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Product Service System Innovation in the Smart City

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Abstract

Product service systems (PSS) may usefully form part of the mix of innovations necessary to move society toward more sustainable futures. However, despite such potential, PSS implementation is highly uneven and limited. Drawing on an alternate socio-technical perspective of innovation, this paper provides fresh insights, on among other things the role of context in PSS innovation, to address this issue. Case study research is presented focusing on a use orientated PSS in an urban environment: the Copenhagen city bike scheme. The paper shows that PSS innovation is a situated complex process, shaped by actors and knowledge from other locales. It argues that further research is needed to investigate how actors interests shape PSS innovation. It recommends that institutional spaces should be provided in governance landscapes associated with urban environments to enable legitimate PSS concepts to co-evolve in light of locally articulated sustainability principles and priorities.

Key words: socio-technical, actor networks, institutions, resource productivity

Introduction

Although for many years technology was seen as a root cause of ecological challenges, today it is frequently also viewed as a means to resolve these and move society toward more sustainable futures. Indeed, environmental innovation is now an established field of research and practice. Traditionally focused on the development of products which hold potential to achieve certain effects such as energy efficiency and resource productivity, recently the analytical focus of such work has broadened to include not only products but also novel configurations of products, services and systems. Founded in the factor four discourse, which argues that gains in resource productivity of between factor 4 and 20 are necessary to put society on a sustainable development pathway, research suggests that these configurations hold significant potential to help realize such goals (Weizsaker et al., 1997).

Given this potential a considerable body of case study research has been initiated to investigate these configurations and the claims associated with them (Mont and Tukker, 2006). Research focused on quite diverse market offerings in various sectors including agriculture (integrated crop management), utility (energy service companies) and transport (car clubs) (Tukker and Tischner, 2006). Various terms have been developed to define, analyse and design such offerings: eco-efficient producer services (Zaring et al., 2001); eco-efficient services (Hockerts, 1999; Meijkamp, 2000; Brezet et al., 2001); eco-services (Beherendt et al., 2003); while the definition developed by Mont (2002) is perhaps the most widely used:

"A system of products, services, networks or actors and supporting infrastructure that is developed to be competitive, satisfy customers and be more environmentally sound than traditional business models".

Three types of PSS have been delineated to analyse and demonstrate the potential of PSS to improve resource efficiency in both intermediate and final markets (cf. Hockerts, 2002; Mont, 2004; Cook et al., 2006; Baines et al., 2007; Cook et al., 2012; Ceschin, 2012; Armstrong et al., 2014):

Product orientated PSS: ownership of the product (material artefact) is transferred to customers and services are provided to help ensure product performance over a given period of time. Examples include maintenance contracts and warranties.

Use orientated PSS: ownership rights related to the product are retained by the service provider (who may or may not have manufactured it) and the customer purchases use of the product over a specified period of time. Examples include, sharing/ pooling, renting and leasing.

Result orientated PSS: similar to use orientated PSS, the product required for service delivery is owned by the service provider (who may or may not have manufactured it). However, in contrast to use orientated PSS the customer purchases an outcome/ result of service provision, which is specified in terms of *performance* not in terms of product use over a period of time. For example, instead of renting a washing machine, households access a laundry service to clean clothes and linen.

Synthetic reviews¹ of case study research (cf. Mont and Tukker, 2006; Tukker, 2015) suggest that gains in resource productivity from PSS are likely to be more

¹ Synthetic reviews adopt systematic approaches to analyzing the theoretical foundations, methods and findings in a body of research (cf. Li, 2007)

limited than early predictions suggested (Tukker and Tischner, 2006; Tukker, 2015). More specifically, gains in resource productivity have been shown to vary according to PSS type. Product and use orientated PSS are unlikely to yield factor four improvements in resource productivity commensurate with initial predictions. Instead factor two improvements are more likely (Tischner and Tukker, 2006). However, because of their focus on functionality (not products) result orientated PSS are thought to still hold significant potential to improve resource productivity. These types have 'Factor X' potential *ibid.*

While PSS are clearly not inherently sustainable, they may usefully form part of the mix of innovations required to move society toward more sustainable futures (Cook, 2014). Indeed, PSS continue to be the subject of a growing literature. PSS concepts have been further defined (cf. Berkovich et al., 2011; Zhang et al., 2012; Boehm and Thomas, 2013), new typologies delineated (cf. Tan et al., 2010; Ostaeyen et al., 2013; Gaiardelli et al., 2014) and design methodologies developed (cf. Sakao and Shimomura, 2007; McAloone, 2011). Disciplinary led research, rooted in design, marketing, business studies, manufacturing management and engineering continue to guide research activity (Boehm and Thomas, 2013; Tukker, 2015). However, as each of these has its own focus and vocabulary, the PSS field is now quite complex and there may be a chance of blind spots occurring (Tukker, 2015).

