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Design to market thinking: exploring the merits of strategic niche management in design thinking

D.F.J. Schraven, P. Arghandeh Jouneghani, H.M. Jonkers and M.J.C.M. Hertogh

Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

ABSTRACT

Sustainability transitions require that sustainable innovations develop and scale-up. Two promising approaches contribute to this purpose. Design thinking (DT) focuses on the creative development of sustainable innovations to achieve desirable, feasible and viable products. Strategic niche management (SNM) addresses how sustainable innovations should be deployed to the market. At first sight, these concepts seem to pursue a complementary mission, yet, academic literature has not explicitly addressed their complementary nature. Therefore, this paper addresses this gap by reviewing, proposing and empirically exploring the merits of SNM and how these can be used in DT through a workshop to increase successful market implementation of sustainable innovations. The study finds that SNM potentially helps the DT design process to (1) change market preconditions for the design, (2) create a protected niche for development, (3) establish a (long term) commercial viability, and (4) create an innovation development plan through definition of a set of testable propositions. The paper concludes that the inclusion of SNM into DT substantially increases the preparedness of an innovation team for a successful market implementation of sustainable innovations and coins the term 'Design to Market Thinking' for the integrated use of SNM in DT.

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Introduction

To achieve wider impact, sustainability transitions are in dire need of strategies to help grow and develop sustainable technologies into products at a larger scale. Deployment of sustainable technologies requires that these strategies include both a sustainable product design (Khan, Vandevyvere, and Allacker 2013) and simultaneous market and business design (Geissdoerfer, Savaget, and Evans 2017) as an integral part of the design. The Design Thinking (or DT) approach forms a strong basis for addressing sustainability with regards to product and innovation design (Buhl et al. 2019). It provides a unique set of analytical steps that could unlock creative solutions to problems, resulting in creation of innovative sustainable products. However, the problem with this is that an explicit link between DT and implementing sustainable innovations into the market is still lacking (Ioannou and Meletiou 2011; Li, Ho, and Yang 2019). Interestingly though, from innovation science, research into market transition theories is occupied with similar problems. Especially strategic niche management (or SNM) considers how innovations should be guided and prepared for a successful market

CONTACT D.F.J. Schraven d.f.j.schraven@tudelft.nl Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN Delft, The Netherlands

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introduction. We argue in this paper that SNM aspects could serve as a necessary addition to DT to increase the chance of successful market implementation of sustainable innovations.

Surprisingly, we find that both as yet distinct approaches have not been combined as of to date.[1] DT and SNM are potentially complementary because they both address the requirement for innovations, focusing on product design and market implementation strategy respectively. It appears that there has been no explicit research study performed on the complementary nature of both research fields. In essence, it raises an unfulfilled question that drives this research paper: *How can the SNM approach build further on DT regarding the market development of sustainable innovations to serve societal needs?*

This paper addresses this question in a sequence of steps. First, the scientific background and conceptual approach of SNM and DT are reviewed and the potential for integration of both is examined. Thereafter, by reviewing recent applications of SNM and DT toward sustainable innovations, we discuss how SNM could serve in DT regarding the market development of sustainable innovations. Herewith, we identify four theoretical aspects in which SNM potentially complements DT. Based on these aspects, an SNM-inspired methodology is set up for increasing the chance of successful market implementation of sustainable innovations. In essence, this methodology aims to prepare an innovation development plan by means of propositions, spelling out expectations that can be tested for a successful introduction of the innovation into the market. Next, we investigate the added value of the new SNM-inspired method by applying it in the design process of a specific innovation, called the Suspended Tree. Based on these steps the wider implications for the proposed approach are then discussed.

This is the first attempt of its kind to explicitly investigate the potential merits of merging SNM with DT, where no other such attempts could be found. We coin this merged approach 'Design to Market Thinking' (D2MT), i.e. an integrative thinking approach that could help sustainable innovations to successfully enter the market.

Research methods

The methodological procedures followed by the authors are structured in three steps. First, we review the academic literature for the theoretical underpinnings from both DT and SNM separately. For both of the concepts, the review focuses on a few concrete topics, namely: (a) their history; (b) their association to the term 'sustainability'; (c) their latest scientific developments; and (d) their association to the terms 'business' and 'market'. From this review, we use key underpinnings to build a framework which describes their relation and combined strengths. Second, we review and conceptualise a set of data collection and analysis methods which in combination follow the theoretical framework. This step involves an in-depth review of the theoretical components of SNM and its available methods. These are used to propose a comprehensive and applicable methodology. Finally, the proposed methodology is empirically applied and evaluated to a real sustainable innovation case. The methods underlying the proposal include an interview with the inventor of the innovation, a workshop setting for a group of experts, with ex-ante and ex-post surveys for these experts.

Theoretical underpinnings and framework

It is surprising that the link between DT and SNM has received so little attention, especially since both concepts are used in papers about sustainable innovations. Recent studies seem to indicate that a lack of explicit linkage of sustainability to DT seems to have withheld this exploration (Buhl et al. 2019; Khan, Vandevyvere, and Allacker 2013). Insofar, the debate has remained fragmented and the conceptualisation into design remains contested (Khan, Vandevyvere, and Allacker 2013). Therefore, an explicit combination of sustainability and DT in a model is still fairly lacking

(Ioannou and Meletiou 2011; Li, Ho, and Yang 2019). This section reviews DT, SNM and synthesises their roles for preparing sustainable innovations for the market.

DT approach

The first book on DT 'creative engineering' by Arnold (1959) focused on DT as a creative approach to make designs for products that have novel functions, higher-performing solutions, lower production costs and better saleability. Recently, DT is a way to design business models (Aceti and Singarayar 2015; Blaschke et al. 2016; Bonakdar and Gassmann 2016; Pahlavi et al. 2017) to bridge the design-implementation gap (Geissdoerfer, Bocken, and Hultink 2016; 2017).

DT is a process for two outputs. On the one hand, DT is used as a process for user-centred designing and includes activities like context analysis, problem finding, framing ideation, solution generation, creative thinking, sketching, modelling, prototyping, testing and evaluating (Cross 2011). On the other hand, DT is used as a process for innovations (Baughn and Suciu 2015; Chen et al. 2018; Ribeiro et al. 2018), which includes the processes of inspiration, ideation and implementation in which designers try to clarify the innovation (Plattner, Meinel, and Leifer 2011).

Regarding innovations, DT starts with inspiration, to grasp the problem or opportunity in hand (Brown 2008). Secondly, ideation refers to generating ideas by divergent thinking (outside of the box) and convergent thinking (zooming and focusing on the different proposals) in order to create synthesis later (Brown 2008). Finally, implementation aims to make the best ideas into something concrete, by means of prototyping. The process is iterative, and not necessarily organised as a sequence of steps (see Figure 1(a)).

The design process for innovations aims to reach a steady point in which a solution is found 'that addresses a human need while being technically feasible and financially viable' (Shapira, Ketchie, and Nehe 2017, 282). Figure 1(b) shows these criteria as the commonly accepted approach for DT (IDEO 2012). The idea is that the final acceptable solution should fall in the overlap between the feasible, viable and desirable solution. In essence, DT departs from the desirable solutions and takes technical feasibility and financial viability as boundary conditions (Shapira, Ketchie, and Nehe 2017).

SNM approach

SNM was conceived in 1994 by Schot, Hoogma and Elzen (1994). Kemp, Schot and Hoogma described SNM as (1998, 168): '[…] the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology'. In essence, SNM tries to overcome the 'valley of death', i.e. a metaphor for the high likelihood of innovation to strand in the marketplace, before any meaningful revenues could be attained (Markham et al. 2010).

