Teaching and Implementation Models for Sustainable PSS Development: Motivations, Activities and Experiences

McAloone, Tim C.

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Chapter 1 Teaching and Implementation Models for Sustainable PSS Development

Motivations, Activities and Experiences

T. C. McAloone

Technical University of Denmark, tm@mek.dtu.dk

1 Introduction

The past two decades have seen increasing efforts to consider the potential negative effects of products' manufacture, use and disposal on the local and global environment (Ehrenfeld, 2001). Over this time efforts have been made to relate the goals and ideals of sustainability to the domain of product development, thus adding new dimensions, such as social and moral values, to the original agenda of environmental improvement. The redefinition of the role of the product developer, from environmentally conscious product developer to sustainably aware product developer has led to new insights into the way in which products are developed and used – and to where environmental effects occur in the lifetime of a product.

The product developer has thus a more complex role in relation to sustainability, as the focus for improvement of a product may not (and very often does not) lie in the physical artefactual ingredients of the product or the processes used to create it. Rather, the focus for improvement of a product's environmental performance most often lies in the manner in which the product is *used* and *consumed*. A product's *use* phase is often environmentally significant, as this is the largest source of environmental impact. A product's *consumption*, or rather, a given user's *consumption behaviour* is even more important, as this dictates exactly how many use-phases, how many products and how much *product redundancy* is created, due to the user's lack of awareness, motivation or ability to consume a product in an environmentally respectful manner (McAloone, 2005).

The problem with both *use* and *consumption* is that the product developer traditionally has very little power over these two elements; they occur after the product has left the factory and entered into the hands of the user (the consumer).

Until the real environmentally harmful phases of a product's life can be harnessed by the producing company, it is often impossible to make the radical (Factor X) environmental improvements to the product itself that are necessary to maintain an environmental equilibrium (e.g. Rejnders, 1998).

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2 Introduction to PSS

An increasing amount of companies are currently taking control over (and accepting responsibility for) a larger portion of their products' life-cycles. Many of these are doing this for reasons other than environmental, but there are also examples where environmentally-based product-life 'takeovers' have been with environmentally-founded goals in mind (McAloone & Andreasen, 2002). In general it can be said that western society is gradually realising the need for optimised resource consumption, leading to a search for solutions and business models, promising not only local optimisation but sustainable consumption from an overall perspective. In parallel, a general shift in focus from the exchange and consumption of goods to the exchange of competences and the consumption of services emerges (Matzen & McAloone, 2006). This activity is now commonly referred to as Product/Service-System (PSS) development.

PSS development gives a number of possibilities to the company, ranging from the re-invention of core-business, through gaining customer loyalty, expanding the customer base, and importantly, to the possibility of removing some of the traditional environmental problems connected to the consumption behaviour of users – although this should certainly not be considered as being a purely inevitable situation.

PSS stimulates the opportunity to adopt a more sustainable approach to business creation, as the physical products can be managed as valuable inventory that remains within the system and not just consumables that disappear from the system. For example, the greatest environmental impact of energy using products (EuP's) is in their use phase, where the use is totally at the consumer's discretion. Environmentally, this most often gives a detrimental situation, as the user has little knowledge of proper usage, or has different usage patterns that were not intended for the given product.

The underlying principle of PSS strategy is to shift from business based on the value of *exchange of product ownership and responsibility*, to business based on the value of *utility of the product and services*. The idea being that the customer pays only for the use of the product when needed and does not have to worry about operation, maintenance or disposal. In this way companies have the opportunity to dematerialise their business by decoupling their value creation with resource consumption (Tan et al, 2006). Value is instead created by supporting the customer's activities related to the use of products and not necessarily through material consumption. This is done through intangible services and knowledge intensification that ensures optimal operation and performance of products in relation to the individual customer's activities. It is believed that PSS approaches will enable and motivate companies to reuse, rationalise and enhance their products and services more efficiently throughout their life phases. This strategy also allows companies to enhance their competitiveness by expanding features, value and benefits not apparent with traditional product-oriented offerings.

2.1 How does PSS differ from product development?

In traditional manufacturing companies the physical product is considered to be at the core of the offering with services being complementary and supplemented in aftermarket activities. With PSS approaches this view changes. Here the customer's interaction with the

product and its related activity is at the centre of attention. Value is created during the activity and based on the performance and outcome of the activity. This shift in view challenges our current understanding of development and the models we use to represent the development task.

