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Design for system innovations and transitions: a conceptual framework integrating insights from sustainablity science and theories of system innovations and transitions

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ABSTRACT

It is increasingly acknowledged that, in order to achieve sustainability, there is an urgent need for radical and transformative restructuring of socio-technical systems that meet our needs. These transformations are referred to as system innovations for sustainability or transitions. Transitions and system innovations cover not only product and process innovations but also changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle and management of firms and have significant implications for design and innovation activity aiming to contribute to the societal endeavour of achieving sustainability. Even though theory on system innovations and transitions is now extensive, it provided explanations regarding how companies and design and innovation activities fit into the big and long-term picture of system innovations and transitions only to a certain extent. In addition, there have not been many efforts in the design for sustainability field to learn from the theories of transitions and system innovations. In this paper, we make an initial theoretical contribution into the design and innovation for sustainability field by integrating relevant insights from sustainability science and system innovations and transitions theories. The result of this integration is a proposal for a prescriptive conceptual framework which explains how wider-scale systemic changes can be addressed at smaller elements of socio-technical systems specifically focussing on the design and innovation level within companies.

1. Introduction

As the discourse of sustainability has matured over the past twenty years, our understanding of the concept has evolved from being an idealized, generalized and static property of individual (system) elements to contextual and dynamic properties of systems themselves (Clayton and Radcliffe, 1996; Faber et al., 2005). This dynamic conceptualization of sustainability assumes that changes will occur over time and space both internally in systems themselves and externally beyond the boundaries of the systems, thus, posits sustainability as a 'moving target' (Hjorth and Bagheri, 2006, p. 76). Internal and external forces influencing change over the environment and all associated sub-systems including society and the economy continuously alter the conditions of sustainability. Since sustainability is a moving target, it needs to be planned through process-based, multi-scale and systemic approaches, which are guided by targets/visions, instead of traditional goal-based optimization approaches (Bagheri and Hjorth, 2007). Since sustainability is a dynamic system property, it cannot be established at the level of individual elements but at the level of systems they are part of.

It is increasingly acknowledged that, in order to achieve sustainability, there is an urgent need for radical and transformative restructuring of socio-technical systems that meet our needs (Ryan, 2013). These transformations cover institutional, social/cultural, organizational as well as technological change (Loorbach, 2010); that is, they need to take place at societal level. The process of societal transformation which needs to take place to achieve sustainability is defined as transitions to sustainable socio-technical systems or system innovations for sustainability. Transitions and system innovations are conceptualised as multi-phase, multi-level dynamic processes which take place over long periods of time and result in mainstream practices becoming outdated and being replaced by a set of new practices (e.g., Berkhout, 2002; Geels,

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2005a; Kemp and Rotmans, 2005; Loorbach, 2010). Transitions and system innovations cover not only product and process innovations but also changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle and management of firms.

Transitions and systems innovations for sustainability are observed and analysed at the level of socio-technical systems and have implications for design and innovation activity aiming to contribute to the societal endevour of achieveing sustainability. This poses a seemingly paradoxical challenge. On one hand, design and innovation efforts are concentrated at the elemental level of individual technologies, products, services, infrastructure, buildings and organization; the level where sustanability is an irrelevant goal. Design and innovation efforts focussing on individual products/services are not transformational and result in only incremental improvements (see Brezet, 1997 for a typology of product development approaches compared to their sustainability gains). On the other hand, the new elements of the new socio-technical systems and cultural meanings associated with these will be ideated and realised through design and inovation efforts. To address the paradoxical challenge mentioned and there is a need for adopting systemic approaches in design and innovation for sustainability (Gaziulusoy, 2015).

Businesses are increasingly directing their attention to addressing sustainability problems with references to the socio-technical systems relevant to their provisions. This evolution in business thinking can be observed, for example, by looking at the communication from the World Business Council for Sustainable Development (WBCSD). WBCSD is an organisation established and led by its corporate members and has a declared aim of galvanising the global business community to create a sustainable future. WBCSD initially promoted product innovation and efficiency as a strategy to address environmental problems (WBCSD, 2000). Later, the WBCSD adopted a more sophisticated perspective acknowledging that sustainability risks are systemic mega-risks that pose unprecedented challenges to companies and government alike (WBCSD, 2004). In 2010, it proposed a vision for 2050 and a pathway that emphasised the need for a new agenda for business and a requirement for system innovation and transformation, with a warning that the window of opportunity might be closing (WBCSD, 2010). Indeed, companies are accepted to be essential actors in this transformation and will have important roles in developing the artefacts and technologies of the new systems (Charter et al., 2008).

Nevertheless, although the importance of design-led innovation for business competitiveness has been well acknowledged (Brown, 2008; Design Council, 2007), sustainability discourse either ignored design or perceived it as part of the problem (Spangenberg et al., 2010). Transitions and system innovations for sustainability field has not been an exception. Even though theory on system innovations and transitions is now extensive, it provided explanations regarding how companies and design and innovation activities fit into the big and long-term picture of system innovations and transitions only to a certain extent. Recent contributions cover the business perspective, design perspective and consumer perspective through cases, examples, and some models (e.g. Tukker et al., 2008; Loorbach et al., 2010) without an integrating overview taking place. The disinterest has been mutual and, except for few recent studies (Ceschin, 2014; Gaziulusoy, 2010; Gaziulusoy et al., 2013; Joore and Brezet, in press), there has not been many efforts in the design for sustainability field to learn from the theories of transitions and system innovations. In a recent work, the first author of this article concluded that, although there are several approaches, tools/methods targeting different phases of the design and innovation for sustainability processes, none of these sufficiently take into account the dynamic relationships between socio-technical systems and the design-oriented innovations emerging within these socio-technical systems (Gaziulusoy, 2015).

