Digital Tools to Support Knowledge Sharing and Cooperation in High-Investment Product-Services

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Abstract. The manufacturing industry needs to adapt their product-services to meet customer requirements in today's rapidly changing markets. This paper presents how technologies can support knowledge sharing and collaboration during product-service processes. This work was part of the European Union Use-it-Wisely project and summaries demonstration results from the project. Six cluster cases from different industry sectors (energy, machinery, space, office workplace, vehicles, and shipbuilding) were developing their tools and processes during the project. Based on the demonstration evaluations, it seems that the Use-it-Wisely project has enabled companies to improve their product-services by using interactive collaborative environments and new business models. Participants that took part in the demonstrations felt that the new approach makes users' work easier, provides competitive advantage, facilitates knowledge sharing and decision making, extends the efficient lifecycle of existing machinery and supports sustainable development.

Keywords: Knowledge sharing · Cooperation · Manufacturing · Product-service system

1 Introduction

In the past, customers invested in high-cost, long-service-life products. Today, they demand complex product-services capable of adapting to new customer goals and rapidly changing markets. Therefore, manufacturing companies are required to advance from using ad-hoc improvements to systematic adaptation. This can be achieved by developing decision-making processes and knowledge-sharing systems [1, 2].

Nonaka [3] states that new knowledge can be created through interaction between individuals. The use of technologies that provide the individuals the same understanding

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of the current issue support knowledge creation and sharing. Computer-supported cooperative work (CSCW) is an approach that addresses use of computer systems in collaborative activities [4]. Collaborative virtual environments (CVE) can be used to support collaborative work between geographically separated workers and between collocated workers [5]. The use of virtual reality (VR) technologies to support knowledge sharing during design has been studied, among others, in [6–8]. Augmented reality (AR) technologies have been used to support knowledge sharing, for example in [9–11]. Participatory design [12, 13] is an approach that supports knowledge sharing, especially during a design process. Review of collaborative working environments and detailed classifications related to collaboration factors have been made in [14, 15].

This paper presents how technologies can support knowledge sharing and collaboration during product-service processes. This work was part of the European Union (EU) Use-it-Wisely (UiW) project [16] and summaries demonstration results of the six cluster cases from different industry sectors (energy, machinery, space, vehicles, shipbuilding, and office workplace). The clusters are presented in Sect. 2 with data gathering methods. Section 3 shows results from the demonstration evaluations. Section 4 discusses results, and draws conclusions.

1.1 The Use-it-Wisely Approach

The Use-it-Wisely research project focused on continuous innovative upgrade of high-investment product-services. The goal of the project was to develop an approach to support systematic adaptation in order to sustain or improve product and service value during the life cycle. The approach builds on the main principles of small upgrade increments and extensive actor involvement in all phases of the process (Table 1).

Table 1. Key assumptions of the Use-it-Wisely approach.

Assumption	Rationale
Small upgrade increments	• Reduced financial risk due to smaller investment • Reduced technical risk due to smaller changes • Shorter disruptions • Shorter implementation time leading to faster response times and enhanced upgrade agility • Reduced environmental impact due to extended use of major system parts
Actor collaboration	• Important system knowledge exists outside of the corporate borders, on multiple levels • System defect, deficiencies and changing user needs are communicated directly and proactively across the network • Sustained actor involvement leads to deeper engagement and firm actor networks, building trust and loyalty between partners

Based on the idea of a continuous incremental upgrade innovation process involving actors across the value chain, a generic framework was defined. The framework covers three main areas: adaptation, collaboration and engineering, and emphasizes model-based approaches and virtual collaboration tools for improved communication and knowledge sharing. Complementary sets of modeling solutions are suggested in each area (Fig. 1). The selected tools and methods were adopted and implemented in each cluster pilot case according to their specific needs and priorities.

