Journal of Cleaner Production 97 (2015) 92–105

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A Multilevel Design Model: the mutual relationship between product-service system development and societal change processes

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ARTICLE INFO

Article history:
Received 17 June 2013
Received in revised form
1 June 2014
Accepted 13 June 2014
Available online 21 June 2014

Keywords:
Innovation
Multilevel design process
Transition management
Sustainable transport
Electric vehicle
Product-service system

ABSTRACT

Change actors like designers play a strategic role in innovation and transition processes towards a sustainable society. They act at all levels of society and need help to find their way through increasingly interrelated innovation systems. To support their efforts, there is a need for a design supportive model that (1) can provide insight into the development of new products and product-service systems, as well as in developments that occur in society as a whole; (2) can provide insight into the relationship between functional problems on the one hand, and more abstract societal problems on the other; (3) describe design processes, change processes and transition processes in a consistent, mutually comparable manner that can potentially be used to structure future design-based initiatives. In this paper a Multilevel Design Model (MDM) is discussed, combining two specific functionalities: First a cyclic iterative design approach that may be generic enough to describe both the design of physical artefacts and the design of product-service systems, as well as the way that complex societal change processes may occur. Second a hierarchical systems approach, where on each aggregation level a similar description of the design, change or transition process is applied. The MDM is discussed by means of a simulated case example in the area sustainable transportation and electric transport, explaining the model may indeed be useful to describe and potentially explain some of the dilemmas that occur during the course of complex design processes.

1. Introduction

1.1. The widening scope of design and the changing role of the designer

In 1959, the International Council of Societies of Industrial Design defined an industrial designer as 'one who is qualified by training, technical knowledge, experience and visual sensibility to determine the materials, mechanisms, shape, colour, surface finishes and decoration of objects which are reproduced in quantity by industrial processes' (ICSID, 1959). The current definition describes design as 'a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanization of technologies and the crucial factor of cultural and economic exchange' (ICSID, 2010). It further explains that the aim of design is to enhance global sustainability and environmental protection, give benefits and freedom to the entire human community, individual and collective, and to support cultural diversity despite the globalization of the world. Today, the important role designers can have in innovation processes towards a sustainable society is fully endorsed at the political level as well, such as in the report 'Design for Growth & Prosperity' of the European Design Leadership Board (Thomson and Koskinen, 2012).

When comparing both ICSID definitions, it shows that the working area of the designer has changed considerably during the last 50 years, shifting from tangible objects to combined product-service systems to the development of complex systems. The role of the designer is becoming more and more entangled with the roles of other actors (where an 'actor' can be defined as either a person, a company or an organization). That means that designers are evolving from being the individual authors of objects or buildings, to being the facilitators of change among large groups of people (Thackara, 2006). The design arena is getting more and more diffuse, and designers are more and more becoming 'solution providers', utilizing their specific qualities, like their capacity to

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http://dx.doi.org/10.1016/j.jclepro.2014.06.043

produce visions of what is possible, and to imagine and visualize things that do not exist but could potentially exist (Meroni, 2007).

One could say this broadening perspective on the role of the designers is nothing new indeed. In 1969 Nobel Prize winner Herbert Simon already concluded that 'everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artefacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare for a state' (Simon, 1969, 111). Victor Papanek, one of the forerunners of the sustainable design movement, made a similar statement when he emphasized that 'all men are designers. All that we do, almost all the time, is design, for design is basic to all human activity. The planning and patterning of any act toward a desired, foreseeable end constitutes a design process' (Papanek, 1985).

However, although all men may be designers, it is important to realize that each kind of design requires a specific expertise. A graphic designer is different than a fashion designer, and a landscape designer needs different skills compared to a game designer. For instance industrial design is a specialism in itself, where specialists are trained to develop new products or physical artefacts that originate from a human action or a machine process. Likewise, the design of product-service systems – defined as a mix of products and services that have been designed and combined so that they are jointly capable of fulfilling final customer needs (Halen et al., 2005) – is a specific design specialism with its own unique tools, methods and necessary expertise. The process of designing a product, for instance a new vehicle, is something rather different than designing a transport service. Let alone the development of a completely new regional transport system including innovative infrastructure and adapted government regulations. The new vehicle may be part of the transport service and be included in the regional transport system, but the system boundary of each of these designs varies considerably.

1.2. The need for a suitable design supportive model

Jørgensen (2012) demonstrates that change actors like designers act at all levels of society and need help – in terms of mapping – in their navigation through the innovation systems, full of conflicting visions, institutions and competing innovations. The question is how designers can take these mutual and complex relationships into account during their design activities. And what systematic approach – in terms of a first categorization of multiple design cycles at different levels of societal activity – could potentially help designers to effectively handle this complex process, in terms of their position and role with respect to the different design phases and activity levels? To answer this question, there is a need for a design supportive model with specific features. First, the model should provide insight into the development of a new physical product or a new product-service system, as well as in developments that occur in society as a whole. Second, the model should provide insight into the relationship between functional and operational problems and objectives on the one hand, and more abstract socio-technical and societal problems and objectives on the other. Third, the model should offer insight into these change processes in such a way that the design processes, change processes or transition processes are described in a consistent, mutually comparable manner that can potentially be used to structure future design-based initiatives.

To find out if current models can offer these specific features, a broad range of existing design or innovation models, in various fields of expertise, have been taken into account. The first group of models originates from the field of Industrial Design Engineering, among others: the Basic Design Cycle (Roozenburg and Eekels, 1998), the Innovation Cycle (Buijs and Valkenburg, 2005), the Double Diamond approach (Design Council, 2007), the VIP approach (Hekkert and Van Dijk, 2011), and several other methods and models (Cross, 2008; Curedale, 2012; Curedale, 2013). Here it is mainly about prescriptive models, especially targeting the development of one new tangible product or a new product-service system that solves a specific functional or operational problem. Even when the wider societal context is taken into account, this is mainly restricted to determine the influence that this context may have on the single product that is being developed, and not to pursue actual changes in the context itself.

The second group of models originates from the field of sustainable product-service system development, among others other the Kathalys method (Brezet et al., 2001b), the Solution Oriented Partnership approach (Manzini et al., 2004; Jegou and Joore, 2004), the Method for System Design for Sustainability (Vezzoli et al., 2014) and several other methods and models (Halen et al., 2005; Tukker and Tischner, 2006; Jegou and Manzini, 2008; Crul et al., 2009; Diehl, 2010; Ceschin, 2012; Vezzoli and Manzini, 2008; Meroni and Sangiorgi, 2011; Reinders et al., 2012), These models are often aimed at the development of one new product-service system, within the context of the broader socio-technical or societal environment, but without the aim of actually changing this broader context. Compared to the previous group of models, the design scope of these models is extended to include the development of product-service systems, which is combined with a strong focus on the issue of sustainability.

The third group of models originates from the field of Systems Engineering, among others the Waterfall Model (Royce, 1970), the Spiral Model (Boehm, 1988), the V-Model (KBST, 2004; Cadle and Yeates, 2008), the Work Breakdown Structure approach (Haugan, 2001) and several methods and models (VDI, 1985; NASA, 1995; Hitchins, 2008; Van Hinte and Van Tooren, 2008). Models in this field of expertise are targeted at the realization of strictly defined, technical objectives. They are prescriptive models that work toward the development of one new technical system, including the underlying subsystems. To separate systems, subsystems and elements, a hierarchical structure based on various aggregation or system levels is used (Haugan, 2001).

