New to Improve

The Mutual Influence between New Products and Societal Change Processes

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proefschrift

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Preface

If you're like me, you'll consider the preface to be the most interesting part of any thesis. Between the lines of the preface you often discover the human side of the study. How did the research process work out? Were there any setbacks during the project? And how did one manage to recover? It will tell the story of who assisted the author during the long and often challenging journey towards the successful completion of the thesis. In my case, this journey started about 25 years ago, when I entered the Industrial Design program at the Technical University in Delft in 1985. This was a great combination of technology and creativity, although I frequently wondered what the added value was of all those new products that had been and will be developed. After my graduate project with Professor Jan Jacobs, where I designed a partition wall for a Fokker 50 airplane interior, I really wanted to gain more practical experience in the field of expertise of industrial design.

In the years since I have gained experience with nearly all different phases of the product innovation process, from designing synthetic injection mold products at Bema Kunststoffen in Zierikzee, to selling office furniture at Ahrend Interior Designs in Rotterdam, and from setting up a small design agency with TilT Design in Delft, to the development of airport designs in places such as Moscow and Hong Kong with NKI Group in Dongen. In 1999 I became a concept developer at TNO Industry in Delft, in the department Sustainable Product Innovation of Tom van der Horst. Tom had recently set up a joint venture with the TU Delft Design for Sustainability research group under the leadership of Han Brezet. This collaboration was known as Kathalys, and its objective was to achieve "leapfrog innovations" that would result in a radical reduction of the ecological impact of products and systems. This way of thinking was completely new for me at that time, but it didn't take long before working on new product-service combinations and striving for sustainable system innovations became familiar territory. During a number of extensive EU research projects I was introduced to the more visionary approach of Professor Ezio Manzini of the Politecnico di Milano, which added an additional social component to the pursuit of a sustainable society.

One of the more memorable projects that I had the pleasure of leading at TNO, was the Mitka program, targeting a radical innovation of individual mobility over a short distance. Together with organizations such as Nike, Gazelle and the TU Delft, we developed an innovative electric vehicle, including the accompanying services. In the project we also collaborated on the concept development of a cycling highway between Eindhoven and Helmond. From our perspective, this project was a huge leap forward in knowledge development in the area of sustainable system innovations, as we were working simultaneously on product + service + infrastructure + legislation. The PhD researcher who studied the project did not really agree with this and concluded that the system innovation paradigm "lacks clear boundaries in both the ambition and the context", as there appeared to be a lot of uncertainty about the relationship between short-term and long-term objectives. In addition, he concluded that environmental ambition must in fact be considered as a "non-rational factor", leading to an "escalation of commitments" of the experts involved in a certain innovation process. In all honesty, some of those involved had the impression that this particular researcher had not fully grasped the intent of the project. On the other hand, the system-oriented design approach apparently needed a much better scientific foundation, which was one of the important motivations to start analyzing all this myself in a more systematic manner.

An opportunity to put this into practice was a substantial system-oriented innovation project under the leadership of TNO colleague Rob Weterings. The subproject that was coordinated by Emma van Sandick ultimately was one of the two experiments that form the foundation of this study. The lively and profound discussions about the direction of the "Autonomous Elderly" project, and the continuous puzzle between the "big picture" and the "small elements", has in fact laid the foundation for the multilevel design model as presented in this thesis. On the more practical side, the enthusiastic cooperation from entrepreneurs Edwin Siemerink and Rob Kuipers of My-Bodyguard played a vital role in this period. In the meantime, developments within TNO continued, resulting in a move from Delft to Eindhoven. In the departments of, consecutively, Herm Verbeek, Jan Smits and Joelle van der Broek I had the privilege of working on the application of rapid manufacturing technology and the use of wearable sensor systems for enhancing human performance. During that period I had the privilege of being involved in the early stages of the new degree program Industrial Design at the Technical University in Eindhoven. Here I became familiar with concepts such as ambient intelligence, persuasive computing and tangible interaction, or in other words, with the radical influence of information and communication technology on the design process. During this period, together with colleagues Tinus Jongert and Ingrid Bakker of the TNO department Prevention and Health and many TU/e experts, among which professor Berry Eggen and researcher Tilde Bekker, we were able to kick-start several design projects surrounding the question how new products can motivate young people to become more active physically. This involved a close collaboration with Henny Beekwilder and Mark van Rooijen of the municipality of Eindhoven, and with Cees van Bladel and Hans van Breukelen of the Stichting Sports and Technology. This collaboration formed the foundation for the "Youth in Motion" project, which is the second experiment that is discussed in this study.

Somewhere in 2005 I mentioned to Professor Han Brezet the idea of working towards a thesis myself. We knew each other from the Kathalys cooperation and the Mitka project, where I primarily played the role of a rigidly organized project manager and he was mostly the visionary professor. His enthusiastic response started the ball rolling, and we agreed that Dr. Sacha Silvester would be closely associated with this process. In the Kathalys period I had already discovered that these two professionals complement each other beautifully, where Han is something like the enthusiastic striker who provides the daring center pass, while Sacha is the reliable mid-fielder who provides the organizational structure. It must be noted here that eventually it is of course the cooperation within the team that determines success. And to complete the metaphor, in this case I happen to be the lucky person who has the privilege of scoring the goal, in the form of this thesis!

To be honest, in 2005 I still had the rather naive belief that it must be possible to wrap up such a thesis in one, or no more than two years. Ultimately it took five years. I confess: To write a thesis during evening hours is a greater challenge than I had anticipated. The fact that eventually it was finished fairly quickly is partly due to the Executive Board of the NHL University of Applied Sciences in Leeuwarden. In 2008, I applied for the position of professor ("lector" in Dutch) in the field of transsectoral innovation. One strict condition for being hired was the successful completion of a scientific thesis. I was well on my way, so I declared self-assured that it would be no problem to finish it in less than a year. "All right, but just to make sure, we'll give you two years, and absolutely no more." Ever since, Diane Keizer and Willem Smink have subtly reminded me that time is up at the end of 2010, encouraging me to enthusiastically focus on this exciting endeavor. Well, it has taken quite a few evening hours, but what do you know, it is finished! What remains is to thank all of the people that have been involved in this voyage of exploration, who taught me how genuine renewal can actually come about, and who have inspired me to pursue my own promising visions for a sustainable future. I have already mentioned a number of them, but the most important ones are yet to come.

My dearest wife, Nynke, who always encouraged me to take up new initiatives, who invariably supported me enthusiastically and who never made any suggestion that it might be an idea to throw in the towel, particularly when I spent a lot of weekends, evenings and holidays writing. My parents, who have helped us consistently in various ways, and not just once in a while, but during the entire five-year period. Regularly looking after the children was certainly no punishment for either one of them, and it was a great help to us. The other family members, who were always interested in the progress of my writing, for example when once again I was working at my computer during a holiday in France. And of course, my three wonderful children, Hannah, Sterre and Pepijn, who quite frequently ask me whether I am again working on "the book", invariably followed by the question: "Are you almost finished?" When one of them recently looked at the bookcase, she sincerely wondered whether all of those books on the shelves took that much time to write, while it takes so little time to actually read them…

That is indeed the next step, that the ideas which are presented in this document will now be read, in the hope that it can serve as an inspiration for many designers and other professionals who are occupied with system-oriented innovation, so that they can design new products, services and systems which are not only "new and improved", but also "new to improve" the world in which we live. As for the impact of such a book, I do realize that it's necessary to put things into perspective, as concluded by the writer of the book Ecclesiastes, when he explains that the writing of new books will never stop and that too much study wears you out. To put things even more into perspective, he also observes that at the end, the Master Designer will assess the eternal sustainability of his creation, which again adds a radically new perspective to the discussion about short versus long-term objectives… But that's a subject for another research project; let's first start with discussing this one.

> *There's no end to the publishing of books,*
> *and constant study wears you out so you're no good for anything else.*
> *The last and final word is this: Fear God. Do what he tells you. And that's it.*
> *Eventually God will bring everything that we do out into the open*
> *and judge it according to its hidden intent, whether it's good or evil.*
> *(Ecclesiastes 12, The Message)*

Summary

The field of expertise of industrial design is changing rapidly. Where only a few decades ago the focus of the designer was totally on the development of tangible products, nowadays it is about the development of ideas, plans, strategies, services and the creation of solutions instead of artifacts. At the same time, there is a growing emphasis on the contribution of design to the realization of global sustainability. This means that new products should not only be "new and improved", but also "new to improve" the society in which they function (hence the title of this research).

