Sustainable Design of Complex Systems, Products and Services with User Integration into Design

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Abstract This is the synthesis of the presentation of the session entitled “Sustainable design of complex systems, products and services with user integration into design” of the LCM-2017 conference. This session was interested in sustainable design which is of high interest for a large range of stakeholders. Indeed, customer’s expectations, regulations and market pressure are some drivers that moves design teams towards the consideration of sustainable dimensions over the life cycle of an industrial system. Integration of users into the product design development becomes more and more crucial, for example, through service oriented offers, involving the users as effective actors of the product design. One of the weak point associated being that users may have bad or unexpected behaviour during use phase, inducing then increased impacts and placing the use phase as the main contributor. New approaches, methods, and tools used by or for industrial stakeholders in order to face such challenges were presented and discussed. The session started with product oriented presentations and proposals, and slightly moved to the concepts of service oriented design and integration of human into the loop.

1 Product and Process

Martin Kirchner (Evonik Technology & Infrastructure), presented the PODeST (Process Optimization and Development through Sustainability) project in which sustainability becomes a parameter for process development and optimisation. Early identification of the potential opportunities and risks associated with new products and processes becomes of high importance, and Evonik’s Life Cycle Management

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E. Benetto et al. (eds.), *Designing Sustainable Technologies, Products and Policies*, https://doi.org/10.1007/978-3-319-66981-6_40

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group implements the standardized process called “PODeST”. It aims at comprehensively optimising processes from a technical, economic as well as environmental perspective while exploiting the high flexibility regarding process design in early process development phases concerning all aspects of process relevance. PODeST is not striving for the highest level of accuracy but rather robustness of results (e.g. right order of magnitude). PODeST is benefiting from synergy effects by making use of mass and energy balance data already acquired during the development and planning phase.

This presentation highlighted the link between environmental evaluation of processes and product design cycle. It also opened the discussion on the Environmental Technology Verification. One key message to succeed in the integration of sustainability in design relied on the usability of tools and methods by engineers and designers, with support of LCA expert if needed.

The presentation of Julien Garcia (Groupe PSA), described the implementation of environmental requirements in the innovation process of complex systems applied to the automotive. The automotive design is restricted by environmental regulations, mainly focusing on reducing emissions of CO₂ and other pollutants emitted by vehicle exhaust pipes. The eco-design strategy of Groupe PSA moves toward a more holistic point of view and experiences life cycle methodology to make environmentally virtuous design choices since seven years. A methodology and a tool have been developed for integrating the Evaluation of the Environmental Performance of Innovative Complex Sub-systems (EEPICS). It allows to integrate the requirements of Groupe PSA’s environment department into the innovation procedures, to extend the environment dimension to the notions “life cycle” and “multi-criteria”, and to generate an organizational learning for both innovation teams and environment/eco-design team. The eco-design framework is the central and structuring framework of environmental requirements integration, allowing the coordination of the development of a set of tools. Indeed, specific evaluation tools are customised and used, including one for evaluating the influence of innovation on vehicle recyclability, and another one for the evaluation of innovation environmental impacts. The outcomes of such analyses support the global learning. An application on the “Stop & Start” technology was carried on, leading to three significant key results involving the innovation teams from the beginning of the eco-design based innovation process facilitates the learning phases, its validation through the quality procedure is essential for the approach to be sustainable; using generic models of vehicle is sufficient to evaluate quantitatively innovative automotive sub-systems.

The discussion, based on questions from the audience focused on the involvement of suppliers and subcontractors in the approach, since innovation process, focusing at products and suppliers, manufacturing systems or end of life solutions highlighted the need of a tool like eco-design at the early stage product development.

2 From Eco-design to Circular Economy

Emma Rex, (RISE), addressed in her presentation the Sustainability of design for circularity, with integration of user and its behaviour into the design choices that can be made to shift from linear to circular business models in the Swedish furniture industry. Circular business models, promoting resource productivity and pollution prevention, are currently supported and encouraged by various policy agendas, resulting in an increased interest in design for modularity, adaptability and remanufacturing. The expected environmental benefits such circular business models offer are usually perceived as obvious, and seldom evaluated. Nevertheless, different design choices will have different impacts on the amount of material used, expected lifetime of products and possibilities for recycling. User behaviour patterns are neither commonly examined, even though user acceptance has been identified as a key enabler for the transition to a circular economy. The study combines interviews with potential users of pre-owned furniture, and customer experiences from furniture producing companies. Five pieces of furniture from three different producing companies are analysed. For each type of application, the environmental impacts of linear versus circular business models are compared through the use of LCA, and different user behaviour patterns are included as scenario analyses. User interviews pointed to the importance of functionality over novelty, and indicated a potential to increase the service content in existing business offers. LCA results further show that the environmental impacts of a shift from linear to circular business models both can decrease and increase, from -30 to +50%, depending on scenario settings, type of impact categories assessed, and assumptions made. Notably, results depend on expected user behaviour following decisions taken in business development and product design. The study demonstrated the importance of including user perspectives when designing for circularity, as well as when evaluating the effects of circular design offers. Also, whilst the calculations in this study revealed the potential direct environmental effects of a circular economy shift in existing industry, they also open up for discussions on indirect and broader sustainability effects following circular design attempts.