The fourth group of models comes from the field of Sustainable System Innovation. These models focus on societal change processes, which are about gradual, continuous alterations, during which the character of society undergoes a certain level of change. During this process, the way that societal functions are being fulfilled change, and a shift is made from one socio-technical system to another. Some of the models used in this field are the Dynamic Multilevel Model (Geels, 2005), the Transition Management Cycle (Loorbach, 2010), the Backcasting approach (Quist et al., 2008) and the concept of Strategic Niche Management (Kemp et al., 1998; Raven et al., 2010). These are mainly descriptive models aimed at understanding socio-technical or societal developments, mostly from studying developments afterwards ('ex post') instead of influencing them in a certain direction ahead of time ('ex ante'). In this field of expertise, physical products and product-service systems are considered as limited building blocks of the whole system. Several models in this field of expertise apply a multilevel perspective, where developments take place on various system or aggregation levels.

Based on the study of existing models (Table 1), the conclusion can be drawn that no existing design or innovation model is

Table 1
Overview current design and innovation models compared to preferred model.

Field of expertise	Field of attention		
	1) Relationship between developments of physical artefacts and product-service systems – compared to changes in society	*2) Relationship between functional problems and objectives – compared to societal problems and objectives*	*3) How is the design/change/transition process described*
Industrial Design Engineering	Targeting development of one new physical product or artefact, within wider environmental context	Targeting operational problems and satisfying functional objectives	Prescriptive models, especially targeting the development of one new physical product or artefact
Sustainable Product-Service System Development	Targeting development of one new product-service system, within the context of the societal context	Aimed at limiting the negative ecological impact of products, within the broader socio-technical and societal context	Prescriptive models that work towards one new sustainable product-service system
Systems Engineering	Targeting development of one new technical system, including subsystems	Targeting realization of strictly defined, technical objectives	Prescriptive models which work up to one new technical system through various aggregation levels
Transition Management	Analysing change of the socio-technical and societal situation. Products are small building blocks of the whole	Targeting socio-technical or societal problems, operating from policy and political objectives	Descriptive and analytical process, aimed at understanding socio-technical or societal questions, especially from political perspective
Preferred Model	Model should provide insight into development of one new product or product-service system, in relation to developments that occur on the socio-technical and societal level, presented in a comparable manner	Model should provide insight into relationship between functional (product or service related) objectives and socio-technical and societal problems	Design and change processes are presented in a consistent, mutually comparable manner that can potentially be used to structure design-based initiatives.

sufficient to live up to the three demands that where formulated for the preferred model. Recent studies have aimed at combining the field of product-service system development and the area of sustainable system innovation and transition management, specifically (Vezzoli et al., 2008; Ceschin, 2012; Ceschin, 2013). These studies offer valuable steps to incorporate the two fields of expertise mentioned, and explain that organizations should not only focus on the development of new product-service systems, but also on the contextual conditions that may favour or hinder the societal embedding of the product-service system itself. However, when looking to the three demands mentioned in paragraph 1.2, specifically the third demand still needs further attention, explaining the demand for a model that may offer insight in such a way that design processes, change processes and transition processes are described in a consistent, mutually comparable manner.

To be able to fulfil this demand, two valuable concepts applied in current models have been used as a basis for an adapted design model. First, an iterative cyclic process to be applicable for both physical artefacts and product-service system design, as well as for the description of socio-technical and societal change processes. Second, a multilevel approach to distinguish between the development of physical artefacts and product-service systems in relationship to the changes that takes place within socio-technical or societal systems. Combining these two concepts leads to the Multilevel Design Model (Joore, 2010; Joore, 2012).

2. Multilevel Design Model

2.1. Introduction

The Multilevel Design Model (MDM) combines two specific features found in existing design and innovation models, which have currently not been combined before. First a cyclic iterative design approach that is generic enough to describe both the design process of new tangible products and new product-service systems, as well as to describe in a simplified manner the way that complex societal change processes may take place. Second, a hierarchical system approach, where on each system level a similar description of the design, change or transition process is being applied.

2.2. Description of the MDM – cyclic iterative design approach

The MDM is based on the description of a design or change process as a cyclic iterative process consisting of four steps or phases: (1) Reflection, (2) Analysis, (3) Synthesis and (4) Experience. These phases can be recognized in many processes and tools that use similar phases, though they may use different names (see Table 2).

The starting point for a design or problem solving process is based on a reflection (1) regarding the current situation. This can also be described as a 'problem' or a (negative) value judgement regarding a specific, existing situation. Another starting point could be the identification of an 'opportunity', which can be considered as a (positive) value judgement of a potential future situation. The positive or negative value judgement is the result of a reflection regarding an existing situation. This phase could also be called the discovery phase, after which a decision has to be made regarding the current situation. If the value judgement regarding the existing situation turns out to be positive, no change is needed and the design process can stop. If the judgement turns out to be negative, change is needed and the design process can continue.

This is followed by a phase where the problem is interpreted and a new desired situation is envisioned and defined in an abstract manner. This is called the analysis phase (2), where it is determined what the requirements of a new situation would be, though the new situation is not yet concretized in the form of a specific solution idea or concept. These requirements can be considered as an abstract description of a new desired situation, while not describing the concrete details of this new situation.

Next is the synthesis phase (3), focussing on concrete idea generation and development. During this step, new creative directions are being explored, resulting in a description of a new possible solution. This phase is often considered as the 'real' design phase, as new concepts and solutions are being generated, created, described and visualized. In product design, this is often done by means of drawing and sketching. In product-service design various other tools are available like the creation of solution maps, future scenario's and storyboards.

When the new concept or solution is simulated or realized in real life, a new situation with new characteristics can be

Table 2
MDM design phases compared to other design and innovation models.

MDM design phases	Basic design cycle (Roozenburg and Eekels, 1998)	Innovation cycle (Buijs and Valkenburg, 2005)	Double Diamond (Design Council, 2007)	Learning cycle (Kolb, 1973)	Creativity process (Wallas, 1926)	Transition management cycle (Loorbach, 2010)
(1) Reflection		Strategy Formulation	Discover	Reflective Observation	Preparation	Evaluating, monitoring, learning (reflexive)
(2) Analysis	Analysis → Criteria	Design Brief Formulation	Define	Abstract Conceptualization	Incubation	Problem structuring, organizing transition arena (strategic)
(3) Synthesis	Synthesis → Provisional Design	Product Development	Develop	Active Experimentation	Illumination	Develop coalitions, transition agenda's (tactical)
(4) Experience	Simulation → Expected Properties	Product Launch and Use	Deliver	Concrete Experience	Verification	Mobilizing actors, executing experiments (operational)
(5) Reflection	Evaluation → Value of the Design					

experienced. This experience phase (4) could be based on a model, a prototype, a simulation or on the final product or solution. Based on this, an evaluation can be made that can form the basis of a judgement regarding the value of the new solution, which brings us back to the reflection phase (1) again. If the value judgement turns out to be positive, the design is finished and the process stops. If it is unsatisfactory, a new design loop could be started again. Together this creates the cyclic iterative process as visualized in Fig. 1.

2.2.1. Comparison with other cyclic iterative design models

In the literature on design, other iterative models have been presented as well. For instance the British Design Council describes a four-phase design process, called the ‘Double Diamond (Design Council, 2007). Here the four design steps are called (1) Discover, (2) Define, (3) Develop and (4) Deliver. Unlike some of the other models presented in the Design Council's desk research, the Double Diamond places specific emphasis on the ‘discover’ phase as one of the most critical, which is also been referred to as the Fuzzy Front End of Design. This is the phase that describes the early stages of the innovation process where ideas form, be it often in an unstructured manner. Other design processes may leave out this phase. For instance this initial reflection or discovery phase is not part of the ‘Basic Design Cycle’ described by (Roozenburg and Eekels, 1998), as this cycle appears to start only after it has been determined what idea actually will be developed. The innovation cycle as described by (Buijs and Valkenburg, 2005) does include a reflection phase, which is described as the formulation of the strategic direction that the company wants to follow. This strategy forms the foundation for the formulation of a design brief, which is the start of the actual development process.