In an extensive review, Schot and Geels (2008) discuss that SNM facilitates sustainable innovation journeys by creating niche innovations, i.e. the creation of protected spaces that allow for the experimentation and development of a technology with the help of users and regulatory structures. Figure 1(c) visualises this process primarily on two axes: the time it takes before an innovation is developed (horizontal axis) and the increased level in which the local activities are more structured (vertical axis). It shows that SNM is a bottom up process which tries to test conventions of the socio-technical regime and landscape. SNM thereby assumes that if a niche is constructed appropriately, it acts as a building block for the innovation to safely develop and mature (into a new configured socio-technical regime). This way it can enforce broader societal changes towards sustainable development (Schot 1998). This protection is needed because new innovations must compete with more established technologies, which have a favourable socio-technical regime, that could work against the premise of new innovations (Mourik and Raven 2006). It involves both niche internal processes,

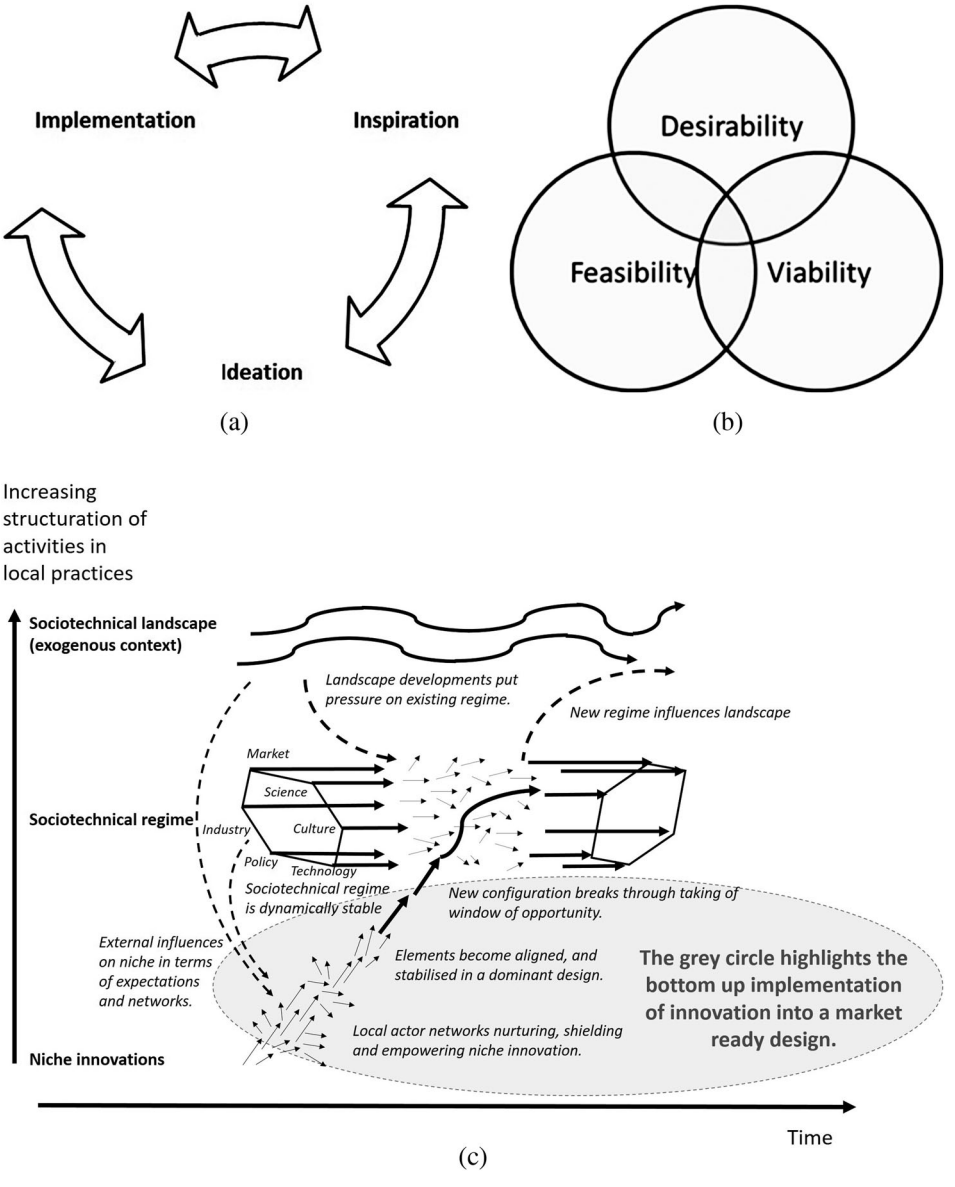

Figure 1. (a) DT's process for innovations (adapted from: Brown 2008). (b) DT's criteria for design innovation (adapted from: IDEO 2012). (c) SNM for Sustainable innovation journeys (adapted from: Schot and Geels 2008). The grey circle shows the bottom up implementation process from innovation to market ready design.

like learning, networking, visioning and the relationship between local projects and global rule (interplay between niche and regime), as well as niche external processes (Schot and Geels 2008), for example changing the actor network composition (Tremblay and Neef 2009). In essence, the grey circle in Figure 1(c) shows the push that the bottom up process of SNM can bring to innovation in order to become part of a dominant design that is more likely to be adopted by the market.

SNM is primarily offered as an analytical tool that helps to assess and modify radical socio-technical innovations from the bottom up (Weber 2003). A few notable angles for SNM tools have been proposed to identify and overcome the barriers that hamper the survival of innovations in the market (Angelina, Vallée, and Louen 2018; Ceschin 2015; Kwon 2012; Mourik and Raven 2006;

Weber, Hoogma, Lane, and Schot 1999). Firstly, tools are offered to set the expectations and acceptance of innovations before these are introduced. Secondly, tools are offered to create a network of actors that require to collaborate on a common goal for the innovation project. Finally, tools are offered to facilitate the learning processes during the implementation of a niche, by understanding the various preconditions that are needed for the implementation of the innovation. The idea here is to dismantle the actual protected space after which the innovation can stand alone. These SNM tools can either be applied in a workshop setting (discussing a specific case) or as an in-depth case study (consulting with an innovation owner).

Complementarity of DT and SNM

A few observations can be made about the complementary nature of DT and SNM. First, it appears that DT has a broader reach in terms of process and in terms of generality than SNM. Second, DT as a process for innovations follows the same rough iterative approach as SNM does, but offers a clearer basis for it by the phases of inspiration, ideation and implementation. Third, the means and ends are the opposite for both DT and SNM. DT focuses on designing an innovation, meeting criteria on desirability, feasibility and viability, and does so by iterating between inspiration, ideation and implementation, whereas SNM focuses on the end-of-the-pipe by facilitating the successful implementation of the innovation, thereby attuning the external preconditions to work in favour of the innovation, by means of creating a niche. Fourth, DT is focused on the creation, whereas SNM is focused on analysing the potential scale-up of that creation. It therefore follows that applying DT should precede the application of SNM. Following these differences, Figure 2 shows how SNM and DT complement each other.

There are a few aspects to DT, which the SNM approach can help to enrich upfront if integrated into DT. Firstly, it is established that DT is missing an explicit linkage to sustainability (Buhl et al. 2019; Khan, Vandevyvere, and Allacker 2013), whilst SNM is primarily focused on sustainable innovations.