With physical products the task is to determine the product's structural characteristics so that the desired properties may be attained, and the product in use then delivers utility and value to the customer. In the area of services we do not have the equivalent insight into the relations between what structures a service and which properties contribute to the customer's perception of utility and value.

We observe two life/cycle systems that must be considered in PSS development: 1) the life cycle of the physical artefact and 2) the activity life-cycle relationship between the providing company and customer, representing a product-oriented and a service-oriented view, respectively (Figure 1). Companies must gain insights into both views in order to achieve the potentials of PSS and to reap the potential environmental benefits of optimising these two life-cycle systems.

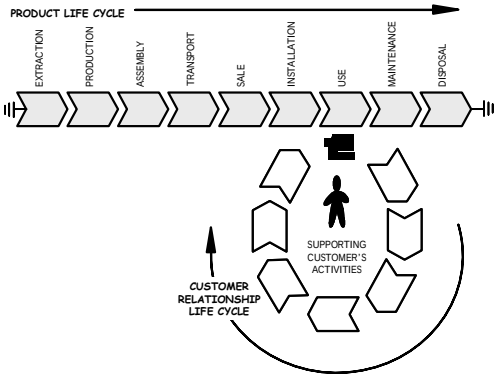

Figure 1 – Two life-cycles must be observed and optimised (Tan et al, 2006)

3 Our research motivations

PSS is relatively new as a research discipline and we still lack overview in order to be able to understand how to design a PSS. For example, who should sit in the project team for the creation of PSS concepts, and with which tools? No longer merely a team of engineers with a set of linear development models..? A PSS requires an orchestration of a complex network of stakeholders, both in- and outside of the company, in order to deliver an *augmented product* to the customer in a satisfactory manner – and to be able to sustain this satisfaction throughout the whole company-customer relationship.

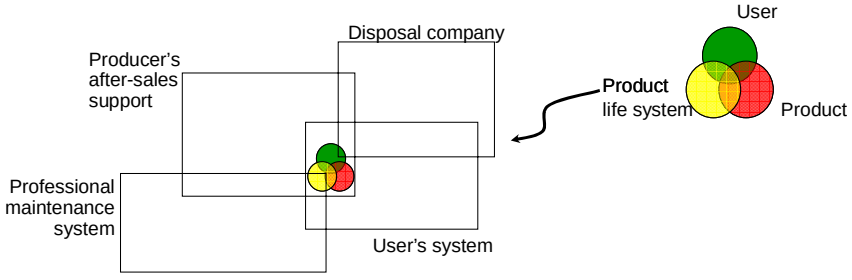

Figure 2 – A PSS is composed as an augmented product (McAloone & Andreasen, 2002)

We therefore see that the area of PSS has a number of important research dimensions, including:

1. A theoretical understanding of the operations-related opportunities inherent in PSS approaches to business, exploring and explaining opportunity parameters pointing towards e.g. the dematerialisation of offerings, optimising of performance or consumption etc. This dimension could also be referred to as PSS as a potential of benefit.
2. A theoretical understanding of the phenomenon of combined product and service offerings, exploring and explaining the inherent virtues and inferiorities of physical products throughout their life cycles and how these can be supported and relieved by service offerings. This dimension could also be referred to as PSS as a theory.
3. A prescription of the structures and management technologies necessary to enable companies and company networks to develop, deliver and operate PSS solutions. This dimension could also be referred to as PSS as a strategy.
4. A prescription of the processes which will enable development teams to identify and take advantage of the potentials referred to in paragraph 1 of this listing. Furthermore a prescription of working tasks and documentation models aiding the development team in the concretisation, communication and realisation of PSS solutions. This dimension could also be referred to as PSS as development methods. (Matzen & McAloone, 2006).

We can prepare ourselves for a significant change in the way that traditional product manufacturing companies deliver their products to their customers – especially in the western world, where companies no longer can expect to compete on a global market with respect to cost, quality or time. It is our hypothesis, that if carried out correctly (aided by professional methods and approaches) the shift from the development, sales and provision of discrete, physical products, to the practice of *functional sales*, provided as a product of PSS-development, will give radical environmental improvements.

For this to be possible, we believe that we need to expand both our *mindset*, in order to be able to understand the proper nature of a PSS and our *design degree of freedom*, in order to be able to carry out professional PSS design. We need to be able to understand how to design the life-cycle first, then the product (Kimura & Suzuki, 1996), to ensure an efficient product, durable company-customer relationship and reduced environmental effect.