In the same article, Gaziulusoy (2015) highlighted that there has not been a rigorous integration of sustainability science into the theory or practice of design and innovation for sustainability and that, as a result, claims about sustainability of products, services and organisations remain unclear and unconvincing. As an emerging transdiscipline, sustainability science itself is in the making and has been defined as a science of design (Miller, 2011). Sustainability science has complex adaptive systems theory as its main tenet and focuses on the dynamic interactions within complex social-ecological systems (Jerneck et al., 2010; Walker et al., 2004). This is both contrary and complementary to theories of system innovations and transitions for sustainability, which also adopt complex adaptive systems theory as a main tenet, but are primarily based on sociological theories of co-evolutionary innovation (Geels, 2005a; Loorbach, 2010). As a result of focussing on social-ecological interactions, sustainability science does not explicitly address socio-technical transformations with implications on production-consumption systems. In addition, sustainability science has little concrete analysis of sociological characteristics of actors and requires operationalisation for application in the social domain (Geels, 2010). On the other hand, by focussing on socio-technical systems, system innovations and transitions theories do not explicitly address the implications of socio-technical transformations on ecological systems. These two paradigms have been competing until recently despite having complementary foci. Nevertheless, a recent inquiry about the future of sustainability science undertaken by researchers from both groups suggested a more integrative research agenda between these two paradigms of transformative systemic change toward theoretically and empirically rich solutions-orientation (Miller et al., 2014). Implications of such integration is not only promising for these complementary fields, but also for other knowledge areas which currently do not feed from a solid knowledge basis on systemic transformations. Design and innovation for sustainability is one of these fields.

Concluding from this problematization, in this paper, we therefore aim to make an initial theoretical contribution into the design and innovation for sustainability field by integrating relevant insights from sustainability science and system innovations and transitions theories. The result of this integration is a proposal for a prescriptive conceptual framework which explains how wider-scale systemic changes can be addressed at smaller elements of socio-technical systems specifically focussing on the design and innovation level within companies. Design and innovation in this paper refers to any innovation activity resulting in the generation of new products within socio-technical systems. The term product is used in its broadest sense and covers end-user products as well as services, experiences and larger artefacts such as infrastructure and buildings.

The following section presents a summary of relevant literature and key insights upon which the conceptual framework is established. Third section presents the conceptual framework and the article is finalised with concluding remarks.

2. Theoretical underpinnings: insights from the literature

2.1. Complex systems and co-evolutionary change

Providing an overarching and all encompassing definition of complex systems is not possible but literature provides insights into the characteristics of these systems. Among the main characteristics of complex systems are unpredictable behaviour, large numbers of components with many dynamic interactions among

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them, decentralised decision-making and irreducibility (Casti, 1986). Complex systems cannot be fragmented without losing their identities and purposefulness (Hjorth and Bagheri, 2006; Linstone, 1999). Funtowicz and Ravetz (1994) classify complex systems as ordinary and emergent. They argue that ordinary complex systems tend to remain in a dynamic stability until the system is overwhelmed by perturbations. Examples of such perturbations include direct assaults to ecosystems like fire or alien invading species. In emerging complex systems, on the other hand, there is continuous novelty and some of their elements possess individuality, intention, purpose, foresight and values. Complex systems interact with their environment and change in response to a change; that is, they are resilient and therefore, can tolerate certain levels of stress or degradation (Clayton and Radcliffe, 1996). In addition to irreducibility, emergent behaviour, and resilience, the other characteristics of complex systems are self-organisation, continuous change, sensitivity to initial conditions, learning, irreducible uncertainty, and contextuality (Cilliers, 1998; Gallopín et al., 2001; Manson, 2001; Cooke-Davies et al., 2007). Complex systems in general are hierarchic or have multiple-levels and each element is a subsystem and each system is part of a bigger system; that is, they are nested (Casti, 1986; Gallopín et al., 2001; Holling, 2001; Gallopín, 2004). Hierarchical structures have adaptive significance (Simon, 1974). This adaptive significance is not due to a top-down authoritative control but rather due to the formation of semi-autonomous levels which interact with each other and pass on material and/or information to the higher and slower levels (Holling, 2001).

These characteristics have certain implications for analysing and intervening in complex systems. First, emergent behaviour, sensitivity to initial conditions and learning which takes place by system components imply that complex systems are time-dependent. This time-dependency is two-fold; both history of the system and the particular moment the analysis is undertaken are relevant to analysis. Second, since context is important to understand complex systems, and there are multiple-levels in a system, an analysis should include more than one level as well as the different perspectives present in the system (Gallopín et al., 2001; Gallopín, 2004). For an effective analysis of a complex system, the analyst needs to oversee the (sub)system being analysed from a vantage point. This vantage point should be at a higher or preferably meta-level to identify a context specific perspective while still acknowledging the interconnections between the (subsystem) being analysed and the rest (Espinosa et al., 2008). Third, it is not possible to study complex systems meaningfully by breaking them into their components. At times when there is a need to define system boundaries, this should be done acknowledging how the part under study relates to the rest of the system. Finally, it is impossible for an analyst to understand a complex system totally and correctly. Therefore, analysing and intervening in complex systems, require making decisions under varying levels of uncertainty.

Because complex systems can only tolerate certain levels of stress or degradation, sustainability of a complex system can only be achieved if the adaptive capacity of it is not destroyed. The subsystems of a system should be able to adapt to changes which occur both in the other subsystems, and as a result, in the entire system. That is, the subsystems must co-evolve to render sustainability possible. The term co-evolution was first coined in evolutionary biology to explain the mutual evolutionary processes of plants and butterflies (Ehrlich and Raven, 1964). Even though the term first emerged in the area of evolutionary biology, it spread in other, especially interdisciplinary, domains studying interactions between natural and human-made systems (Norgaard, 1984, 1995; Rammel et al., 2007; Winder et al., 2005). Some of the domains which use the co-evolutionary approach to explain, analyse and manage interacting natural and social systems include technology studies, organisational science, environmental and resource management, ecological economics and policy studies (Rammel et al., 2007; Kallis, 2007a).

It is important here to note that, despite many similarities between biological evolution and social, cultural, technological and economic change, there are differences as well (Rammel and Van Den Bergh, 2003; Kallis, 2007b). In the wider context of sustainable development, co-evolutionary change does not necessarily happen on a reactionary basis as generally happens in ecosystems. Rather, in socio-economic or socio-technical levels, it can also be deliberately aimed at both the individual and collective levels by system components in accordance with the conditions influencing the system (Holling, 2001; Cairns Jr, 2007; Kemp et al., 2007a). Co-evolution is reflexive and refers to the mutual change of all system components. During this mutual change, one component may or may not dictate a change over other(s).