However, it appears that translating this ambitious vision into reality is not so obvious. When analyzing four related fields of expertise (industrial design engineering, sustainable product development, systems engineering and sustainable system innovation) it appears that current design and innovation models are either too focused on the development of one single product or system, and therefore deal insufficiently with the socio-technical and societal aspect at hand, or they may handle an abstraction level that is so high that the aspect of concrete product development is not sufficiently dealt with. This conclusion has led to the following research question:

> "How can the design process and the role of designers be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner?"

Based on the analysis of current design and innovation models, the demands for an ideal design model are formulated. (1) This should preferably provide insight into the development of one new product while interlinking it with developments at the socio-technical and societal level. (2) It should provide insight into the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives that are being met by means of the functioning of a socio-technical system. (3) It should provide insight into the course of the product design process as related to the course of socio-technical and societal change processes. (4) And it should provide insight into the potential role of the designer, in relation to individual companies as well as in relation to other societal actors. These four issues together cover the what, why, how and who of the subject under investigation.

Although existing models don't seem to offer the desired insight, it appears that distinguishing between various system or aggregation levels may be an effective way to provide the desired understanding. Therefore a new multilevel design model is developed which is based on four system levels, that of the product-technology system, the product-service system, the socio-technical system and that of the societal system. The new multilevel design model is subsequently tested by means of an action research strategy, in the form of two prolonged design projects. The first project is called "Autonomous Elderly" and focuses on the societal challenge that occurs as a result of the aging of society. In this project, the development of a new assisted living center in the Dutch city of Apeldoorn is interlinked with the development of the Guide Me, a personal tracking system that enables people with early onset Alzheimer disease to live independently for a longer

time. The second project is called "Youth in Motion", focusing on the societal challenge posed by the fact that many young people are overweight as a result of a lack of activity. In this project, the development of a "Sports Promotion Field Lab" in the Dutch city of Eindhoven is interlinked with the development of the interactive Make Me Move play floor, designed to encourage young people to be more active.

The conclusion of this research is that the implementation of a multilevel design model can help to describe, and potentially structure, the design process and the role of designers, in such a way that the mutual relationship between new products and the socio-technical and societal context in which these products function is taken into account in a systematic manner. However, while applying a straight-forward design approach is already complicated when developing regular products (as all industrial designer will confirm), it should be kept in mind that it doesn't come near the complexity of initiating changes at the level of socio-technical or societal systems.

1 Chapter 1: Introduction

1.1 New and improved - new to improve

1.1.1 Introduction

"New and improved!" This slogan is mentioned on nearly all new products that appear on the market, and there are quite a few of them. Each year, thousands of new products are developed and introduced worldwide. Often these are existing products that have undergone a small improvement, while others involve radical new products that fulfill a totally new function. With many of these new products, designers play an important role. This study is focused on the design process, specifically as viewed from the perspective of the industrial designer. This appears to signify a simple definition, but appearances can be deceiving. After all, what actually is a "designer"? 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 artifacts 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, 3).

In order to more closely define the boundaries of the working area, we will briefly examine the history of the field of expertise and the anticipated developments in the near future. As a matter of fact, the first expert to be considered as an industrial designer was originally an architect. Whether it was the Englishman Christopher Dresser (1834-1904), or the German Peter Behrens (1868-1940) is a subject of discussion, where most authors agree that the latter is more deserving of the title, particularly due to his close relationship with the industrial concern Allgemeine Elektrizitäts-Gessellschaft – AEG (Denison, 2005). Especially his designs of tea kettles, clocks, lamps and fans are generally associated with the field of expertise of industrial design. Since that time, just like in so many other fields of expertise, more and more specialization and demarcation has been created, a process that leads to a multitude of specialties that are all simply referred to with the term design: fashion design, graphic design, interior design, intelligent product design, game design, interactive design, system design, exhibition design, software design, web design, experience design, sound design, color design, urban design, landscape design, to mention just a few of them.

This study is focused on industrial design, a specialty which itself has changed since branching off from architecture. In a retrospective on the 40th anniversary of the Faculty of Industrial Design at the Technical University in Delft, Dean Cees de Bont indicates that in the initial years of the study, 90% of all students graduated on a physical subject, against only 30% in 2009. The remainder graduated on concepts ideas plans and strategies (Visscher, 2009, p31). While early designers were especially focused on the development of physical products, nowadays the emphasis is apparently more on "solving problems". This can be accomplished through a new product, but there are many other ways. Where early industrial designers, according to De Bont, "primarily designed objects that go 'poof' when you drop them", students now also learn that an object is not always the best solution for a problem (Visscher, 2009, p31). Various other authors confirm that design is less and less about providing physical products and more and more about delivering "experiences" (Pine and Gilmore, 1999), shifting attention from "ownership to access" (Rifkin, 2000, 85) and creating the need for "solutions" instead of artifacts (Manzini et al., 2004). Incidentally, the development of these artifacts is itself highly subject to change, especially as a consequence of applying more and more information and communication technology. The effect is that products are functioning less and less as "standalone". Mark Weiser, head of the Computer Science Laboratory at Xerox PARC, predicts this development when he emphasizes that the computer in the 21st century will continue to "disappear" and will become part of other products, which in turn are part of increasingly complex technological and social networks: "The real power of the concept comes not from any one of these devices; it emerges from the interaction of all of them" (Weiser, 1991).

In that framework there is frequent talk of a "third industrial revolution" that is drastically changing the way society functions. In an analysis of the consequences of this development, Stefano Marzano, CEO of Philips Design, argues that the consequence of all these developments is that the assumptions about the usefulness and necessity of new products are constantly being debated. It may even be necessary for us to redefine our assumptions in the area of ethics, authenticity, responsibility and sustainability. That means that "new disciplines will need to work together to redefine their assumptions about our most fundamental needs. What is required is a commitment on behalf of all to continue to question what kind of world we want to live in and how we want to live and communicate within it, and then to address those questions as a group" (Aarts and Marzano, 2003, 11). For that matter, crossing the once-defined boundaries between fields of expertise is something that is inextricably linked with the innovation process. Economist Joseph Schumpeter (1911) already describes the core of innovation as the creation of "Neue Kombinationen", where different knowledge areas are combined in a unique way. More recently, urban studies theorist Richard Florida emphasizes the increasingly narrow collaboration between the various fields of expertise when he stresses that "the rise of the Creative Economy is drawing the spheres of innovation (technological creativity), business (economic creativity) and culture (artistic and cultural creativity) into one another, in more intimate and more powerful combinations than ever" (Florida, 2002, 201).

The consequence of this is that the societal impact of all of these renewals continues to increase. After all, a new product does not only influence its direct environment, it also influences all other individuals that it is in contact with through the network that it is part of. The world is becoming increasingly "flat"(Friedman, 2005) and increasingly "connected" (Prahalad and Krishnan, 2008). The result is that we are increasingly dependent on these highly sophisticated and complex systems. "Fortunately, most of the systems function most of the time very well. But, at the moment something goes really wrong, the consequences can be huge" (Brombacher, 2007). And it is a well-known fact that the functioning of new products does not always go well. For designers, the challenge that they are facing is the fact that small actions can have big effects – often unexpectedly – "and designers only recently have been told, with the rest of us, how incredibly sensitive we need to be to the possible consequences of any design step we take" (Thackara, 2006, 7).

1.1.2 A shift towards sustainability

Much of the research that has been conducted around this theme stems from the perspective of ecological sustainability, resulting in a new design area that we will call "sustainable product development". This field of expertise can actually be considered as the "core area" of this research. This field of expertise is closely related to that of industrial design engineering, albeit that it is explicitly focused on reaching sustainability objectives. In this framework, the book "Design for the Real World" (Papanek, 1985) can be considered a milestone, urging designers to not only focus on the wishes of the market economy but also to accept their societal responsibility. Inspired by this idea, industrial designers in the 1980s and 90s are more and more focused on the topic of sustainability. Initially it involves only a few individuals, for example in the form of a thesis about the application of energy analyses during the design process (Kemna, 1981), but this field of expertise gains momentum after the publication of "Our Common Future" (Brundtland, 1987).