4 Activities

In recognition of the need to bring a closer relationship between the theories and practices of LCA, ecodesign, innovation and product development, the Sustainable Innovations Group was established at The Technical University of Denmark, DTU, in 2005. Our group comprises teachers, researchers and consultants in the field of sustainable innovation and it is our goal to reap the advantages of both the analytical and synthesis approaches to environmental improvement, and to set our work in the context of providing models and methods for the development of

ecologically and economically sustainable solutions to students and to organisations.

At the core of our current project activities within our group are a series of PhD students, researching in design methodological aspects for product/service-system solutions and in aspects and constraints of implementing PSS in industry. Industrial partners comprise both manufacturers of electro-mechanical devices, public institutions and branch organisations – all interested in exploring options of PSS in their field of activity.

In the following we will briefly introduce our activities in the industrial implementation and then dedicate a little more time to describe our undergraduate teaching of PSS.

4.1 Industrial implementation

For a number of years we have worked with companies, developing and implementing ecodesign strategies and methods/tools. These activities with industry have been an integral part of our theory- and method development research, where a number of descriptive and normative results have been produced (e.g. Olesen et al, 1996). In the late 90'ies it seemed that an ecodesign saturation point was reached, where companies had reached a limit to the viability of the environmental improvements striven for or claimed to be achievable. The low-hanging fruits had been plucked and the only opportunities left for making significant environmental improvements lay in the product life phases that lay beyond the producing company's reach and responsibility.

The emergence and development of PSS as a strategy has therefore meant that some of the earlier 'unreachable' phases of the product's life-cycle (and the customer's/user's activity cycle) can now be planned for and designed into the PSS. As a result of this, our collaborative activities with industry focus on the advancement of supporting models for the development of sustainable PSS solutions, based on an understanding of product- and service life-cycles, and on the transition from a product-oriented strategy to a service-oriented strategy. Our research is empirical in nature and our models so far have been largely descriptive.

4.2 Teaching PSS

We see our teaching activities in the area of PSS as giving the opportunity to test and develop our descriptive models of industrial activities into more normative tools and techniques for the students.

At DTU we have had an increasing focus on sustainable PSS development teaching for the past five years. Currently we have two courses amounting to 15 ECTS points, where we educate fifth semester bachelor students in sustainable PSS development. In the following we describe our approach.

4.2.1 The Design & Innovation programme at DTU

The product developers we are educating today will hold large responsibilities in the industry of the future. From our dialogue with Danish companies we have derived an important set of criteria for professional

product developers, including: the ability to synthesise (creative ability); to visualise and communicate; to stage the design process (Andreasen et al, 2000); to utilise knowledge and skills in related subjects and areas; to utilise and lead specialists in related subjects and areas; to function well in, or lead, a design team; and to be aware of the social, environmental and sustainability ramifications of their involvement in industry.

The above criteria have formed the basis for a new five-year bachelor-master programme at DTU, entitled *Design & Innovation* (www.design-ing.dk). We educate our students with a focus on three core competence areas:

- Technical engineering competencies
  Reflective, technological engineering competences, which refer to the reform of teaching and integration of the core engineering curriculum.
- Socio-technical competencies
  Competencies to be utilised in the creation and renewal of systems and situations and where complex, political decisions confront the engineering field's way of modelling and optimisation.
- Creative/synthesis competencies
  Aimed at integrating technical and social components during the development of products, systems, processes and services. The education emphasises the development of the students' personal, creative potential, engagement and enthusiasm, professional insight and the mastery of methods.

The students acquire these competencies via a series of themed semesters in the bachelor programme, and by specialising in the master programme. In the fifth semester of the bachelor programme, the semester theme is "Innovation for sustainability", which is where the students are educated in sustainable PSS design.

4.2.2 Description of PSS course

The Design & Innovation education programme is project-based and integrates disciplinary teaching models throughout the syllabus. On the fifth semester of the bachelor programme, we have two courses:

- Product life and environmental issues (5 ECTS points)
  A theoretical course in product life thinking, Design for X, environmental regulation and ecodesign.
- 'Product/Service-Systems' (10 ECTS points)
  A project-oriented course, placing the focus on learning and practising techniques for the consideration of whole product-lives, stakeholder galleries, customer activities, and product/service offerings.