The design process is somewhat comparable to the four learning phases as described by Kolb (1973). His learning cycle includes the (1) Reflective Observation, where one watches others or develops specific observations about one's own Concrete Experience. Then there is (2) Abstract Conceptualization, where one is creating theories that may explain the previous observations. Third there is (3) Active Experimentation, where new problems are being solved and decisions are made based on the lessons learned previously. Then there is (4) Concrete Experience again, which may form the basis of a new learning cycle. Similar processes are involved in the design process and the learning process, where both learning and designing can be considered as a special kind of problem solving (Eekels, 2002, 623).

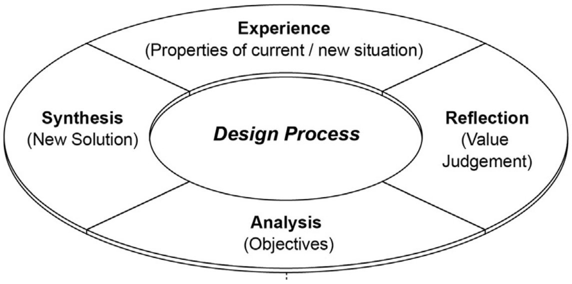

Fig. 1. Typical Design Cycle as applied in MDM.

Another analogy is the resemblance of the design process compared to the creativity process as described by Graham Wallas (1926) in his book ‘Art of Thought’. In his model, a four-stage process explains the way that creative insights and illuminations come about. Firstly (1) Preparation, during which someone's mind is fixed on the problem and explores the problem's dimensions. Then follows (2) Incubation, where the problem is processed in the unconscious mind, apparently without anything happening on the outside. Third is the (3) Intimation and Illumination phase, where one gets the impression that a solution is on its way, followed by a moment that the creative idea actually reaches ones conscious awareness. Sometimes this phase is divided in two separate parts. Then there is (4) Verification, during which the new idea is consciously verified, elaborated, and then applied in practice.

The basic design or change process that has now been described is simple and generic enough to offer insight into the development of physical artefects and product-service systems, as well as into the way that complex societal change processes take place. The four step cyclic iterative approach appears to provide this insight in a consistent, mutually comparable manner that can potentially be used to structure future design-based initiatives.

However, another aspect has been added to the MDM to enable it to explain the relationship between the development of a relatively small physical artefact or a product-service system, and the complex societal system that these are part of. To do this, the cyclic iterative approach was combined with the concept of a hierarchical multilevel approach.

2.3. Description of the MDM — hierarchical system levels

Based on an analysis of existing hierarchical models, specifically the V-Model for System Engineering (KBST, 2004; Cadle and Yeates, 2008) and the Dynamic Multilevel Model (Geels, 2005), the MDM is based on four aggregation or system levels. These are described as the product-technology system (indexed by P), the product-service system (indexed by Q), the socio-technical system (indexed by R) and the societal system (indexed by S).

Technological products form the basic level of the MDM. These can be defined as physical objects that originate from a human action or a machine process. As these objects are made up of technical components, the term ‘product-technology system’ is used. This refers to tangible, inextricably linked technical systems, physically present in place and time. With most of these artefacts, you could ‘drop them on your toes’. Product-technology systems generally fulfil one or more clearly distinguishable functions. A system dysfunction occurs as soon as one or more technical components are missing.

The second level of the multilevel design model is formed by product-service systems. A product-service system is built up of physical as well as organizational components, which form a united and cohesive whole that together fulfils a specific function, usually definable in time and place. The system fulfils one or more clearly defined functions that can no longer be performed if one of the technical or organizational components is missing. The product-service system can indeed be compatible with certain policy, legal, social, cultural or infrastructural elements, but these do not form an inextricable part of the product-service system (Joore, 2008a).

The third level of the multilevel design model is the socio-technical system. This can be defined as ‘a cluster of aligned elements, including artefacts, technology, knowledge, user practices and markets, regulation, cultural meaning, infrastructure, maintenance networks and supply networks, that together fulfil a specific societal function’(Geels, 2005). Changes that take place at this level are often referred to as a ‘system innovation’, which can be defined as ‘a large-scale transformation in the way societal functions are fulfilled. A change from one socio-technical system to another’ (Elzen et al., 2004, 19). At this level a large number of components are combined that are not necessarily formally related to each other. Several elements together form a joint system that fulfils a combination of functions that have a narrow, joint relationship with each other. Product-service systems, accompanying infrastructure, government legislation and cultural as well as social aspects may form a mutually interdependent whole. In contrast to the first two levels, the socio-technical system continues to function if one or more elements are missing, and elements may even assume each other's function.

The highest level of the multilevel design model has been defined as the societal system, being ‘the community of people living in a particular country or region and having shared customs, laws, and organizations’ (Oxford dictionaries). This is, just like the previous level, built up from a combination of material, organizational, policy, legal, social, cultural or infrastructural elements. Changes that take place at this level are often referred to as a ‘transition’, which can be considered as a gradual, continuous process of societal change, where the character of society (or of one of its complex subsystems) undergoes structural change. While the socio-technical system can more or less be defined and demarcated, at the societal system level a complete summary can no longer be made of those elements which do or do not make up the components of the system. It extends over several influence spheres and domains, where the boundary between these areas cannot easily be determined. Also the societal system does not fulfil one distinct function, but is made up of functions that are not necessarily related.

2.3.1. *Comparison with other hierarchical models*

The hierarchical distinction between different system levels can be found in several other models and methods. An overview of various hierarchical models and approaches is given in Table 3. For instance, Victor Papanek relates the development of a new product to the system in which it functions. As an example he discusses a relatively modest theme like ‘doing the dishes’ in light of the drinking water problem for the fast-growing world population: ‘The rethinking of ‘dishwashing’ as a system might make it easier to clean dishes, as well as solving one of the basic survival problems: water conservation (Papanek, 1985, 246). He emphasizes that problems are endless, and not enough breakthrough thinking is done. In this Papanek distinguishes between the ‘generic problem approach’ and the ‘specific problem approach’. The first is aimed at the broader system and the second at a concrete and defined situation. Also other experts in the area of sustainable product innovation have shifted their focus from the optimization of products to the fundamental change of complex systems (Weterings et al., 1997, 18; Brezet et al., 2001a, 11). Here the underlying objective is to achieve a ‘factor 4’ or ‘factor 10’ reduction (Von Weizsäcker et al., 1998) with regard to the ecological impact of these products and systems. The result is that, ‘moving from an initially narrow focus on the artefact itself, the field has expanded to cover the whole technical life cycle and the institutional infrastructure in which the artefacts are produced and employed’ (Ehrenfeld, 2001, 2008).

Coming from a totally different perspective, designers that deal with the development of ‘smart products’, based on the application of information and computer technology, realize the importance of the context in which a product functions. Andrews (2003, 213) distinguishes three innovation levels: First the immediate context, in which individual and product communicate directly with each other. Second the ecological context, in which various products communicate with each other. Third, the systemic context, where relationships exist within wider technological and social networks of products and people. Subsequently, nine possible configurations can be distinguished, from no individual to one individual to multiple individuals, and from no product to one product to multiple products. The most elaborate configuration consists of ‘multiple products – multiple users’ (Feijs and Kyffin, 2005, 73).

