Advanced Integrated Manufacture by Application of Sustainable Technology through Product Lifecycle: a Circular Economy Approach

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ABSTRACT

An approach has been developed for sustainable integrated manufacture, covering the whole product development process from material acquisition till the product end of life treatment, which is part of the CIRC4Life project supported by the European Commission's Horizon 2020 programme. The approach consists of three new circular economy business models (CEBMs) including Co-creation of products/services, Sustainable consumption and Collaborative recycling/reuse. The CEBMs are supported by an eco-point approach, information and communication technologies, traceability techniques, online data mining, and other enable techniques/methods. In this paper, the overview and three new CEBMs are presented, followed by a case study of domestic lighting products, illustrating how the approach is implemented in an industrial application.

CCS CONCEPTS

Social and professional topics → Computer supported cooperative work

KEYWORDS

Integrated manufacture, Information and communication technology, Onlinedata mining, Lifecycle impact analysis, Product design and manufacture, Sustainability, Circular economy, Traceability, Lighting products

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INTRODUCTION

An approach of sustainable integrated manufacture has been developed which is presented in this paper. The integrated manufacture is conducted within product development process through product life cycle, including material acquisition, design, manufacture, logistics, retail, product in service, product end of life treatment, and recycle/reuse. It is the outcome of the research conducted as part of the CIRC4Life project supported by the European Commission's H2020 programme, which consists of 17 partners across eight countries of European Union for three years commencing May 2018, and is led by the authors' team as the project coordinator [1].

The CIRC4Life project aims to develop three new circular economy business models (CEBMs): co-creation of products and services, sustainable consumption, and collaborative recycling and reuse, which are demonstrated in four industrial sectors, including LED lighting products, vegetable farm, meat supply chain, and recycle/reuse of computer tablets. The aim is achieved by integrating various techniques/methods throughout the product life cycle, including co-creation method to bring end-users to the early stage of product development, mining consumer needs from commercial Websites, environmental lifecycle assessment (E-LCA) and social lifecycle assessment (S-LCA), sustainable production, eco-point method, information and communication technology (ICT) and traceability techniques, consumer-supply chain interaction, living lab methods to involve stakeholders in product development process, and others.

Sustainable integrated manufacture is also called as *sustainable product development, eco-design and manufacture,* or others, which apply sustainability techniques and methods through product life cycle. This topic has received researchers' great attentions, for example, myEcoCost project developed a method to calculate EcoCost scores for consumers to aware their impacts on the environment due to purchases of products [2]. Franze and Ciroth [3] applied both E-LCA and S-LCA in their assessment of product impacts. Different from the existing research, the CIRC4Life approach presented in this paper further develops the eco-point method based on the Eco-Cost method by including an eco-account infrastructure, consisting of eco-debits, eco-awards and eco-balance, which is more comprehensive than Eco-Cost. In comparison with the approach presented in [3], the CIRC4Life approach combines the E-LCA and S-LCA in a much wider environment.

In this paper, the overall structure of the platform integrating the three CEBMs and related techniques/methods are presented first. The key methods and techniques are then presented. At the end, a case study of domestic lighting products is presented to illustrate the CEBMs and integrated approach.

2OVERVIEW OF THE APPROACH

Figure 1 shows the CIRC4Life approach, where the three CEBMs, 'co-creation of products/services', 'Sustainable consumption' and 'Collaborative recycling/reuse', cover the whole product lifecycle. Instead of the linear manner of current product lifecycle, the CIRC4Life is a circular approach, which is achieved by reducing the waste, recycling/reusing end of life products, and eliminating harmful emission.

To support the three CEBMs, the *information technology*, *traceability technique*, and *eco-point method*, are developed and utilized. The *information technology* is applied to handle all the data processing and management tasks, and to develop a necessary IT platform and other related software tools in order to implement the CEBMs. The *traceability technique* is applied to capture the product information throughout the product lifecycle, using relevant tools such as barcode, RFID and NFC. An *eco-point* is a cumulative value which

accounts for an aggregate of the ecological impacts throughout the product's whole value chain.