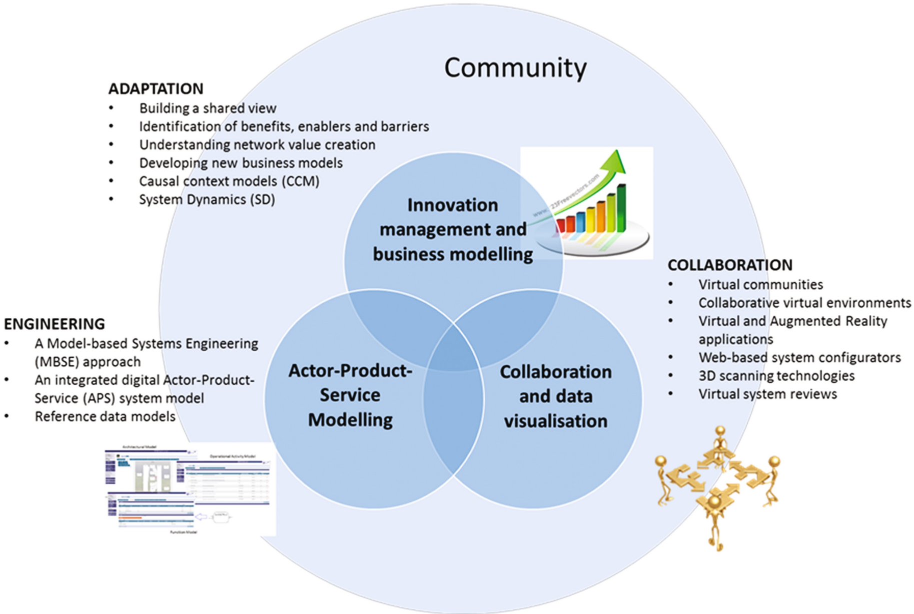

Fig. 1. The Use-it-Wisely framework [17].

2 Descriptions of the Use-it-Wisely Clusters

The data gathering procedure and methods are described in this chapter. In addition, all six clusters (CLs) are presented here. In this paper, the CL means a group of partners working together. All CL groups include at least one industrial partner and one research partner.

2.1 Participants and Data Collection Methods

The six clusters demonstrated their developments on nine occasions. In total, 45 participants (male = 35, female = 10) took part in the demonstrations. All clusters used the same questionnaire to collect information about experiences related to system demonstrations and how its future potential is seen. The clusters were able to add their own specific questions and collect other data as well. The questionnaire included questions regarding the user experience in a four-point Likert scale (4 = strongly agree and 1 = strongly disagree). The same Likert scale was used for the value/benefit statements (e.g. “This system could provide value to our company”). In both cases, participants were able to elaborate their selection in the Likert scale if they chose to do so. Furthermore, open questions were asked about system improvements, information presentation to support decision making and communication, and exploitability of the systems in other domains.

2.2 Cluster 1: Energy

The main goal of the CL1 demonstration was to show the different possibilities and technologies for the development of an innovative collaborative prototype system that will work as a decision support tool for lifecycle management of power plant steam turbines [18]. The aim was to provide: (1) interactive 3D models of the turbines, (2) visualization of augmented information over the 3D models in order to understand its structure and issues, (3) information linked to the 3D model, regarding the inspection results and (4) a discussion management tool to share information and comments related to an inspection result. Two different demonstrations were arranged: first, a demo session was focused on demonstrating the applicability of the tool for potential use in other areas within the company, and the second session was to evaluate the usability and the acceptance of the tool by their current users (Fig. 2).

Fig. 2. Cluster 1 demonstrations: inspection result management tool with information linked to the 3D model, and the demonstration workshop.

2.3 Cluster 2: Machinery

The CL2 approach illustrated a new business model, new processes, procedures, and utilization of technical tools in the mobile rock crushing industry. The purpose of the CL2 demonstration was to demonstrate a new upgrade delivery process based on 3D scanning and augmented/virtual reality (AR/VR) technologies. Industry representatives were able to evaluate AR/VR technologies and the potential value of project results. Two demonstrations were provided in CL2: supporting design (and/or sales) by using an AR application, and scanning initial data by using a scanning application (Fig. 3).

Fig. 3. Cluster 2 demonstrations: a new upgrade model seen on top of a real machine by using the AR-application, and a scanned point cloud of the current machine.