Crucially, despite significant investments in research, there is growing concern that PSS have not been widely implemented in either intermediate or final markets (Vezzoli et al., 2012). With a few notable exceptions, insufficient attention has been given to understanding PSS innovation and how this process may be managed and orientated (Tukker and Tischner, 2006; Baines *et al.*, 2007; Ceschin, 2012; Cook 2014). For example, research in the PSS field has tended to focus on supply side design issues which emphasise PSS functionality (cf. Roy, 2000; Maxwell et al., 2006; Geum and Park, 2011), while more nuanced aspects of PSS consumption which may play a key role in PSS innovation such as the symbolic meanings of PSS offerings has been somewhat overlooked until recently (cf. Mylan, 2015; Catulli et al., 2017).

Considerable research has been undertaken to develop common PSS definitions and classification frameworks which can be mobilised in design processes and implemented in various contexts (cf. Tukker and Tischner, 2006; Vasantha et al., 2012; Tukker, 2015). Consequently PSS research emphasizes the need to gather knowledge around common definitions and classification frameworks which can be widely applied (cf. Mont and Tukker, 2006; Vasantha et al., 2012; Tukker, 2014). Standardization of approaches has been proposed, partly to move PSS research beyond a 'pre-paradigmatic' stage (Tukker, 2015). With respect to PSS development and implementation, the logic of these recommendations is founded on the view that PSS implementation can be supported by context independent knowledge embodied in PSS design concepts, methods and tools. Barriers and drivers to a linear implementation sequence are identified and should be managed accordingly.

This positivistic engineering approach is both implicit and pervasive in much PSS research. Such linear accounts emphasise 'research – design – implement'. A plethora of 'barriers' and 'drivers' associated with this linear process have been identified (cf. Gottberg et al., 2008). However, among other things, the problem with such accounts is their structuralist origins: variables such as drivers and barriers are not fixed immutable facts but mobile phenomena which are outcome of context specific institutional interests and practices. Such reductionist views also tend to analytically decompose PSS innovation into discrete variables and do not allow us to investigate PSS as they are encountered by various actors; they

rarely explicate sufficiently the complex environment in which PSS innovation proceeds and are unlikely to help practitioners to navigate such environments and realise the multiple opportunities that diverse PSS offerings may provide for transition to more sustainable futures (Cook, 2014).

While the current approach to PSS research can be productive, since among other things standardisation can help attain economies of scale, it may be problematic if it is the *only* one underpinning PSS research. For example, PSS innovation proceeds somewhere and thus is a situated process for which context matters. Yet little attention is paid in PSS research to the interplay of the universal and particular, and associated knowledge claims and recommendations. In PSS research, space is often reduced to essentialist categories such as nation states or regions. For example, PSS research shows that in the Netherlands computer leasing was five times more popular than in any other country and mobility PSS such as car clubs are well established in Germany and Austria (Behrendt et al., 2003). This is troubling, as PSS are frequently implemented in urban environments such as towns and cities (e.g. car clubs, cycle hire schemes) and ways to help resolve implementation challenges may be partly found in understanding how PSS are developed *through* and *embedded* in such places. Here space is not simply a contextual empty container for PSS innovation to proceed over time. Rather it comprises heterogeneous elements and trajectories (Massey, 2005) with different affordances and potentialities, for PSS in this instance. Thus the aim here is not to develop best practices with implicit problems and solutions related to spatial categories such as towns and cities. Rather to explicate the situatedness of PSS innovation, its multiplicity and construct a more promising basis for interventions which give this complex innovation process a better chance of responding to locally constructed sustainability issues.