Table 3
MDM system levels compared to other design and innovation models.

MDM system levels	Design for the real world (Papanek, 1985)	Design for Sustainability (Brezet et al., 2001a)	Intelligent products (Andrews, 2003)	Systems Engineering (Haugan, 2001)	Transition Management (Geels, 2005)	Levels of discourse (Brown and Vergragt, 2007)	Means-end-chain (Roozenburg and Eekels, 1998)
S: Societal System		System Innovation	Rethinking Values	System	Transitions (landscape)	Preferences relative to social order	Values
R: Socio-Technical System	‘The Real Problem’	Function Innovation	Systemic Context	SubSystem	System innovations (socio-technical regime)	Dominant interpretive frame	Needs
Q: Product-Service System	‘General Case’	Function Redesign	Ecological Context	Element	Process innovations (niche)	Problem definition for particular technology society coupling	Functions Characteristics
P: Product-Technology System	‘Special Case’	Product Improve-ment	Immediate Context	Component	Product-innovations (niche)	Problem solving	Form

From a more technological perspective, the area of Systems Engineering focuses on the development of complex technological hardware and software systems like aeroplanes or computer programs. System engineers may distinguish systems, elements, subsystems, assemblies, components and parts. Especially the V-model (KBST, 2004; Cadle and Yeates, 2008), also known as VEE model, V-Diagram or V-Cycle, somewhat resembles the MDM. The top-most level reflects the total system, which is the wide end of the V. This is where the demands that the entire system must meet are formulated. At the underlying levels, the system is divided into subsystems (components, modules, units, elements, items), and each of these can again be divided into subsystems. At the lowest level it is about the smallest building blocks of the system, represented by the point of the V. In a software system these are the ‘ones and zeros’ of the software code, in a technical system these are the ‘nuts and bolts’ of the construction. Depending on the complexity of the system, more or fewer levels can be implemented. An essential difference between the MDM and the V-model used in Systems Engineering is the fact that socio-technical and societal issues are explicitly part of the MDM (Joore, 2008b; Joore and Wachter, 2009). Simply said, the height of the MDM is much higher than the Systems Engineering V-model.

A rather different field of expertise is the area of Transition Management. Here a distinction is made between transitions that take place on the landscape level, system innovations that take place on the level of the socio-technical regime, and process and product innovations, that may take place at the niche level. At the macro-level, also referred to as the ‘landscape’, changes take place in the areas of politics, culture, worldview and paradigms. The meso-level consists of several socio-technical systems or ‘regimes’. Such a regime can be defined as the composition of structures, knowledge, customs, technology, products, skills, procedures, needs of users, institutes and infrastructure (Hoogma et al., 2002, 19). The dynamic multilevel perspective explains that developments at various aggregation levels influence each other and exert ‘pressure’ on developments in the adjacent level. Apparently, innovations always start in ‘niches’ (Kemp et al., 1998) where small-scale changes take place. If experiments are conducted within these niches, one may speak of a ‘transition experiment’ (Kemp and Van Den Bosch, 2006), a ‘bounded socio-technical experiment’ (Vergragt and Brown, 2004), or a ‘societal innovation experiment’ (Van Sandick and Weterings, 2008). Such an experiment can be regarded as a small-scale real life ‘laboratory’, like a kind of prototype but then of a changed society. From this one can learn on a small-scale how a modified societal system can function. Successful innovations on niche level may influence the development of the socio-technical system through a ‘fit-stretch’ pattern (Hoogma, 2000). Initially a solution may ‘fit’ seamlessly into an existing system, which then ‘stretches’ itself. For instance, the first automobiles were considered as carriages without a horse, and that's exactly what they looked like (‘fit’). Later on, they acquire their own identity and in turn the new automobiles influence the way in which people move (‘stretch’). Developments in the niche are influenced by developments at the regime and landscape levels, for example in the form of legislation which can have a strong influence on the chance of success of certain products (Van Den Hoed, 2004).

In contrast to the multilevel perspective as used in the field of expertise of Transition Management, which may suggest that the transition towards a sustainable society may be directed with a more or less ‘managerial approach’, Jørgensen indicates three critical concerns aligned with the assumptions of the ‘Dutch school of transition studies’. They involve (1) a lack of navigation support for the actors —in our terms designers — in arena's full of conflicts on visions, problems and directions; (2) the fact that designers can be engaged at several levels in transition processes at the same time; and (3) the transparency of the co-development role of the involved academic approaches itself, which is at least not presented as an identifiable, subjective power in the change process. Therefore, more appropriately and specifically fitting the need of designers for self mapping and navigation through sustainable innovation processes, Jørgensen proposes the ‘Arenas of Development’ model that builds on actors-networks as drivers in dynamic changing spaces and boundaries, with multiple identities (Jørgensen, 2012).

Again another perspective is the area of ‘learning’ and ‘problem solving’. When analysing complex innovation processes, Brown and Vergragt (2007) focus on the ‘level of discourse’ of various actors and divide these into four levels. The most concrete is the ‘problem solving level’, aimed at solving specific problems within a well-defined framework. At the second level, it is about a ‘problem definition in relation to a specific technology—society coupling’. Here the broad outline of the problem is framed, but still within a previously determined reference framework or value system. The third level deals with the ‘dominant interpretation framework’. Here it is determined what is considered important and how and why data is interpreted and assessed. The fourth and highest level concerns the ‘worldview’ that one maintains. This is about the fundamental preferences related to the way society is structured. This level is based on the ultimate values that each actor maintains and relates to political, cultural and religious preferences, among others.

The hierarchical approach somewhat resembles the means-end chain that is often used by designers. Physical artefacts have specific characteristics that perform a specific function. The need to perform this function is derived from the underlying values of the user. Objectives and means form a chain, in which each element in the chain is an objective and a means, depending on the direction you're looking. Money is a means to buy a car, a car is a means to travel from A to B, travelling is a means to get to work, etcetera. The objectives to be achieved are located further and further away in time, and the limits of reasoning are reached when an objective can no longer be considered a means, but is valuable in itself. That is when the objective represents its own intrinsic value, in contrast to the instrumental value of objectives that are also considered to be means (Roozenburg and Eekels, 1998, 141). The means-end relationship can be regarded as a hierarchical relationship. From a bottom-up perspective, each design is then a means to achieve a higher objective. In a top-down approach, the starting point is at the objectives and it is a matter of determining the means to accomplish these objectives. The functioning of a product can be described as follows: Form → Characteristics → Function → Needs → Values. The design process follows this sequence in reverse. During this process, backwards reasoning is applied from Values → Needs → Function → Characteristics → Form. Reasoning from form to function can occur in a rather structured manner. However, reverse reasoning from function to form, which is applied in the design process, is a creative process that can at best be methodically stimulated, but never logically guaranteed.

2.4. Combined Multilevel Design Model

Combing the four system levels and the four design phases brings us to the combined Multilevel Design Model. The generic design cycle that forms the basis of the MDM (Reflection → Analysis → Synthesis → Experience) is combined with the four system levels (Product-Technology System, Product-Service System, Socio-Technical System, Societal System). Together this leads to the model as presented in Table 4. Basically, a

Table 4
Legend Multilevel Design Model – specific description.