2.2. *Operational time-frame for sustainability interventions*

When considering sustainability, selection of a temporal frame of analysis becomes an important issue since, as discussed in the previous section, the systems of concern are time-dependent. These systems change over time and their interdependent components have different paces of change. These components can be regarded as operational contexts within which sustainability is tried to be achieved. The change speed of one operational context influences the change speed of others. Strategising for sustainability requires a long-term future orientation. Long term, however, is not a static, predetermined time span to be applied to the whole of systems. Rather, it is determined in line with the nominal temporal (and also spatial) scales of the operational contexts whose sustainability is of concern (Costanza and Patten, 1995). For cities, for example, the nominal life span can be accepted to be 1000 years or more. However, for a human being, the nominal life span, and hence the ‘long term’ in which sustainability is monitored and assessed will be around 70 years.

When the sustainability of a complex system is of concern, there is a continuum of hierarchically interdependent operational contexts of varying sizes to which the concept of sustainability can be applied. In Fig. 1, Operational Context 1 (e.g. a city) subsumes Operational Context 2 (e.g. a suburb in that city) which subsumes Operational Context 3 (e.g. a street in that suburb) and so on in a nested systemic structure. There is a time delay between changes taking place in larger operational contexts and impacts of these changes being observed by and responded to in smaller operational contexts. The changes that occur in smaller operational contexts create feed-back loops which influence larger operational contexts, again with time delays. According to the position of the operational context of focus in this nested hierarchy, the length of ‘long term’ should change; as the operational context widens, the length of strategic outlook should extend in order to cover subsumed operational contexts and to connect them both spatially and temporally (Gaziulusoy and Boyle, 2008). Nevertheless, this is not a one-way linear relationship; while strategising at higher-order operational contexts requires longer and wider scales to cover lower-order contexts, lower-order contexts are externally bound by this larger scale no matter what their internal scale is (Holling, 2001). As an illustrative example, climate and vegetation can be considered. Climatic cycles are much longer than vegetation cycles. Successive generations of the same type of vegetation are dependent on annual rainfall and temperature. In accordance with the resilience of vegetation, variations in rainfall or temperature between years are tolerable to some extent. But as climatic change affects the rainfall or temperature over the long term, first, some

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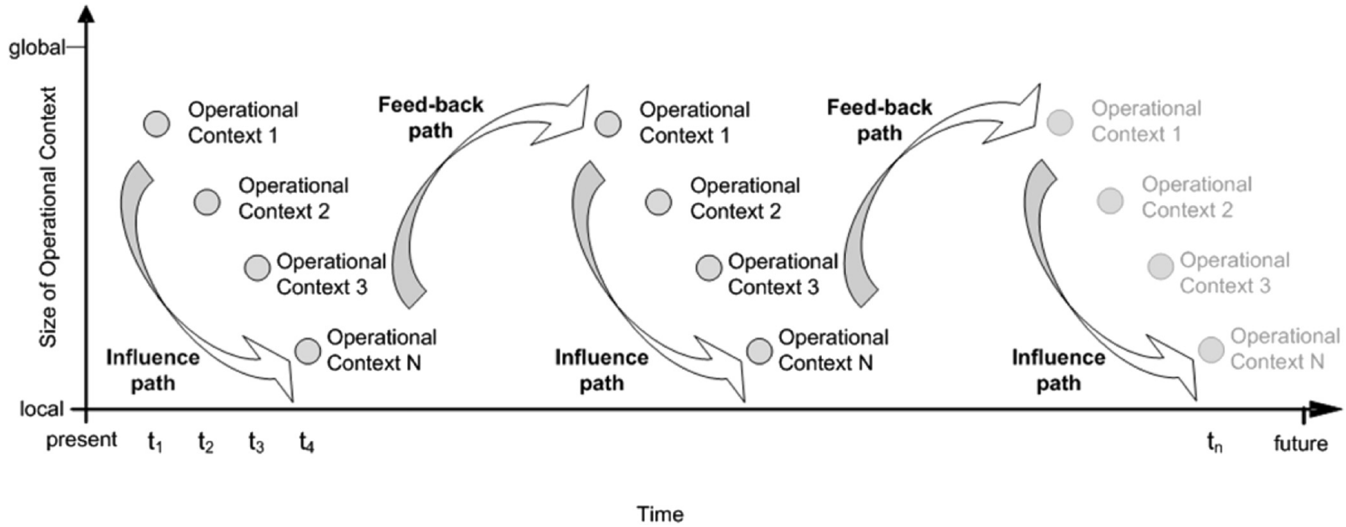

Fig. 1. Temporal and spatial scale versus size of the operational context.

characteristics of the vegetation and then the type of vegetation will need to change. This also applies to human–nature interactions, as the previous example could easily be adapted, for example, to agriculture-climate or technology-resource cases. Therefore, lower-order operational contexts should be aware of issues and scales of higher-order operational contexts, first, to guarantee their success and, second, to guarantee sustainability of higher-order contexts.

2.3. Co-evolving contexts of change in socio-technical systems

The findings presented in Sections 2.1 and 2.2 confirm the need for analysing the dynamics of co-evolutionary influence patterns relevant to design and innovation activity within the socio-technical system to be able to influence system innovation for sustainability at design and innovation level. In general, society and technology shape each other on an ongoing and bilateral basis (Geels, 2005a, 2005b); i.e. they co-evolve. Institutional and social/cultural changes generally take place before and, consequently, influence organisational and technological changes (Freeman, 1992). In general, institutional and social/cultural changes are more fundamental and powerful than organisational and technological changes for radical transformations in socio-technical systems (van den Hoed, 2007). For example, science and research policy determines the direction of investment and thus influences technological change along that direction. Similarly, international laws and agreements determine the characteristics of international trade unions. Societal norms and values determine, to a large extent, how social organisation is structured.