Figure 1: The CIRC4Life approach

The functions of the three CEBMs are further detailed below [4]:

In the Co-creation of Products/Services model, the approach of bringing end-users closer to the design and production phases is implemented, including:

 The end-user requirement is addressed at the beginning and subsequent stages of the product development. Big data technology is applied for mining the data and identifying patterns of preferences from customer online reviews of products via the websites of e-commerce companies and online stores. Such large amounts of online product specific data will then be analysed to form the product design specifications (PDS) including the sustainable features. This will largely reflect the consumers' preferences in the product development.

 The product concept and prototype developed based on the PDS are then evaluated by Living Labs to customise the end-user requirements.

 Consumers are engaged to discover their needs and co-create products in terms of price, quality, environmental and social values, innovations, retail options, etc. in workshops. These will be carried out early in the project to inform the questions, and analyse the answers from stakeholder case studies.

In addition, the involvement of stakeholders along the supply chain will be handled by an online system, and necessary tasks are conducted to enable that the supply chains become more traceable, and thus create new opportunities for innovation and co-creation of products.

By benefiting from the co-creation features, sustainable production methods, such as lifecycle assessment (LCA) framework, design for recycling and reuse, and sustainable production are implemented. New services will be developed, such as leasing products to end-users and means of waste reduction.

In the Sustainable Consumption model, the following are conducted:

 A method to calculate the eco-points of products and services are developed with LCA methods and the knowledge developed by the previous FP7 myEcoCost project [5]. The eco-points can be displayed for each products, which can help end-users in making positive purchasing decisions, as well as to measure the eco-behavior of the enterprise and stakeholders.

 To share knowledge with end-users about product's eco-information. In so doing, the traceability technology is applied to link the eco-information to barcodes or RFID tags attached to the products, and by scanning such codes with a smartphone, the end-user can access such information from product databases.

 To enable the end-users to set-up their individual eco-cost accounts and to show the eco-points related to their purchasing and recycling activities, and hence the end-users aware their daily footprints on environment.

 Support for end-users to actively implement the circular economy via awareness raising and knowledge sharing activities. Specific workshops for end-users will be

organised. Such proposed measures would include, for instance, the incorporation of eco-credits when acquiring a specific product, the incorporation of a set of recommendations and useful information related to the environmental performance, awards granting, etc.

The Collaborative Recycling and Reuse model enables the stakeholders in the supply chain to interact with each other to facilitate the (re)use of end-of-life (EoL) products or waste streams. For the EEE (electrical

and electronic equipment), an incentive scheme will be developed to award credits to people who recycle EoL electronic products. The key issues to be handled include:

- The eco-points method developed in the Sustainable Consumption model will be applied to calculate the eco-credits.
- The eco-credits will be paid by an incentive scheme.
- In order to recycle/reuse EoL products, the EPCIS (Electronic Product Code Information Service) and traceability data carriers such as barcode and RFID will be applied to recode the product's information and eco-points.
- An Internet based recycling system will be developed and implemented for people to recycle EoL products and receive credit points. In addition, methods for upcycling or reuse of the collected electronic products in part or the whole product will be implemented.

3APPLICATION OF THE CIRC4LIFE APPROACH IN THE DEVELOPMENT OF DOMESTIC LIGHTING PRODUCTS

The CEBMs are demonstrated via the domestic lighting products manufactured by Ona Product SL, a lighting product producer in Spain.

3.1Co-creation of lighting products

In order to address the consumers requirements in the design of the lighting product, an online data mining method is developed, which consists of three modules: *data scraping*, *data mining/processing*, and *consumer requirement mapping* [6]. As shown in Figure 2, the consumers views about the domestic lamps shown on Ona's Website are captures and then processed using the *data scraping* and *mining/processing* modules. The processed data represent the consumer needs/preference on Ona's existing products. Those data are then analysed, and, based on the analysed results, a new set of product design specifications (PDS) are derived using the *consumer requirement mapping* module. The PDS will govern the product development process. Because the amount of data shown on the e-commercial Website is large and the views are frequently updated, this online data mining method can effectively and timely reflect consumer preference and needs.

Figure 2: Online data mining in ona website

In order to ensure the product's sustainability, the lifecycle assessment (LCA) is conducted at the product creation stage. In this project, the ReCiPe method [7] is applied in the LCA. This method include seventeen mid-pint indicators and three end-point indicators. Figure 4 shows the LCA results of the Ona product shown in Figure 3.