Design phase	Experience initial situation (0)	Reflection (1)	Analysis (2)	Synthesis (3)	Experience new situation (4)
Symbol (see Figs. 2 and 3)	P0, Q0, R0, S0	P1, Q1, R1, S1	P2, Q2, R2, S2	P3, Q3, R3, S3	P4, Q4, R4, S4
General description	Starting position, characteristics of current (sub-) system	Value judgement problem definition, 'discover' phase.	Objectives for new (sub-) system, 'define' phase	Creation of new (sub-) system, 'develop' phase	Characteristics of new (sub-) system, 'deliver' phase
Societal System (S)	S0 – Properties of society	S1 – Value judgement regarding societal situation, definition of societal problem	S2 – Preferences regarding social order, based on worldview and values, resulting in objectives for ideal new societal situation	S3 – Vision development process, resulting in future vision for new societal situation	S4 – Living in society, executing societal experiment
Socio-Technical System (R)	R0 – Properties of current socio-technical system	R1 – Value judgement regarding socio-technical situation/system deficiency	R2 – Dominant interpretative framework, leading to objectives for new socio-technical system	R3 – System design process, leading to proposal for new socio-technical system	R4 – Experiencing new socio-technical system, e.g. by means of niche experiment
Product-Service System (Q)	Q0 – Properties of current product-service system	Q1 – Value judgement regarding functioning of product-service system, resulting in functional problem	Q2 – Determining functional demands and requirements to be met	Q3 – Design of a new product-service system	Q4 – Using and experiencing new product-service system
Product-Technology System (P)	P0 – Properties of current product-technology system	P1 – Value judgement regarding functioning of product-technology system, definition of operational problem	P2 – Target definition regarding new product and technology, leading to program of demands	P3 – Product design process, leading to (prototype of) new product-technology system	P4 – Simulation, testing, using and experiencing new product

similar process can be discerned at each level of aggregation. Of course it should be noted that this design or engineering approach is a simplification of reality. The higher the system level, the less seizable the process is. Although societal changes can certainly not be controlled in an engineering manner, the MDM could be helpful in determining in what phase of development a specific change process appears to be, and what could be the potential contribution that the designer could offer.

With regards to the visualization of the MDM, two variant have been developed. The first version of the MDM visualization emphasizes the V-shape aspect and has a more or less linear structure, presenting the design and change processes as going from 'left to right'. This is presented in Fig. 2. In this representation, a reverse arrow explains the iterative aspect of the MDM. The advantage of this way of visualizing is that most people find it more easy to understand a process that is presented in a more linear manner, although caution should be taken to emphasize that the 'step by step' approach that this figure presents is definitely a simplification of a complex reality.

The second version of the MDM emphasizes the cyclic iterative nature of the model more explicitly. See Fig. 3. Although the cyclic aspect of the model is better explained in this version, a kind of three dimensional perspective is needed to present both the hierachical system levels as well as the cyclic iterative process in one figure. Experience has shown that several people find it somewhat difficult to grasp the concept behind this three-dimensional

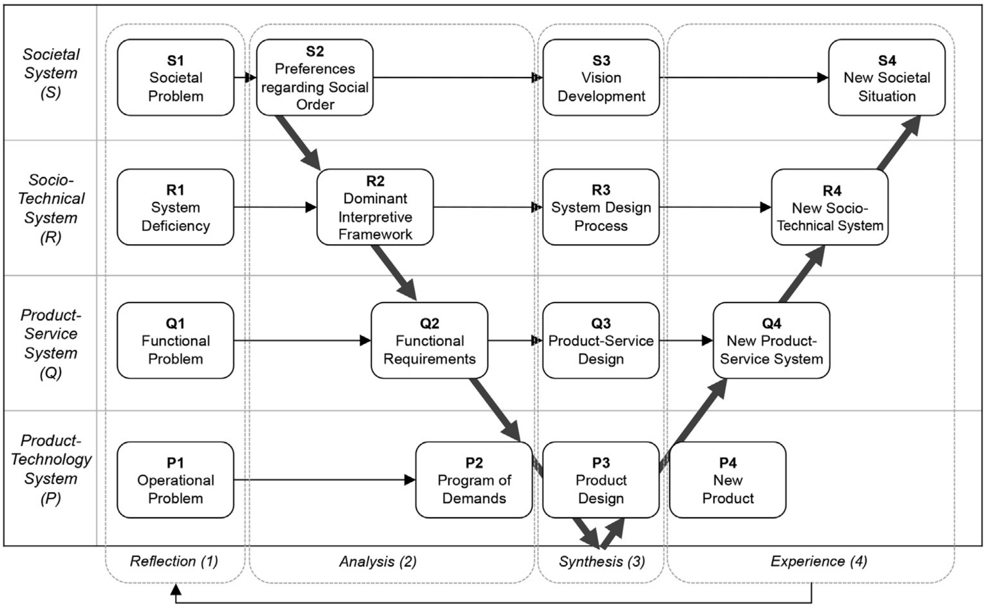

Fig. 2. Multilevel Design Model (Linear representation).

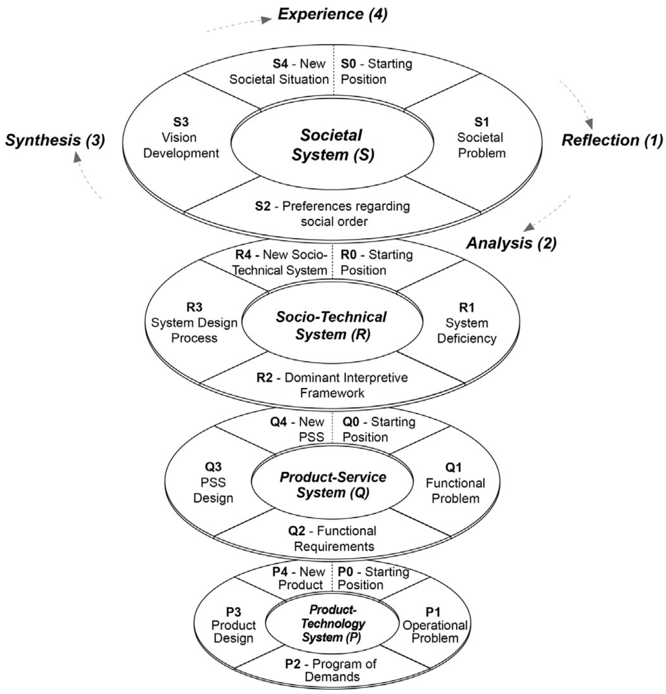

Fig. 3. Multilevel Design Model (Cyclic representation).

presentation of the MDM. Later on in this paper, a case analysis will be visualized using both versions of the MDM, presenting exactly identical information in two rather different visual representations (see Fig. 4 and 5).

3. Simulating the application of the Multilevel Design Model

3.1. Example — sustainable transportation

So does the new model offer the necessary insights? In paragraph 1.2 the need for a new design model, with three specific features, was explained. Based on these features, the Multilevel Design Model was discussed. The question is if the MDM indeed provides insight into the development of a new physical artefact or product-technology system, a new product-service system, as well as in developments that occur in society as a whole. The second question is if the MDM indeed provides insight into the relationship between functional and operational problems and objectives on the one hand, and more abstract socio-technical and societal problems and objectives on the other. The third question is if the MDM indeed offers insight into these change processes in such a way that the design processes, change processes or transition processes are described in a consistent, mutually comparable manner that can potentially be used to structure future design-based initiatives. The way that the MDM provides these insights will be explained by looking at a simulated example case in the area of sustainable transportation. The choice to use examples from this domain was made because the field of transport is complex enough to discuss the potential merits and demerits of the MDM. At the same time, the area of transportation is well known to most people, so no specific in depth expertise is needed to understand the examples in this field of expertise. The example is visually represented in Figs. 4 and 5.

With the description of the case, there are two options with regards to the order that the different phases or steps of the MDM are being presented. The first option is to discuss the design or change process on each system level separately. That would mean first discussing the development of new products in the

Fig. 4. MDM linear visualization — sustainable transport.