To help resolve the PSS implementation challenge this paper explores PSS innovation in an urban environment: Copenhagen. In this locale urban development is far from static but inflected with multiple concepts such as the sustainable city as well as more recently, the smart city (De Jong et al., 2016 and Joss, 2015). As such the paper focuses on PSS as part of such developments. It generates useful insights on the situated nature of PSS innovation to help resolve implementation challenges identified in literature as well as contemporary policy relevant insights. Adopting an interpretivist socio-technical perspective on innovation, this paper draws on case study research focusing on Copenhagen city bike scheme: a use orientated PSS. This paper is structured in three further sections. Section 2 sets out the approach and method undertaken. The case study is presented in section 3. Discussion and conclusions are presented in section 4.

Approach and method

There are multiple strands of environmental innovation research each founded in slightly different ontologies and epistemologies and thus emphasising different problems and solutions (cf. Shove, 2011). Based on neo-classical economics, there is a considerable body of work (cf. Skea, 1995) which conceptualises investments in environmental innovation as a problem of decision making by rational and profit maximising economic agents with perfect information about their actions. Seen in this way, price signals initiate innovation and shape diffusion. Research focuses on identifying market failures and adjusting prices to reflect externalities. Such processes therefore follow a logic of 'once a force is applied then a predictable de-formation will result' (Berkhout and Gouldson, 2003).

In contrast, the neo-schumpeterian school views investments in technical and organisational innovations as the outcome of satisficing behaviour under conditions of uncertainty by economic agents with bounded rationality who are embedded in historically assembled social structures (Dosi, 1988). Producers and consumers make decisions on the basis of habit and past experience, and are influenced by what they learn through institutionally situated processes in a search for solutions to problems that have been recognised as important. They are unable to judge the consequences of their actions as the private costs and social benefits are not fully known, because end points are highly uncertain, or because there may be a diversity of views about what the outcomes could be. In other words, uncertainty is a key feature of the innovation process. Building on these insights, a further stream of research has arisen which focuses on national scale transitions to more sustainable socio-technical systems which satisfy societal demands for among others mobility, energy and food (Elzen et al., 2004). Several analytical approaches have been developed to understand such transitions including most notably the multi level perspective (MLP) which underpins a significant proportion of work in the field (*cf.* Geels, 2004; Geels, 2005). The MLP is a middle range theory based on a number of ontologies including evolutionary theories of technological change and interpretivist social science drawn from Science and Technology Studies (STS) (Geels, 2011). It is founded on the view that innovation has *both* social and technical elements which co-constitute one another. The MLP is based on a three level nested hierarchy composed of a landscape, socio-technical regime, niche environments. Transitions are defined in the MLP as socio-technical regime shifts. These come about through interacting processes within and between the three levels of the MLP *ibid.*

A further notable strand of research extends this socio-technical perspective and draws upon interpretivist social science to explicate environmental innovation processes in detail. This case study based approach was initiated by among others, Guy and Shove (2000) to challenge assumptions about environmental innovation (sustainable buildings in their case) and identify alternate useful insights. According to Moss et al. (2005), Guy and Shove's (2000) seminal argument is threefold. First, they argue that non-technical barriers and drivers cannot be easily separated from contexts and question the ability of improved knowledge dissemination, incentives and sanctions to overcome these. Second, they criticise the linear narrative surrounding the development of sustainable technologies: from invention, design and demonstration to application and dissemination. Their work suggests that the reality of innovation is frequently at odds with this model path and is characterised by delays, set backs and reversals; there are often varied options and trajectories available to actor constituencies, who are influenced substantially by interests and the local context of action and thus defy linear interpretations and management. Third, they challenge the focus, in promoting sustainable building on creating incentives for individuals assumed to acting according to rational motives alone and on targeting select groups of decision makers in particular. They argue that this narrow focus runs the risk of overlooking contextual issues that prevent individuals from action rationally and the potential importance of actor groups beyond the immediate decision makers.

Time and place take on a particular importance in framing the opportunities available (Guy and Shove, 2000; Guy, 2011). Practically, some contextual factors may be turned to advantage and others may pose difficulties. Given the need for insights which explicate the complexities of PSS innovation in various contexts, this paper builds on this interpretivist socio-technical view of environmental innovation. It draws on case study research focused on the

Copenhagen city bike scheme to explore and gain insights on the following three themes:

1. The PSS innovation process, pathways and circulations
2. Matters associated with the spatial context for PSS innovation
3. Actors and actor networks associated with PSS innovation