Inspired by this United Nations report, various research groups are being established in the area of sustainable design. For example, the Design for Sustainability research group is heading off in Delft, The Netherlands in 1992, headed by Han Brezet, the Italian Politecnico Milan establishes the interdepartmental research center INDACO in 1995, headed by Ezio Manzini, in Britain the Centre for Sustainable Design is established in that same year, headed by Martin Charter and at the Australian Royal Melbourne Institute of Technology, Chris Ryan is working on the subject of Design and Sustainability from 1990 onwards. Research institutions such as the Dutch TNO also begin to occupy themselves with the subject, for example in the Ecodesign program (te Riele and Zweers, 1994). The acquired experience is recorded in the PROMISE Manual (Brezet, 1994), which was adapted and published by the United Nations Environment Program in 1997 (Brezet and van Hemel, 1997) and in revised form in 2009 (Crul et al., 2009). The collaboration between TNO and TU Delft results in the founding of the Kathalys Center for Sustainable Product Innovation in 1997, with the mission to "initiate and introduce leap-frog sustainable product innovation, with a factor 4 ambition level, and a time perspective of 3 to 10 years" (Brezet and van der Horst, 1999, 4) (Brezet et al., 2001c). Parallel to this development the European Union supports a number of research programs around the theme of product-service combinations, such as MEPPS (Halen et al., 2005), Homeservices (Halme et al., 2004), HICS (Manzini et al., 2004) (Jegou and Joore, 2004), Prosecco and Innopse. The theme is explored further within the thematic network Suspronet (Tukker and Tischner, 2006) and, emanating from this, in the SCORE! project (Tukker et al., 2008) (Geerken and Borup, 2009) (Tischner et al., 2010) (Lahlou, 2010).

Over time, a shift of focus has occurred here where attention is increasingly moving 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 artifact itself, the field has expanded to cover the whole technical life cycle and the institutional infrastructure in which the artifacts are produced and employed" (Ehrenfeld, 2001). The fact that this system approach is still alive in 2010 is evident from the report "Vision 2050", in which the World Business Council for Sustainable Development (WBCSD) presents a vision of a world "well on the way to sustainability by 2050". Their findings suggest that there is no simple, single path to reach this goal, but rather "the need to design, build and transform complex systems" that will in turn "provide the foundation for survival and human development throughout the 21st century and beyond" (WBCSD, 2010, 64).

1.1.3 An ambitious definition of industrial design

The connection between this need to design, build and transform complex systems (WBCSD, 2010, 64) -- where the underlying objective is the creation of a sustainable society -- and the work of the industrial designer is being emphasized by the definition of industrial design, as formulated by the International Council of Societies of Industrial Design (ICSID):

Aim: Design is 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.

Task: Design seeks to discover and assess structural, organizational, functional, expressive and economic relationships, with the task of:

- Enhancing global sustainability and environmental protection (global ethics)
- Giving benefits and freedom to the entire human community, individual and collective
- Final users, producers and market protagonists (social ethics)
- Supporting cultural diversity despite the globalization of the world (cultural ethics)
- Giving products, services and systems, those forms that are expressive of (semiology) and coherent with (aesthetics) their proper complexity

Design concerns products, services and systems conceived with tools, organizations and logic introduced by industrialization - not just when produced by serial processes. The adjective "industrial" put to design must be related to the term industry or in its meaning of sector of production or in its ancient meaning of "industrious activity". Thus, design is an activity involving a wide spectrum of professions in which products, services, graphics, interiors and architecture all take part. Together, these activities should further enhance - in a choral way with other related professions - the value of life.

Therefore, the term designer refers to an individual who practices an intellectual profession, and not simply a trade or a service for enterprises. (ICSID, 2010)

The definition mentions the development of "objects, processes, services and their systems in whole life cycles". This emphasizes that industrial design is not only focused the development of new products, i.e. physical objects and artifacts, but encompasses a much broader working area. Emphasis is also placed on the role of design for the "innovative humanization of technologies". Design "translates", as it were, impersonal technology to more personal applications. Besides the actual product development, the ICSID emphasizes the task of design as the realization of "global sustainability and environmental protection", the establishment of "benefits and freedom to the entire human community" and the support of "cultural diversity", which can be summarized as the pursuit of global ethics, social ethics and cultural ethics. Last of all it stresses that a "wide spectrum of professions" is involved in the design process. These must collaborate intensively in order to "further enhance the value of life". As a matter of fact it can be noted that the relationship with business is only mentioned in the very last line of the ICSID definition, and even then primarily to place it in a broader perspective.

The broad focus of this definition is not self-evident. This can be seen when we compare the above definition to ICSID's first definition of industrial design, which was officially adopted at their first congress and General Assembly in Stockholm, Sweden in September 1959:

"An industrial designer is 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. The industrial designer may, at different times, be concerned with all or only some of these aspects of an industrially produced object.

The industrial designer may also be concerned with the problems of packaging, advertising, exhibiting and marketing when the resolution of such problems requires visual appreciation in addition to technical knowledge and experience.

The designer for craft based industries or trades, where hand processes are used for production, is deemed to be an industrial designer when the works which are produced to his drawings or models are of a commercial nature, are made in batches or otherwise in quantity, and are not personal works of the artist craftsman." (ICSID, 1959)

When comparing both definitions, it is clear that the working area of the industrial designer has been considerably widened during the last 50 years. Where the 1959 definition puts great emphasis on the "materials, mechanisms, shape, colour, surface finishes and decoration of objects", the new definition talks about "the multi-faceted qualities of objects, processes, services and their systems in whole life cycles", and while the 1959 definition emphasizes the production of these products in industrial processes, the new definition explicitly mentions that it is not only about products that are produced by serial processes, and it maintains a much broader perspective on the role and task of design, emphasizing its responsibility with regard to its contribution to sustainability in a globalizing world.

All in all, there appear to be three developments that enhance each other, as will be further discussed in chapter 3: First, a broadening of the working area of designers, where it's no longer only about the development of new products, but about the development of processes, services and complex, interconnected systems. Second, an organizational development where actors are increasingly collaborating across the boundaries of various fields of expertise and disciplines. This is not only about collaboration between companies, but particularly also about collaboration between government, societal organizations and knowledge institutions. Third, the responsibility to strive for sustainability, for global, social and cultural ethics, for ways to "further enhance the value of life". Located in the middle of all these developments, at least when viewed from the perspective of this study, is the designer, the design process and the new product. That new product must therefore not only be "new and improved", but must also become "new to improve" the wider context in which it functions (hence the title of this study).

1.2 Current knowledge situation

1.2.1 Industrial Design Engineering

Now the question is how this issue is dealt with within the area of industrial design engineering and related fields of expertise. The position of new products within the broader societal context is reflected in the mission statement of the "largest university-based design course in the world" (Delft University of Technology, 2008a) which states that "the Faculty of Industrial Design Engineering's concern is to study, innovate and improve the development of durable products and their related services for people, on the basis of the balanced interests of users, industry, society and environment" (Delft University of Technology, 2008b). On the other hand is also becomes clear from this statement that the main focus of industrial design lies in the development of durable products or artifacts. This impression is confirmed when taking a closer look at the domain of industrial design engineering, as will be done in chapter 3 and 4, looking among others to the Basic Design Cycle (Roozenburg and Eekels, 1991), the Delft Innovation Model (Buijs and Valkenburg, 2005), the Vision in Product design (ViP) method (Hekkert and van Dijk, 2000) and the theory of the Evolutionary Product Development (Eger, 2007). Here it becomes clear that the main focus is still the development of one, more or less solitary product or service. Although these artifacts are by themselves small-scale systems, most models emphasize the development of the composite whole and pay less attention on the manner in which this whole is assembled as a system, let alone what position the product takes within the larger system context that it is part of. Having said that, experts focusing on the development of Intelligent Products (Aarts and Marzano, 2003) (Andrews, 2003) (Feijs and Kyffin, 2005) do put the design of products somewhat more deliberately in the wider system context that it is part of. However, the main approach that is taken here is that from a user perspective, and the societal issues mentioned in the definition of the ICSID don't seem to appear a deliberate target to be achieved by this area of design either.

1.2.2 Sustainable Product Development

Stemming from the area of industrial design, the core area of research that is important for this study is the field of expertise we will call "sustainable product development". As mentioned before, the focus of designers that occupy themselves with sustainability has been shifting for more than a decade towards the larger context that these products are part of (Weterings et al., 1997) (von Weizsäcker et al., 1998) (Brezet et al., 2001a) (Ehrenfeld, 2001). Having said that, in the analysis resulting from the SCORE! research network, supported by the EU's 6th Framework Program, the position of designers is still being described as rather action oriented and perhaps even simple-minded:

> *"At the risk of creating caricatures, the positions of practitioners in these fields tend to be characterized as follows. Designers, who are action-oriented, simply start with all their great creativity to work on new sustainable solutions, only to be caught by the unpleasant surprise that the world for some reason does not implement many of their beautiful ideas" (Tukker et al., 2008, 10).*

Although this description may indeed be considered as a kind of caricature, it may contain some truth. Although much research has been conducted in the area of sustainable product development, the actual results that are being achieved remain relatively modest. In fact the approach now favored seems to be more of a bottom up approach, searching for grassroots initiatives of people inventing sustainable ways of living, and finding ways how designers can strengthen or multiply these bottom up initiatives (Meroni, 2007)(Jegou and Manzini, 2008). Although this may be a very promising approach, the question is if it is possible to really combine the development of "small products" with the design of the "bigger system" at the same time.