Figure 3: The lamp ©Ona Product SL

Figure 4: The LCA results

The LCA results reveal that the product use phase and the product assembly (manufacture) phase produce the major negative impacts on the three end point indicators, i.e., human health, resource and ecosystems. Therefore, to reduce the product's negative impacts, necessary actions have to be taken in relation with manufacture phase, such as to use recycled materials, and the use phase, such as reduce energy consumption, etc.

A set of sustainable production methods, such as eco-design, design for recycling and reuse, modular design, consumer – supply

chain interaction, eco-point based assessment of production, social LCA, and effective integration through product supply chain are developed and utilized in the creation stage.

3.2Sustainable consumption

The following aspects are conducted regarding the sustainable consumption of the domestic lighting products:

 The eco-points method will be applied into the domestic lighting products. The eco-information of the products, including the eco-points, will be informed to customers when the product is on sale. To do this, the traceability and interoperability methods will be applied to monitor the eco-information of products. When choosing the products, customers can access the eco information via the eco-shopping app with their smart phones, to help consumers to select more environmental products.

 The eco-information will be included in the product manual and provided for consumers together with product's manufacture information.

 The eco-shopping in the online store of the lighting products will be available. The customer can view the product's eco-information, the customers receipt shows the information of both the cash payment and eco-point related to each item purchased, and the eco-points can be recorded into the consumer's eco-account.

3.3Collaborative recycling and reuse

This task enables the consumers to recycle their lighting products when they arrive at the end of life (EoL). The main work to be demonstrated during the recycling stage include:

Customers recycle their EoL lighting products on demand via the logistic or the Internet-based recycling system:

 For the logistic recycling, customer can recycle their products by sending them back to collection points or contacting the company for collection if the delivery service scheduled is applicable. The intelligent bin approach developed will be used for the consumers to dispose the EoL lights, the features of which can then be demonstrated using the EoL lights

 For the Internet based recycling, consumers can utilise a self-service recycling/collection system, which could be placed at collection points like shop or car park, to conduct recycling activities. With integrating with multiple ICT technologies (e.g. RFID, NFC and Internet), the system will allow for remote tracking of information data of different light products and quick disposal of multiple lights.

After completion of the recycling, the customer will be awarded eco-credits, to encourage them to keep on the participation. The eco-credits will be used to record and track the environmental impacts that consumers recycle and reuse their products every day.

The EoL product will be sorted at the recycling centre, then the components in working condition will be returned to the manufacturer for producing new lights. In order to make it easy to recycle, design for disassemble and modular design will be applied.

4CONCLUDING REMARKS

The circular economy approach presented in this paper consists of three new CEBMs including 'co-creation of products/services', 'Sustainable consumption' and 'Collaborative recycling/reuse', which cover the whole product lifecycle. The CEBMs are supported by an eco-point approach, information technology, traceability techniques, and other enable techniques/methods.

The circular economy approach is illustrated with domestic lighting products which proved the applicability of the CEBMs. Relevant methods and techniques, such as the online data mining consumer preferences and needs and LCA, are presented which provided insight how the methods/techniques are utilized within the approach.

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REFERENCES

[1] CIRC4Life project Website www.circ4life.eu.

[2] Von Geibler, J. et al, (2014), 'Forming the Nucleus of a Novel Ecological Accounting System: The myEcoCost Approach', Journal 'Key Engineering Materials', Volume 572, ISSN 1013-9826, pp78-83

[3] Franze, J. and Ciroth, A. (2011) 'A comparison of cut roses from Ecuador and the Netherlands', International Journal of Life Cycle Assessment, 16(4), pp. 366–379. doi: 10.1007/s11367-011-0266-x.

[4]CIRC4Life, 2018, 'A circular economy approach for lifecycles of products and services', Part B of Annex 1, Grant Agreement Number 776503, European Commission.

[5]myEcoCost project Website www.myecocost.eu.

[6]ADMEC team, 2018, A model for online mining consumer views for eco-product development, Deliverable 3.3 of the CIRC4Life project.

[7] Huijbregts, M.A.J. et al, (2016), ReCiPe2016: A harmonized life cycle impact assessment method at midpoint and endpoint level Report I: Characterization, RIVM Report 2016-0104, National Institute for Public Health.