Consistent with the canon of case study research, data were collected from multiple sources using multiple methods (Robson, 2002). Data were initially collected via observations made on three field visits to Copenhagen. During these visits the cycle infrastructure and new city bike scheme were observed. The author even hired one of the bikes to gain first hand experience of cycling round the city and using the metro and over ground trains as part of an integrated journey. Smart city developments such as city diagnostics were also observed during the field visits. Observations were recorded in the author's research diary. Relevant policy and management documents were also reviewed. These included statutory planning documents, other policy documents expressing city policies and guidelines as well as social media such as blogs. In depth semi structured interviews were conducted with four key informants. A purposive sampling strategy was followed. As such, interviews were conducted with actors from the municipality, a Copenhagen based urban design consultancy, an engineering consultancy an academic institution based in the city. An interview guide was developed and used in the interviews. Topics which formed the basis of the guide were identified from literature, observations and relevant documents. Topics included technologies, anticipated user behaviour, transport systems integration. While allowing for a degree of consistency, this topic based approach allowed responses arise as part of a conversation. The aim here was to develop a thick description of PSS innovation in Copenhagen . Data were analysed using a coding and clustering methodology. An initial coding template was developed from the topics set out in the interview guide and used to analyse data collected. The template was modified as new insights emerged and codes and clusters developed. Thus results were generated by both literature and data collected. Crucially, temporal and spatial aspects of the results were used to construct a case study narrative, which is presented in the next section.

Copenhagen City Bike Scheme

Copenhagen is the capital of Denmark and has a population of approximately 760,000. It is a relatively prosperous city and is frequently cited as among the world's most liveable cities. Underpinning life in the city is an integrated transport system of which extensive cycling infrastructure forms a key part. Developed from traffic calming measures in the 1970s, the city has a network of cycle paths that enable cycling within and between all major parts of the city (Gehl, 2010). Cycling safety and comfort are paramount. To achieve these goals, Copenhagen cycle paths generally conform to a particular design: cycle paths are physically divided from other lanes by kerbstones and are often situated behind buffer zones (e.g. parked cars) that separate them from motorized lanes (see Figure 1). This has helped develop a strong cycling culture in Copenhagen. Some 41% of journeys to work or education are undertaken using a bicycle. The well established policy framework for cycling in the city, which is supported by key transport actors, aims to perpetuate and extend this trend to 50% by 2025.



Figure 1 – Cyclists on a Copenhagen Cycle Path in adverse weather conditions

Multiple smart city transport projects form a key part of efforts to meet this objective. Actors engaged in these are grouped in a triple helix and include research institutions, private sector firms and public authorities. Similar to many other smart cities (*cf.* Hollands, 2008; Aoun, 2013; Kitchin, 2014; Albino et al. 2015), by deploying sensing and data management infrastructures, Copenhagen aims to make vast volumes of urban information available to augment city management and promote technological entrepreneurship. Specifically, Copenhagen posits a future in which open data are available to achieve:

- Innovation
- Growth
- Citizen involvement
- Entrepreneurship
- Relevant solutions

The application of digital information and knowledge to achieve such goals in cities entails an elaborate, complex process of defining data types and categories, generating and harvesting data, assembling often disparate data sets and computing and modelling data to provide integrated information and intelligence. Indeed, a big data platform or hub is central to the initiative. This digital platform centralizes data from a range of public and private sources. Such hubs are based on sophisticated machinery, systems and software – from super computers to mapping and modelling programmes, and from geo-spatial information systems to remote sensors. Such advances in digital knowledge have begun to exert profound changes in the way cities are configured – conceptually, spatially and functionally.

There are a number of smart city projects focused on cycling, such as the intelligent lighting for bicycles at inter sections project and the new Copenhagen city bike scheme “Bicyklen”, which is based on a smart bike and is integrated physically and digitally within the Copenhagen transport system. Launched in 2013, this use orientated PSS and forms a key part of the overall Copenhagen cycle system and indeed, the city’s integrated transport system. It replaces a Copenhagen city bike scheme which had run for 18 years. The previous scheme was based on 2,500 bikes and over 100 coin-operated bike stands. Bicycle hire was free; a coin deposit was paid to secure the return of the bike. The previous city bike scheme was mainly used by visitors to the city (tourists) and Copenhageners (citizens). However, commuters rarely used the service. In Copenhagen the tendency was to use one’s own bike, such as a cargo bike to carry luggage and/ or children.