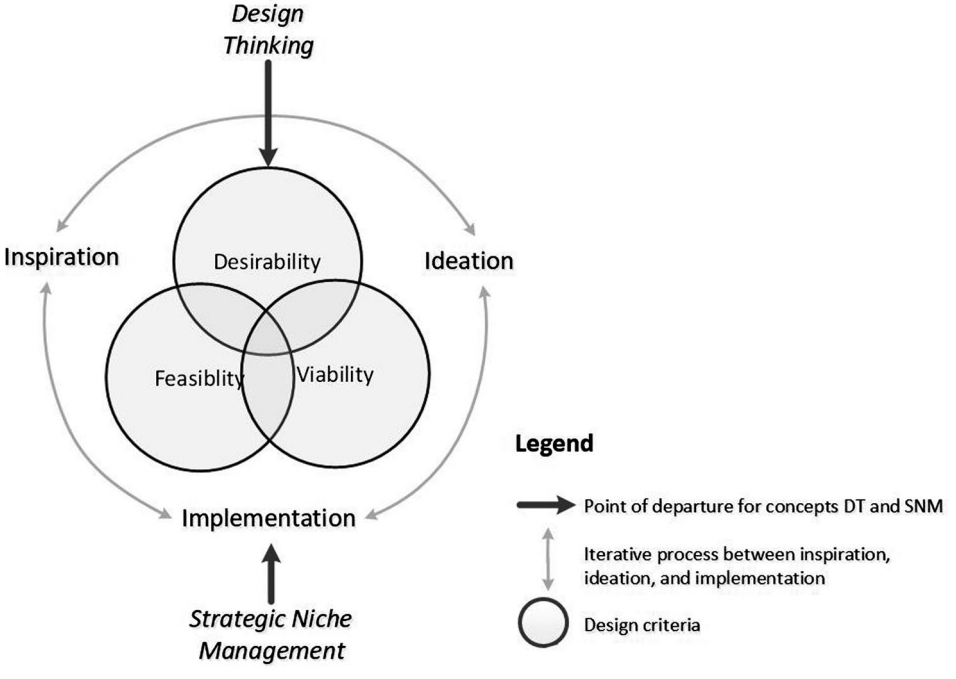

Figure 2. SNM and DT points of departure to designing innovations.

This gap is opened up by Buhl et al. (2019) as one of the first who explored why and how DT could foster the development of sustainability-oriented innovations (SOI) with five principles (i.e. problem framing, user focus, diversity, visualisation, experimentation and iteration). They noted that 'a systematic and detailed discussion of the application of DT for SOI development is still missing' (1248).

Buhl et al. (2019) identified four challenges concerning implementing SOI (see Table 1). Firstly, the innovation scope is hard to grasp due to the multidimensional sustainability targets (like environmental, social and economic impacts). DT is about designing the innovation by means of integrative thinking, meaning that professionals could include sustainability (environmental, social and economic outputs) fully into their design innovation (Kurucz, Colbert, and Wheeler 2013), next to the desirability, feasibility and viability (Garcia and Dacko 2015; Shapira, Ketchie, and Nehe 2017). The integration means that the sustainability outputs still require to meet consumer demand and be economically viable (Sherin 2017). A DT approach could be left with unwanted trade-offs if it needs to either make trade-offs between consumer demands now and future livelihoods later (Govender 2017). Here, SNM can investigate the market preconditions for the product design and could help modify these in order to neutralise the trade-off.

Secondly, user needs and behaviour have an influence on sustainability impacts, thereby adding the complexity of trade-offs between traditional design criteria, i.e. the desirability, feasibility and viability (Shapira, Ketchie, and Nehe 2017) and the sustainability aspects. Here, DT creates value propositions that can be tested on their actual delivery. Complementary, SNM helps to create a protected space, or niche, in which the product can safely experiment for the scale-up.

Thirdly, although stakeholders are needed, their involvement may introduce conflicting interests due to a lack of literacy on sustainability (Lebo et al. 2014). In addition, Klotz et al. (2018) suggest that designers might overlook climate change implications for their designs due to their narrow-sighted thinking. Klotz et al. (2018) suggest that this could be overcome if DT were to vividly imagine the future. Here, SNM adds value, since it inquires how long-term transitional goals should direct modifications into the innovation. In so doing, it considers how the different stakeholders can reach commercial viability, which DT finds difficult to apply (Furue and Washida 2017; Sorabayashi, Sasaki, and Uchihira 2017). Commercial viability goes beyond DT's financial viability criterion: if a product is offered in a financially viable way it does not necessarily mean all involved businesses benefit in a mutually accepted way. Commercial viability focuses on sharing the pains and gains, bearing market risks (e.g. higher costs for sustainability) and merits (e.g. societal benefits) equally.

Finally, the assurance of positive sustainability effects means that the simultaneous pursuit of the sustainability criteria may impede each other in the long run. SNM offers to facilitate the learning processes during the implementation of a niche. Herewith, it helps to create a testbed or roadmap for innovation for the development of evidence for its readiness and sustainability effects. This leads to a strategy for the appropriate time to break down the actual protected space.

Table 1. DT and SNM strengths to Buhl et al.'s challenges for SOI.

Buhl et al.'s (2019) challenges	DT key strengths (Buhl et al. 2019)*	SNM key strengths (as proposed by authors)
Innovation scope	Problem framing	Changeability of market preconditions, e.g. from now into the future.
User needs	User focus	Niche focus
Stakeholder involvement	Diversity	Commercial viability (long term)
Assurance of positive sustainability effects	Experimentation and iteration	Creation of development steps

*A fifth strength is called 'visualisation'. It is not included in this table because its resolution to the challenges is diffused by Buhl et al. (2019).

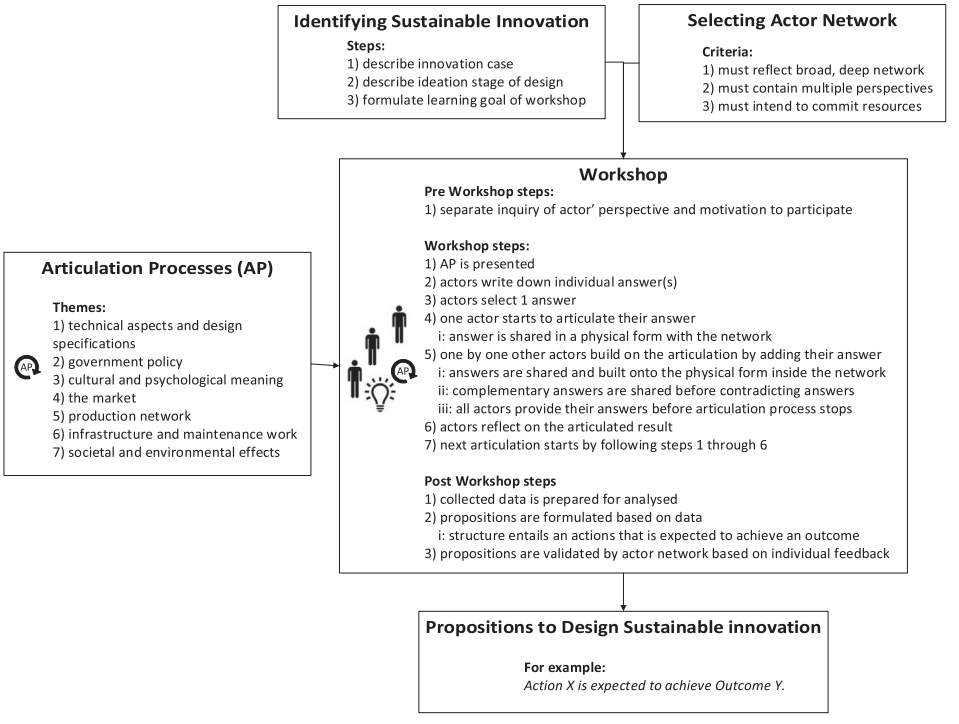

Figure 3. Research Design: Workshop for actors to articulate propositions to influence.