One of the more ambitious initiatives to develop "leapfrog" sustainable solutions within a broader system context is the Mitka project (Joore, 2000) (Joore, 2001) (Luiten et al., 2001a) (Brown et al., 2003). This research project was conducted within the framework of the earlier mentioned Kathalys cooperation of TNO and Delft University of Technology, and was conducted in collaboration with among others leading Dutch bicycle producer Gazelle, the European headquarters of Nike and design studio Van der Veer Designers. In the project an effort was made to develop of a completely new mobility system, including an electric powered tricycle, accompanying services and corresponding infrastructure. The project was analyzed by Berchicci who advises that it would have been better to use a "bricolage approach", taking small steps instead of aiming at a "breakthrough" approach in which a complete new system is designed in one big move. His conclusion is that much more insight is needed, in order to really understand how design initiatives such as the Mitka project can really be successful:

> *"The system innovation paradigm often lacks clear boundaries in both the ambition and the context. If we want to create a new sustainable mobility system, to what extent do we need to change it? What are the boundaries for the creative destruction process? In the Mitka case, the PSS concept of a new vehicle with dedicated services soon became a system itself. The services encompass not only maintenance service but also new infrastructures (such as high speed bike highway, electric rechargers in several places in the city, special shed etc.) (…) How to balance short-term goals with the long-term ones? A stringent and clear definition of the boundaries of the system is needed" (Berchicci, 2005, 209) (Berchicci, 2009, 197).*

The question seems to be if it is at all possible to actually design a larger socio-technical system in a similar way that new products are being designed. For this purpose, insight is needed in the way that the design process and the role of designers can be described, and potentially be organized, in such a way that the relationship between new products and the bigger system in which these products function, can be taken into account in a systematic manner. In order to gain this insight, it may be useful to tap into some new fields of expertise.

1.2.3 Sustainable System Innovation

When analyzing the Mitka project (Brown et al., 2003) consider it as a "bounded socio-technical experiment", where a socio-technical system can be defined as "a cluster of aligned elements, including artifacts, technology, knowledge, user practices and markets, regulation, cultural meaning, infrastructure, maintenance networks and supply networks, that together fulfill a specific societal function." (Geels, 2005). The field of expertise that occupies itself with the way that large scale societal developments take place will be called "sustainable system innovation". Within this field of expertise, a design related approach is the Participatory Backcasting method (Quist, 2007), also referred to as "Backwards-Looking Analysis" (Lovins, 1976), or Energy Backcasting (Robinson, 1982). Variants of this approach are developed by The Natural Step (Holmberg, 1998), (Nattras and Altomare, 1999), the Dutch program for Sustainable Technology Development (DTO) (Weaver et al., 2000, Aarts, 2000) and the European Sushouse project (Vergragt, 2000). These methods are trying to influence developments at a socio-technical systems level, changes which are often referred to as a "transition". Such a transition can be defined as "a gradual, continuous process of societal change, where the character of society (or of one of its complex subsystems) undergoes structural change (Rotmans et al., 2000, 11). This is where changes take place in technical, infrastructural, societal, institutional, socio-cultural as well as economic areas, all closely related to each other (Rotmans et al., 2001) (Elzen et al., 2004) (Loorbach, 2007). The field of expertise of "transition management" tries to guide these changes in a desired, sustainable direction. The building blocks to accomplish this include small scale experiments, conducted within a defined niche environment, also referred to as "transition experiments" (Kemp and van den Bosch, 2006), "societal innovation experiments" (van Sandick and Weterings, 2008), or the previously mentioned "bounded socio-technical experiments" (Vergragt and Brown, 2004). It is related to the investigation around "strategic niche management" (Schot et al., 1997), where innovations come about within defined niches, to allow them to grow into maturity, as it were, in a closed environment. Within this field of expertise, the "learning" aspect plays an important role (Argyris, 1976) (Hall, 1993), as with these initiatives it is not only a matter of achieving concrete results. At least as important is the learning process that the parties involved may experience. When the attitude towards a certain situation has sufficiently been adjusted, the expectation is that actors will automatically adjust their actions to the newly acquired insights (Grin and Grunwald, 2000) (Vergragt and Brown, 2004).

Although this field of expertise is rather far removed from the area of industrial design, the expectation is that valuable insights can be learned here, which could possibly be combined with the more hands on approach of industrial designers, benefiting both areas of expertise. Where previously the position of designers was described as perhaps a bit naïve and too much action-oriented, the same report gives a description of system innovation experts as being very good in analyzing and learning, but not that well in acting:

> *"Finally, system innovation specialists preach the need to perform analyses of complex systems, visioning exercises, and 'learning by doing' and 'doing by learning' experiments to understand how change should be fostered (Elzen et al. 2004)—an approach that would probably make the average sustainable designer or non-governmental organization (NGO) rather impatient and, indeed, could provide a pretext to postpone virtually self-evident choices, since one can always learn more" (Tukker et al., 2008, p11).*

While realizing that this description may resemble, like the one related to designers, somewhat of a caricature, there probably is some truth in it as well. Combining both perspectives may perhaps turn out to create a fertile combination of knowledge, combining the more practical approach of designers with the more abstract and analytical insights of system innovation experts.

1.2.4 Systems Engineering

A field of expertise that is essential to take into account when considering the development of complex systems is the field of expertise of "systems engineering". This specialty originated in the 1940s within Bell Telephone Laboratories (Schlager, 1956) and was further developed by Arthur D. Hall (1962). Although complex systems have been developed for centuries (e.g. the Egyptian pyramids, or Roman aqueducts), the field of expertise was not recognizable as a separate discipline before World War II. The increasing complexity of industrialized systems leads to a formalization of the field of expertise in the mid-1900s, stimulated by space travel, military developments and software developments. According to the International Council on Systems Engineering, a system is "an interacting combination of elements to accomplish a defined objective. These include hardware, software, firmware, people, information, techniques, facilities, services, and other support elements" (INCOSE, 2000, 10). Systems engineering is the interdisciplinary field of expertise that facilitates the creation of successful systems according to a logical, systematic and iterative process. This results in a system architecture where elements and subsystems are arranged and are assigned a function, in order for the system to satisfy stated demands. Some of the models that are being studied include the *"Waterfall model" (Royce, 1970), the Spiral Model* (Boehm, 1988) and the *V-model* (KBST, 2004, Cadle and Yeates, 2008, 73). Also included is a discussion of the Work Breakdown Structure approach (Haugan, 2001) as a component of systems engineering.

With this field of expertise, the emphasis is explicitly on the technical system aspect and the manner in which a complex system and the components of the system are developed relative to each other. Although there seems to be no clear link to the societal issues mentioned before, the reason to look into this domain is that it is a rather practical, design oriented field of expertise. The expectation is that the systematic approach that is being used to develop this kind of complex technical systems can be a valuable contribution to the sometimes more intuitive working style used in the field of expertise of design. Also it appears that the systematic manner in which the big system is systematically being divided and structured with regard to the elements that are part of this system, may provide a valuable insight that can be used in this research.

1.2.5 Overview of the fields of expertise

Concluding, we arrive at four different areas of expertise that will be taken into account in this research, being (1) Industrial Design Engineering, (2) Systems Engineering, (3) Sustainable Product Development and (4) Sustainable System Innovation. When positioning these areas in relation to one another (see Table 1-1), the first two areas have a more or less "neutral" approach, the other two have an explicitly normative or sustainability focus. Another distinction is related to the degree that the emphasis is on the development of a single product or service (group 1 and 3), or on the development of composite systems (groups 2 and 4). It should be noted that in reality, no strict separation can be defined between the various fields of expertise, but instead, methods and models may converge and overlap in various areas.

When asking the question is if any of these existing design and innovation models provide the insight regarding the way that the design process and the role of designers can be described in such a way that the relationship between new products and the socio-technical or societal system in which these products function, can be taken into account in a systematic manner (as will be done in chapters 3 and 4), it appears that a number of models may be too focused on the development of a single concrete product or system, and therefore deal insufficiently with the socio-technical or societal aspect. Other models may handle an abstraction level which is too high, so the aspect of concrete product development is not sufficiently dealt with. It will however become apparent that existing design and innovation models offer valuable points of departure for further development, particularly with regard to the question how the design process can be described in such a way that the mutual relationship between new products and the societal context in which these products function can be taken into account in a systematic manner.