Through their project work the students are trained in identifying and analysing environmental issues in a holistic perspective; synthesising environmentally improved solutions to consumption needs; and developing strategies towards the realisation of these solutions. At the time of writing this paper we are on our third year of running these two courses, which have approximately 55 students attending each year.

4.2.3 A normative approach to PSS

As previously mentioned, we pair our industrial research activities and descriptive results with our teaching activities, which are often normatively designed and delivered to the students. The main reasons for doing this are that this activity strengthens our understanding of the industrial situations observed; delivers a clear and concrete set of steps to the students; and allows us as researchers and model-builders to reflect on our theoretical framework and model synthesis.

In our course on sustainable PSS development the students are presented with an object (washing machine, barbeque, transport system, etc.) as point of departure for their project and then required to follow the steps listed below, throughout their 13-week engagement in the course:

1. Create a product life gallery
   - graphical representation of the product's life, focusing on encounters with various life-cycle systems and the related environmental effects.
2. Identify the functional unit provided by the product
   - based on existing theories for Life Cycle Assessment (LCA).
3. Carry out an 'Analysis, Diagnosis, Focusing and Goal-Setting' exercise
   - to take stock of and plan changes to the environmental effects.
4. Sketch the actor-network (the system), describing its nodes (the stakeholders) and the connections (value-chains, information chains etc.)
   - to fully understand the stakeholders involved in the emerging PSS.
5. Identify and sketch the customer activity cycle
   - a mapping of the customer's experience with respect to their needs satisfaction.
6. Describe the physical artefact(s) that are necessary to deliver the service-system
   - the 'packaging' for the PSS, developed in the previous steps.

We find it useful and interesting to exemplify the above six steps in the following, in order to show the level of depth and description the students are required to go into.

Stage 1 - Product life gallery

A product life gallery is the physical result of a largely qualitative mapping of the product's lifecycle, detailing the functional unit, stakeholders, environmental effects, DFX impacts, environmental trade-offs and dispositions/delegations (Olesen, 1992). The gallery is prepared by a group of 7-8 students within the first three weeks of the project course, and forces the students to carry out a great deal of detective work regarding the product. The result is one large graphical overview of the product's environmental profile (see Figure 3).

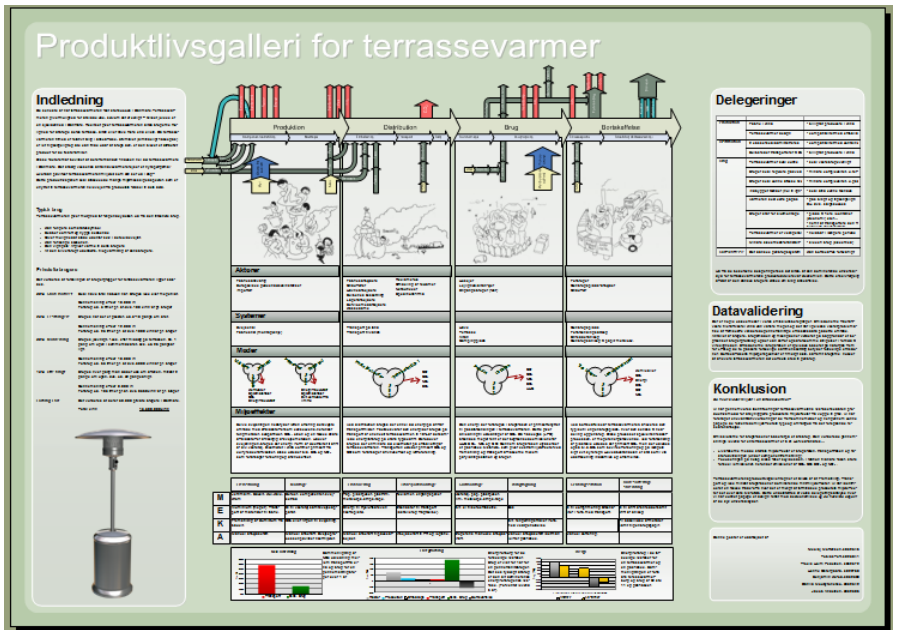

Figure 3 – Product life gallery for terrace warmer (Student project submission, 2005)

Stage 2 – Functional unit

The functional unit is identified at this stage of the project, in order to begin the definition of the 'service' that the product under analysis should provide to the user. The functional unit is described here as a quantified performance expectation of the product, over a given usage period and frequency. In the case of the terrace warmer in Figure 3 above, four different functional units were chosen, to display four contrasting use/ownership scenarios.