Proposing a methodology to unlock the merits of SNM in DT

In this section, we develop a way in which SNM can build further on the market development of a sustainable innovation to serve societal needs. Figure 3 shows the overall research design and methodological procedures, which are elaborated in the following sections.

SNM's articulation processes (APs)

The first methodological note is that once there is a conceptual or prototype design SNM can develop a design innovation scenario. Many barriers for a sustainable innovation originate from uncertainty and perceptions, for which SNM helps to learn about the needs, problems and possibilities of such a sustainable innovation (Kemp, Schot, and Hoogma 1998). Therefore, SNM has seven APs guiding the learning process in order for the new technology to become socially embedded.

The seven APs are outlined in Table 2, showing the number, label and focal question. The logic of this table is that every articulation process revolves around a theme, which can be answered through a focal question as to the point of departure. For example, AP1 focuses on answering the question of whether there are limitations to the technology or whether certain adjustments are still to be made before implementation. These APs offer a good starting point for articulating during the design process, regarding how to approach the implementation of sustainable innovations.

Setting for data collection and analysis

Data collection and analysis should follow the way in which an AP takes place. For this to work, APs can be elaborated upon within the context of a protected space. By doing so, enabling a broad learning process regarding the needs, problems and possibilities of the new technology (Kemp, Schot,

Table 2. APs for creating testbed for implementation.

#	Labels for SNM articulation process (AP)	Resulting focal question
1	Cultural and psychological meaning	*Which symbolic meaning can be assigned to the sustainable innovation?*
2	Government policy	*What legal and governmental policy changes would you deem necessary for the market introduction of the sustainable innovation?*
3 (A&B)	Infrastructure and maintenance network	*Which party/parties should be responsible for the maintenance (A) and recycling/ waste management (B) of the sustainable innovation?*
4	Technical aspects and design specifications	*What technical adjustments to the current design of the sustainable innovation could be suggested?*
5 (A&B)	Production network	*Which party/parties should produce (A) and market (B) the sustainable innovation?*
6	The market	*How to market the sustainable innovation in an economically sound manner?*
7	Societal and environmental effects	*What effect will the new technology have on the environment and society as a whole?*

and Hoogma 1998). This means that SNM literature highly recommends physically bringing together actors from different environments for shared networking and learning activities to bridge the 'Valley of Death' (Schot and Geels 2008). Hence, a workshop is a suitable setting to iteratively trigger articulation among actors about the conceptual design of a product. The design of the product can be modified based upon the output of the workshop.

Selecting the actor network

In order to select participants that can help articulate the needs for a sustainable innovation, it is important to note that the collective set of participants (1) must reflect a deep, broad network (no dominant group from industry), (2) must contain multiple perspectives and (3) have the willingness to commit resources to the project (Schot and Geels 2008), i.e. a need for the innovation to succeed (Smith and Raven 2012). Following these requirements for an actor network (Schot and Geels 2008), the participants of the workshop should be populated by the product concept developers, potential end-users, government bodies, technical experts, innovation managers, potential investors and third parties.

Workshop approach

The purpose of the workshop is to unlock and explore the empirical impact of four potential merits of SNM (see Table 1) for the design of sustainable innovation. In so doing, the workshop is proposed to take place after the ideation phase to iterate new input to advance the intermediate conceptual product design by propositions.

Pre-workshop phase

In this stage, individuals are asked for their motivation to participate. The Nominal group technique is followed, i.e. technique in which individuals are answering for themselves before introducing it to the group (VandeVen and Delbecq 1974). This is done to separate individuals' answers and guarantee unfettered, multiple perspectives.

Workshop procedure

The workshop follows the APs of Kemp, Schot, and Hoogma (1998) each question has its own respective time for the actor network to articulate an implementation strategy. After presenting the AP question, individual answers are gathered. This step follows the Nominal group technique and should be brief. It is followed by the collective articulation, which is inspired by the Interactive group approach. This technique allows the participants to open up to each other, in order to achieve cross-fertilisation among the actors in the network (Delp, Thesen, Motiwalla, and Seshardi 1977).

Provided that a workshop setting has limited time, some rules are established. One rule is that participants bring their articulated answers into the discussion one at a time. This is done by placing their answer in some physical form, say a card, into the group, for example, a table which is preferably clearly visible in the centre of the group. After that, the other actors then discuss the proposed answer. The remaining participants are free to articulate their answer at any time and place their card in a position that is reflective of either supporting, expanding or contradicting the answers already played. Participants are given a moment to elaborate their position and then a group discussion follows again.

SNM advocates the alignment of goals (Schot and Geels 2008). Therefore, the discussion and placement of answers needs to be monitored, such that the supporting and expanding cards are played before the contradictory cards. In so doing, the group first engages in an aligned answer before dissipating into camps. Before another AP starts, the workshop moderator summarises the outcome to the main question, and the actor network jointly reflects on this. Each participant receives the opportunity to state whether he or she is satisfied regarding the answers on the cards and their positions on the table. Based on the discussion it is then still possible to reposition the answer such that goals and expectations can be aligned.

Post-workshop phase

The moderator analyses all the data (i.e. the card content and positions, the notes and the discussion) to formulate propositions. Each formulated proposition has the structure of an action that is expected to achieve a certain outcome. It is important that these propositions are based on the actual articulation by the actor network (Kemp, Schot, and Hoogma 1998). These propositions are validated by presenting these again to each actor for feedback. This follows SNM's principle to learn and steer (Schot and Geels 2008).

Results

In this section, we investigate the merits of SNM by means of a case in its ideation stage. First, the case is introduced, we then report on the workshop results, both in terms of process (workshop events) and in terms of product (established propositions) as a basis for the implementation strategy.

The sustainable innovation case: the Suspended Tree

The Suspended Tree (or ST) is a tree with roots, which are not embedded in the ground but with clout packed together and held by springs in a box-structure (see Figure 4). The nutrients and water for the tree are supplied by a computer system, which is monitored through the internet. In this way, the tree is a self-sustaining and mobile living system which can reduce the weight by an expected 50% due to the absence of a below ground-root system and its accompanied soil, according to the inventor.

ST' is a useful case to study, since the weight reduction creates a multitude of application possibilities for upscaling the innovation. For example, ST could be placed on roof tops, which are abundant in large cities and could preserve the load-capacity of the buildings. Another example for the application is the use of STs in open public spaces instead of trees planted on the side of the road. It is argued by the inventor that this helps preserve underground infrastructures (e.g. sewers and cables) because suspended trees would then replace trees rooted in the ground. This could prevent costly adjustments to the underground infrastructure.

The inventor portrays that the innovation is sustainable for a few functions. For example, it can reduce CO_2 emissions and create green spaces in cities with no available space for trees. Also, it can help reduce air pollution, the urban heat island effect and sewer overloads due to the lack of rainwater retention. Besides these benefits, the ST itself needs further development, convincement and a market introduction plan for the benefits to be up-scaled.

Figure 4. The Suspended Tree.

The process

This section discusses the actual process of organising our workshop for the ST.

