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Procedia CIRP 26 (2015) 52 – 57

www.elsevier.com/locate/procedia

12th Global Conference on Sustainable Manufacturing

Enhancing Technological Innovation with the Implementation of a Sustainable Manufacturing Community

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Abstract

The global challenge of sustainable value creation can be coped with by raising human awareness about it all around the world. Increasing process effectiveness and efficiency in view of shrinking natural resources, increasing competitiveness and profitability by selling functionality and service instead of physical products give strategic references for the development of the so called sustainable manufacturing community (SMC). Ubiquitous application of modern information and communication technology (ICT) for shaping responsible global citizenship by knowledge transfer can expand learning and teaching productivity by magnitudes, can strengthen the leverage of help for self-help, can enable initiative and creativity for entrepreneurial approaches in the global village without losing local differentiation. Elements of an architecture for an SMC and the concrete case of smart wheel urban mobility with an outlook for an exemplary German Vietnamese collaboration perspective are considered.

Peer-review under responsibility of Assembly Technology and Factory Management/Technische Universität Berlin.

Keywords: Open Knowledge, Sustainability, Sustainable Manufacturing Community

1. Introduction

A worldwide increase in wealth based on current technologies' resource consumption rate would be critical for human life on earth [1]. Open knowledge allows a broad public to benefit from research focusing on solving this dilemma. The community-based approach, described in this paper, is going beyond the one-way approach of traditional knowledge spreading by adding the element of crowdsourcing, where a broad public can contribute with specific knowledge and innovative ideas. The community introduced in this paper and the platform on which it shall be implemented on will focus on sustainable manufacturing and will therefore be called Sustainable Manufacturing Community (SMC), having a core competency in manufacturing but at the same time the broad scope inherent to the topic of sustainability.

1.1. Sustainability challenge

The Brundlandt commission defined sustainability as meeting “the needs of the present without compromising the ability of future generations to meet their own needs” [2]. But already today the over 7 billion people living on earth are consuming 1.5 times more resources than earth can provide in terms of its biocapacity. It is estimated by the World Wide Fund For Nature that by following this irresponsible path of unharmonized growth and resource consumption humanity will in 2050 overcharge earth's biocapacity by a factor of around three [3].

The sustainability challenge truly needs an interdisciplinary approach to be tackled. Due to the fact that manufacturing has already many intersections by itself it can therefore be a good starting point for the SMC addressing some parts of significance of this challenge.

Peer-review under responsibility of Assembly Technology and Factory Management/Technische Universität Berlin.
doi:10.1016/j.procir.2014.07.177

1.2. Cycling as an example for sustainable mobility

Mobility is one of the major areas of human living. At the same time mobility is responsible for a large share of the human ecological footprint on earth. In Europe and North America the transportation sector is responsible for 24% of the total greenhouse gas emissions, contribution to climate change and at the same time harming health with air pollution. In a 2014 report the World Health Organization states that significantly increasing the share of bicycles in the modal split of intra city mobility could create a significant amount of green jobs in the bicycle industry and related services as well as contribute to human health and reducing the environmental impact of transportation [4]. Taking this into account supporting smart urban wheel mobility in terms of bicycle transportation is an exemplary case for the SMC targeting in itself all three sustainability dimensions.

2. Open Knowledge

Plato's definition on knowledge as true belief stabilised in a specific way, by explanatory reasoning, seems to withstand the test of time relatively well. True belief refers to a justified cognitive content which is accepted as true. The stability refers to that this true belief will not easily change with time. An important aspect for this definition is that knowledge requires explanation [5]. More common understanding is that it is facts, information and skills contained about a particular subject, or alternatively theoretical and practical understanding of a specific subject [6].

The term openness of a specific object such as knowledge, referring to that access to it, cannot be restricted. Therefore, open knowledge must be accessible, redistributable and reusable without any legal, social or technological restrictions [7].

2.1. Open innovation and crowdsourcing

Traditionally, organisations work in such a way that an employee is given a task to fulfil. As the fulfilled tasks grown numbers so does the organisational knowledge of a specific subject. The amount of knowledge that the organisation gains, is then limited by the capabilities of its employees. Open innovation occurs when organisations open boundaries to communities of people, thus enabling more people to contribute than are within the organisation [8]. Within a competitive market framework, open innovation aims to obtain different, improved or new ideas for organisations, directly from its current or potential consumers. This traditional view of open innovation is to gain competitive advantage through quicker response time, lower costs and a greater market acceptance [9].

