An ICT Platform Facilitating Circular Economy Business Models

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Abstract The CIRC4Life project aims to develop and implement a circular economy approach through three circular economy business models. In order to support these three business models, around the whole value chain, an ICT platform is created, including various end user tools; central and distributed databases; and external backends. We present the methodology for the system design, the architecture of the ICT platform as well as the main ICT components of the system.

Keywords: ICT for circular economy, ICT design, Circular Business Models, Circular Economy, Data for Circular Economy.

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1 Introduction

The circular economy moves away from the traditional "take-make-dispose" economic model to one that is regenerative by design (Ellen MacArthur Foundation, 2012), (Fellner *et al.*, 2017) and considers the products alongside the value chain. However, existing business models for the circular economy have limited transferability, and there is no comprehensive framework supporting every kind of company in designing a circular business model (Lewadofksi, 2019).

As part of the CIRC4Life (www.circ4life.eu) project, three new circular business models "co-creation of products and services", "sustainable consumption", and "collaborative recycling and reuse" will be created.

The Co-creation of products and services model will bring end-users closer to the design and manufacturing phases by identifying consumer preferences and evaluating product specifications and prototypes via Living Lab to customize end-user requirements. The sustainable consumption model will develop a method to calculate the eco-points of products based on a Lifecycle Assessment: i) assessing the product Lifecycle ii) providing a traceability solution to monitor the product's sustainability along the value chain, and iii) supporting end-users and stakeholders to actively implement the circular economy via awareness raising and knowledge-sharing activities. The collaborative recycling/reuse model will develop a system for stakeholders to interact with each other in order to facilitate the use or reuse of end-of-life products, waste reduction waste implementation of the eco-credits award scheme encouraging people to recycle or reuse.

In trying to identify ICT platforms that could be enablers for the circular economy, one can find in the literature various attempts at online LCA platforms that aim to support products across their Lifecycle (Varghese, 2010),(Ligthart *et al.*, 2019) or to create simplified online approaches for products (Ramos *et al.*, 2016) or deal with how to create simplified LCA approaches for SMEs(Buttol *et al.*, 2012).

On the other hand, LCA tools are not enough to support fully circular business models, and additional tools have been created for the assessment of products at the end of life (Stewart *et al.*, 2011), (Alamerew *et al.*, 2019). Furthermore, cutting-edge technologies such as big data and the internet of things (IoT) have the potential to leverage the adoption of CE concepts by organizations and society, thus making them more present in our daily lives (Nobre, 2017). However, regardless of the technology used to collect the necessary data, this work proposes a multilayered ICT toolbox as an enabler of circular decisions. The aim of this paper is to identify the needs of Circular Business models, in addition to LCA, and create a single ICT platform that can serve all the stakeholders involved.

2 System Design

To design the ICT platform, an iterative approach comprising three steps was followed. Figure 1 visualizes the iterative procedure, starting from the identification of the end-user requirements, proceeding with the definition of the system/technical requirements and finishing with the system architecture of CIRC4Life.

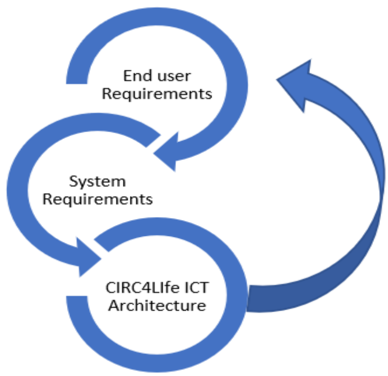

Figure 1: Methodology for the collection of user requirements, system requirements and definition of the system architecture.

In the following chapters, the actions taken at each of the steps are further elaborated.

2.1 User Requirements

The main purpose behind the collection of end user requirements is to satisfy user needs by introducing the appropriate system specifications into the design of the ICT architecture. A general process comprising four steps, as described by (Maguire *et al.*, 2002) and shown in Figure 2 was used for user requirement collection.

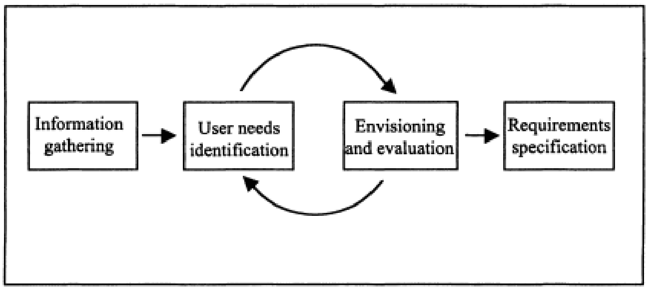

Figure 2: Process for user requirement Analysis.

Information Gathering: The first step of the user requirements analysis is to gather information about the users and stakeholders and the processes that need to be supported by the ICT platform.

User needs Identification: Then the user needs identification was conducted by analysing scenarios and using cases that could be served by the system.

Envisioning and evaluation: In this phase the general architecture of the ICT platform was used as a basis for comparison with the user needs.

Requirements Specification: Finally, the user requirements were formulated considering a generic definition in order to accommodate to the greatest possible extent any future requirements that could derive from newly created Business Models.