Forming the ST actor network

The following actors were selected for the actor network of the ST:

- The city of Delft as the government body close to the original development site;
- Three different technology adopters (Moore and McKenna 1999): The University (as early adopter), a construction firm (as an early majority) and Highways agency (as a late majority);
- The inventor (product concept developer);
- A scientist from the university (technology expert);
- The incubator firm (as management role during first prototyping);
- A local environmental group, promoting a green local landscape (third party);
- A Dutch bank (resourceful actor).

Step 1: pre-workshop

Despite some cancellations, five actors participated: municipality, Highways agency, technology expert, incubator firm and the inventor. The card-system enabled two additional actors (i.e. the University and the Environmental group) to provide input separately to complete the data. These consultations followed the workshop procedure. Although the latter input lacked group interaction, still the post-workshop involved all actors for feedback.

Step 2: the workshop

Generally, the procedure was meticulously followed. The 'card game' was perceived as a clear, well-structured and enjoyable approach.

Each question ended with a placement of the cards[2], except AP 7 (this one was not answered due to a lack of time). The three most informative AP's are provided in Figure 5. The cards are presented by coloured boxes and are positioned in the original place on the table after an AP was final. On the cards, there are three pieces of information, for example in AP 5A: '2. Social work facility [Gov. body]'. This can be read as: the government body placed the remark 'Social work facility' as the second in line during AP 5A. Some cards have dotted lines, these cards originate from the two post-workshop individual consultations. Some articulations concluded in consensus with one card cluster, namely AP 4 and others without consensus with two clusters, like AP 3A.

It became clear that participants had difficulty to discuss within the allocated time. The workshop worked well with six participants but may get out of bounds with more actors. Furthermore, the generality of the questions resulted in some out-of-the box discussion points. Also, participants disliked causing contradicting camps, explaining why some cards were placed next to others' cards instead of separate. This appeared to show unity, while content-wise this did not apply (see AP 5A).

Step 3: post-workshop

The propositions (in Table 3) were established by means of triangulating the inputs of the cards, and their placements, to the audio recordings of the workshop. In sequence, the discussion points underpinning the propositions were verified and validated in consultation with each participant individually. This fits SNM's 'learning' concept (Schot and Geels 2008). A statement was considered to be a proposition if it was backed by at least one other participant, however often multiple participants reached consensus, i.e. showing consensus that an action is expected to influence the ST's market implementation.

The output

In some propositions, the influence was less clear, because the link was not directly mentioned by the participant, but appeared logical to insiders (e.g. proposition 16). Most propositions were

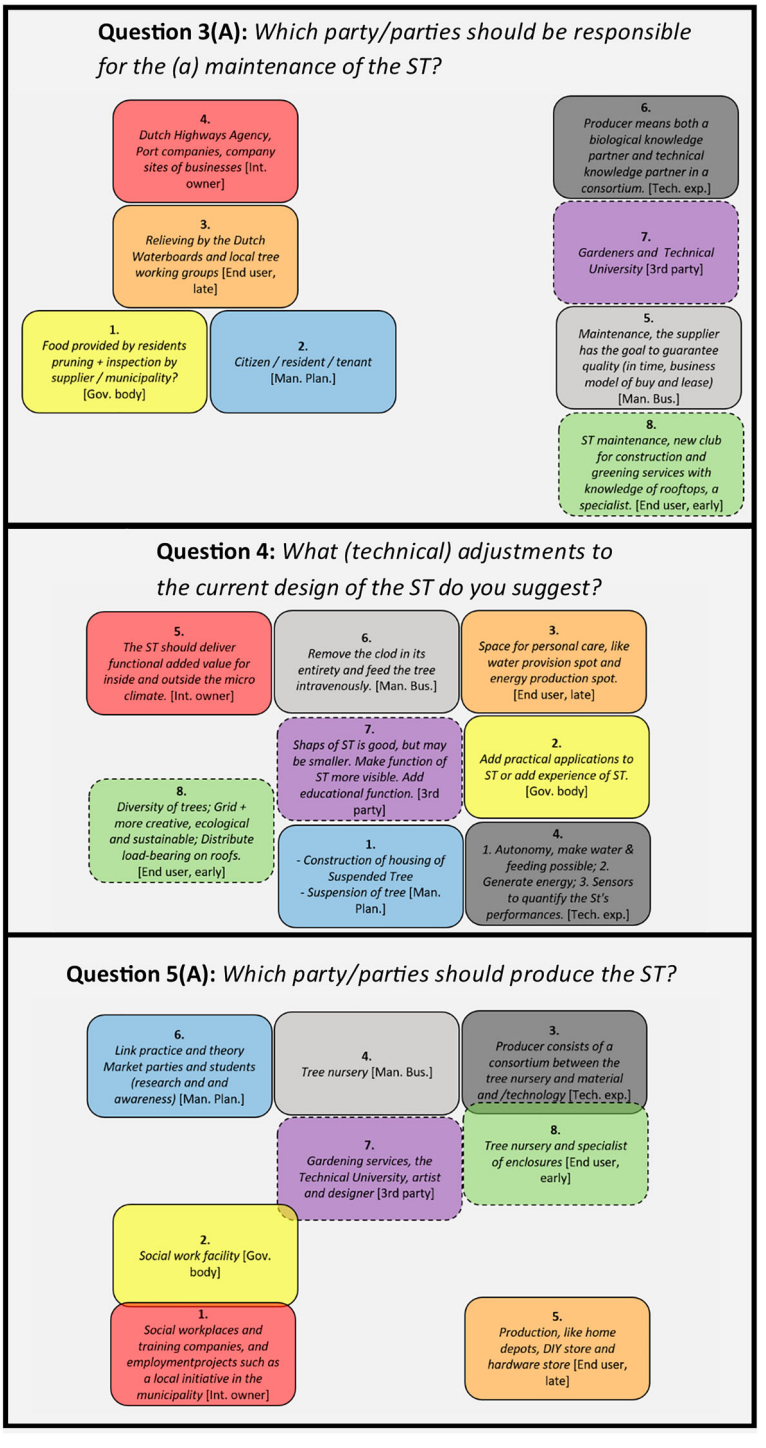

Figure 5. Card placements by actor network after AP 3A, AP 4 and AP 5A.

based on statements on a card, however, in some cases, new propositions were formulated during the discussion (e.g. proposition 15). Due to the more brainstorm-like nature, the workshop proved to be less suitable to create smart propositions. Propositions appeared to be mixed at the macro level

Table 3. Propositions for market introduction of the Suspended Tree (ST).

#	Propositions (articulated as expectations to be tested)
1	Monetising the ecosystem services of the ST forms narratives for the ST.
2	Creating custom narratives on sustainability topics for the technology advocates empowers the market introduction of ST.
3	Creating a more environmentally minded government stimulates city greening with the ST.
4	Linking the ecosystem services of the ST to other societal issues and domains better defines the ST's value.
5	More insights on building regulations and other governmental norms prevents legal impediments of the ST's market implementation.
6	Experimenting with different ownership constructs optimises the maintenance and recycling tasks of the ST.
7	Forming a consortium composed out of the tree nursery and engineers finetunes the production processes of the ST.
8	Selecting technology advocates supports the ST's market introduction.
9	Increasing the ST's experience makes the product more appealing for potential buyers.
10	Alternating the construction of the ST increases the general socio-technical competitiveness of the ST.
11	Adding social workplaces to the consortium delivers more governmental support for the ST's market implementation.
12	Selecting a single marketing company provides outlines of the marketing strategy for the ST.
13	Applying showcases of the ST raises the interest of potential investors.
14	Creating multiple different models of the ST increases the general socio-technical competitiveness of the ST.
15	Utilising sustainability-oriented subsidy schemes increases the general socio-technical competitiveness of the ST.
16	Reforming the current performance criteria levels the playing field for the ST in comparison to ordinary trees.

and micro level. While this shows the wider impact that the propositions aim at, it makes their prioritisation more difficult.