Stage 3 – Analysis, Diagnosis, Focusing & Goal-setting

This stage of the project is intended to firstly create a consolidation of a historical study of the product's life cycle effects in order to identify what environmental effects occur (*analysis*), and a *diagnosis* of who, where and when the identified environmental effects were disposed for or actually caused. After these facts have been established, a *focusing* exercise is carried out in order to pinpoint areas of environmental improvement, before moving onto a *goal-setting* exercise, which elicits how and where to realise the environmental improvements related to the delivery of the functional unit identified in stage 2 (maybe by a quite different product than the one originally assessed).

Stage 4 – Actor-network

Based upon Actor-network theory (Latour, 1991) the students are required to map all of the stakeholders they can identify for their case product and to map the flows of value, communication, service, information, transport and materials (where appropriate).

This activity is important, as a PSS solution may not necessarily entail an alteration to the physical artefactual ingredients of the product itself, but of the network within which the product is a part. The following two figures show examples of the actor-network for a coffee vending machine before and after the students had effected changes in the direction of sustainable PSS design. The actual coffee vending machine in this case didn't change at all, but the actor-network was completely re-designed.

Before

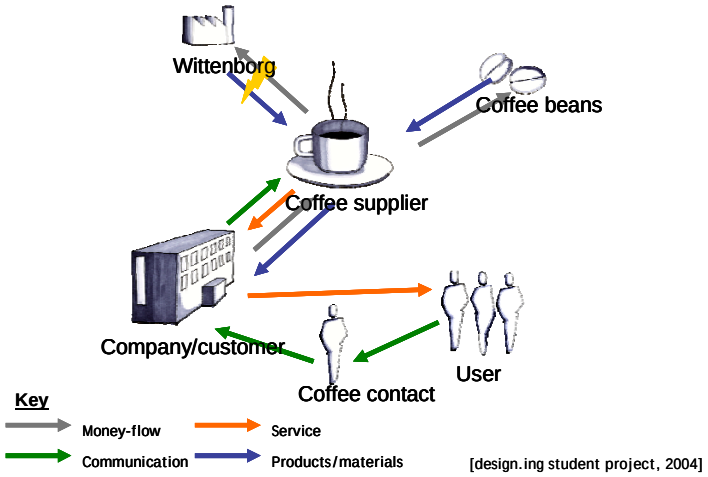

Figure 4 – Actor-network for coffee vending machine (Student project submission, 2004)

After

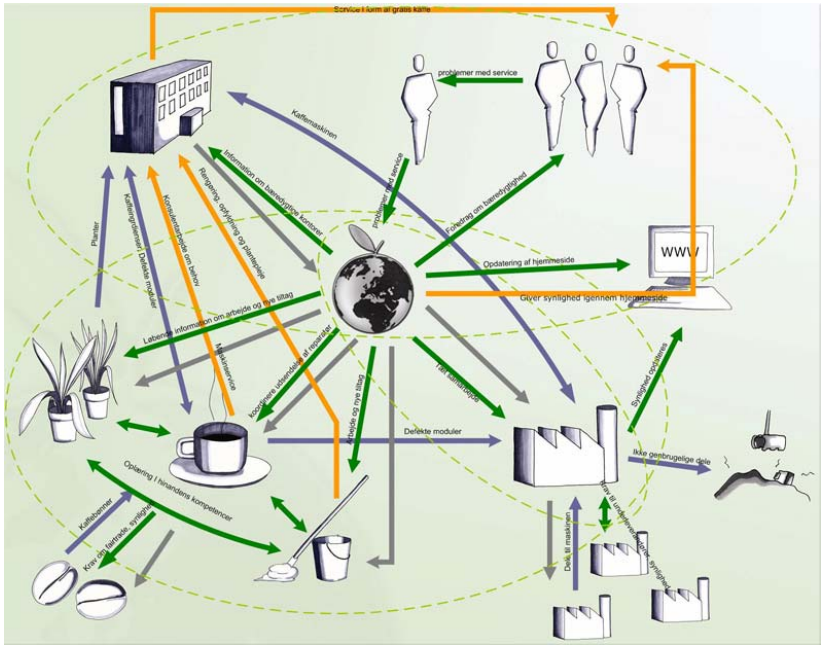

Figure 5 – Actor-network for coffee vending machine after PSS exercise (Student project submission, 2004)