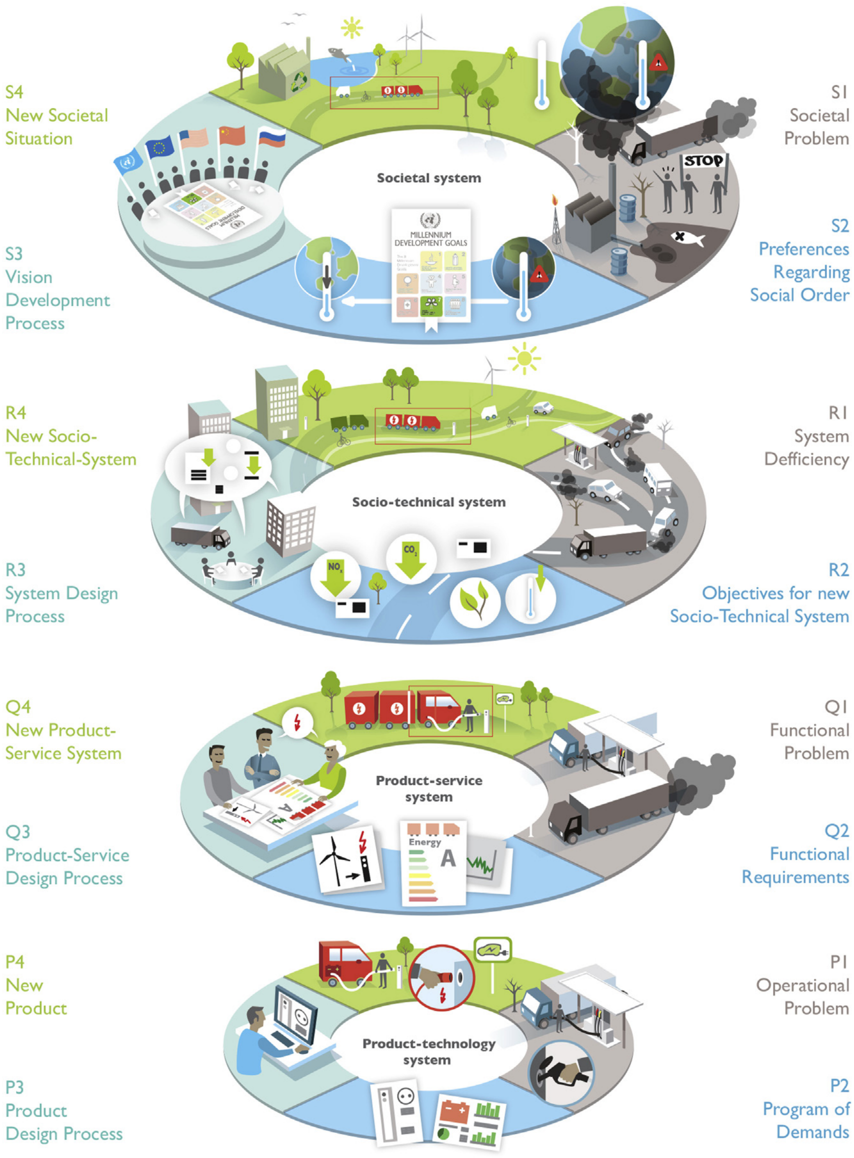

Fig. 5. MDM cyclic visualization – sustainable transport.

transportation area, going trough each of the four phases of the design cycle. Then discussing the development of new product-service systems, discussing each of the four phases again. Then the change processes on socio-technical level. And then the societal change processes. However, this approach would make it somewhat difficult to explain the mutual relationship between the developments on the various system levels. Therefore the case is presented by first looking at the reflection phase, while looking at all the system levels from the same perspective. Here it is being discussed how the reflection on each of the system levels is related to the reflection on the other levels. Then the analysis phase is being discussed, again comparing each of the system levels from the same – analysis – perspective. Then the synthesis phase is being discussed, and finally the experience phase is reviewed, each time comparing developments at the various system levels from a similar perspective. Thus, the mutual relationship between the developments at the various system levels will be discussed.

3.2. *Example of reflection phase*

In the reflection phase, it is about the consideration of the problem area. Traditionally, product designers focus on the product-technology level, creating new product and artefacts. That would mean that their problem analysis will also focus on this level, for instance focussing on the problem of energy consumption of transport vehicles. The problem definition could focus on the fact that trucks use a certain amount of gasoline per kilometre, and on the amount of CO_2 and NO_x that these vehicles expel. Distinguishing between the various system levels may help to determine who to involve during the design process. In most cases, one organization can be identified that delivers the product, for instance a vehicle production company. With regards to the customers, it will generally be about a limited group of users who are in direct contact with the vehicle.

When broadening the system boundaries of our reflection to the level of the product-service system, it is not so much about the energy consumption of one vehicle, but for instance about the energy consumption that is used when transporting certain objects over a specific distance. Here the reflection could discuss the overall efficiency of a specific transportation system, for instance focussing on the question how the load factors for freight transport could be improved. At this level, the amount of actors involved may be somewhat broader than on the product level. Often there may exist a more or less formal relationship between them, for example as consumer-supplier or as cooperating business partners, for instance in the case of a fleet owner that applies its vehicles to deliver a taxi or transportation service.

At the socio-technical level, the reflection could be looking at road transport as a whole, where transport vehicles, rental trucks, freight trains and other means of transport meet each other on public roads. They are joined there by buses, pedestrians and cyclists. Here the problem definition would not be so much about one vehicle or a specific transport service of one organization, but about the way that transportation in a certain region is organized. Perhaps there are huge traffic jams at certain times of the day, while during other time slots there is hardly any traffic at all. The resulting congestion may cause extra amounts of poisonous emissions, which could be avoided by spreading traffic more evenly over time. At the socio-technical level, agreements between involved actors are less tightly defined, although they can be formalized collectively, for example in the form of legislation, traffic rules, transport regulation, or collective standardization of vehicle elements. For instance, life would be very complicated if each new vehicles would need a totally different type of gasoline to be able to function properly.

At the societal level, it can be about traffic rules, the insurance and licenses that a company must have, the fuel stations, the price that is paid for that fuel, the availability and prize of parking places and the attitude of citizens towards the various forms of transportation. Problems may cross the boundaries of the transport system itself. For instance, noise pollution and toxic emissions as a consequence of road transport may affect the health of people, also when these people are not part of the transport system itself. The transport system can function perfectly, even when everybody living along highways becomes ill. This indicates that this problem is apparently located at the societal system level and can no longer be resolved within the boundaries of one delimited socio-technical system. Or, when looking at traffic jams in inner cities, the fact that all employees have to be at work exactly at the same time may be seen as a societal challenge, as spreading working hours somewhat more could greatly help in reducing traffic congestion during peak hours. At the societal level, the influence of the system extends to all sorts of actors that do not maintain any deliberate relationship with each other, but become implicitly related as developments touch several sectors of society.

3.3. *Example of analysis phase*

In the analysis phase, it is about the criteria that a desired new situation should meet. These criteria may differ, depending on the system scale. On the societal system level, it can be about rather abstract concepts, for instance with regards to the definition a smart, sustainable inclusive society (European Commission, 2010). These objectives and preferences are largely based on the actors worldview and values, and can be described as the preferences regarding social order. Here, political perspectives may play a role. For instance, where some actors may emphasize the importance of public transport for all, other actors may not be interested in public transport, but fiercely defend the right for every individual to own their own vehicle.