Once the user requirements were described, these were categorized in the following categories:

1. Design: Aspects relevant to the CEBM of The Co-creation of Products and Services model.
2. Use: Aspects relevant to The Sustainable Consumption model.
3. Recycle/Reuse: Aspects relevant to The Collaborative Recycling and Reuse model. 4.Generic: Aspects that are generic and relevant to the whole project scope or other non-functional requirements.

Finally, a link to the related ICT system to which the requirement applies is associated with each user requirement. This part was retrofitted after the completion of all the user requirements and the initial system design, being the link to the system requirements and the whole architecture of the system.

2.2 System Requirements

The starting point for the definition of the system requirements was the full list of collected user requirements. A complete list of the characteristics of the TO BE created system was made in order to fully match functional and non-functional user requirements (Robertson & Robertson, 2007). This was the starting point for the draft version of the system requirement, which through an iterative round of ICT design, were formulated to their final version as seen in Figure 3.

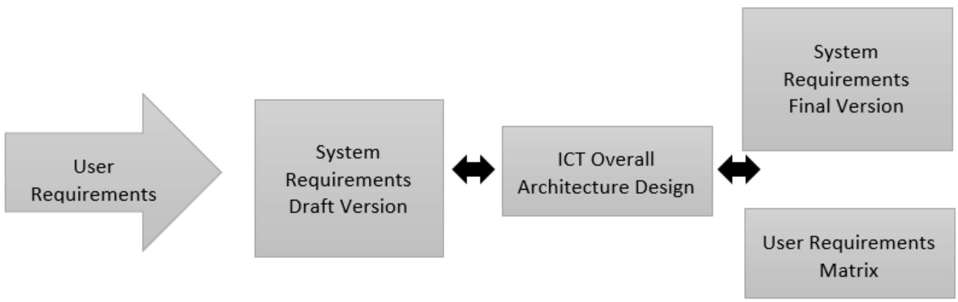

Figure 3: CIRC4Life system requirements process.

The system requirements were then formulated as seen in Table 1 to offer a complete view of the system needs and the association to the business models.

Table 1: Table summarizing the format of the system requirements collection.

Attribute	Description
Unique ID	It identifies each requirement through a unique identifier.
Type	It specifies the type of requirement. Two types of requirements are considered – **Functional Requirements (FR):** These are the fundamental or essential subject matter of the product. They describe what the product must do or what processing actions it is to take (Robertson & Robertson, 2007). – **Non-Functional Requirements (NFR):** These are the properties that the functions must have. These requirements are as important as the functional requirements for the product's success (Robertson & Robertson, 2007)
Priority	The priority of a requirement is the decision on the importance of the requirement's implementation. The priority depends highly on the specific domain of the application Priority is divided by (Bradner, 1997): – MUST: This means that the definition is an absolute requirement of the specification. – SHOULD: This means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course. – COULD: This means that an item is truly optional.
Category	The category is used to aggregate the requirements into coherent sets. The following set of categories shall be used: – Product Design – Product Usage – Recycle/Reuse

	– Interoperability – Performance – Usability – Reliability – Security – Legal – Openness
Description	The description is the intent of the requirement. It is a statement of what the requirement must fulfil.
Rationale	The rationale is the reason behind the requirement's existence. It explains why the requirement is important and how it contributes to the system's purpose (provide mapping to the project objectives whenever possible).
Fit Criterion	A fit criterion is a measurement for a requirement. It is needed because some requirements are too vague or ambiguous to be properly useful. For example, "The system shall be easy to use" is well-intentioned, but not yet able to be implemented. However, if you add a fit criterion such as "75 % of first-time users shall be able to buy the correct cinema tickets within 90 seconds, without using the help functionality" makes it clear to the designer what is needed to make the product successful. (Robertson & Robertson, 2007)
Relevant User Requirement (s)	As per the user requirement in the section above
Dependencies	Indicate if the requirement depends on another one. Relations between two or more requirements should be traced.
Conflicts	Conflicts between requirements imply that there exists contradiction upon system implementation, or one requirement makes the implementation of another requirement less feasible.
Comments	Any additional comment or observation regarding the specific requirement. In particular, it should include comments on possible technology limitations or identify aspects that may be only partially relevant to the scope of the project (or even beyond the scope).

Related ICT system	A mapping towards the system in which the system requirement is implemented

Once the whole system architecture was created, this was retrofitted to the system requirements to ensure that the whole architecture was in accordance with each system requirement.

3 ICT Platform Design

Taking into consideration that the ICT platform is designed to serve new business models that have not yet been verified in the market, the risk of changing user requirements was identified. This problem has been previously analysed even outside the context of ICT (Land ,1982), and a ''future analysis" technique was introduced. Within the ICT context, the notion of flexibility in the design in order to consider potential future changes was considered a success factor for any ICT system (Oei *et al.*, 1994). In this context, a tailorable approach for ICT system design was introduced, making it possible to adapt to different users and needs (Stamoulis, 2002). Over the software community, Service oriented Architecture (SoA) was proposed as a way to adapt easily to different providers but also to accommodate any change to the users or the requirements (Bennett, 2000) and (Bugden, 2004) . Furthermore, all the advantages of a service system compared to a component-based system were analysed (Elfatatry, 2007).