Leimeister et al. suggest that open innovation would be best suited carried out through crowdsourcing [10], an act where the tasks are placed in a call. There are three core practices being used to target people; lead-user methods, internet toolkits and idea/design competitions [11]:

1. Lead-user method: Highly skilled knowledge bearers receive an exclusive invitation to participate to solve a certain task. The lead-users either get invitations with directions on how the tasks should be fulfilled or little or no directions in the invitation.
2. Internet toolkit: Means to obtain skilful individuals through internet portals. These online toolkits can be either exclusive to an invitation, exclusive to a certain profile or participative.
3. Idea/design competitions: Competitions are held for the best solution to a specific problem and the community can contribute with solutions. Some idea competitions make the community itself do a pre-screening of ideas and then select the best idea according to the organisation's preference.

People partake in such crowdsourcing activities due to intrinsic, extrinsic or multiple incentives. These incentives cover monetary reward, recognition, philanthropic behaviour and altruistic behaviour. Zhao and Zhu discuss that the incentive mechanisms of organisations involved in crowdsourcing have to be designed pertinently and appropriately, securing that efforts and quantities of contributions remain entering [12].

2.2. Community

Communities are generally understood as social units that share common values and norms. The sizes of communities vary and they are often distinct segments of society such as the scientific community. Communities are excellent resources of knowledge but have a participation inequality that has to be considered. The participation inequity specifies that in a participating community, only a small amount of the community members have a motivated attitude and contribute actively. A Slightly larger amount of the community contributes occasionally but most community members only consume the information that the other two groups of community members generate [13]

2.3. Sustainable manufacturing commons

The term commons usually refers to a commonly owned property (e.g. land, rivers and waterways) or commonly owned creations (e.g. design, songs and licences). Members of society are usually allowed to pass through physical commons and to utilise renewable resources as long as profit is not made from them. However, there are examples of unregulated environmental commons where profit can be made by the utilisation of the resources in them, such as from small-scale fishing and small-scale vegetation harvesting.

Creative commons (CC) is a licensing model that grants a person or an organisation the right to utilise a certain intellectual property, usually with some conditions [14]. Product documentation is based on a copyright protection within the CC licences. This means that neither the product idea nor the invention is copyright protected.

Sustainable manufacturing commons are in this paper defined as bundles of knowledge, concepts, technologies, practices, business opportunities, standards, procedures and regulatory approaches that reduce environmental impact, promote adaptation of technologies that use renewable materials and energy, increase wellbeing of people but simultaneously enhance efficiency, effectiveness and production of the proprietary capital and labour that use it.

3. Sustainable Manufacturing Community

3.1. The aim of the community

The SMC aims for bridging the gap between saturated and hungry markets by enabling the access to product-based and process-based knowledge for everyone. The resource consumption of early industrialized countries must decrease, while keeping the same quality of life. Also the emerging countries need to increase their quality of life, without increasing the resource consumption. The SMC is trying to contribute to meet the challenge. The SMC focuses on the three dimensions of sustainability: economic, environmental and social. It gives individuals the chance to participate in a global network of experts as well as engaged individuals to reach the overall goal of sustainability.

The SMC is a web-based non-profit platform set out to collect knowledge that is advantageous for sustainable manufacturing. Community members can formulate their knowledge on the platform as long as they fulfil the structural requirements of a value creation module (VCM). A VCM can be used to describe any kind of value creation. The VCM contains five value creation factors (VCF), which are process (how?), product (what?), equipment (by what?), organization (when? where?) and human (who?) [15]. The VCM are arranged by product's lifecycle phases e.g. product design, profess design, manufacturing, assembly, usage and end of life. Fig. 1 shows how contributions are made by the community, specified according a VCM. Horizontal integration of the VCM means that direct cooperation and competition between different contributions is built into the system. Requests can be made from members of the community (description for creating value). The VCM combinations are evaluated according to a multi criteria analysis that shows how different combinations are ranked differently according to the three dimensions of sustainability: environment, economic and social.

The outcome of this VCM-lifecycle phase arrangement is that contributions can be made to the platform independently of the pre-existing work, i.e. contribution on how to recycle a specific product can be made without the product's design being available. The platform aims for enabling individuals to develop, manufacture, maintain and repair as well as recycle their own sustainable products. This will lead to a higher independency in satisfying customer's needs. Full lifecycle phase consideration for a specific product is achieved when adequate contributions have been made on all lifecycle phases. A share-reuse-and-improve approach is applicable for each contribution and the SMC's structure opens the possibility to use one VCM for more product lifecycles by similarity assessment.