Stage 5 – Customer Activity Cycle

The practice of modelling the Customer Activity Cycle (CAC) is adopted from a research model by Vandermerwe (Vandermerwe, 2000) and used by our research group to model the customer's needs and activities, as opposed to the product's life cycle. The CAC's main virtue is the way in which it prompts the designer into a consideration of the sequence of activities of his customer, hereby contributing to the knowledge of the designed offerings use phase. The CAC modelling technique has been actively developed throughout the period where we have used it in our teaching, to provide a series of synthesis-oriented aspects that the original model did not include.

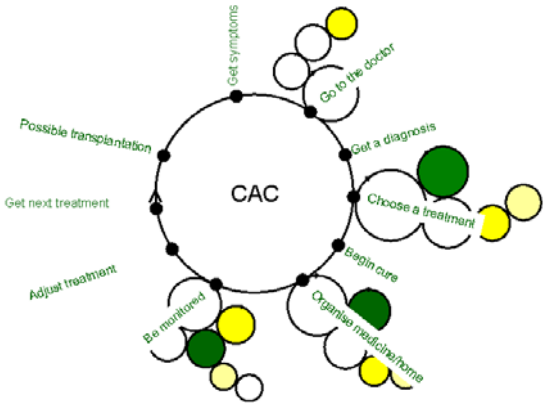

Figure 6 – CAC model for a sick patient; example taken from (Vandermerwe, 2000)

Stage 6 - Describe the physical artefact(s) and the PSS

The final assignment in the course is a description of a concept for a new PSS, with radically improved environmental performance. Here the students are asked to model the stakeholder network and their relations, explain the life-cycle activities associated with the PSS and argue for the benefits for stakeholders as well as the environment.

In the example in Figure 7, a service to provide clean clothes in the home could replace washing machines. Dirty clothes would be picked up at the home at regular intervals and returned back clean and folded. The clothes would be tracked by a microchip tag, sewn in, that would contain washing instructions and user information. A virtual wardrobe would allow the user to see what clean clothes were available, suggest what to wear or offer deals on new clothes to buy online.

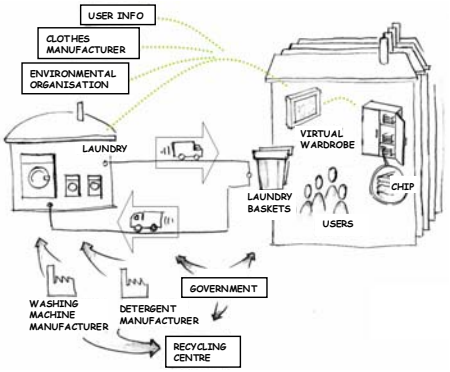

Figure 7 – An example of a PSS concept description (Student project submission, 2004)

5 Experiences

We have chosen the point of departure for our industrial research and teaching activities where PSS is a strategy that is focused on the provision of usage value of products through integrated solutions of products and services over an extended (for the company) product life period. An underlying principle behind a PSS strategy is to shift focus from business based on the value of the transfer of product ownership and responsibility, to business based on the value of utility of the product and services.

Through our efforts to teach PSS to large groups of students, we have learned many important and enlightening lessons regarding the development of methods and tools for sustainable PSS design. In fact, the focus of the products delivered as start-points to the students for their projects in 2004, 2005 and 2006 respectively, has purposely been altered each year, in order to test different aspects of the models under development (this work is detailed in a separate paper (Tan & McAloone, 2006)).

We are experiencing that companies are beginning to approach the topic of PSS development in a more consolidated fashion. For the first years of PSS implementation, it has been uncertain as to who inside a company should be allowed to orchestrate and design a PSS. We are experiencing from our approach described in this paper, that the orchestration of a PSS requires an equal amount of orchestration within the company itself. Therefore our model development for use in teaching is also beginning to make a full loop integration back into industry, where we are currently modelling actor-networks, customer activity cycles and product life galleries with and for companies who wish to adopt PSS strategies.

We are aware that there are many areas where our methods have weaknesses, holes and maybe even contradictions. But we believe that our empirical-methodical balance is an efficient and trustworthy way of gaining deep insight into complex relationships. And we are busily building the frameworks for a PSS methodology through the various PhD- and other research projects in our group.

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