Discussion

In this section, the demonstration of the four SNM merits following the workshop application are discussed.

Firstly, SNM is proposed to test the *changeability of market preconditions* for the product design. This way it could relieve unwanted trade-offs between consumer demand and future livelihoods (Govender 2017; Sherin 2017). The SNM workshop delivered exemplary propositions about the changeability of market preconditions (especially propositions 1, 2, 3 and 16). First, changeability seems to start with the exploration and creation of narratives about the ST innovation. For example, proposition 1 suggests that ecosystem services, which the ST provides, should include monetary values and create narratives e.g. a new way to value ecosystem services for tangible benefits. Also, proposition 2 is hinting at the benefit of custom narratives to sustainability topics. However, the workshop also helped generate these narratives, for example: 'combatting global warming, mitigation of city heat stress, benefiting the public health' and offer these to users for a price. Second, the actual testing of the changeability of market preconditions will take place in a later stage when technology advocates armed with convincing narratives will engage in discussions with key actors for the development of the ST. For example, proposition 3 targets the government's mind-set on the environment and especially city greening. Also, proposition 16 targets the method to calculate value, proposing an alternative that can change the playing field in competition with ordinary trees.

Secondly, SNM is proposed to have a *niche focus* by which it can safely investigate the implications of the innovations' scale-up within boundaries. The workshop showed what a niche focus can add to DT through various propositions and discussions. First, knowledge from the intricate actor network helped to generate the insight that building regulations should be checked for deploying ST on the rooftop of buildings, in order to avoid legal impediments (proposition 5). Second, the niche focus helps to design a pilot for experimenting with the product design. In the case of the ST, suggestions were done for alternative revenue models (proposition 6) and delivery models (proposition 7). Finally, the niche focus surfaced in the workshop by concrete suggestions on how to protect the ST in the short term. Specifically, it delivered the step to tap into social workplaces as a potential partner in delivering the innovation (proposition 11) and applying for a Dutch 'Mia Vamil' subsidy as a tax scheme, which supports investing in environmentally friendly

technology (proposition 15). These examples earmark a broader set of proposals that go beyond DT's user focus.

Thirdly, SNM is proposed to create *commercial viability among stakes* where DT is falling short in its application (Furue and Washida 2017; Sorabayashi, Sasaki, and Uchihira 2017). The content of propositions alone does not demonstrate this merit. For example, it only addresses who to recruit into the consortium, like technology advocates (proposition 8), investors (proposition 13) and social workplaces (proposition 11). However, the merit speaks more from the workshop process underlying. The APs led to lively discussions helping the parties to present, argue and align their ideas into propositions. In one example, one discussion on AP 3 and 5 led to the agreement the consortium needs the tree nursery, technology experts and a managerial party for setting up the production process. In another example, the articulation also showed two distinct stakes surfacing on whether to include social workplaces, namely the social inclusivity and the business marketing. Still, the workshop demonstrated that this could be aligned as a common mission for shared commercial viability to experiment with another iteration on the product design.

Fourthly, SNM proposed the ability to *create developmental steps*, specifically by facilitating the learning processes during the implementation of a niche. This leads to a strategy for the appropriate time to break down the actual protected space. The workshop delivered propositions that were accepted by the actor network. This very list shows an enumeration of tasks to include in the DT process as necessary development steps (Table 3). For example, to actively use custom narratives on sustainability topics to advocate and empower the innovation (proposition 2). It has actually also helped to formulate very specific narratives for the ST itself, for example: combatting global warming, mitigation of city heat stress, benefiting the public health, preventing sewer overloads. It also created the idea to conduct a societal cost-benefit analysis (proposition 4), which can actually test these narratives as the design is prototyped and piloted.

Overall, a closer look at the demonstration of merits through the ST workshop helped to elaborate some patterns on the role that SNM has in DT. Figure 6 is intended to clarify this role. It is demonstrated that SNM can use the developmental state of the sustainable innovation as input to set up APs for the existing actor network. SNM APs can produce discussion points that serve as input to formulate propositions on a distinct set of developmental steps, most notably: deployment experiments (e.g. piloting delivery models), consortium building (e.g. recruiting investors or advocates), niche protection measures (e.g. subsidy schemes, short term resources), and changing market preconditions (e.g. changing influential minds or accepted methods). We coin these four activities as Design to Market Thinking (D2MT).

Conclusions

Recent literature noted that DT is missing an explicit linkage to sustainability (Li, Ho, and Yang 2019; Ioannou and Meletiou 2011). The authors of this study noticed that a strong potential could lie in the SNM approach, in which a link to sustainability already ran deep since its inception (Kemp, Schot, and Hoogma 1998). The focus of our study is unique, in that no other study was found to link DT and SNM so explicitly.

From our literature review, four potential SNM merits could be detected, namely that SNM can: (1) change market preconditions for the design, (2) create a protected niche for development, (3) establish a (long term) commercial viability beneficial for all involved stakeholders, and (4) create an innovation development plan through definition of a set of testable propositions.

The propositions generated by means of the ST workshop have proven that: (1) SNM can potentially nullify DT's trade-off between 'desirability, feasibility and viability' and sustainability by means of changing the market preconditions for the product, (2) SNM is of a broader orientation compared to DT's user focus, allowing to safely investigate the implications of the innovations' scale-up within set boundaries, (3) SNM can realise alignment amongst the involved stakeholders for shared