2.4 Cluster 3: Space

The goal of the CL3 was to develop tools and processes based on continuous improvement and customization of a system through model-based engineering with a focus on collaboration and direct involvement of a customer (Fig. 4). The scope of this approach is making the system adaptable to various space missions. The components of the architecture are [19]:

– System Models, Simulation Models and Services Process Manager support the interdisciplinary work between people and also between tools through dedicated adapters. It also includes the definition of engineering or project services to be provided to a customer.
– System Simulation and Visualization supports the visualization of the product, of the activities and of the simulation results.
– Simulation Execution provides system level simulation, integrating discipline-level simulations, or provides early simulation at system level.
– Extranet Interface is the gatekeeper assuring a safe flow of data.

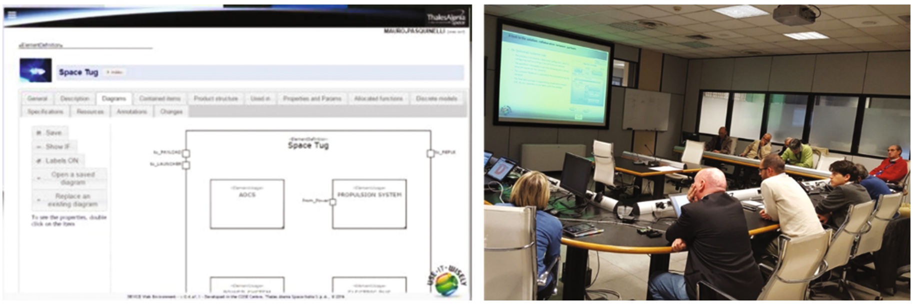

Fig. 4. Cluster 3 demonstrations: the Services Process Manager [19], and the demonstration workshop.

2.5 Cluster 4: Vehicles

The tools developed in CL4 aimed to facilitate collaboration amongst actors around the continuous improvement and operation on the shop floor of the factory [20, 21]. In addition, the approach provided a way for manufacturing engineers at Volvo (truck manufacturing company) to benchmark and discuss processes across production sites throughout the global operations network of Volvo. The demonstrator consisted of a virtual model of the Volvo factory. The virtual model was a hybrid using both measurements captured using 3D imaging technology and CAD data. The demonstrator was accessed using a virtual reality technology kit from HTC (Fig. 5).

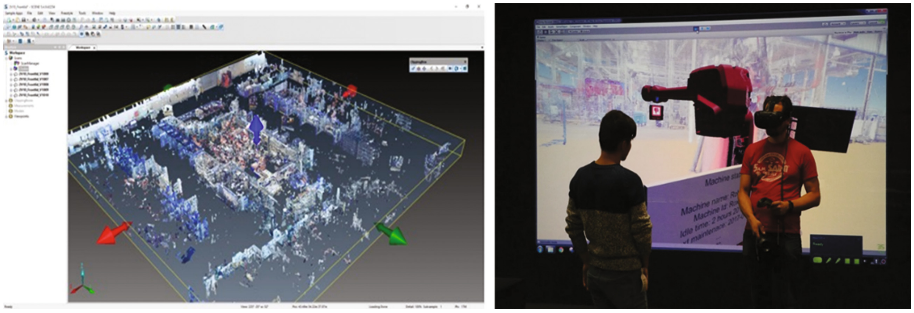

Fig. 5. Cluster 4 demonstrations: example of scanned factory, and user experiencing the scanned factory by using virtual reality technologies.

2.6 Cluster 5: Shipbuilding

The CL5 approach was to develop a user-friendly, dynamic, information-rich technical metafile for the vessel that incorporates all aspects of the vessel including; initial customer specifications, required regulations, shipyard designs, final sea-trial data and post-delivery surveys and inspections in the context of small passenger boat development and upgrade. The aim of the CL5 demonstrations was to show the workflow, the tools and the concept developed within the UiW project to stakeholders from all relevant actors: shipyards, class associations, end users, naval academia (Fig. 6). Furthermore, the demonstrations aimed at capturing the potential for added value from the stakeholders. The tools include (1) a system dynamics business model focusing on the design and ideation phase, (2) a vessel configurator online tool, (3) a design support plugin, and finally (4) a digital service to accompany the vessel throughout its lifecycle.