The question of multiple cycles arisen in the discussion, as well as how to build scenarios representative of the users' behaviour, and include them to the environmental impacts. Emma Rex explained that user behaviours have been decomposed into several typologies, allowing a scenario-based analysis. The discussion also touched on the service oriented solutions.

Venkata Krishna Kumar Upadhyayula (Umeå University) presented a concept where Life Cycle Assessment is used as a Decision Making Tool for Designing Products and Engineering Systems contributing to Circular Economy. Implementation of circular economy largely depends on three factors: (a) development of industrial infrastructure capable of enhancing the resource productivities on one hand and minimizing environmental externalities on the other, (b) understand the market dynamics & consumer behaviour to promote sustainable consumption practices, (c) building sustainable cities and communities with smaller ecological

footprints. However, in reality transformation leading from linear to circular economy faces multiple challenges. For example, (a) limitations of existing engineering practices which results in leakage of hazardous pollutants into biosphere, (b) introduction of new materials into economy with uncertain life cycle implications, or (c) effect of unsustainable consumer behaviours etc., are some factors that hamper implementation of circular economy. To overcome these, the future products and engineering systems must be designed for “circular economy” so to ensure circulation of technical nutrients within technosphere, return of biological nutrients safely to biosphere and decoupling economic growth from social and environmental externalities can be easily facilitated. The presentation detailed a structured framework for using Life Cycle Assessment as a tool to design new products or engineering systems for circular economy and supporting case studies were also shown.

The presenter opened on social issues to be addressed to ensure sustainability and was questioned about the reduction of the environmental footprint without reducing social and economic values.

3 User Integration

Birgit Brunklaus (RISE) discussed on LCA learnings from service design, therefore focusing on the influence of user behaviour in the design of sustainable systems, with the case-study of the leisure sector. The development of services in replacement of the traditional product selling model seems to be one solution for reducing resources consumption and emissions of pollutants. Similarly to products, services are designed to fulfil customers’ needs, despite they are seldom involved in the design of products and they usually are in the design process of services.

A literature review of service design and LCA studies of leisure services like the opera and theatre, tourism related services, and movies, have been performed from the supplier and consumer perspectives respectively, in order to (a) identify similarities and differences between service design and Life cycle based approaches, and (b) to derive some propositions to further develop the Life Cycle based approaches (LCA, S-LCA, LCC) in order to integrate user into the design process.

The discussion referred to the integration of users into the LCA methodology, especially on the translation of users’ behaviours characteristics into quantified items.

Finally, Gregor Waltersdorfer (University of Luxembourg) discussed in his presentation a meaning-based perspective of potential users on the implications of products and services for sustainability. He proposed a design method called “MeaningMap” and a sequence for meaning-based reasoning in design, which can support designers in considering meanings by potential users. He illustrated the integration of the user perspective into design of service systems, involving sharing bikes or washing machines. Integrating the perspective of potential users into design allow to take into account their limits in the perception of the economic,

social and environmental impacts induced by products and services, due to their different personal values. More precisely, capturing users' meanings enables designers to analyse different aspects: (a) what is perceived by individual potential users, (b) how do potential users conceptualize their evaluations, and (c) which evaluations show low or high levels of agreement. The presenter argued that this knowledge can inform designers on which aspects of products and services they need to prioritise in order to improve its perceived implications for sustainability, and which aspects they need to further clarify in order to improve their communicative potential. Considering the meaning-based perspective of potential users can complement more traditional product-centred approaches such as LCA in early phases of the design process.

This proposal questions the robustness of the users feedback quantification, and how to turn these information into designers choices and contribute to product evolution.

4 Conclusion

The topics addressed in this session were also completed with nearly twenty posters, addressing and illustrating the will to integrate environmental considerations early in the product design phase fitting the circular economy paradigm.

Considering user centred design within a life cycle thinking approach in order to ensure the development of sustainable systems open numerous questions and requires new conceptual and methodological developments, consensus based and scientifically consistent in order to assess quantitatively users' behaviours. User oriented sustainable design intuitively leads to develop service-based models instead of product-based solutions. Then sustainable design methods and tools should be integrated with the Product Service Systems design method, which remains challenging.

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