Figure 2 The Copenhagen Bicycle Scheme: Bicycle and Docking Station

In response Bicyklen was developed to appeal to a variety of user groups, but most notably commuters, which is something of a change in relation to the previous city bike system. The new city bike service follows a well-established city bike service design in that it comprises a number of bicycles and docking stations (see Figure 2); users pay a fee to hire a bike for a given (usually quite short) period of time. There are multiple docking stations in the city, from which bicycles are available 24 hours/ 365 days per year. However, in contrast to many city bike services which use very simple bicycles, the bicycle element of the new Copenhagen city bike scheme is technologically advanced. For example, it is electrically assisted, it has a belt drive for easy maintenance, it is made of non-standard components that are difficult to steal as it includes a Global Positioning System (GPS) which sends a signal if the bicycle travels over 60kph (i.e. if it is the back of a motorized vehicle after been stolen) and a handle bar mounted tablet. The latter is particularly important, as it enables payments for service to be made (e.g. via a Copenhagen travel-card), journeys to be planned and tickets (e.g. rail) to be bought. In other words, it is an important piece of smart technology which helps embed the city bike service within Copenhagen's integrated transport system, comprises not only of bicycles but also trains, the metro system, buses, and taxis. The cycle service can be accessed on a pay per hire basis as well as via monthly subscription. The aims and features of the Copenhagen city bike scheme are:

- offers point-to-point travel that seamlessly integrates with existing urban transport
- the smart bike integrates with www.rejseplanen.dk and displays current timetables
- easy and simple online booking with an overview of available bikes at each charging station

- charging stations are located close to existing urban transport for ease of use and journey integration
- city sites can be viewed all through the smart bikes on board computer attractions, museums, events, restaurants, weather and more bikes

There is a well-established network of actors involved in the development of cycling in Copenhagen. Much work to promote cycling proceeds under the auspices of the Cycling Embassy of Denmark, which is a network of cycling professionals from local authorities, non-governmental organisations and private companies. There are also other key 'cycling' actors including Jan Gehl (architect and urban designer) and Mikael Colville-Andersen (commentator and blogger – Cycle Chic). The new city bike service was developed by a network of actors including the city municipalities and a firm from the private sector. To help ensure that the new city bike service forms part of Copenhagen's integrated transport system, a key partner is the national railway operator, which extends the network of actors involved beyond the traditional nexus for city bike services.

Following its launch in 2013, the Copenhagen city bike scheme was far from an instant success. In 2015 the bikes were used for only 169,834 rides. However, uptake increased to over 700,000 trips in 2016. A highpoint came on 10th September 2016 when there were some 7300 hires. Data show some 80% of trips using the city bikes were undertaken by people with monthly subscriptions, of which 60% were Danes. The cycle scheme seems to be popular among 25 to 35 year olds and crucially, commuters who tend to rent and leave bikes at train and metro stations. In aggregate data suggest there may be a commitment to the service among certain groups of Copenhageners and that the scheme is meeting its aims of appealing to commuters.

Key actors such as Colville-Andersen argued that the initial problems with the scheme arose partly because the 'smart' bike was too complex, heavy and costly. He argued that Copenhageners were ignoring the bikes and declared them a tourist gimmick. Interestingly, he also suggested that the city should have copied the decade old OV-Fiets system from Dutch railways instead of being seduced by over complicated technology. Indeed, increased uptake in recent years, the company (Gobike A/S) supplying the bikes closed in spring 2017. The scheme is now provided by the Pendlercykel foundation (www.bycyklen.dk), which receives funding from the Copenhagen and Frederiksberg Municipalities and the train operating company, DSB.

City bike schemes such as the one in Copenhagen, are no longer the preserve of public sector organisations. Indeed since its launch, a number of competing offers have been developed. Many hotels provide simple 'three speed' bicycles for visitors to use during their stay in the city. Furthermore, technology enabled bike rental firms such as Donkey Republic, which provides 24/7 bike rental are now also available in Copenhagen. Such services enable users to rent bicycles using a smart phone app, which can be used to access rental bikes that are available various locations in the city. Partly in response to such offerings, users can now access the Copenhagen city bike scheme using a smart phone.

Further, similar to many innovations developed in Copenhagen, the city bike scheme has been rolled out in another city, in this case, Stavanger, Norway. Indeed, ideas for cycling innovations such as the new city bike service flow into, through and out of the Copenhagen cycle actor network. For example, adoption and diffusion of cycling innovations proceeds under the banner of Copenhagenisation. Cities such as Portland, Mexico City and New York City have adopted a number of Copenhagen's cycling innovations. These include

Copenhagen style cycle lanes that use kerbstones and buffer zones to separate traffic.