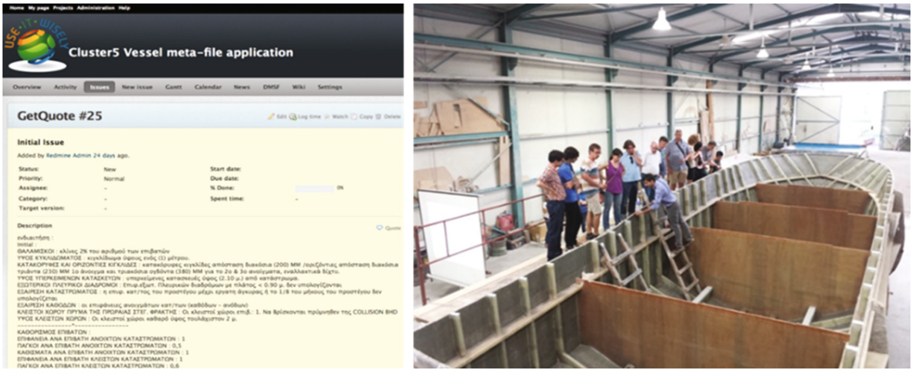

Fig. 6. Cluster 5 demonstrations: the vessel meta-file application and the demonstration workshop at shipyard facilities.

2.7 Cluster 6: Office Workplace

The approach of CL6 was to achieve flexibility, adaptability and modularity in office furniture product designs, as well as to develop a new business model through new product-service strategies based on the circular economy model. The aim of the CL6 demonstration was to show the Gispen Circular Economy Framework to designers, engineers and product managers at Gispen and systematically evaluate its usability and added value. The demonstration was split into two separate sessions: to evaluate usability of the Circular Design Framework checklist, and to evaluate usability and usefulness of the Circular Life Cycle Analysis (C-LCA) methodology (Fig. 7).

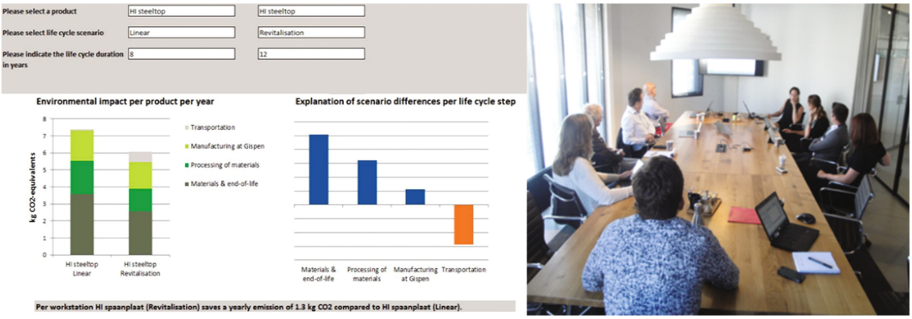

Fig. 7. Cluster 6 demonstrations: the Circular Life Cycle analysis tool, and the demonstration workshop.

3 Results

In this chapter, results from the different cluster demonstrations are illustrated as merged to show an overall view of the UiW approach.

3.1 The Overall Experience

The overall experience of the UiW's cluster systems was positive (Fig. 8). Participants agreed that the use of the systems was easy (e.g., "easy interface" (CL1)) and "very intuitive" (CL1)). However, some commented that further development would be needed. The participants were able to see immediate benefits of the use of the systems. There was also agreement on the system's good level of usefulness in relation to participants' work. In addition, the participants would recommend the systems to other people.