3.2. Technical structure

The SMC is a web-based platform which enables networking of interested individuals. It has a project-oriented structure, where each projects contains product- or process-based results. The projects are sorted by the life cycle of the physical product, which they belong to. In addition, they can be allocated towards a module of the physical product. This simplifies the teamwork by enabling the user to also just deliver partial solutions. All project contents are shared in the community. One main focus of the technical structure is on the user-friendly design of the project illustrations. This is obligatory, so the projects on the platform can be understood and manufactured by other users. Also a user-friendly design encourages many users to participate in the specific project. Furthermore a strong link of the SMC to social media will increase the growth of the platform.

Based on the available skills a focus on his or her own interest can be realized. Furthermore a characteristic for each project must be presented. Within this characteristic a project description, a duration for the projects as well as needed capacities can be described. Project management tools are offered for each project. To meet the demand of an open community the documents for every project are accessible for every user. Each project can be followed, joined or shared by social media.

Profiles are offered for all participants. The technical as well as social background of each user is described here. It can give a first quick overview for visitors, when they are searching for an expert on a specific field. Furthermore it gives the user the chance to add information about the user, which is not covered by other modules of the profile. Also the skills and access to machines and tools are shown. The information about the user can be used for forming a new team based on project description. Experts on the compulsory

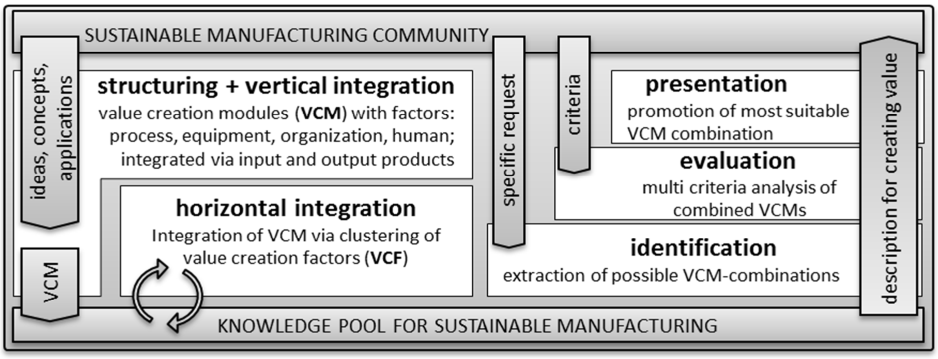

Fig. 1. Framework of the Sustainable Manufacturing Platform [16]

subjects can be found. Thus the team leader can send invitations for his project based on the skills of each user. The shown location of each user can strengthen local teams, working on a physical product. Also services can be offered more easily when they are assigned to a location. In addition, all projects of a user can be seen within his/her profile classified by the status of each user on the project. This can be follower, member or team leader.

4. Example

4.1. Bicycle

For demonstration purposes smart urban wheel mobility, exemplified by the bicycle, was selected for the SMC. Any product that follows the prerequisites of the SMC structure can be added to it. The bicycle was exemplarily chosen, because it enables, as described in the introduction, sustainable mobility. It is also not a too complex product, fulfilling the needs of a large target audience for cheap and easy transportation of passengers and cargo. The low complexity compared to for example a car, allows the individual to modify, repair and maintain their own bicycles. In addition, the development, manufacturing and recycling is also possible for individuals. Another advantage of the bicycle is that it can be adapted to the local requirements. So the design can be chosen according to the material available in that specific area. Furthermore, we can add the activities of the CRC 1026 as a first content and therefore an argument for visiting and participating in the SMC.

4.2. Stakeholders

The SMC has various stakeholders. The stakeholders can be grouped in individuals, companies and research institutions. They contain e.g. followers, individuals who are interested in topics of repair and maintenance, developers, self-help workshops, manufacturers, individuals, who are interested in sustainability and student groups.

SMC has various stakeholders. Followers, individuals who are interested in topics of repair and maintenance, developers, self-help workshops, manufacturers, individuals, who are interested in sustainability, student groups as well as researchers and companies.

The individuals who are interested in the field of repair and maintenance are able to view instructions, pictures and videos on various technical problems. Developers can use the platform as a platform to advertise their designs, but also to communicate with other designers as well as with users from other phases of the product lifecycle. Manufacturers can offer processes in a global network, share their experience and have a knowledge transfer with other phases. The platform enables self-help workshops to share their knowledge and to promote their shop within repair videos. This can help acquire customers. The shops can also use the platform to promote their tools, gadgets and machines needed for more complex processes. Various student groups can work globally on the platform. Researchers can use the platform as a showcase for their results and to collaborate with others.