Even though it is reasonable to state that institutional arrangements and social/cultural structures determine the direction of change in organisational and technological components in general, there are many exceptions to this. An example is infrastructure as the technological foundation supporting society. Infrastructure lasts for a long time, most of the times longer than a century and in some cases for several centuries (e.g. Paris' sewerage system dates back to 1370 (Sewers of Paris, 2001)). As a result, many technological and social activities, as well as development of policies particularly those related to public health or transport, need to take the characteristics and capacity of the infrastructure into consideration. In addition to such exceptions, even in the non-exceptional cases where institutional and social/cultural changes come before and influence organisational and technological changes, since change is continuous, in return, organisational and technological changes influence institutional and social/cultural changes. Therefore, it can be said that, chronologically there is a 'semi-hierarchy' of influence patterns; the term 'semi-hierarchy' is used to indicate that there is no strict rule about which comes first in the institutional-social/cultural and organisational-technological couples. Fig. 2 shows some of the different elements of socio-technical system influencing change on a co-evolutionary basis. These elements are grouped under four types of socio-technical system component: institutional, social/cultural, organisational and technological. For example, user/consumer is a small-scale, social/cultural-type element while infrastructure is a large-scale, technological-type element. The circular arrows in the figure indicate that the change is continuous and dynamic, and, every element influences each other.

Despite the hardship associated with analysing the dynamics between different types of the socio-technical system components, there are easily observable patterns between different scales of them. Complexity increases as the scale becomes larger. Consequently, as the scale gets larger, managing change becomes harder and the pace of change gets slower. Also, smaller scales of one type of socio-technical system component are hierarchically dependent on larger scales of the same type. For example, products are determined by the relevant technological regimes and the technological regimes are determined by the technology system. Similarly, change in the large scale of a particular type of socio-technical system component is likely to require change in smaller scales of the same type. Nevertheless, smaller scale socio-technical system components may or may not be able to induce/influence change in the larger scales of the system depending on their agency; i.e. the ability to act and influence change over the course of events (Giddens, 1984). Strategic implementation of agency is considered to be pivotal in transformation processes and individual agency within empowering networks can contribute into transformation at systemic levels (Westley, 2002; Westley et al., 2013).

2.4. Design perspective: levels of innovation for sustainability

Brezet (1997) defined four levels of design innovation for sustainability (Fig. 3). The first level is product improvement. Product improvements are focused on reducing single environmental impacts for existing products. Examples include end-of-pipe measures taken to mitigate contamination or retrofitting existing

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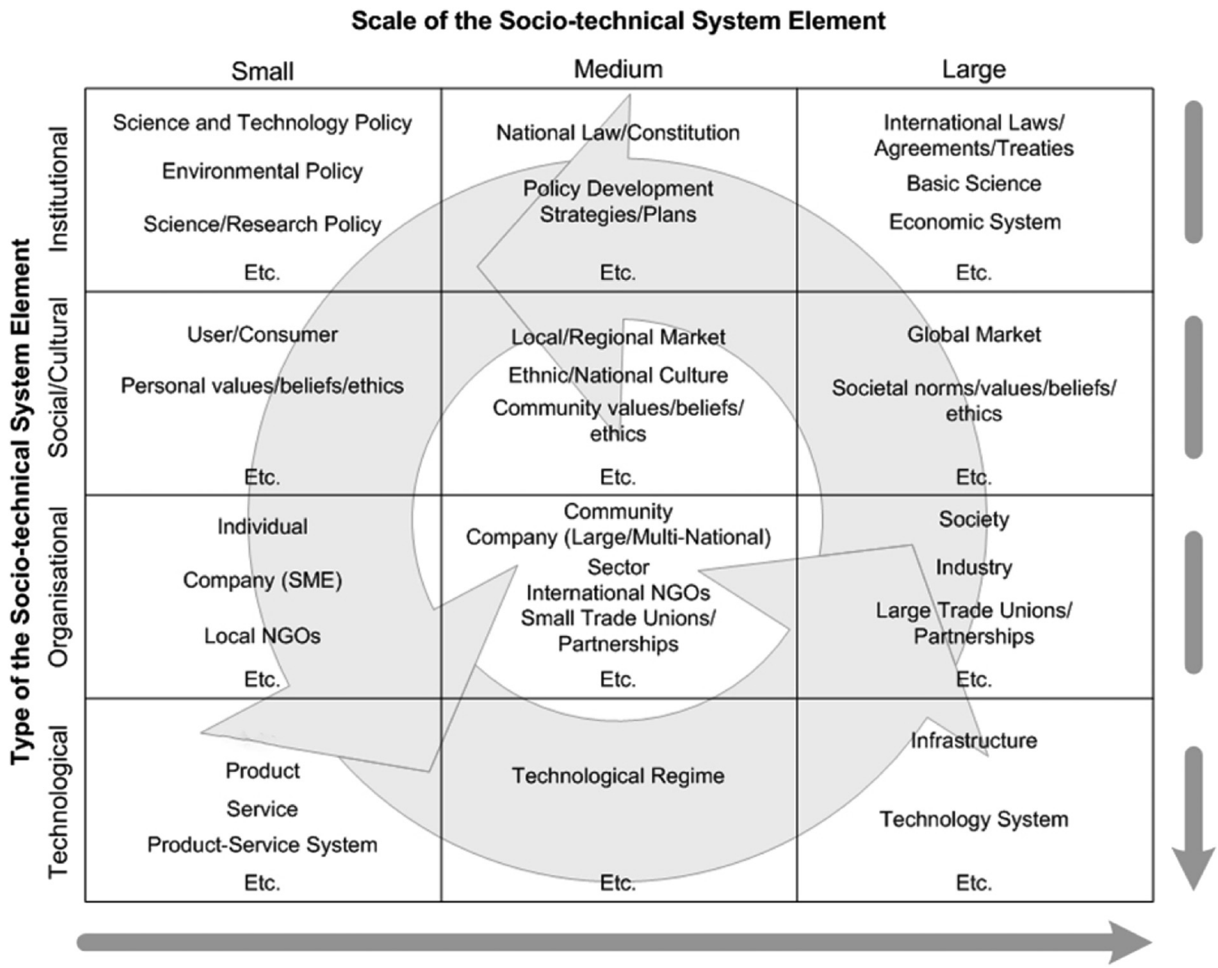

Fig. 2. Co-evolutionary dynamics within the socio-technical system.

