency	Consumption		
Cars (20%)	-	711180	-	3288600	-	2122200
Toyota Yaris (40%)	7.8 L/100km	336960	15 kWh/100km	648000	0,084 kg CO2 /km	725760
Toyota Prius (35%)	4.4 L/100km	166320	45 kWh/100km	1701000	0,104 kg CO2 /km	786240
Volkswagen Golf (25%)	7.7 L/100km	207900	16,8 kWh/100km	453600	0,113 kg CO2 /km	610200
e-bikes and e-scooters (50%)	n/a	n/a	1,8 kWh/100km	486000	0,05 kg CO2 /km	2700000
Bicycles (30%)	n/a	0	n/a	0	n/a	0
	Total	**711180 L**	**Total**	**3774600 kWh**	**Total**	**4.822,20 ton CO2**

Energy consumption of Transportation	UK emission factor	CO2 eq. for the energy consumption
3774600 KWh	0,309 Kg CO2 eq. / KWh	1.166.351,4 Kg CO2 eq.

Estimated energy consumption of treated waste	Total Packaging waste	Packaging waste energy consumption	Total Cutlery waste	Cutlery waste energy consumption
600 kWh / ton	10.978,54 ton	6.587.124 kWh	44,02 ton	743,13 kWh

Kraft Paper CO2 eq.	Kraft Paper Packaging Carbon footprint	Reduction in CO2 eq. using Kraft Paper Packaging
519 kg CO2 / ton	6566,2 ton of CO2	3400 ton of CO2 eq.

APPENDIX D: Sustainability scorecards for the current scenario

Environmental Pilar				
↓ KPI Service Modules →	Packaging	Transport	Cutlery	
Module Efficacy	100%	100%	100%	Effic. 100%
Solid Waste Generation	100%	-	100%	100%
Carbon Footprint	100%	100%	100%	100%
% of secondary raw materials	-	-	-	-
Energy Consumption	100%	100%	100%	100%
Atmospheric emissions	n/a	100%	n/a	100%

Economic Pilar	Effic. 0%
Direct Employment	90%
Total Employment	-
Community involvement	-
Average Wages	80%
Worker's Satisfaction	92%
Occupational Health / Safety	-
Inclusiveness	18%
Qualification of Workers	-
Commitment with Environment	-

Economic Pilar	Effic. 40%
Revenue	100%
Opperational Cost	30%
Profit	56%
Market Share	100%
Electricity Cost	-
Cost of Capital	-
Raw Material Cost	-
Labor Cost	90%
External Environmental Cost	-

100%

<100%

APPENDIX E: Individual 10R scorecards for the current scenario

R3 Reuse					
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficacy	-	-	-	-	R3
Solid Waste Generation	-	-	-	-	33%
Energy Consumption	-	-	-	-	33%
Carbon Footprint	-	-	-	-	-

R8 Recycle					
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficacy	-	-	-	-	R8
Solid Waste Generation	-	-	-	-	64%
Energy Consumption	-	-	-	-	64%
Carbon Footprint	-	-	-	-	-

R9 Recover					
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficacy	#REF!	#REF!	#REF!	#REF!	R9
Solid Waste Generation	-	-	-	-	17%
Energy Consumption	-	-	-	-	17%
Carbon Footprint	-	-	-	-	-