4.3. Knowledge base

To kick-start the SMC the researchers of the Collaborative Research Center (CRC) 1026 "Sustainable Manufacturing – shaping global value creation" can be used to add first content and users, interested in both gaining knowledge from and adding knowledge to the platform. Within the CRC the so called demonstrator is supposed to show the research results in an application case and is therefore an especially suitable source for content for the SMC. The demonstrator uses not only the bicycle, as part of the mobility area of human living, but also the wind turbine as an example for the area energy and the gas turbine as a product of the intersection between both areas, contributing to both mobility and energy. These other applications can later be implemented in the SMC.

The demonstrator consists of four layers from a methodical point of view: physical implementation, technology integration, value creation networks and the SMC itself. All CRC subprojects contribute to these layers. On the layer of physical implementation tangible objects are shown in the so called laboratory of sustainable manufacturing. The technology integration integrates products and processes into sustainable systems, while the value creation network's layer focusses on the analysis of coopetition driven interrelations of different value creation modules and networks. At the same time, next to the described methodical point of view, the CRC contributions can be arranged around the lifecycle of the bicycle, from product development to reprocessing and from there back into the lifecycle. A simplified example for this approach is giving in Fig. 2.

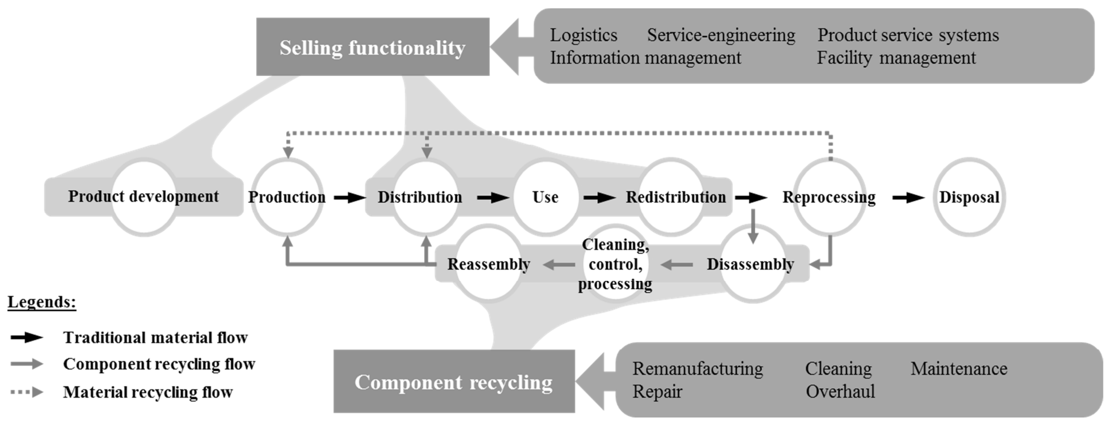

Fig. 2. Life cycle approach of the CRC [17]

4.4. Exemplary content

In the following a few selected examples of the first content for the SMC are described. This exemplary content consists of scenarios, a technology pool, life cycle assessments, assembly and repair workplaces and a value creation module database, all in context of smart urban wheel mobility.

In the first phase of the product life cycle, specifically at the beginning of the product development, where very fundamental design decisions are made, it is especially important to keep possible future developments in mind. This is possible e.g. via the use of scenarios. A variety of methods concerned with the development of different kinds of scenarios is presented in current literature. For the SMC surrounding field and technology scenarios will be described. Surrounding field scenarios are scenarios derived by the analysis of external factors, which are set to be not alterable [18]. Sustainable technology scenarios on the other hand describe the possible combination of different technologies to achieve sustainable solutions.

Content for the SMC are therefore both the exemplary generated surrounding field scenarios for the development of bicycle mobility in Berlin as well as the according technology scenarios for different bicycle designs and operation and repair systems.

In addition the technology pool, which is used for the creation of technology scenarios and in which technologies are described by their underlying functions and split up into systems and system elements with their in- and outputs regarding material, signal and energy [19] can be made available on the SMC to grant access to this database to the users. Users of the SMC can then add new technologies to the pool and/or extract information from the database.

In a next step the tools used to create those scenarios, in addition to the technology pool, could be made more user friendly and also added to the SMC. Then the users could create their own scenarios and work on common scenario projects.