infrastructure to improve environmental performance. For instance the contamination caused by a washing machine can be reduced by installing a filter at water outlet or energy efficiency of a building can be increased by installing insulation. The second level is product redesign. In product redesign, the product concept remains almost intact but the product is fully redeveloped with an environmental life-cycle perspective. The examples include new washing machines or new buildings with superior overall

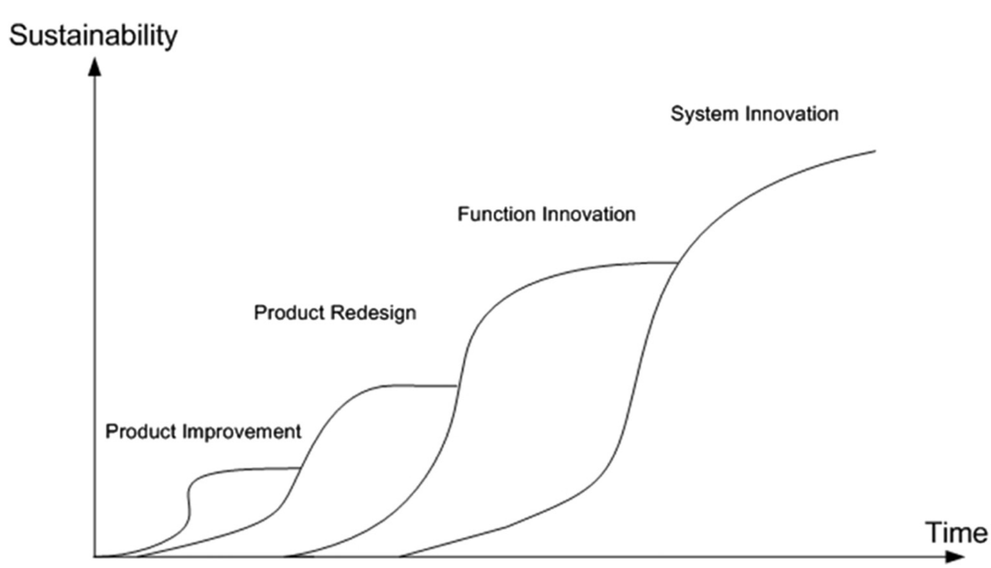

Fig. 3. Levels of design innovation for sustainability (based on Brezet (1997)).

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environmental performance. The first and second levels are where most of the efforts are focused in companies at the moment, driven mainly by regulatory push/push mechanisms (Dunphy et al., 2007; Greenstone, 2003). These first two levels focus on products and are performed within the realm of established technologies and social uptake of established technologies. The third level is function innovation. At this level, the innovation is not limited to existing product concepts but related to how the function is achieved. This level generally constitutes a transition from artefact focus to system focus. Product-service systems fall under this category. Several examples include systems designed for urban mobility encouraging use of alternative modes of different transport options —public transport, cycling, walking-over personal automobiles, providing solar energy solutions for a fixed fee over extended periods of time and online platforms which enable sharing of personal cars, tools and bicycles. The fourth and final level of innovation defined by Brezet (1997) is system innovation. At this level, the whole socio-technical system complete with its artefacts, structure, economic models, socio-cultural values set and institutional framework is replaced by a new system. The historical examples of system innovations include shifting to automobiles from horse and carriage and steam ships from sailing ships (Geels, 2005). In the context of sustainability, currently there are system innovations and transitions unfolding mostly focussing on decarbonisation of energy systems, housing sector and cities (Eames et al., 2013; Kemp et al., 2007b). There is a need for system innovations in all provisional systems supporting urban life including mobility, food and housing.

System innovations and transitions require long-term planning (i.e. 50 years or more) due to the complexity embedded both in natural and social systems, the dynamic nature of sustainability requirements and the need for structural transformations. The time frames required for system innovations are far beyond the ones usually used by companies for planning (Jansen, 2003). In addition, product/service development cycles are getting shorter as the global competition increases and lean product/service development practices become more widespread. Nevertheless, it is proven that as the complexity and innovative content of products increase, the development cycles become longer (Griffin, 1997a, 1997b). In cases of radical innovation, the technological and market uncertainties require longer learning periods, and therefore, more time needs to be invested (Herrmann et al., 2007). Case studies (e.g. Lynn et al., 1996; Veryzer Jr., 1998; Abetti, 2000) have shown that for radical innovations, time-to-market cycles as long as and sometimes longer than ten years is common. In addition, recent case studies suggest (some) companies are moving beyond optimizing performance and starting to be proactively involved in broader social change processes by rethinking and restucturing their existing business (Loorbach and Wijsman, 2013). This is an indication that there is an emerging trend of adoption and implementation of agency by companies strategically in the context of system innovations and transitions. It is also discussed in the literature that companies should acknowledge the long-term visions of the society during their strategy development (Bagheri and Hjorth, 2007) which then will guide the design and innovation decisions (Hallstedt et al., 2013).

3. The conceptual framework: integrating theoretical insights towards a practice-relevant model for design and innovation

3.1. Combining levels of innovation, co-evolutionary dynamics and time-frame

In order to link the activities of design and innovation teams to system level innovations two particular challenges need to be addressed: The first challenge stems from the complexity associated with different socio-technical contexts within which simultanaous transformations are anticipated to occur during system innovations and transitions. The second challenge relates to the time-frames traditionally used by design and innovation teams which are relatively short compared to time-frames system innovations and transitions take place. In this section, based on insights from the literature review, these two challenges are addressed by developing a systemic and time-phased model.

Fig. 4 shows the socio-technical contexts of change required to be intervened at each level of innovation. Towards the upper levels of innovation for sustainability, the complexity of the problem increases because the context of change required widens. At the first two levels, a company is a sufficient entity for analysis and action. However, towards upper levels the change requires the collaboration of many stakeholders, some of which are not recognised as stakeholders currently. For system innovation to take place there is a need for change at institutional level, i.e. at the very fundamentals of society including norms, values, socio-cultural practices, and the underlying assumptions of the economic system, as well as organisational and technological change. As a result, in planning for system innovation for sustainability, companies and design and innovation teams face a challenge which is not comparable in scale to any previous challenges the industry has faced. On one hand and in the short term, companies have to design/redesign products to meet immediate business priorities like decreasing the cost and time-to-market while assuring quality, market appeal, competitiveness, and compliance to ever-toughening legislation and standards. On the other hand, in the medium and long term, in addition to the generic and short-term business goals, they should develop new technologies and organisational models in order not to become redundant through the processes of system innovations and transitions. So, their challenge is to remain competitive within current markets but also innovate in an adaptive manner to remain competitive throughout system innovations and transitions which will create markets with entirely new expectations and rules. This is referred to as the requirement of running 'shadow-track' strategies (Van Bakel et al., 2007). Running shadow-track strategies require mediating the time-frames required for system innovation with those used by companies and design and innovation teams.