Table 1-1: Focus of the four fields of expertise

	Development of single products	Development of composite systems
Neutral focus	1) Industrial Design Engineering	2) Systems Engineering
Focus on sustainability	3) Sustainable Product Development	4) Sustainable System Innovation

1.3 Research question

In the previous paragraphs the ambition of designers to have a positive impact on society as whole has been discussed, among others exemplified by the definition of industrial design of the ICSID, stating the design should contribute to, briefly summarized, global sustainability. The question that is relevant here is what exactly is the relationship between the ambitious, long-term societal objectives that the ICSID speaks of, and the more operational focus of the "normal" industrial designer who is occupied with the development of one new product for one company that has to be available in stores within a couple of months. To mention both aspects together in one definition is one thing, but putting things into practice is another. Is it indeed possible to organize the design process in such a way that the resulting products have a positive influence on society? In fact, what exactly is the relationship between those new products and the socio-technical or societal context in which these products function?

It appeared that efforts to achieve global sustainability by means of design, among others stemming from the field of expertise of sustainable product development, appeared to have a limited rate of success. Looking to, among others, the experiences in the Mitka project, it appears that more insight is needed in the way that the design process and the role of designers can be described, and potentially be organized, in such a way that the relationship between new products and the bigger system in which these products function, can be taken into account in a systematic manner. In order to gain this insight, some related fields of expertise may provide valuable clues with regard to ways how to achieve this insight. For this purpose we have looked briefly into the area of sustainable system innovation and the area of systems engineering. However, the first field of expertise turns out to be rather analytical and detached from practical activity, while the second is rather practical indeed, but lacks the societal perspective we are looking for. Therefore the following research question has been defined:

Research question: "How can the design process and the role of designers be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner?"

1.3.1 Subquestion 1: Product and society ("what")

The research question can be divided in several subquestions. First, the research question speaks about the relationship between new products and the societal context in which these products function. This issue is related to the increasing complexity of the wider context that new products are part of, where it is not only about the functioning of physical artifacts, but about the combined functioning of products, processes, services in complex, interconnected socio-technical or societal systems. To shed more light on this issue the first subquestion is defined as:

Subquestion 1: What is the relationship between (new) products and the socio-technical or societal system that they are a part of, and how can this relationship be described in a systematic manner?

1.3.2 Subquestion 2: Problems and objectives ("why")

The research question speaks about the functioning of products within a certain socio-technical or societal context. The question here is how the functionality of a certain product relates to the functionality of the larger context that it is part of. One could say that the functionality of a product is determined by the problem that is being solved or by the objective that is being achieved by means of its specific properties. The same could be said about the functionality of a certain socio-technical system, as it fulfills a specific societal function (Geels, 2005). In other words, certain societal problems are being solved, or societal objectives are being achieved, by the functioning of the socio-technical system. Now the question can be asked how the problems and objectives at the product level relate to the problems and objectives that are being considered at a societal level. This leads to the second subquestion:

Subquestion 2: What is the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives which are being met by means of the functioning of a socio-technical system, and how can this relationship be described in a systematic manner?

1.3.3 Subquestion 3: Design process ("how")

The research question speaks about the way that the design process can be described, and potentially be structured. The implicit expectation, or hope, is the possibility to organize the design process in such a way that new products actually can make a positive contribution to society. To understand if this is possible at all, it is necessary to understand the way in which the product design process occurs, especially with relation to the way that socio-technical or societal change processes take place. Then the question is if and how the product design process can be structured in such a way that the socio-technical and societal change processes are consciously being incorporated during this process. This leads to the third subquestion:

Subquestion 3: What are the similarities and differences between the product design process and the way that socio-technical and societal change processes take place, and how can these processes be interlinked in a systematic manner?

1.3.4 Subquestion 4: Designer and actors ("who")

The research question speaks about the role of the designer during the design process. Here the first question is what exactly the role of the designer is, and how this role is actually changing with regard to the other actors involved, as a result of the developments surrounding the product design process. The next question is what role, if any, the designer can play when relating the product design process to the way that socio-technical and societal change processes take place. This leads to the fourth subquestion:

Subquestion 4: How can the (potential) role of the designer, with regard to the product design process, as well as with regard to the way that socio-technical and societal change processes take place, be described in a systematic manner?

1.4 Research approach

The research approach is being explained in chapter 2, and follows a four-phase approach, based on (Popper, 1999, 14). Based on an inventory of "problem situation 1", a "tentative theory" will be formulated. This can be viewed as a conjecture, to be critically examined in a process of "error elimination". The outcome of this phase will result in a new "problem situation 2". The broad outline of the initial "problem situation 1" has been sketched in paragraph 1.1 and will be discussed in more detail in chapter 3 and 4. In phase 2, the development of the "tentative theory", takes the form of a new multilevel design model and corresponding propositions which will be discussed in detail in chapter 5. Phase 3 (explained in section 2.4) is the critical examination of the new theory, in a process of "error elimination". This phase is not really about falsifiability, but about testing the internal consistency of the new theory by means of an action-research approach in which two multi-year practical design and innovation projects will be executed. The first experiment is described in chapter 6 under the title "Autonomous Elderly". It focuses on the societal question of aging and dovetails with the development of a new assisted living center in the Dutch city of Apeldoorn. At the product level, the project fits closely with the development of a personal localization system, the Guide Me system. The second experiment, described in chapter 7, is entitled "Youth in Motion". It deals with the societal question surrounding young people with obesity as a consequence of a lack of movement. Particular attention will be paid to a number of projects in the area of sports stimulation in the Dutch city of Eindhoven. At the product level, the project is a close fit with the development of an interactive, luminous gaming floor, the Make Me Move system. Based on the results of the two experiments an analysis will be made in chapter 8 to determine the extent to which the new multilevel design model is indeed capable of describing the design process and the role of designers in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner. This will lead to a reflection on "problem situation 2", which is presented in chapter 9, including a discussion of the consequences of this research for various actors and recommendations for possible supplementary studies. The exact research approach is explained in chapter 2.

1.5 Structure of the thesis

This thesis consists of nine chapters. Chapter 1 (Introduction) describes the background of the study, introduces the research question and presents a broad outline of the approach to finding the answer to this question. It contains the structure of the thesis and defines the limits of the study as well as a number of concepts. Chapter 2 (Research Approach) includes a discussion of the research approach, indicating the philosophical thought framework that forms the basis for conducting this study. A conceptual model is introduced, and four research issues are being introduced (product and society, problems and objectives, design process, designer and actors). In chapter 3 (Products and Society) the four research issues are being discussed, looking from a more broad and philosophical perspective. Chapter 4 (Inventory of Design and Innovation Models) includes an inventory of various innovation models. This will include an examination of how the four research issues are viewed within four fields of expertise (industrial design engineering, sustainable product development, systems engineering and sustainable system innovation). In chapter 5 (A Multilevel Design Model) a new multilevel design model is described, based on the analysis in chapter 3 and 4, and corresponding propositions are formulated on the basis of this model. In this chapter it also the selection process of the two practical experiments is being explained. Chapter 6 (Autonomous Elderly) includes a description of the first practical experiment. The second practical experiment is discussed in chapter 7 (Youth in Motion). The propositions are tested in chapter 8 (Analysis of Experiments), on the basis of the outcomes of the two practical experiments, without further discussion of the broader consequences of these results. Finally, chapter 9 (Conclusions and Recommendations) includes a discussion of the extent to which an answer to the research question can now be given. Potential implications of the study on the field of expertise are discussed and suggestions are made for possible supplementary studies. If we align these nine chapters next to the four phases of the study, we can roughly state that "problem situation 1" is discussed in chapters 3 and 4. The "tentative theory" is discussed in chapter 5. The process of "error elimination" is discussed in chapters 6 to 8 and the discussion of "problem situation 2" is in chapter 9. Schematically this looks as Figure 1-1.