When looking at the socio-technical system level, the criteria one uses are based on the dominant interpretative framework, leading to objectives regarding the transport system as a whole. Here it can be about specifying the amount of traffic jams or accidents per year that are being considered as acceptable, or about figures specifying the maximum sound or pollution levels per year for a certain city neighbourhood.

At the product-service level the objectives can be about the determination of functional demands and requirements to be met, for instance regarding a specific transport system of one particular organization. Here the demands can be about bringing a specific amount of people or goods from location A to B, within a certain time frame, with a maximum amount of CO_2 or NO_x per travelled distance.

On the product-technology level, the demands can be about very concrete aspects like the size and quality of the tires, the material of the chassis and the type of engine being used. Of course the specification of these elements may influence the performance on the higher system levels, be it in a more indirect manner. For instance, the average energy use of a specific kind of vehicle may influence the overall amount of energy used in a certain product-service system, but only if that specific vehicle is being used. Choosing another vehicle may result in a slightly different outcome for the energy calculation, although the results will be more or less within the same order of magnitude.

With regards to the selection of design criteria, distinguishing between the various system levels may help to choose what adaptation strategy to follow with regards to the existing socio-technical situation. Simply said, two extreme approaches may be distinguished. On the one extreme, a new product or service can be developed so that it is perfectly adapted to the existing societal situation. In this case, a new vehicle or transport service will be totally adapted to the current traffic regulations. On the other extreme, one could decide not to bother about the current situation at all, and develop a completely new transport solution that would need traffic rules and new infrastructure. While the first approach (complete adaption to the current socio-technical system) seems to be the most obvious one to apply, this way of working may prevent the development of radical, out of the box transportation solutions. The other approach (not minding about the current socio-technical system at all) may result in the development of radical new transport solutions. However, this approach may also result in a situation in which it is necessary to adapt the current socio-technical system, even before the new product or product-service system can function at all. For instance when new infrastructure or new legal transport regulations are needed for the new transportation concept to function properly. While the first approach may carry the risk of very limited and incremental innovation, the second approach may carry the risk of getting stuck with a great new design that could take a very long time before it could ever be implemented.

3.4. *Example of synthesis phase*

With regards to the synthesis phase, it is about designing or creating the new solution. When this is aimed at the development of one new product-technology system or one new product-service system, this synthesis can be done by means of a drawing, a computer model or a storyboard. There are many synthesis tools available for this phase, as this is often regarded as the ‘real’ design phase, focussing on the creating of totally new concepts and ideas.

At the socio-technical level, the nature of the synthesis process may become more abstract and less tangible. Here it could be about the design of a combination of products, services, organizational, infrastructural and policy elements. Many different actors can be involved at this level, each with their own agenda. It may be important to include them in an early stage of the design process, as perhaps their effort will be an indispensable part of the proposed solution. However, it often will be unpredictable to determine beforehand which elements a certain new socio-technical system will consist of, and which actors will be necessary to create this new solution. With ‘a car’ one knows fairly well which components are necessary, but with a ‘transportation system’ this is less obvious.

At the societal system level the synthesis process could be aimed at the development of a future vision regarding a new societal situation. This could for instance include the development of new policy plans, where the secondary conditions and underlying objectives for new developments are outlined. Here the form of the design is more like developing a common thought framework, a shared vision or a common vocabulary. One could even wonder if it is still possible to talk about a real ‘design’ phase here at all. This does not mean that this level is not relevant, on the contrary. The ‘rules of the game’ are in fact determined at the societal level, serving as a basis for all other considerations.

Apparently, consciously distinguishing between the various system levels of the MDM may help to determine what specific expertise is needed during the synthesis phase of a project. For instance, while designing a new electric vehicle, expertise about engineering, materials, production processes, draft angles and other technological details is needed, e.g. (Gorter et al., 2011; Gorter et al., 2012). When developing a transport service, it isn't about the design of the physical artefact, but about business model generation and developing innovations in which the vehicle has become part of an overall ‘transport solution’. At a still higher level it can then be about the development of a future vision of the way mobility will develop in a wider sense during the next 10 years, and the way that policy measures may influence this development. It seems obvious that experts who are skilled in designing the technical details of a new vehicle, don't necessarily have the same qualities as experts that are skilled in the development of transport solutions or future visions aimed at what mobility will look like in the year 2020.

3.5. *Example of experience phase*

At the experience phase, it is about testing and encountering the properties of the new solution in practice. This may result in a description of the properties of the new solution, preferably done in an objective and neutral manner. This way, the reflection and value judgement regarding these properties can be separated from the experience itself.

When experiencing the properties of a new product-technology system, it is about testing a physical artefact that is meant to fulfil a clearly defined primary function. The preferred properties may be described with objective figures like size, weight and length of the product. In the case of a new vehicle, the function may be aimed at transporting people or things. As soon as certain technical components of the system are missing, the product ceases to function as such. For example with a flat tire or an engine that's out of order. The direct relationship with the vehicle as a product-technology system most often is limited to individual persons, such as the driver, passengers and the maintenance mechanic. Experiencing the properties of a new technological product may often be done in a laboratory setting, with users experiencing and commenting on the design in a protected environment.

When broadening the system boundaries, this phase may focus on experiencing and testing a new product-service system. For instance an electric transport service, made up of technical as well as organizational components. Each of these components is crucial for the successful functioning of the system. If, for example, the truck driver is missing or communication problems arise so clients can't reach the company anymore, the transport service may no longer function. The product-technology system ‘electric vehicle’ may still function perfectly well, but the product-service system ‘transport service’ no longer works. Experiencing and testing a new product-service system may need a broader setting than testing a product, for instance introducing the service for several weeks or months in a small-scale experiment in a real life environment or living lab environment.

For the product-service system to function properly, good infrastructure and corresponding traffic regulations are necessary. When introducing electric vehicles, battery-charging units may be essential. However, these do not form an inseparable component of the product or the service itself, which brings us to the level of the even broader socio-technical system. Here it is about the design of a cluster of solution elements and subsystems, which are closely related but not completely inseparable. In case one of subsystem fails, its function can often be taken over by another subsystem. If the buses stop running, people will take the bicycle. If diesel becomes too expensive, people will buy a car that runs on gasoline. However, switching to electric transport may not be so easy, as battery-charging points may currently be hardly available. Perhaps current petrol stations could provide this charging service, but then it may become clear that the current position of fuel stations is not suitable to locate these battery-charging points, as they are often located in rather remote areas. While this is not a problem when filling up a tank of gasoline in a few minutes, these remote areas are not very attractive when waiting several hours for a battery to be charged. At this level, one may run into chicken-egg dilemma's: If no battery charging points are available, the acceptance of electric vehicles will be hindered. At the same time, companies will only invest in the development and placing of battery charging points, when a substantial amount of electric vehicle owners are willing to pay for their use. When looking to the societal level, government may play an intermediary role to bridge certain of these chicken-egg dilemma's, for instance when deciding to support the placement of battery charging points in inner city areas. However, even when supported by policy regulations, it will still take a substantial amount of time until these battery-charging stations are as readily available as regular fuel stations. To support the objective description of a current or new situation on societal level, tools like the Environmental Performance Index (Athanasoglou et al., 2014) could be helpful to describe and compare different situations in an objective manner. Finding out the effect of socio-technical or societal system changes would need even more space and time than testing a product or a product-service system, for instance to measure the impact of the introduction of a certain policy regulation over a longer period of time. Here the livings labs approach (Scott et al., 2012), the concept of strategic niche experiments (Raven et al., 2010) or bounded socio-technical experiments (Vergragt and Brown, 2004) may be helpful.