Referring back to the discussion about the operational time frames, as the operational context widens, the length of planning should extend in order to cover subsumed operational contexts and to connect them both spatially and temporally. In Section 2.3, it was

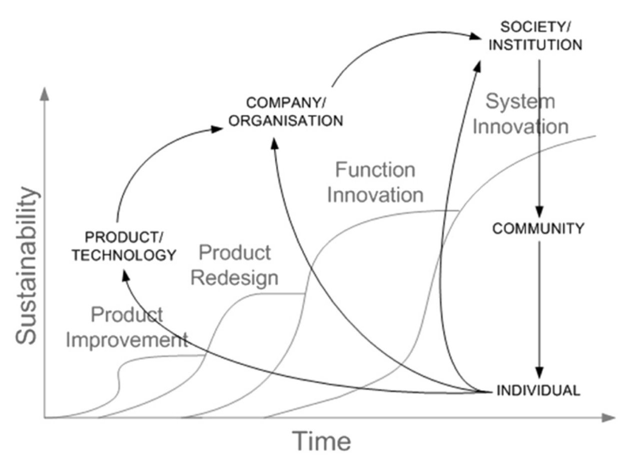

Fig. 4. The contexts of change in relation to levels of design innovation for sustainability.

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stated that social and institutional innovations will influence organizational and technological innovations and then will be influenced by new organizational structures and technologies in a recurring manner. Therefore, based on a systemic hierarchy, society is the widest operational context relevant to system level innovation followed by the company and the design and innovation team. Fig. 5 temporally and spatially positions types of innovation relevant for different operational contexts and relevant types of innovation based on the operational time frame model (Fig. 1). According to this positioning, institutional and social/cultural innovations should be subjected to the longest planning period followed by organizational and technological innovations. There will be feedback paths established from smaller-scale, shorter-term innovations informing both each other and innovations taking place at longer time spans and in wider operational contexts as the implementation progresses.

Fig. 6 combines the levels of innovation (Fig. 3) and the different scales of socio-technical system components (Fig. 2) in order to link system innovation to the activities of design and innovation teams. Since innovation is systemic, design and innovation activity has to be considered in the context of the company. Therefore, design and innovation function needs to be systemically positioned in the company, and the company needs to be systemically positioned in the society. In order to achieve this, the time frames applicable to the three operational contexts (i.e. society, company and design/innovation) and the mechanisms of aligning the activities of design and innovation teams to the transformation which needs to take place in the wider society to achieve sustainability needs to be clarified.

As shown in Fig. 6, the planning periods applicable to the levels of innovation can be defined as operational in the short term, strategic in the medium term and visionary in the long term. The short term used here covers ten years which is the longest business planning period for most companies. It is acknowledged that there are indeed shorter periods that businesses need to make decisions and take action within, such as daily, monthly or annual periods.

The strategic period should shape the operational period through the setting of goals at the organisational (company) level. Individual companies have very limited ability to influence change at the larger components of the socio-technical system, i.e. institutional, social/cultural, especially in the short-term. Nevertheless, it should be emphasised once again that companies are part of society and thus, even though they fall into small/medium scale within the socio-technical system, their strategic goals should not be contradictory to visions of society. On the contrary, their strategic goals should be aligned with the meta-goals desired at societal level to achieve sustainability. In order to achieve this alignment the planning periods applicable to companies (operational and strategic) need to be linked to the long-term planning period; theoretically, at the end of the long-term planning period the whole socio-technical system should have been transformed. This is not conceived as a linear and one-way process but instead a reflexive one; through implementation of strategic agency, it is expected that companies and design and innovation teams will influence societal visions, thus being proactive in contributing into steering system innovations and transitions.

3.2. Social function fulfilment, system innovation and product/service development

To operationalise the model presented in previous section and make it relevant for design and innovation practice the concept of 'social function' is useful as a boundary object as it is used both in system innovations and transitions theory and in design theory and practice. In system innovation theory, socio-technical systems are defined by the social function fulfilled by them (Geels, 2004); such as housing, mobility and energy. In planning for system innovation for sustainability, focussing on social function fulfilment broadens the thinking which was previously limited to material and technical aspects of cultural, behavioural and organisational domains of innovation, and therefore, provides more leverage points to influence the system change (Ryan, 2008).

Innovating to find alternative ways of fulfilling a social function is not a novel concept for design and innovation teams. Indeed, this is one of the main strategies applied by product/service designers in new product/service development. However, social function fulfilment, as currently understood from the perspective of product design/development, corresponds to the third level of innovation for sustainability (see Section 2.4). Therefore, it does not consider social/cultural and institutional innovations in product/service development although these types of innovations are essential to achieve innovation at system level.

Fig. 7 is a model to describe social function fulfilment from the perspective of product/service development with a systemic understanding. The model conceptualises social function fulfilment in the wider context of the socio-technical system. As stated before, a