Transport	R1
Fuel Consumption	50%
Energy Consumption	50%
Carbon Footprint	-

Transport	R2
Fuel Consumption	80%
Energy Consumption	73%
Carbon Footprint	-

Utensils	R0
Solid Waste Generation	90%
Energy Consumption	90%
Carbon Footprint	-

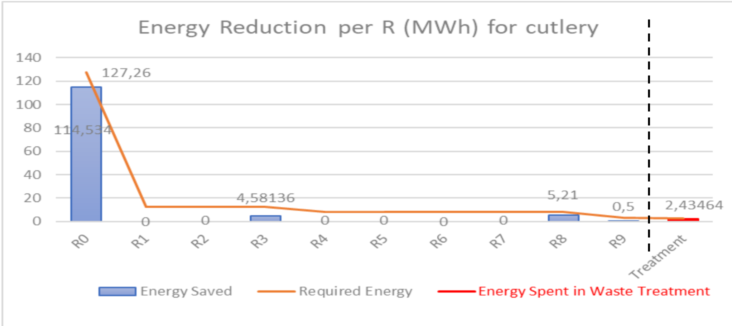
100 - 80%
79 - 40%
< 40%

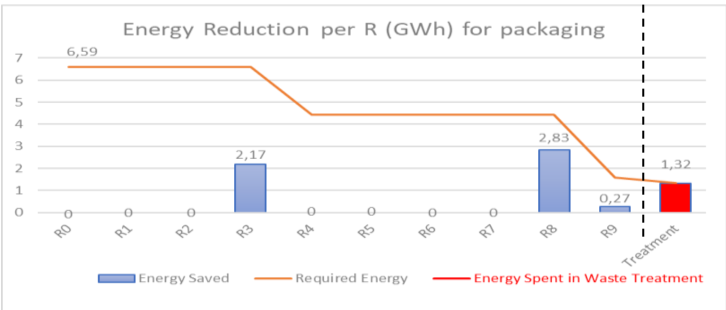
Utensils	R3
Solid Waste Generation	36%
Energy Consumption	36%
Carbon Footprint	-

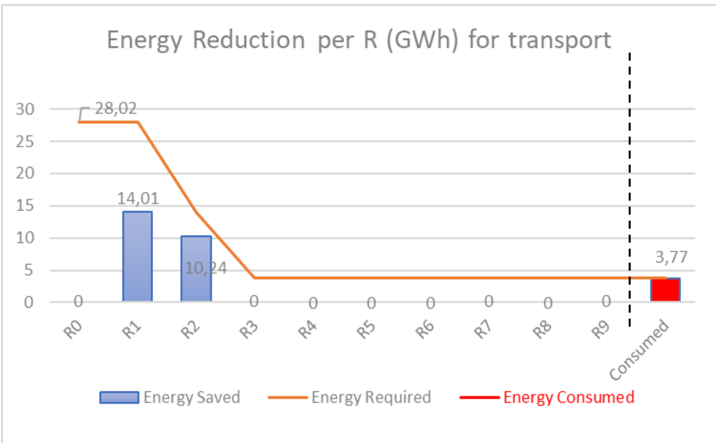
Utensils	R8
Solid Waste Generation	64%
Energy Consumption	64%
Carbon Footprint	-

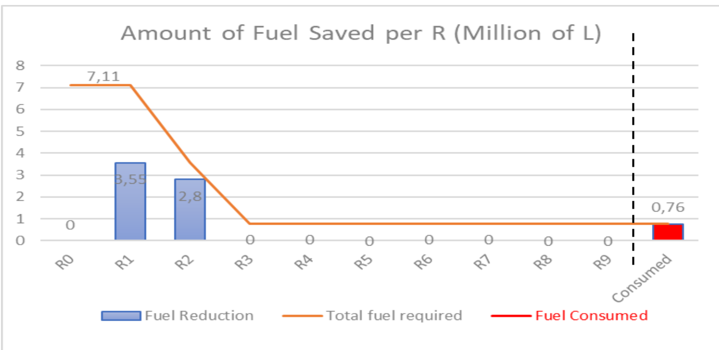
Utensils	R9
Solid Waste Generation	16%
Energy Consumption	18%
Carbon Footprint	-

APPENDIX F: Charts with waste and energy reduction per R









APPENDIX G: Circular scorecards for the intermediary and pessimistic scenarios

100 - 80% | 79 - 60% | 59 - 40% | < 40%

	Service Modules →	Packaging	Transport	Cutlery
		29%	65%	64%
Smarter Product use and manufacture	R0 Refuse	5%	-	90%
	R1 Rethink	-	50%	-
	R2 Reduce	-	90%	-
Extend lifespan of product and its parts	R3 Reuse	65%	-	36%
	R4 Repair	-	-	-
	R5 Refurbish	-	-	-
	R6 Remanufacture	-	n/a	-
	R7 Repurpose	-	n/a	-
Useful application of materials	R8 Recycle	64%	-	64%
	R9 Recover	17%	-	17%

100 - 80% | 79 - 60% | 59 - 40% | < 40%

	Service Modules →	Packaging	Transport	Cutlery
		22%	62%	64%
Smarter Product use and manufacture	R0 Refuse	2%	-	90%
	R1 Rethink	-	50%	-
	R2 Reduce	-	85%	-
Extend lifespan of product and its parts	R3 Reuse	50%	-	36%
	R4 Repair	-	-	-
	R5 Refurbish	-	-	-
	R6 Remanufacture	-	n/a	-
	R7 Repurpose	-	n/a	-
Useful application of materials	R8 Recycle	64%	-	64%
	R9 Recover	17%	-	17%

APPENDIX H: Individual 10R scorecards for the optimistic scenario

R3 Reuse					
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficacy	75%	75%	0%	75%	R3
Solid Waste Generation	75%	75%	0%	75%	73%
Energy Consumption	75%	75%	0%	75%	73%
Carbon Footprint	-	-	-	-	-