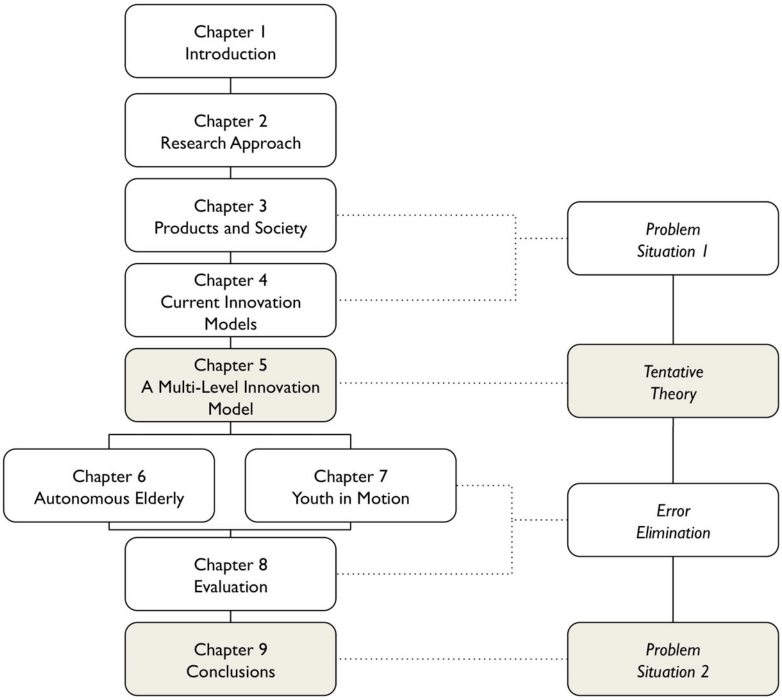

Figure 1-1: Chapter arrangement

1.6 Definitions

In this section, several concepts are being defined. Here it should be noted that chapter 5 includes a discussion of the concepts "product-technology system", "product-service system", "socio-technical system" and "societal system" in the framework of the new multilevel design model.

1.6.1 System

The concept "system" is derived from the Greek word "sýstēma", which means "a whole compounded of several parts". Initially one may consider the discussion by Herbert Simon in "The Architecture of Complexity": "Roughly, by a complex system I mean one made up of a large number of parts that interact in a nonsimple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole." (Simon, 1962) For the purpose of this research, the definition as used by the International Council on Systems Engineering is used, as it is neutral enough to be used for both technical and organizational system configurations.

- *System: An interacting combination of elements to accomplish a defined objective. These include hardware, software, firmware, people, information, techniques, facilities, services, and other support elements" (INCOSE, 2000, 10)*

1.6.2 Product, product-service, product-service system

The word "product" was derived from the Latin "prōdūce(re)", which means "to create". Everything that is offered in the marketplace and that satisfies a certain need can be viewed as a product, whether you can touch it or not. In this study, "product" will be used specifically when it is a matter of the physical artifact. Simply said, when it is about objects "that you can drop on your feet". When discussing intangible products (e.g. an insurance, a maintenance contract or an airplane trip) the term "services" is used. When discussing the combination of products and services, the term product-service systems is used. Here, the definition as formulated in the research project Suspronet will be used (Tukker and Tischner, 2006, 24).

- *Product: A physical object that originates from a human action or a machine process.*
- *Product Service (PS): a mix of tangible products and intangible service designed and combined so that they jointly are capable of fulfilling final customer needs. This concerns hence only the offer to a client. Terms like "mix" or "combination" might be added, but this is not necessary.*
- *Product-Service System (PSS): The product-service including the network, infrastructure and governance structure needed to "produce" a product-service.*

1.6.3 Society, societal system, socio-technical system

The origin of the word society comes from the Latin societas, a "friendly association with others." Societas is derived from socius meaning "companion". Thus the meaning of society is closely related to what is social. Implicit in the meaning of society is that its members share some mutual concern or interest in a common objective. As such, society is often used as synonymous with the collective citizenry of a country as directed through national institutions concerned with civic welfare. In this research, the terms society, societal system, societal context and societal situation are used in a mutually interchangeable manner.

Certain clusters of aligned elements in society can fulfill a societal function, combining social as well as technical elements, hence these clusters can be called "socio-technical systems". With regards to the broader societal context, sometimes the concept of the "socio-technical landscape" is being used. Although this term is closely related to the concept of society as a whole, in this research we will not use the phrase landscape but only refer to more widely used phrase "society".

- *Society / Societal system / Societal context / Societal situation: The community of people living in a particular country or region and having shared customs, laws, and organizations (Oxford dictionaries)*
- *Socio-technical system: A cluster of elements, involving technology, science, regulation, user practices, markets, cultural meaning, infrastructure, production and supply networks. The elements of socio-technical systems are created, maintained and refined by supply-side actors (firms, research institutes, universities, policy makers) and demand-side actors (users, special-interest groups, media) (Geels and Kemp, 2007, 442)*
- *Socio-technical landscape: The exogenous environment that is beyond the direct influence of actors. The content of the socio-technical landscape is heterogeneous and may include aspects such as economic growth, broad political coalitions, cultural and normative values, environmental problems and resource scarcities (Geels and Kemp, 2007, 443)*

1.6.4 Design, innovation, product design, product innovation

With regard to the definition of "design", we will refer to the earlier mentioned definition of ICSID, describing it as a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles (ICSID, 2010). A definition of product design can be derived from this. The concept of "design" is closely related to the concept of "innovation", although both notions refer to their own conceptual frameworks. It appears that design is more about the conception and creation of new entities, and innovation is more about the commercial or industrial implementation of this new (Schumpeter, 1934). Where design is closely related to invention, innovation is aimed at "bringing invention into use" (Schön, 1967). This study is aimed at a combination of design and innovation, with an emphasis on the design perspective. With regard to the degree of originality to be achieved, in this study no distinction is made between incremental, radical or fundamental innovation (Booz Allen & Hamilton Inc, 1982) (Olson et al., 1995).

- *Design: See definition of ICSID in section 1.1.3*
- *Product Design: The creative activity whose aim is to establish the multi-faceted qualities of a new physical object*
- *Innovation: The commercial or industrial implementation of something new – a new product or production process, a new market or new forms of commercial, business or financial organization (Schumpeter, 1934)*
- *Product Innovation: The introduction of a new product - that is one with which consumers are not yet familiar - or of a new quality of a product (based on Schumpeter, 1934)*

1.6.5 Design process, design process model, design model

The American Heritage Dictionary defines design as: "To conceive or fashion in the mind; invent," and "To formulate a plan". This definition puts the emphasis on the process that is followed to create a new product, process or service, consisting of a series of activities and methods which are pulled together in a way which meets the requirements of a problem or project. When modeling this design process, we can come up with a "design process model". A model is "a theory-based set of descriptions about the object world". In this definition, modeling is a process in which observed facts are filtered by a theory to formulate a world which itself is complete in terms of the theory (Tomiyama et al., 1989). With regard to "design models", two groups can be distinguished: First, the "design artifact models", modeling the way that a physical artifact can be described, for instance by means of a Computer Aided Design model. Second, the "design process models". Such a design process model should explain how the design process unfolds -- why it succeeds in some cases and why it fails in others. A model should also be able to predict future successes and failures and provide some estimate of the resources needed to develop good designs (Ullman et al., 1988). In this research, we will not discuss design artifact models. The phrase "design model" will be used when referring to "design process models".

- *Design process: "The specific series of events, actions or methods by which a procedure or set of procedures are followed, in order to achieve an intended purpose, goal or outcome" (Best, 2006, 208)*
- *Design model / Design process model: A systematic description of the design process, describing what actually happens during this process, prescribing how this process can be performed and explaining about the rationale of the process (this research)*

1.6.6 System innovation, transition, societal change process

Although each change to "a system" can be viewed as a "system innovation", the concept is often viewed 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). However, as this research is not only about large scale transformations, but also about more modest changes that may occur within socio-technical systems, we will use the more descriptive term "socio-technical change process".

The term "societal change process" will be used for changes that take place on the level of society as a whole. This concept closely resembles the often used concept of "transitions". However, this research is not only about structural, large scale societal change, but also about more modest, small scale changes that may occur. And while the term "transitions" is used often in the field of expertise of sustainable system innovations, in the area of design the phrase is hardly known. That is why the more descriptive term "societal change process" will be used.

- *System Innovation: 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)*
- *Socio-technical change process: A (small scale or large scale) transformation in the way societal functions are fulfilled. A change from one socio-technical system to another (this research)*
- *Transition: A gradual, continuous process of societal change, where the character of society (or of one of its complex subsystems) undergoes structural change (Rotmans et al., 2000, 11)*
- *Societal change process: A gradual, continuous process of societal change, where the character of society (or of one of its complex subsystems) undergoes a certain level of change (this thesis).*

1.6.7 Sustainable, eco-efficient

The term eco-efficient will be used to discuss the aim of causing minimum negative environmental impact while having maximum economic added value. The term sustainable will be used to discuss the aim of causing minimum negative environmental impact while maximizing social well-being and maximizing economic added value.