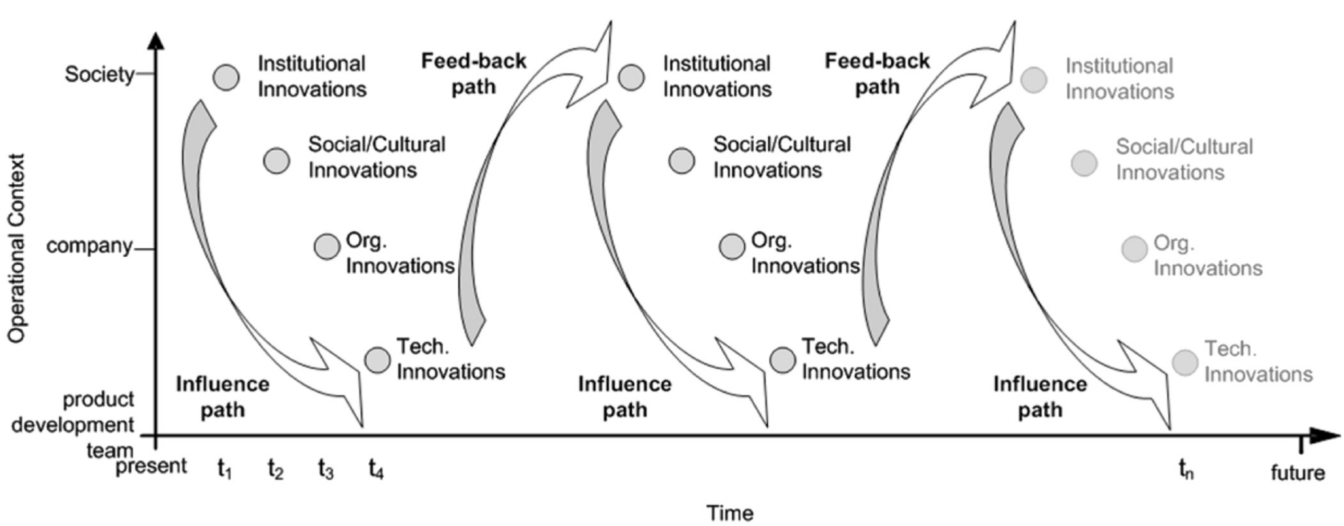

Fig. 5. Temporal and spatial positioning of different types of innovations relevant to system innovations and transitions for sustainability.

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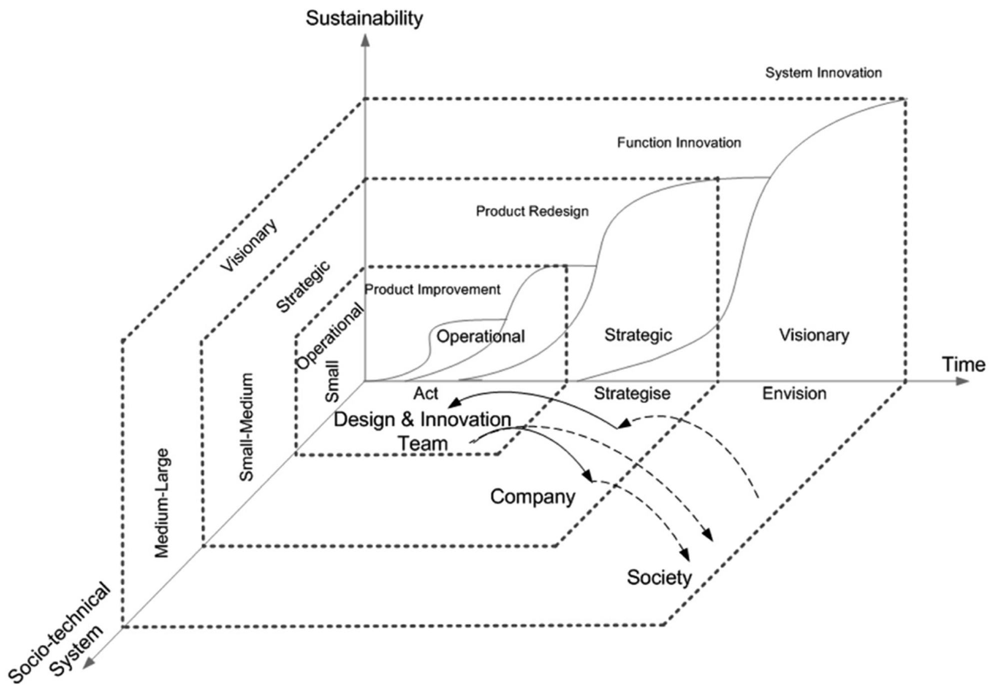

Fig. 6. A model to link design and innovation activity to system level innovation.

socio-technical system has institutional, social/cultural, organisational and technological components. Social function cannot solely be described technologically but needs to be referenced to the other components of the socio-technical system as well (Scholl, 2008). Fulfilling a social function requires consideration of several -institutional, social/cultural, organisational as well as technological-variables simultaneously. These variables include materials, production techniques, infrastructure, culture, social norms/values, cognitive/physical abilities of the user and legislation/regulation which govern the production and use of a product/service. These variables all together determine the conditions and limits of fulfilling that social function within the socio-technical system of concern. In this systemic approach to conceptualising social function fulfilment, these variables are co-dependent. Each of them is subject to change during the systemic transformation towards sustainability. Therefore, they need to be acknowledged

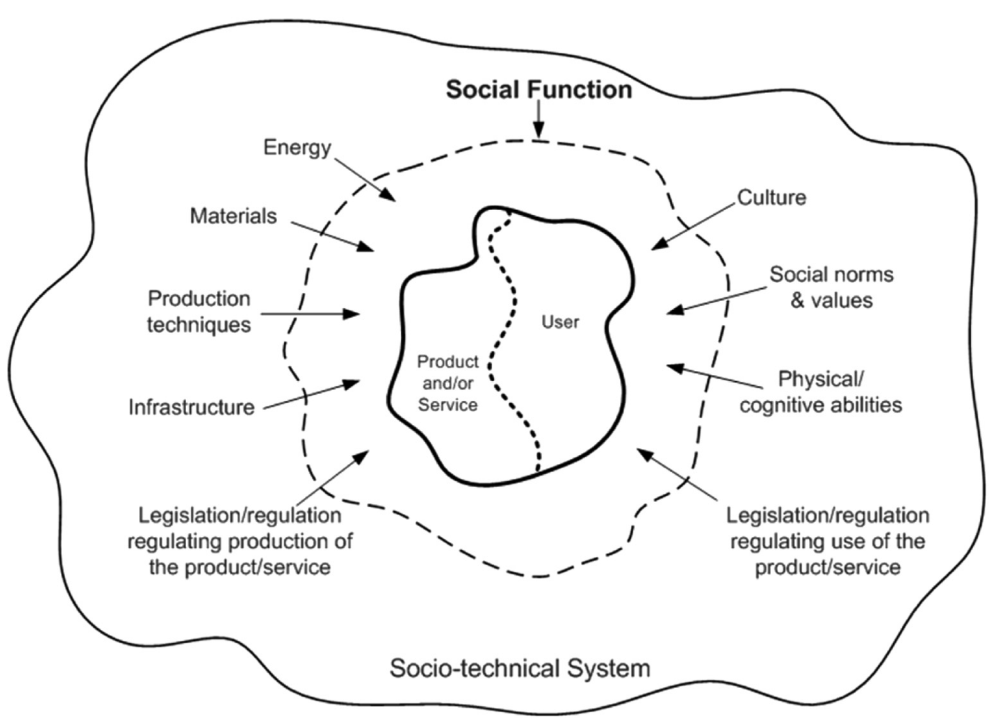

Fig. 7. A model for social function fulfilment in product/service development.