However, Copenhagen actors suggest that such innovations cannot be simply extracted and transferred to other cities in blueprint form, even though the city council provides consultancy to other cities around the world on the inclusion of cycling in city commuting cultures. Rather, actors argue that Copenhagen's cycling innovations may inspire, motivate and guide innovation elsewhere, which is undertaken by local actors to meet local challenges. Here then, designs are not transferred and simply uncritically applied elsewhere. Rather the concepts and design principles travel, stimulate and shape innovation in various locales. For example, Gehl Architects argue that the Copenhagen bicycle system is based on five design principles, which are known as the Five Cs: Consistent, Connected, Continuous, Comfortable, Convenient. Here Gehl Architects do not argue that the five Cs should be simply applied in other cities but rather used to provide a basis for stimulating, suggesting and guiding cycling developments elsewhere.

Discussion and Conclusions

This paper contributes to ongoing research which aims to help resolve the PSS implementation challenge. By following an alternate socio-technical view of innovation founded in interpretivist social science, it has generated new insights on PSS innovation. The case study shows that PSS Innovation is a complex process, which cannot be easily isolated from its context. The Copenhagen city bike scheme is a key component of smart transport developments in the city: cycle infrastructure as well as overall transport system. ICT plays a key role in mediating integration, with assets from the smart city such as the tablet.

The city bike scheme was far from an instant success, it suffered from poor uptake and multiple set backs after its launch. Key commentators such as Colville-Andersen questioned the overall design of the scheme and the utility of the electronic smart bikes in particular. Here other PSS design pathways were posited such as simply copying the decade old OV-Fiets system from Dutch railways instead of being seduced by over complicated smart technology. In common with many innovations, this suggests a singular pathway to successful PSS innovation is unlikely to emerge. Rather the process is underdetermined, fluid and thus shaped by actor interests.

Following its launch, the PSS also faced competition, e.g. from hotels providing bikes and Donkey Republic. The Copenhagen city bike scheme responded by among other things allowing access to its bicycles using smart phone apps. Actors associated with the PSS therefore had to identify and respond to alternate competitive offerings and broader changes in context as they arose. Indeed, while considerable effort may be needed to launch a PSS, it is likely that an equivalent if not more effort is required to maintain and sustain a PSS over time. This suggests that PSS are not some sort of 'fixed' product which is simply diffused but malleable service offerings, which can be (re)developed in response to changes in context.

Actor networks play a key role in the innovation process (*cf.* Jordan and O'Leary, 2011; Munoz and Lu, 2011) The city bike scheme (a PSS innovation) was developed by actors working in various arenas situated in formal (e.g. associated with the municipality) and informal (e.g. blog posts) institutional landscapes. Seen in this way, actors such as those identified in the case study make sense of the city and propose ways in which PSS might meet locally articulated city goals. In this regard, the case study revealed various circulations of knowledge associated with PSS innovation. First, the Copenhagen bike scheme has been

affected by PSS offerings developed in other times and places. For example, uptake of the previous Copenhagen city bike scheme among commuters, informed development of the new city bike service which was designed specifically to meet the needs of this group. Second, a city bike service which uses a smart bike has now been established in Stravanger, Norway. Indeed, the actor network associated with cycling in Copenhagen has a track record of mobilising innovations developed in the city. Here actors involved argued that urban innovations do not provide blueprints that can be simply extracted, transferred to and applied in another place at another time. Rather concepts, design principles which embody ideas associated with successful innovations can be transferred to stimulate and guide urban cycling innovation elsewhere.

Clearly PSS innovation does not proceed in a vacuum. Actors draw on various sources and bring various bits of information and meaning into the process, e.g. knowledge of city bike schemes in other cities. Knowledge flows between industrial sectors as part of PSS innovation have been investigated (cf. Cook et al., 2006; Cook et al., 2012). However, the case study shows that PSS innovation is not only shaped by sector interactions but those between *places*. Concepts, forms and practices associated with cities and PSS may flow from other places and into innovation episodes in a particular locale. Concepts, forms and practices developed in particular locales such as Copenhagen may shape debates and play a key role in constructing the relations that constitute sustainable and smart city initiatives and PSS.