- *Eco-efficient: Causing minimum negative environmental impact while having maximum economic added value (Tukker and Tischner, 2006, 24).*
- *Sustainable: Causing minimum negative environmental and social impact while maximizing social well-being and maximizing economic added value (Tukker and Tischner, 2006, 24).*
- *Sustainable innovation: The renewal or improvement of products, services, technological or organizational processes that not only deliver an improved economic performance, but also an enhanced environmental and social performance, both in short and long term (Bos-Brouwers, 2010)*

1.7 Summary

Chapter 1 includes an initial definition of the research area, starting with an overview of changes occurring in the field of expertise of industrial design, a specialty which itself has changed substantially since branching off from architecture at the end of the 19th century. Where several decades ago, industrial design was totally focused on the development of physical products, recently the working area has broadened considerably in the direction of ideas, plans, strategies, services and the development of "solutions" instead of artifacts. Incidentally, the development of these artifacts is itself also subject to change, especially as a consequence of applying more and more information and communication technology, which results in integrated systems that are functioning less and less "standalone". The consequence of this is that the societal impact of all of these renewals continues to increase. After all, a new product does not only influence its direct environment, it also influences all other elements that it is in contact with, through the network that it is part of. This poses the question how we should deal with this potentially major impact of new products on the bigger socio-technical and societal system in which these products operate.

Much of the research that has been conducted around this theme stems from the perspective of ecological sustainability, resulting in a new design area that we will call "sustainable product development". In this field of expertise, a shift of focus has occurred where attention is increasingly moving from the optimization of products to the fundamental change of complex systems. Moving from an initially narrow focus on the artifact itself, the field has expanded to cover the whole technical life cycle and the institutional infrastructure in which products are produced and employed. This can for instance be recognized in the statement of the World Business Council for Sustainable Development (WBCSD, 2010), who emphasizes that it is necessary to design, build and transform complex systems that will provide the foundation for survival and human development throughout the 21st century and beyond. This ambitious goal is shared by the International Council of Societies of Industrial Design (ICSID, 2010), who emphasizes that the task of design is to enhance global sustainability and environmental protection, to give benefits and freedom to the entire human community, and to support cultural diversity despite the globalization of the world.

That the broad focus of this definition is not self-evident can be concluded when looking to the prior definition of industrial design as was officially adopted in 1959 (ICSID, 1959). When comparing both definitions, it is clear that the working area of the industrial designer has been considerably widened during the last 50 years. Where the 1959 definition puts great emphasis on the "materials, mechanisms, shape, colour, surface finishes and decoration of objects", the current definition talks about "the multi-faceted qualities of objects, processes, services and their systems in whole life cycles". And while the 1959 definition emphasizes the production of these products in industrial processes, the new definition explicitly mentions that it is not only about products that are produced by serial processes, maintaining a much broader perspective on the role and task of design, emphasizing its responsibility with regard to its contribution to sustainability in a globalizing world.

All in all, there appear to be three developments that enhance each other. First, a broadening of the working area of design, where it's no longer only about the development of new products, but about the development of processes, services and complex, interconnected systems. Second, an organizational development where designers and other actors are increasingly collaborating across the boundaries of various fields of expertise and disciplines. And this is not only about collaboration between companies, but also between government, societal organizations and knowledge institutions. Third, a growing emphasis on the need to actively contribute to sustainability, from an ecological as well as from a social perspective. Located in the middle of all these developments, when viewed from the perspective of this study, is the designer, the design process and the new product. And that new product must therefore not only be "new and improved", but must also become "new to improve" the society in which it functions (hence the title of this research).

Several efforts have been pursued to structure the design process in such a way that it incorporates this sustainable systems perspective in a systematic manner. However, when studying the fields of expertise of industrial design engineering and sustainable product development, it appears that still a lack of insight exists regarding the way that the design process and the role of designers can be organized in such a way, that the relationship between new products and the socio-technical or societal context in which these products function are taken into account systematically. Critics may even comment that many designers that want to contribute to sustainability can be considered to be rather naïve, describing them as action-oriented people who simply start to work on new sustainable solutions, only to be caught by the unpleasant surprise that the world for some reason does not implement many of their beautiful ideas. Others emphasize that it is necessary to create clear boundaries regarding both the ambition and the context of system oriented design initiatives, and to clarify more explicitly how to balance short-term goals with long-term ones. The fact that this knowledge apparently is missing has led to the set-up of this research.

To gain more insight in this issue, in addition to the area of industrial design engineering and the area of sustainable product development, two related fields of expertise have been studied: The area of sustainable system innovation and the area of systems engineering. Both fields of expertise contain their own unique perspective on the systems design issue. However, also when looking at those fields of expertise, still no answer can be found clarifying how to organize the design process and the role of designers in such a way that it systematically incorporates the relationship between new products and the socio-technical or societal context in which these products function. It appears that a number of design and innovation models may be too focused on the development of one single product or system, and therefore deal insufficiently with the socio-technical and societal aspect at hand. Other models may handle an abstraction level that is too high, so the aspect of concrete product development is not sufficiently dealt with. Based on this outcome, the following research question and related subquestions have been formulated, dealing with the "what", the "why", the "how" and the "who" of the subject.

Research question: How can the design process and the role of designers be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner?

Subquestion 1 ("what"): What is the relationship between (new) products and the socio-technical or societal system that they are a part of, and how can this relationship be described in a systematic manner?

Subquestion 2 ("why"): What is the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives which are being met by means of the functioning of a socio-technical system, and how can this relationship be described in a systematic manner?

Subquestion 3 ("how"): What are the similarities and differences between the product design process and the way that socio-technical and societal change processes take place, and how can these processes be interlinked in a systematic manner?

Subquestion 4 ("who"): How can the (potential) role of the designer with regard to the product design process, as well as with regard to the way that socio-technical and societal change processes take place, be described in a systematic manner?

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2 Chapter 2: Research Approach

2.1 Introduction

2.1.1 Research philosophy

In the previous chapter the relationship between the development of new products and the course of societal change processes was examined. Based on this description, the question was posed how the design process and the role of designers can be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner.

In this chapter we will explain the route to be taken to find answers to this question. This search for new knowledge can be compared to determining the contents of a "black box". Like a wrapped-up present, where the recipient tries to guess what is inside. Before the researcher can start the process of determining the contents of the black box, he must first decide which philosophical perspective he wants to base this investigation on. How does the researcher view reality? Does he think that it is feasible to ever discover what is in the black box, or does he believe that it is only about getting a clue of the contents, totally dependent on the person who is holding the package? This mental framework is important because the way a research question is formulated, the way an answer is sought, and the way the outcome of this investigation is interpreted, all depend on the philosophical perspective maintained by the researcher, even if he is not aware of this (Johnson and Duberley, 2000). It just so happens that there are a multitude of schools maintaining their own paradigm regarding this issue, and they all have their own way to determine how to discover the contents of the black box. For example, Plato could view the black box as a reflection of a world purely of ideas, which exists outside of space and time. To touch the box and to physically handle it would not even be a consideration for him; the logical thought process must lead to insight, while separated from the physical reality. His colleague, Aristotle, rejects Plato's dualism and is convinced that man can indeed see, hear, feel and experience things as they really are. The discovery of the contents of the black box must therefore be based on a sensory-perceptible reality (Klukhuhn, 1995). Francis Bacon expands on this empirical approach, convinced that only ordered observations and goal-oriented experiments lead to generally valid knowledge.

During the 1920s, a group of researchers referred to as the "Wiener Kreis" (Vienna Circle), expands on this approach towards logical positivism or logical empiricism. They maintain the basic assumption that reality is made up of ordered, fixed, measurable and unchangeable building blocks. They add to this that knowledge is only relevant if it is based on observing this objective reality (Easterby-Smith et al., 2002, 28). Something that cannot be objectively observed and analyzed, cannot be considered as scientific, rational knowledge. The demarcation criterion, or the manner in which scientific knowledge can be distinguished from non-scientific knowledge, is further developed by Karl Popper in the form of critical rationalism. When searching for the contents of the black box, he believes that we can never completely open the box containing the truth. Determining the content of the "truth box" can only happen on the basis of our observation from the outside. And this observation is never 100% objective, but always takes place on the basis of a certain theory. The researcher will never know whether a theory is the absolute truth. He must therefore search for critical tests that can falsify the theory. The more critical tests that can be endured, the higher the degree of "corroboration" of a theory (Popper, 1959). The degree of corroboration is an indicator for the verisimilitude. The better the corroboration of a theory, the higher the verisimilitude, or the "truth content" of the theory.