Another project which can be added to the SMC is the collection of Life-Cycle-Analysis (LCA) results made for different bicycles and their components, e.g. for bicycle made out of bamboo and aluminum. The LCA is a method used to evaluate the environmental burden of a product or service. Additional social or economic aspects can be added to give a more complete picture [20]. Corresponding to the LCA results a manufacturing manual for bamboo bicycle frames is presented. In Fig. 4 the CAD model and the manufactured bamboo bicycle frame are exemplary shown.

Fig. 4. Bamboo frame CAD model (left) and manufactured frame (right)

To create modular bicycles, being able to be adjusted for different use situations (e.g. commuting bicycle, cargo bike) a bicycle could be build out of standardized aluminum profiles. During the use phase, especially in a bicycle sharing concept, the bicycles status, e.g. regarding location, tire pressure etc., could be monitored via a sensor system connected to a smartphone app. An example of such a bicycle concepts by CRC researchers is illustrated in fig. 5.

Fig. 5. Modular "lego" bicycle build out of standardized aluminium profiles (left) and sensor equipped bicycle (right)

A project focusing on the assembly, use and end of life phase, in specific the repair and overhaul of bicycles with instruction material and the corresponding tools and workplaces can be used as first content as well. Such instruction material could be rather simple in the form of explanation material for a tool box with selected tools for easy maintenance tasks, as shown in Fig. 6, or as an advanced learnstrument workplace.

Fig. 6. Tool box with selected tools and instruction material for easy repair maintenance in self-help repair shops [21]

Not only learning material is presented but also corresponding workplaces, which are enhanced with learnstrument aspects. A learnstrument is an artefact which automatically demonstrates its functionality to the user [22]. Integrated into a workplace this can enable a worker to both fulfil the required repair and overhaul task and at the same time gain the required knowledge with the integrated web-based multimedia instruction system. How such a system could look like, in combination with a mounted 3D tracking system is illustrated in Fig. 7.

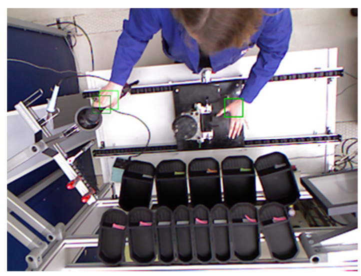

Fig. 7. Learnstrument enabled assembly and repair workplace

The instruction material itself but also additional information to build such learnstrument workplaces can be shared on the SMC, commented by other users and further developed in joint projects.

In addition to the described technology pool for bicycle design another database for value creation modules could be made available via the SMC. As described in chapter 3 the whole SMC follows the principle of VCMs. The VCM database can be used to configure value creation chains and networks in the context of bicycles e.g. by enabling the reutilization of materials or components.

The SMC will also be used for education projects between different partners around the world. Exemplarily, this is done with the cooperation for building up a sustainable urban wheel mobility laboratory at the Vietnamese German University in Ho Chi Minh City, Vietnam, using workplaces and tools of the sustainable manufacturing laboratory of the CRC 1026 and adapting them to the potentials of an emerging economy.

5. Summary and Outlook

The SMC approach goes for ubiquitous applications of modern information and communication technology (ICT) for shaping responsible global citizenship by knowledge transfer. It can expand learning and teaching productivity by magnitudes, can strengthen the leverage of help for self-help and can enable initiative and creativity for entrepreneurial innovative holistic approaches in the global village without losing local cultural differentiation. In this paper a web-based platform for open knowledge as an essential element of the SMC is introduced. It is exemplarily applied on smart urban mobility systems, laying emphasis on bicycle transportation. The platform includes information about prototypes of bicycle components, equipment for manufacturing, maintenance and repair and also different scenarios for urban mobility development. It provides free access for stakeholders to encourage individuals for participating in exchange of ideas and joint implementation of innovative solutions.

First implementations in joint project courses between universities of emerging and early industrialized countries encourage for further joint development on crowdsourcing for innovative sustainable processes and products. International university cooperation can help in spreading and expanding the knowledge base continuously. Sooner or later this will help winning users outside the initial CRC 1026 and university network to achieve the intended global impact of the SMC.

Acknowledgements

We extend our sincere thanks to all who contributed to preparing this paper. Especially, we thank the German Research Foundation for the funding of the Collaborative Research Centre 1026 "Sustainable Manufacturing – shaping global value creation" (CRC 1026/1 2012). The responsibility for the content of this publication lies with the authors.

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