4. Evaluation

4.1. *Insights resulting from simulating the use of the MDM*

The description of the case example based on the MDM shows that the development of new sustainable products and product-service systems, in this case a new energy efficient transport system, is very much interwoven with developments in the broader socio-technical and societal context in which these new products and product-service systems will be functioning. It appears that applying the MDM on a complex change process like this, may indeed provide insight into the relationship between processes that occur on the various system levels. Consciously separating both the various design phases (reflection, analysis, synthesis, experience), as well as the various system levels on which these change processes make takes place on, appears to be helpful to map or plot the various developments that take place during this process.

With regards to the reflection phase, distinguishing between the various system levels may clarify the different types of problems that will be taken into account, focussing on either a very closely defined and measurable issue like the exact gasoline use per transport kilometre for a specific vehicle, or focussing on a broader problem like the toxic emissions of all combined transportation in a certain region of the country. Also, it will help to determine what actors to involve, either focussing on the specific problems that end-users are facing, or on problems that may involve a broad several stakeholders in society as a whole.

With regards to the analysis phase, distinguishing between the various system levels may help to determine what requirements should be met during the design process. This distinction may explain what goals a project aims to achieve. Here it can be about very specific operational or functional objectives, for instance reducing the amount of gasoline per transport kilometre for a specific vehicle with 2%. Or it can be about much broader aims like the reduction of the amount of CO_2 and NO_x emissions during a one-year period in a specific city or province. Applying the MDM in this phase may also help to choose what adaptation strategy to follow with regards to the existing socio-technical situation, either totally adapting to the current situation – resulting in limited design freedom – or not adapting at all, resulting in much more design freedom, but additionally a much higher risk of failure.

With regards to the synthesis phase, distinguishing between the various system levels may help to determine what specific creative expertise is needed during the project. When working on product-technology level, a specialized product-designer could be needed. While when working on socio-technical level, someone with experience in long term future scenario's could be better equipped for the task. The distinction will also help to determine what tools and methods to use. On product level, this could mean applying artefact-oriented approaches like sketching, physical models and CAD models. On socio-technical level it could mean working with tools that can handle more abstract plans, like future scenario's, storytelling or the use of a common vocabulary.

With regards to the experience phase, distinguishing between the various system levels may help to determine the way that a certain new solution can be simulated and tested. To evaluate a new product-technology system, like a new vehicle, a delimited laboratory environment could be sufficient. Whereas testing a new socio-technical system, like a radically new transport system that need new regulations and infrastructure, could only be tested in a long term societal niche experiment or bounded socio-technical experiment.

4.2. *Potential users of the MDM*

In the introduction of this paper, we explained that change actors like designers do act at all levels of society and need help to navigate their way through the complex interrelated innovation systems. With this question in mind, the prospective use of the MDM has been discussed. Based on that, the question can be asked how these actors actually will benefit from applying the MDM, and what is the expected advantage for various kinds of actors.

First, the MDM may be used by design researchers, supplying them with a tool to analyse design projects by means of suitable multilevel design perspective. Although various other multilevel models exist, none of these are specifically developed with a designers perspective in mind. Adding this viewpoint may help design researchers to clarify their unique perspective compared to professionals from other fields of expertise like sociologists or transition researchers. Among others, the MDM is currently being used to find out how design processes in the area of health care can be described in a systematic manner, related to the research in the area of health care (UCF, 2012, p38). It is also being used in the Aalborg Design for Sustainability Course, among other linked to research related to the Cradle to Cradle Islands project (Möller et al., 2012). Linked to the development of Leeuwarden as the Cultural Capital Europe 2018, the MDM is currently being used to clarify various initiatives related to the contribution of small companies to the long term societal goals of Dutch province of Friesland. In addition, the results of several European programs with sustainable living labs, such as the D2D Intereg project, Living Green, EcoMind, Sustainability Maker and LeNSES (Vezzoli et al., 2014), in which the authors are involved, will provide valuable new insights in the years to come.

Besides the MDM as a tool for researchers, the model may potentially be used by designers that are actually developing new products and product-service systems, and are caught in the complexity of their efforts, especially with regards to the connection of their new design within the overarching socio-technical context. Mapping a specific project on the MDM – both before and during their project – may help them to select the appropriate tools and methods to be used. Also, the mapping exercise may help them to determine on what level they actually want to focus their efforts. For instance, if before or during the course of a design project, the designer finds out that a change in regulations is needed, the MDM may help them to understand that they are actually shifting their design project to a higher system level. This new insight will help them to not just let this occur, but make a conscious choice if this is indeed what they and the other involved stakeholders have in mind. Besides the designers themselves, we expect the model to be beneficial for design managers that are involved in complex change projects, helping them to determine what kind of expertise they may want to hire for a specific task, and what kind of skills are being required for a particular endeavour. For instance, if a project is exclusively focussed on the design of a physical artefact, they may want to hire a different design professional than when their initiative is aiming at the realization of a complex societal change process. Applying the MDM may also help these managers to determine the way that a certain new solution can be tested, choosing for instance between short term in house laboratory experiment or a long-term socio-technical niche experiment.

All in all the MDM appears to be specifically useful in the initial reflection and analysis phase of complex design initiatives. Where the current version of the model may mainly be helpful as a descriptive tool for design researchers, we expect that adapted versions of the model may be beneficial as a prescriptive tool for designers and design managers, enabling them to map a specific project with regards to the relevant hierarchical system level, and to plot their efforts with regards to the design phase that is under consideration.

5. Conclusion

This research was initiated based on the observation that the role of designers is broadening, from the creators of physical artefacts to the potential role of facilitators of complex societal change processes. To support the widening role of the designer, there is a need for a design supportive model that can (1) provide insight into the development of one new physical artefact or a new product-service system, as well as in developments that occur in society as a whole, (2) provide insight into the relationship between functional and operational problems and objectives on the one hand, and more abstract socio-technical and societal problems and objectives on the other, and (3) offer insight into these change processes in such a way that the design processes, change processes or transition processes are described in a consistent, mutually comparable manner. Current design and innovation models are insufficient to support designers with this effort, because they are either too much oriented towards the development of one specific new product or service, or they are too abstract and conceptual to potentially be used to structure future design-based initiatives.

In this paper the Multilevel Design Model has been discussed as a way to analyse and describe the design process from a more or less cognitive or intellectual perspective. The MDM distinguishes four typical design phases and four typical system levels on which design and innovation processes may take place. Based on the description of design and change process in the area of sustainable transportation, it was explained that the MDM may provide insight into the relationship between processes that occur on the various system levels. Apparently the MDM does support the description of complex change and design processes in a consistent, mutually comparable manner. Currently, it has been applied mainly as a descriptive model, analysing retrospectively the design dilemma's that can be explained by applying the model. A next step will be made to use the multilevel approach for more ex-ante navigational advice, supporting professionals in a more hands on manner with their design efforts and improving the impact of future design-based initiatives.

The authors recognize the limits of the MDM model with regards to the categorization of design phases and system levels in the first place, supporting designers in their activities towards a sustainable societal system. More research is necessary to determine the influence between the various system levels, especially with regards to the way that this mutual influence has an effect on the design process itself. Here the work of Jørgensen (2012) on Arenas of Development and Ehrenfeld (Stichting Kulturele Haadsted 2018, 2013) on Sustainability by Design are expected to further enrich the model. Likewise, new insights in the synergy of on the one hand new green venture development and on the other hand sustainable product design can be included. Along the same line, Keskin et al. (2008) developed a green product-service-business synergy and effectuation model, which could become a further valuable cornerstone of an elaborated version of the Multilevel Design Model. In time this knowledge will help to increase the success rate of new sustainable solutions, speeding up the transition towards a more sustainable society.

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