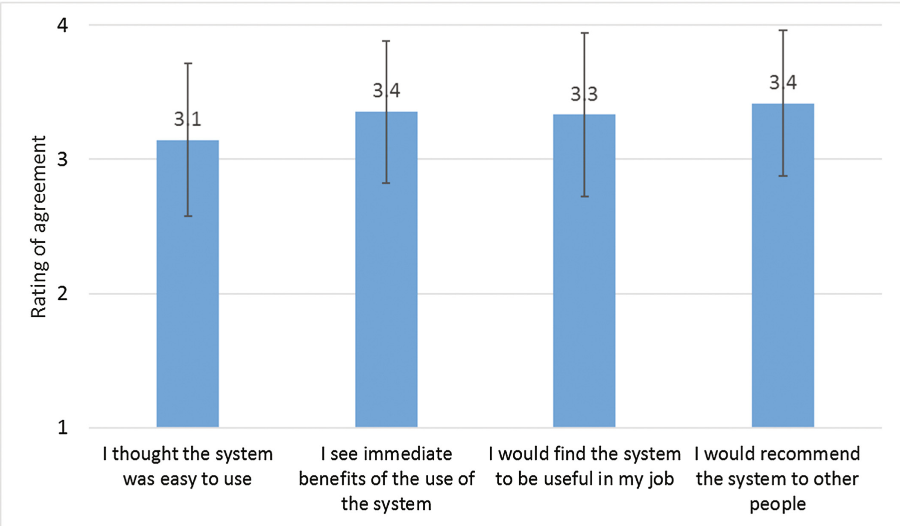

Fig. 8. The overall average user experience of the clusters. Error bars represent a standard deviation between participants. Rating of agreement scale is between 4 = strongly agree and 1 = strongly disagree.

Some of the systems were seen as being immediately beneficial, such as making it easier to understand complex components (CL1) or to support discussions (CL6). However, some systems were seen to need further development (e.g., more automation (CL3), and better resolution of the point cloud (CL4)).

The participants agreed that the systems were useful in their job (e.g., "it provides a possibility to cooperate with other people" (CL1)). The participants mentioned also that it could be useful in training. Some people had doubts about its usefulness (e.g., "indirectly yes" (CL6)). The answers regarding recommendation of the system to others were all positive (e.g. "it does not require expensive tools or knowledge" (CL2); "I think this is an advantage for the journey towards virtual manufacturing" (CL4), and "yes, since I could see the benefits" (CL4)).

System improvements comments were mainly related to following topics: mobile interface, real-time, link to external data, integration into other software, stability, automation, guidance, clear definitions and image quality.

82% of the participants saw that presenting information as shown in the systems would help them make better decisions (e.g., "Yes, we assume most of the time things are 'better', but this gives you the backbone to support it (CL6)"). Four of the participants were not sure if the systems could help in decision making (e.g. "It's not necessary for plant personnel because they already know the turbine very well. However, it could be really useful for non-expert people." (CL1)). Three participants did not see how the system could support them (e.g. "Frankly speaking, no, taking into account my current work." (CL3)).

Most of the participants (84%) thought that the system could improve communication within their organization (e.g. "It is a good demonstration of improvement in decision support using modern tools" (CL5)).

The participants suggested other domains where the systems could be utilized, such as aeronautical and petrochemical sectors, training, inspection, operation support, maintenance, any other industrial complex tool development, real estate, buildings, crime scenes, archaeology, gaming, movies, manufacturing, tender processes, transportation, and many fields where materials are used/produced/wasted.

3.2 Value and Benefits

The participants were asked to estimate the potential value of the UiW systems to users, companies, customers, networks and society (Fig. 9). In general, the systems seemed to be valuable at all levels. However, it might have been easier for the participants to distinguish value and benefits at the user and company levels than at higher levels (e.g., society).