Transport	R2
Fuel Consumption	95%
Energy Consumption	88%
Carbon Footprint	-

APPENDIX I: Individual 10R scorecards for the intermediary scenario

R0 Refuse

Packaging	Chinese	Indian	Pizza	Others	
↓ KPI / Components →					
Efficacy	0%	0%	50%	0%	R0
Solid Waste Generation	0%	0%	50%	0%	5%
Energy Consumption	0%	0%	50%	0%	5%
Carbon Footprint	-	-	-	-	-

R3 Reuse

Packaging	Chinese	Indian	Pizza	Others	
↓ KPI / Components →					
Efficacy	50%	50%	0%	50%	R3
Solid Waste Generation	50%	50%	0%	50%	47%
Energy Consumption	50%	50%	0%	50%	47%
Carbon Footprint	-	-	-	-	-

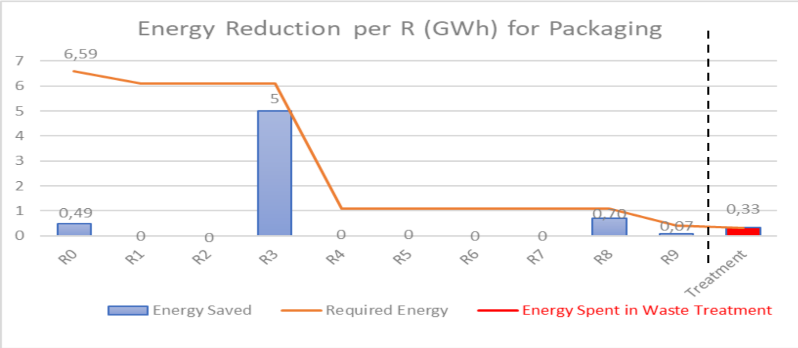
Transport	R2
Fuel Consumption	90%
Energy Consumption	83%
Carbon Footprint	-

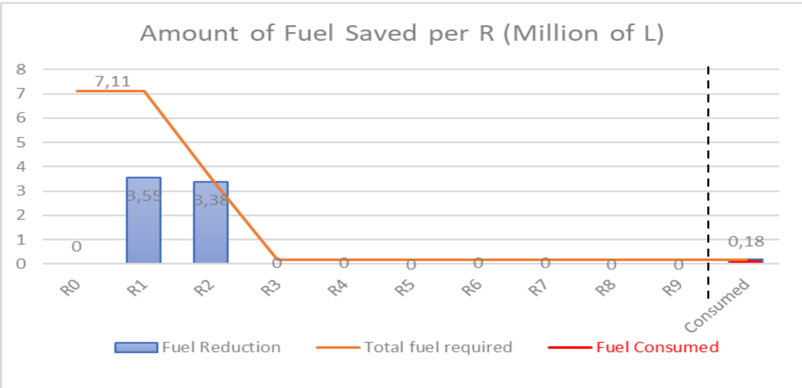
APPENDIX J: Individual 10R scorecards for the pessimistic scenario

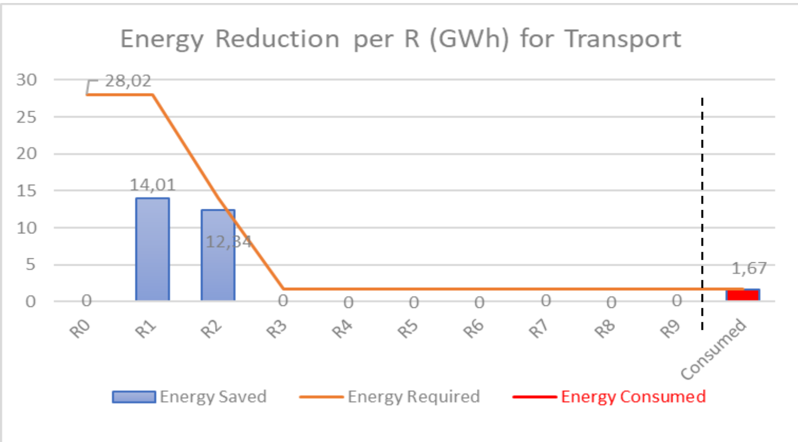
Packaging					
↓ KPI Components →	Chinese	Indian	Pizza	Others	
Efficiency	0%	0%	25%	0%	RO
Solid Waste Generation	0%	0%	25%	0%	2%
Energy Consumption	0%	0%	25%	0%	2%
Carbon Footprint	-	-	-	-	-