Considering the above, it was decided to use a SoA approach serving the end user parts of the system, whereas by design the system allows local components to use any other preferred architecture. A similar model is described by (Paik, 2017) as a system with multiple layers which can adapt to changing business models.

3.1 ICT Overview

Considering the above, it was decided to create an Ecosystem of subsystems, with different layers being served by a central platform of SoA architecture.

In this context, a data layer is introduced, which comprises all the data providers to the system, including the Escrow Database of the Products and any other legacy data that could be potentially needed by the projected business models.

Three independent modules with business logic serve all 3 CEBMs:

1. Recycle/Reuse Module, including the recycling bins
2. Traceability Module
3. LCA Module

The Core platform of the system includes all the databases needed, in a harmonized data format, the webservice/API manager for service provision and the Access Control manager to ensure security of the whole system.

Finally, four different end user environments provide all the interfaces needed by the system users:

1. End Users Toolbox (Consumer Eco Account, Eco Shopping Module)
2. Retailer Tool for Eco Accounting
3. Impact Assessment Tool
4. Stakeholders Interaction Toolbox (Brokerage System, B2B system for Stakeholder Interaction)

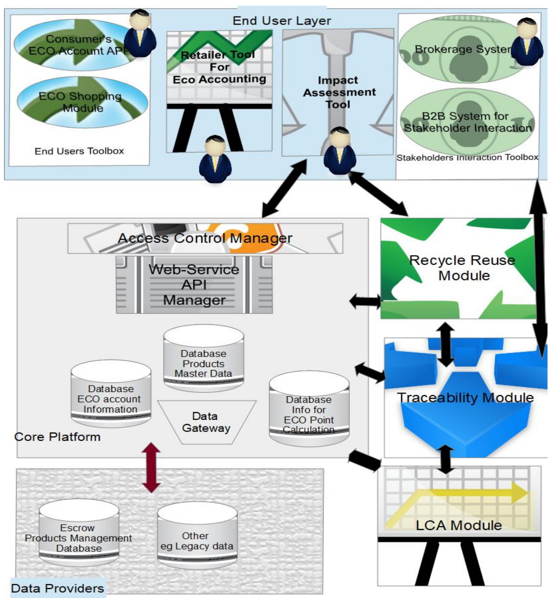

Figure 4: Overall ICT system architecture.

As can be seen in the graph above, in order to ease the development and further adaptation/maintenance of the system, few end user tools are merged. This gives the possibility of modular development, which could better serve the 3 CEBMs in the heterogenous context of the four different demonstration cases of the CIRC4Life project.

3.2 ICT Components Overview

The main components of the ICT platform and their main functionality are as follows:

Retailer Tool for Eco Accounting: This tool enables the consumer to buy the product at the store and get the related eco information via a receipt showing both the cash payment information and the eco-point information of each item purchased at the check-out point.

End Users Toolbox: Enables the consumer to view the eco-information related to the consumer's purchasing and recycling activities, such as eco-points and sustainable production information, by scanning the traceability tool (e.g. barcode or QR code) embedded in the product.

Impact Assessment Tool: A system to display the impact of various materials and contribute to the design of new products. The system could also provide information about recycling/reuse of materials.

Stakeholder Interaction Toolbox: A system that allows the interactions of stakeholders around the value chain, offering the possibility of matchmaking and exchange of services and materials.

Traceability Module: Capturing interfaces are used to gather data from the partners and load it into the traceability module. Access applications are developed to transform the data and provide APIs to the platform through which it can be used. Traceability data is used to monitor individual products throughout their lifecycle.

Recycle/Reuse Module: This module is used to capture and store online recycling and reuse data of EoL products such as tablets, lights and meat products, and then reward users for the recycling events.

LCA Module: The tool provides the functions to conduct LCA online to analyse the product's environmental/social impacts through their lifecycle, in order to calculate their impact in a standardized format of ECO points.

Core Platform: A core system backend that handles all the data needed for the eco-Point computation (product purchasing), eco-Credit computation (product recycling), the user transaction history, as well as a SoA that handles all the services needed by the frontend systems.

Data Provider: Database and entry systems that handle interaction with external systems and data entry containing product data and supporting resources describing the product and used as an intermediate data input interface to the core platform.

4 Conclusions

Circular Economy business models require flexible ICT systems that can collect and exchange large amounts of data in a centralized way. Service Oriented Architecture is explored as one of the possibilities for serving multiple users across their buying and recycling habits. Through this iterative approach, it was found that Circular Business Models can be better served through modular systems which can adapt to changing user requirements. Furthermore, such an approach allows the Business Models to consider a large variety of data sources and tools, giving them the opportunity to be further refined. Especially for Circular Business Models that require interaction among stakeholders alongside the value chain, this is an additional enabler.

The architecture discussed here is currently under development and will be demonstrated in the scope of the H2020 funded project CIRC4Life.

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