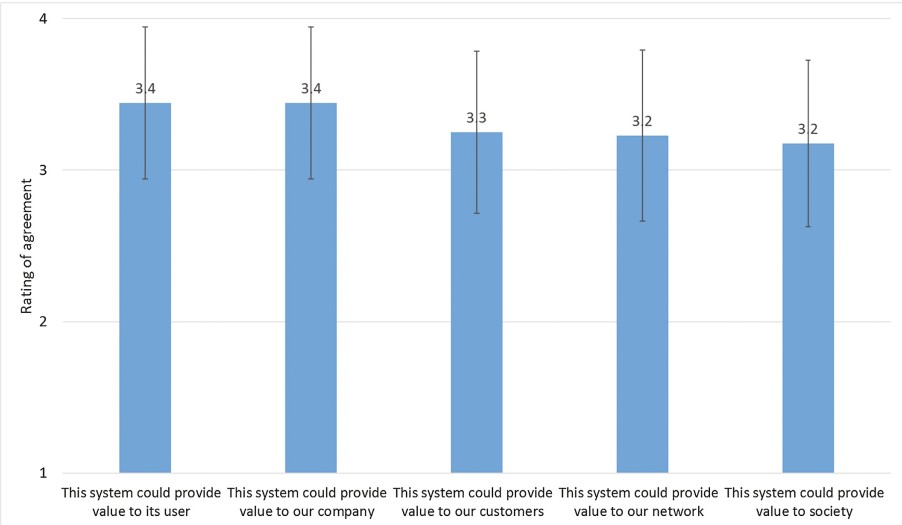

Fig. 9. Participants' average estimations of the potential value the developed systems can provide. Error bars represent standard deviation between participants. Rating of agreement scale is between 4 = strongly agree and 1 = strongly disagree.

According to the participants, the main benefits originated from the perceived utility of the system in practical work. The visual presentation also provided better understanding and could be used to support discussions. The systems could improve the availability of relevant knowledge and therefore support decision-making. The systems make work steps (e.g., data gathering, calculations, estimations) fast and efficient. These systems can change work processes to be more systematic and structured. They improve focus, data is more accurate and prevents skipping important steps/things, potentially decreasing the number of mistakes. Some of these systems can provide the possibility of trial and error testing.

Participants saw that company-level benefits could be such things as a competitive advantage and company image improvements (e.g. "the use of the system shows that a company is serious about sustainable product development" (CL6)). The use of systems can raise trust in customers towards manufacturing companies. The systems can increase efficiency of processes and make their management easier. The systems could improve awareness inside companies because all people would have access to the same information. The systems can support sharing data between roles in a consistent way. Cost reduction was mentioned also (e.g. "especially with new inspections and a new team" (CL1)). Benefits can be derived also when using the systems for training. Especially, CL 6's system could make circular principles more practical and understandable for different stakeholders.

The participants said that customers could benefit from the use of the systems by gaining a better understanding of current issues. The systems can provide faster and more accurate cost estimations and quotations for customers. The customers could use some of the systems by themselves. The systems provide companies the possibility to share common practices and applicable solutions with their customers. Engineering and technical services may become quicker throughout the product lifecycle.

The participants commented that the main benefits for the networks were due to ease of sharing information and knowledge. The use of systems can enhance cooperation in the project team and between different companies. Some of the systems provide users the possibility to be in the same environment even though they are physically located in different places.

The participants had only a few comments on potential societal impact. The systems could decrease travelling and material use (e.g. "do not need real prototypes always" (CL2)). Safer operations and fewer accidents/errors. Old machines can be upgraded to be more efficient. The systems can provide data to assess environmental footprint and help circular development.

4 Discussion and Conclusions

The Use-it-Wisely project has developed processes and tools for companies to be able to adapt their product-services to new customer requirements and rapidly changing markets. These processes and tools provide a global, visual and interactive platform for cooperation, and make companies' processes more systematic, efficient and agile. In addition, approaches apply circular economy principles and therefore support sustainable development. Project results are exploitable also in other industry domains.

Demonstrations illustrated that these technology systems could be used in many ways to support knowledge sharing and cooperation: (1) companies can gather customers' requirements more systematically and provide better-quality products; (2) cooperation inside the project team could be enhanced; (3) knowledge transfer between different hierarchy levels in the company could be improved, and (4) people in distributed locations could have the same interactive view of a product (e.g. by using distributed virtual environments). In addition, these same technologies could be used during the whole product lifecycle (e.g., in design, manufacturing, training, operation).

In the future, some of the processes and systems should be developed further to ensure better usability. There is also a need for discussion about software autonomy/ independence and open-source issues. In addition, integration with existing systems should be developed further. It was also found that bringing innovations into large companies can be challenging.

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