Transport	R2
Fuel Consumption	85%
Energy Consumption	78%
Carbon Footprint	-

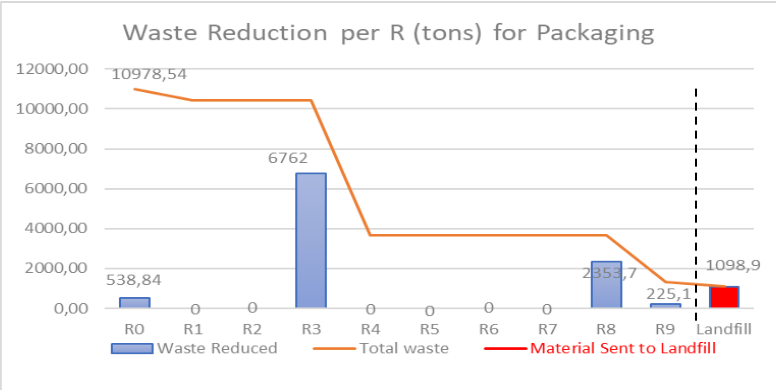
APPENDIX K: Charts with waste and energy reduction per R optimistic scenario

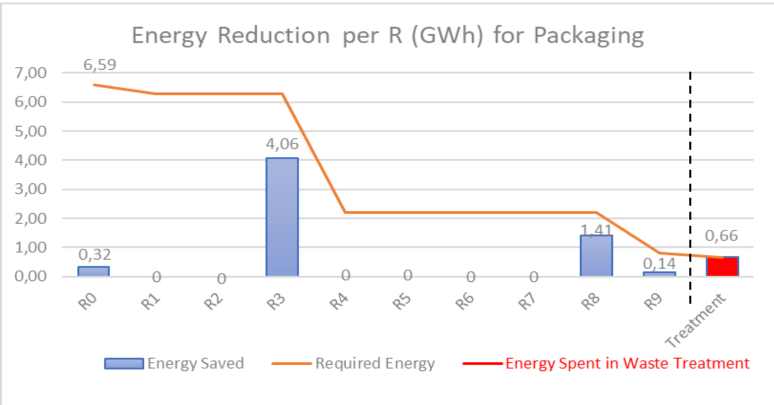


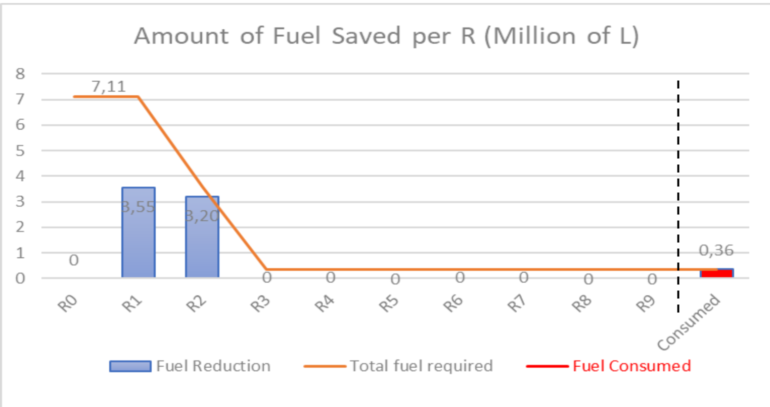


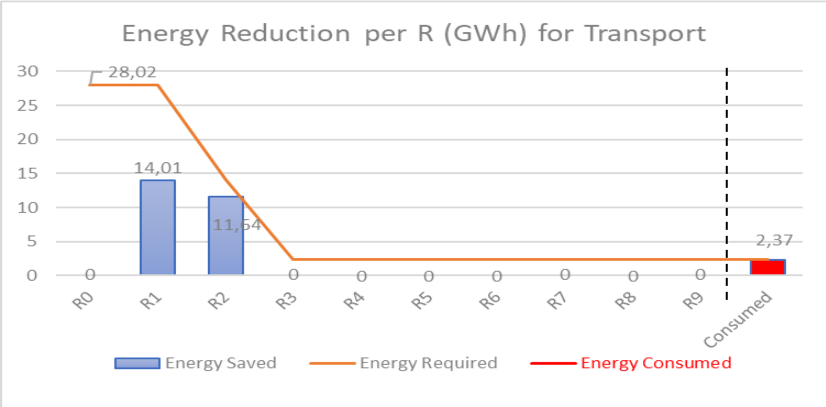


APPENDIX L: Charts with waste and energy reduction per R intermediary scenario









Energy Reduction per R (GWh) for Transport
30
25
20
15
10
5
0
28,02
14,01
11,54
0
0
0
0
0
0
0
0
2,37
R0
R1
R2
R3
R4
R5
R6
R7
R8
R9
Consumed
Energy Saved
Energy Required
Energy Consumed

APPENDIX M: Charts with waste and energy reduction per R pessimistic scenario