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individually yet considered simultaneously in system innovation as complementary to each other. It should be noted that the size of the physical variables (materials, infrastructure) may vary independently of the social function since a function can be met in multiple ways some of which may be more material intensive than the others.

System innovation should enable fulfilment of the same social function in the future through a combination of innovations in institutional, social/cultural, organisational as well as technological contexts of the socio-technical system. From the perspective of design and innovation teams this means adopting a proactive and systemic approach in design and development of the products/services by taking both physical and non-physical variables, which can be influenced at the product/service development phase, into consideration. Fig. 8 provides a model to explain system innovation at product/service development. According to this model, if in developing alternatives to fulfil a particular social function, the physical (e.g. materials, infrastructure, and production techniques) and non-physical (e.g. regulations, social norms and values, cognitive abilities of the user(s)) variables are considered and leveraged simultaneously, system level innovation can be influenced through activities and decisions of the design and innovation teams. If institutional, social/cultural, organisational and technological determinants of a social function are considered simultaneously, neither the capacity and characteristics of present technologies nor the expectations of present market and user becomes a focal point around which innovation will shape. Instead, the focal point becomes the social function to be fulfilled. This way, possible combinations of physical and non-physical variables together enabling that function to be fulfilled can be conceived. As a result, design and innovation teams can have a proactive role to play in much wider and longer-term changes which need to happen at institutional and social/cultural levels.

4. Concluding remarks

There is a need for development of theoretical insights and practical approaches to align design for sustainability practices taking place at micro- and meso-levels of socio-technical systems, i.e. design and innovation teams and companies, with the systemic changes that are unfolding within the wider society. As an initial contribution, in this paper we presented a conceptual framework.

The conceptual framework is developed by integrating theories from sustainability science, system innovations and transitions theories and design perspective on system innovations. It is prescriptive; i.e. it does not explain existing practice in companies and design and innovation teams but provides a normative framework on how practice should and could happen in the context of unfolding system innovations and transitions. The key messages of the conceptual framework for companies and design and innovation teams include adopting a systemic and long-term perspective and interpreting insights emerging from this perspective strategically with references to shorter time frames they have to operate. A practice-relevant implication of this message is that the conceptual framework is not a pack-and-go solution for an individual company to immediately adopt and start using on its own. The conceptual framework should be considered with references to the ‘new role’ companies have to play in the context of system innovations and transitions as proactive change agents (Loorbach and Wijsman, 2013). This role involves strategic envisioning, tactical networking, operational innovation and reflexive monitoring and evaluation. It would be naïve to argue that playing this new role is an easy task for companies or assume that any company can or would be willing to play this role. For one, the unexamined assumptions of mainstream and still dominant literature on business and innovation focus on incremental interventions which can be achieved within single companies and in short time frames (Parrish, 2010). This is in alignment with the short-comings of a neo-liberal economic system that offers only marginal incentives for companies to adopt innovation perspectives beyond current market demands. Nevertheless, as demonstrated in Section 1, currently there is an emerging observable shift in collective business mind-set towards adopting systemic and long-term perspectives. Also, findings of Boons and Lüdeke-Freund (2013) indicate that the process of sustainable innovation involves establishing interorganisational networks including other companies but also wider stakeholders. Evidences of such learning-oriented networking can be found in the globally increasing number of consortiums bringing together universities, industry and government on projects focussing on system innovations and transitions (InContext, n.d.; Retrofit UK, 2050, n.d.; VP 2040, n.d.). It can also be argued that several sustainability transitions have moved from predevelopment to taking-off and several from taking-off to acceleration phase. In line with these developments in literature and practice, the conceptual framework presented in this paper provides heuristics for companies to become strategic mediators between macro-level systemic societal change processes and micro-level design and innovation activies that take place within their organisation.

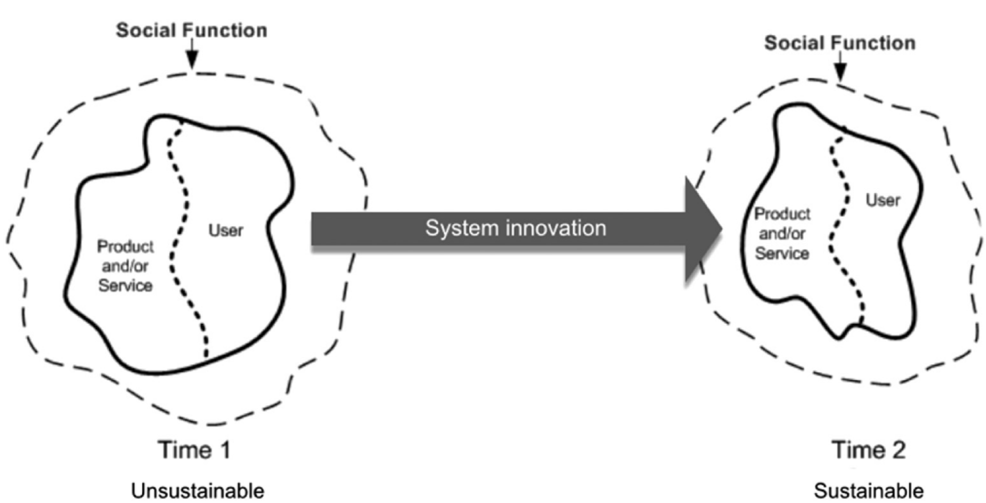

Fig. 8. System innovation at product/service development level.

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