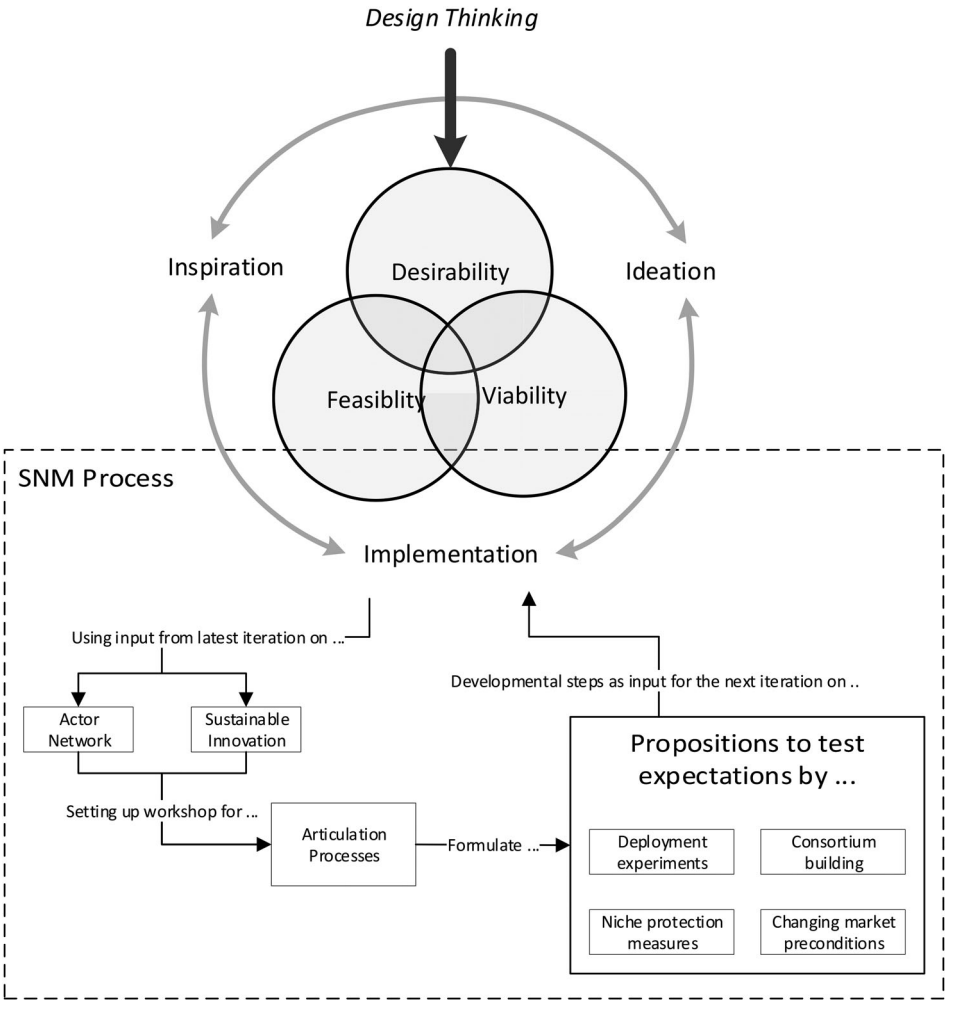

Figure 6. Design to Market Thinking approach using merits of SNM into DT.

commercial viability to be taken into account within next product design iterations, (4) SNM can facilitate the learning process in such a way that it creates pre-conditional development steps that are required for the market implementation aiding DT's process. We emphasise that since the SNM approach can create market pathways, it contributes most to DT's principle of implementation.

In conclusion, it is striking that the academic linkage between DT and SNM is so scarce. This study suggests there is more to be gained on this link, as more research is picking up on needs for bridging the design-implementation gap, which DT strives to cross, for example with sustainable business models (Geissdoerfer, Bocken, and Hultink 2016; 2017). Our study shows that the inclusion of SNM, unlocks a certain market focus into DT that makes considerations on desirability, viability and feasibility less about the product alone, and more about the product and its deployment to the market. In essence, the propositions generated from the ST workshop demonstrated an important pattern that can form the very basis for this broadening of DT. Actors seemed to posit developmental steps on (a) deploy experiments, (b) consortium building, (c) niche protection measures, (d) change of market preconditions. These key activities embody the additional dimension of market orientation in DT, which we coin Design to Market Thinking (or D2MT).

Limitations and future research

This study was based on the idea to combine SNM and DT on a workshop application, and hence some methodological limitations must be noted. First and foremost, this research reports findings from one workshop, leaving much to scrutinise before it can be generalised. However, provided this was a first explicit attempt at connecting SNM and DT, the findings should be viewed as a promising basis for an intricate connection. Future research should therefore focus on multiple and different innovations and include SNM practices in the DT procedures.

Second, the workshop missed the articulation of environmental and social effects of the innovation and the input from the bank actor. The workshop was therefore not able to explore the full potential of sustainability effects to market introduction and potentially investigate the role of the financial viability principle from DT. Therefore, it is important that more workshops are conducted in which APs and actors are completely covered and represented.

Notes

1. In Scopus, the following search query was conducted on 6th of April 2021: (TITLE-ABS-KEY ("design thinking") AND TITLE-ABS-KEY ("strategic niche management")) confirming that there were no results found.
   In Web of Science (both Core Collection and All Databases) the following search query was conducted on the 6th of April 2021: ALL FIELDS: ('strategic niche management') AND ALL FIELDS: ('design thinking') confirming that there were no results found.
2. The full overview of the card placements per AP are provided in supplementary materials.

Notes on contributors

D.F.J. Schraven is an Assistant Professor at the Faculty of Civil Engineering and Geosciences (CEG). He focuses on sustainable and circular innovations in the infrastructure and building sector. Particularly, he is interested in strengthening the market power of sustainable innovations in the construction sector by studying the business (model) experimentation and innovation of these innovations both with data analysis and field experiments.

P. Arghandeh Jouneghani is an M.Sc. graduate from the Faculty of Civil Engineering and Geosciences at Delft University of Technology with a specialisation in Construction Management Engineering. His focus area is the transition towards sustainability within the built environment, with a main interest in the market implementation of sustainable innovations.

H.M. Jonkers received his Ph.D. degree from Groningen University in 1999. After 7 years working as a research scientist at the Max-Planck-Institute for Marine Microbiology in Bremen he moved to Delft University of Technology where he is currently leading as Associate Professor the Sustainability Group within the Materials & Environment section of the materials, Mechanics, Management and Design department at the CEG Faculty of the Delft University of Technology. His main research concerns development of bio-adapted-, self-healing-, and sustainable construction materials.

M.J.C.M. Hertogh is a Full Professor of Integrated Design and Management at Delft University of Technology. He is an expert in the field of major infrastructure programmes. He initiated the network Netlipse, is a strategic advisor of the Ministry of Infrastructure and Water Management, and was programme director himself.

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ORCID

D.F.J. Schraven http://orcid.org/0000-0003-0647-1172

References

Aceti, J., and T. Singarayar. 2015. "Business Model Design." In *Design Thinking: New Product Development Essentials from the PDMA*, edited by M. Luchs, K. Scott, and A. Griffin, 265–280. John Wiley & Sons, Inc.

Angelina, S., D. Vallée, and C. Louen. 2018. "The Barriers in the Implementation Process and the Operation of Innovative Urban Transport: The Case of BRT Jakarta." *WIT Transactions on the Built Environment* 176: 69–80. doi:10.2495/UT170071.

Arnold, J. E. 1959. Creative Engineering: Promoting Innovation by Thinking Differently. Edited With an Introduction by William J. Clancey.

Baughn, C., and C. Suciu. 2015. "The Intersection of Design Thinking and Twenty-First Century Approaches to Innovation." Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE, 2015 January, 64–72.

Blaschke, M., M. Cigaina, U. V. Riss, and I. Shoshan. 2016. "Designing Business Models for the Digital Economy." In *Shaping the Digital Enterprise*, edited by G. Oswald, and M. Kleinemeier, 121–136. Springer, Cham: Springer International Publishing Switzerland. doi:10.1007/978-3-319-40967-2_6.

Bonakdar, A., and O. Gassmann. 2016. "Design Thinking for Revolutionizing Your Business Models." In *Design Thinking for Innovation*, edited by W. Brenner, and F. Uebernickel, 57–66. Cham: Springer. doi:10.1007/978-3-319-26100-3_4.

Brown, T. 2008. "Design Thinking." *Harvard Business Review* 86 (5): 84–92.

Buhl, A., M. Schmidt-Keilich, V. Muster, S. Blazejewski, U. Schrader, C. Harrach, M. Schäfer, and E. Süßbauer. 2019. "Design Thinking for Sustainability: Why and how Design Thinking Can Foster Sustainability-Oriented Innovation Development." *Journal of Cleaner Production* 231: 1248–1257.

Ceschin, F. 2015. "The Role of Socio-Technical Experiments in Introducing Sustainable Product-Service System Innovations." In *The Handbook of Service Innovation*, edited by R. Agarwal, W. Selen, G. Roos, and R. Green, 373–402. Publisher: Springer London. doi:10.1007/978-1-4471-6590-3_18.

Chen, S., R. Benedicktus, Y. Kim, and E. Shih. 2018. "Teaching Design Thinking in Marketing: Linking Product Design and Marketing Strategy in a Product Development Class." *Journal of Marketing Education* 40 (3): 176–187.