Practically, this suggests that 'fixing' PSS solutions in best practice narratives that highlight universal definitions, designs and methods as well as the problems that such solutions may resolve, should be avoided. Instead an innovation is needed which recognises that meanings and characteristics of PSS are locally constructed perhaps along with sustainable and smart city initiatives. Since sustainability does not fall evenly across space (Castree, 2006), the meaning of PSS is likely to vary between places and even across places at the neighbourhood level (Massey, 2005). Thus appropriate institutional environments are needed to enable actors to consider the meaning of PSS, their nature and characteristics and to identify plans for implementation in a particular locale. In no way should this be taken to mean that anything goes. Rather, knowledge needs to be sought from multiple sources to explore the multi-scalar environmental and social impacts of PSS. For example, smart bicycles forming a part of PSS may increase demand for Information Communication Technologies (ICT) with significant upstream and downstream environmental and social impacts.

These insights highlight a further tension in PSS literature. On the one hand, the case study emphasizes the complex and contingent nature of PSS innovation as well as the role of context in such processes. On the other, PSS research (cf. Tukker, 2015) emphasizes the need for concepts, typologies and methods which may be universally applied. In their purest form these two views respectively suggest:

- 1) Extreme localism and thus a need to reinvent the PSS in every time and place where it is applied.
- 2) Context (time and place) has little impact on PSS development.

However, rather than resolve this tension a productive way forward may lie in the co-evolution of universal concepts, typologies and methods and locally contingent processes and geographical contexts through which they are implemented. Seen this way, PSS innovation may be understood as a form of meso-level praxis in which the meaning of PSS and pathways to implementation are made by various

groups of actors in particular situations. Universal concepts are needed to prompt and assist in such endeavours. However, narratives of the origins of PSS concepts, their typologies and their methods are also needed to enable actors (at other times, in other places) to determine their applicability.

Such co-evolutionary dynamics have been extensively explored in design studies. Dorst and Cross (2001) show that creative design concepts (innovations) are developed through an iterative process, in which design problems and solutions co-evolve. Seen in this way, PSS innovation involves exploring two conceptual spaces: a problem space and a decision space, with developments in each one informing the other. Such co-evolutionary dynamics has been observed in design meetings (Wiltschnig et al., 2013). Design solutions are posited by participants in response to requirements that define the design problem. Following evaluation in light of requirements, design solutions are modified. But interesting, so too are the requirements, in light of a novel solution attempt. Empirical evidence suggests that in commercial settings team leaders guide this process. As design ideas are generated, team leaders modify requirements and thus the problem space. This then stimulates other team members to generate further design ideas. Thus design does not necessarily involve creative leaps between problem and solution in the mind of leading designers. Multiple participants engaged in the iterative construction of a bridge between design problem and solutions *ibid*.

Thus a clear role in co-evolutionary PSS innovation can be assigned to knowledge of these and other urban innovations developed in other times and places. While such processes may be complex and a capacity for control absent, there is likely to be a capacity to act in pursuit of better outcomes. Further research is needed to address this issue, including:

- To identify arenas in city institutional landscapes, both formal and informal, in which multiple actors can come together to develop PSS for their city to meet among others, locally articulated needs and requirements.
- To identify ways in which PSS concepts and methods extracted from PSS innovations elsewhere can be effectively and efficiently introduced to this process to enable legitimate decision making. This may involve the development of narratives which articulate how PSS concepts were extracted and transferred to the meeting; understanding the context in which a PSS was successfully developed elsewhere.
- To identify ways to purposively mediate co-evolutionary PSS development processes. In commercial settings the role of the team leader in modifying the design problem is crucial. A similar role needs to be assigned in PSS processes involving multiple actors from both the private and public sectors. Urban planners may be well placed to manage such collective sense making and build bridges between both problems and solutions in particular.

Crucially though, institutional landscapes should promote democratically legitimate governance – ones in which diverse stories can be told and the voices of a wide range of actors, including those beyond the traditional nexus, can be heard and make a difference are needed. To this end, further research is required to unpack PSS innovation in various contexts. Users are notably absent from the case study presented above. Here users should not be reduced to a list of variables, which may chart optimal paths through the city but reveal little about what it means to experience these. Rather nuanced understandings of how users *encounter* PSS in the city are needed to shape and guide PSS innovation. A workable toolbox needs to be created to support such activity. Rich descriptions

of how PSS have been constructed in innovation episodes elsewhere should be included to help enable effective deliberation.

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