Cross, N. 2011. *Design Thinking: Understanding how Designers Think and Work*. First Edition. Berg, Oxford, New York: Oxford. doi:10.5040/9781474293884.

Delp, P., A. Thesen, J. Motiwalla, and N. Seshardi. 1977. *Systems Tools for Project Planning*. Indiana University, Bloomington: International Development Institute. ISBN: 0-892-49021-7.

Furue, N., and Y. Washida. 2017. "Scanning and Design Thinking: Organizational Roles for Innovation." *Foresight* 19 (4): 337–353.

Garcia, R., and S. Dacko. 2015. "Design Thinking for Sustainability." In *Design Thinking: New Product Development Essentials from the PDMA*, edited by M. Luchs, K. Scott, and A. Griffin, 381–400. John Wiley & Sons, Inc. doi:10.1002/9781119154273.ch25.

Geissdoerfer, M., N. M. P. Bocken, and E. J. Hultink. 2016. "Design Thinking to Enhance the Sustainable Business Modelling Process – A Workshop Based on a Value Mapping Process." *Journal of Cleaner Production* 135: 1218–1232.

Geissdoerfer, M., P. Savaget, and S. Evans. 2017. "The Cambridge Business Model Innovation Process." *Procedia Manufacturing* 8: 262–269.

Govender, I. 2017. "Wicked Leadership for Sustainable Business Development." Proceedings of the 5th International Conference on Management Leadership and governance, ICMLG 2017, Sant Petersburg, Russia, 591–599, ISBN: 978-1-63439-609-7.

IDEO. 2012. Design Thinking for Educators' Toolkit.

Ioannou, K., and M. Meletiou. 2011. "Sustainable Friendly Design: Process and Artifact." *Design Principles and Practices: An International Journal—Annual Review* 5 (3): 355–366.

Kemp, R., J. Schot, and R. Hoogma. 1998. "Regime Shifts to Sustainability Through Processes of Niche Formation: The Approach of Strategic Niche Management." *Technology Analysis and Strategic Management* 10 (2): 175–198.

Khan, A. Z., H. Vandevyvere, and K. Allacker. 2013. "Design for the Ecological age Rethinking the Role of Sustainability in Architectural Education." *Journal of Architectural Education* 67 (2): 175–185.

Klotz, L., E. Weber, E. Johnson, T. Shealy, M. Hernandez, and B. Gordon. 2018. "Beyond Rationality in Engineering Design for Sustainability." *Nature Sustainability* 1 (5): 225–233.

Kurucz, E. C., B. A. Colbert, and D. Wheeler. 2013. *Reconstructing Value: Leadership Skills for a Sustainable World*. Publisher: University of Toronto Press/Rotman. ISBN: 9781442611535.

Kwon, T.-H. 2012. "Strategic Niche Management of Alternative Fuel Vehicles: A System Dynamics Model of the Policy Effect." *Technological Forecasting and Social Change* 79 (9): 1672–1680.

Lebo, N., C. Eames, R. Coll, and K. Otrel-Cass. 2014. "Toward Ecological Literacy: A Permaculture Approach to Junior Secondary Science." *Australian Journal of Environmental Education* 29 (2): 241–242.

Li, W.-T., M.-C. Ho, and C. Yang. 2019. "A Design Thinking-Based Study of the Prospect of the Sustainable Development of Traditional Handicrafts." *Sustainability* 11 (18): 4823. doi:10.3390/su11184823.

Markham, S. K., S. J. Ward, L. Aiman-Smith, and A. I. Kingon. 2010. "The Valley of Death as Context for Role Theory in Product Innovation." *Journal of Product Innovation Management* 27 (3): 402–417. doi:10.1111/j.1540-5885.2010.00724.x.

Moore, G. A., McKenna, R. 1999. *Crossing the Chasm: Marketing and Selling High-tech Products to Mainstream Customers.* 2nd ed. New York: HarperPerennial.

Mourik, R. M., and R. P. J. M. Raven. 2006. A practioner's view on strategic niche management. (ECN-E; Vol. ECN-E-06-039 EN). ECN.

Pahlavi, G. R., D. Purnomo, A. Bunyamin, and A. P. Wulandari. 2017. "Ramie (Boehmeria Nivea) Decortication Waste bio-Briquette Business Model Canvas with Design Thinking Approach." *AIP Conference Proceedings* 1826 (1): 020014-1–020014-8. doi:10.1063/1.4979230.

Plattner, H., C. Meinel, and L. J. Leifer. 2011. *Design Thinking: Understand, Improve, Apply. Understanding Innovation*. Berlin; Heidelberg: Springer-Verlag, xiv–xvi. doi:10.1007/978-3-642-13757-0.

Ribeiro, M. M. L. B. B., M. Au-Yong-Oliveira, F. Lima, and R. Afonso. 2018. "Research on Innovation Processes at a Firm Located in a Country Averse to Uncertainty." In *Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE*, edited by Carlos Costa, Manuel Au-Yong-Oliveira, and Marlene Paula Castro Amorim, 1023–1031. Academic Conferences and publishing limited.

Schot, J. 1998. "The Usefulness of Evolutionary Models for Explaining Innovation. The Case of the Netherlands in the Nineteenth Century." *History and Technology* 14 (3): 173–200. doi:10.1080/07341519808581928.

Schot, J., and F. W. Geels. 2008. "Strategic Niche Management and Sustainable Innovation Journeys: Theory, Findings, Research Agenda, and Policy." *Technology Analysis and Strategic Management* 20 (5): 537–554.

Schot, J., R. Hoogma, and B. Elzen. 1994. "Strategies for Shifting Technological Systems. The Case of the Automobile System." *Futures* 26 (10): 1060–1076.

Shapira, H., A. Ketchie, and M. Nehe. 2017. "The Integration of Design Thinking and Strategic Sustainable Development." *Journal of Cleaner Production* 140 (1): 277–287.

Sherin, A. 2017. "Sustainable Thinking." In *Routledge Handbook of Sustainable Product Design*, edited by Jonathan Chapman, 101–111. London: Routledge. doi:10.4324/9781315693309.

Smith, A., and R. Raven. 2012. "What is Protective Space? Reconsidering Niches in Transitions to Sustainability." *Research Policy* 41: 1025–1036. doi:10.1016/j.respol.2011.12.012.

Sorabayashi, T., Y. Sasaki, and N. Uchihira. 2017. "Matching Potential Customer Needs to Technology Seeds: Using a Virtual Catalog to Extract Customer Needs in B2B Manufacturing Companies." Portland International Conference on Management of Engineering and Technology (PICMET), Honolulu, HI, USA, 2493–2498. doi:10.1109/PICMET.2016.7806710.

Tremblay, A.-M., and A. Neef. 2009. "Collaborative Market Development as a pro-Poor and pro-Environmental Strategy." *Enterprise Development and Microfinance* 20 (3): 220–234.

VandeVen, A. H., and A. L. Delbecq. 1974. "The Effectiveness of Nominal, Delphi, and Interacting Group Decision Making Processes." *The Academy of Management Journal* 17 (4): 605–621. doi:10.5465/255641.

Weber, K. M. 2003. "Transforming Large Socio-Technical Systems Towards Sustainability: On the Role of Users and Future Visions for the Uptake of City Logistics and Combined Heat and Power Generation." *Innovation* 16 (2): 155–175.

Weber, M., Hoogma, R., Lane, B., & Schot, J. W. (1999). *Experimenting with Sustainable Transport Innovations. A workbook for Strategic Niche Management.* Seville/Enschede: Universiteit Twente.