The assumption that a world exists that can be measured with the aid of objective methods (instead of determining this with the aid of more subjective perception, reflection and intuition), will have the result that positivistic researchers within the organizational and social sciences, just like their colleagues from natural sciences, will start searching for generally valid patterns concerning the way organizations act. In this way, management of these organizations can understand and influence their environment in a scientific manner (Johnson and Duberley, 2000, 40). However, socio-constructivists are questioning the applicability of an objective natural science model to social sciences (Klein and Myers, 1999, 67). After all, the natural environment cannot interpret or influence its own environment, while people can. Therefore, reality is not an objective, but a social construct. It only acquires significance when people give it significance (Weick, 1995). The question is whether the socio-constructivist approach can be considered scientific, since it is so dependent on the context where the research takes place. It frequently appears more like anecdotes, which may indeed provide much insight, but will contain very little predictive value in a different context. The positivistic critic will therefore indicate that this lack of generalizability renders the outcome unusable. The response of the socio-constructivist will be that the outcome is indeed generalizable, but that these generalizations are frequently so obvious that they are barely usable.

All in all, this research will be conducted as much as possible from a critical rationalistic perspective. The search for generally valid principles will however take place with the necessary restraint, considering the fact that design and innovation processes are directed by the behavior of people whose behavior can only be captured in part by objective, refutable theories, as justifiably stated by the socio-constructivists. Therefore the outcome can best be described as a critical rationalistic study with a socio-constructivist accent.

2.1.2 Conceptual model

To visualize the issues that are relevant to this research, a conceptual was developed, displayed in Figure 2-1. Issues related to the development of products are indicated with the letter P. Issues related to the socio-technical and societal context are indicated with the letter S. The role of the designer, as well as other actors involved, is indicated with the letter A. The actual change process leading from the starting position (PS1) to the new situation (PS2) is indicated with the letter X, as this can be considered as the "black box" in which we want to gain insight. The meaning of the symbols is clarified in Table 2-1. In section 1.3, the four research issues that are relevant for answering the research question were discussed. These can now be "mapped" on the conceptual model.

The first research issue (products and society) was derived from subquestion 1 and refers to the "what" aspect of the research. We see this again in the conceptual model, in the relationship between product P and socio-technical or societal system S. This is about the way that the systemic relationship between them can be presented. In Figure 2-2 (top left) the way that the "product and society" issue can be recognized in the conceptual model is clarified.

The second research issue (problems and objectives) was derived from subquestion 2 and refers to the "why" aspect of the research. This is about the functioning of both the product and the functioning of the socio-technical or societal system, and the problems and objectives that are being met by means of this functionality. The question here is what, if any, is the relationship between both kinds of problems and objectives. In Figure 2-2 (top right) the way that the "problems and objectives" can be recognized in the conceptual model is clarified.

The third research issue (design process) was derived from subquestion 3 and refers to the "how" aspect of the research. This research issue is related to the way the actual change or transformation process takes place, at the product level as well as at the socio-technical or societal level. The expectation of this research is that both processes influence each other, and the question is how the design process can be described in such a way that this mutual influence is taken into account in a systematic manner. For the time being this issue is indicated as a joint process, as a "black box" of which we want to gain a better understanding. In Figure 2-2 (bottom left) the way that the "design process" can be recognized in the conceptual model is clarified.

The fourth research issue (designer and actors) was derived from subquestion 4 and refers to the "who" aspect of the research. In Figure 2-2 (bottom right) the way that this issue can be recognized in the conceptual model is clarified. Here everything that takes place with regard to product development, socio-technical or societal change process, is all considered as one single umbrella variable, and the role of the actors and the designer as another. The arrow between the two variables indicates their mutual relationship.

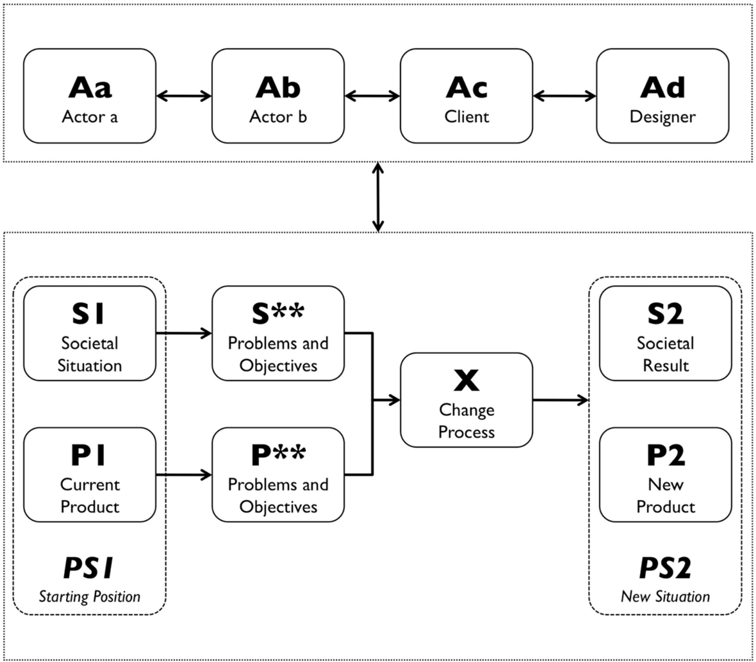


Figure 2-1: Conceptual model

Table 2-1: Legend for the conceptual model

Symbol	Meaning
PS1	Starting position
P1	Product in starting position
S1	Socio-technical or societal situation in starting position
P**	Product related problems and objectives
S**	Socio-technical or societal problems and objectives
X	Change process
PS2	New situation
P2	New product
S2	New socio-technical or societal situation
A	Actors involved

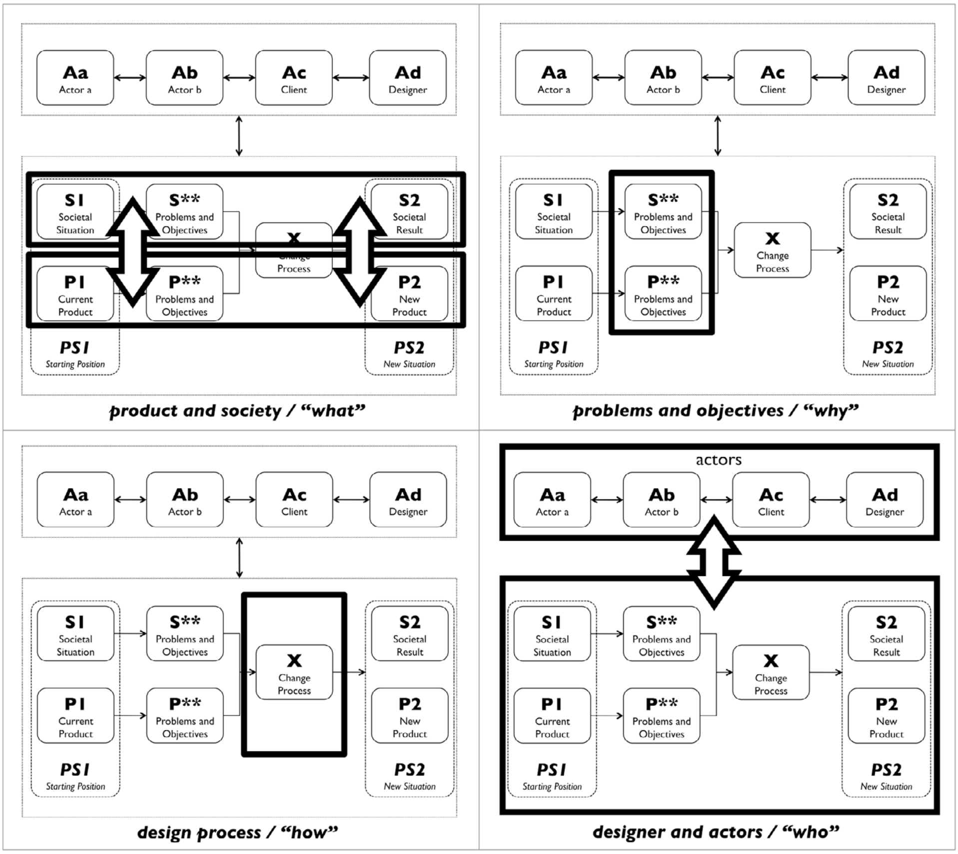


Figure 2-2: Relation between conceptual model and research issues

2.2 Research Phase 1: Problem Situation 1

This research is based on a four-phase approach, based on Popper (Popper, 1999, 14). Problem situation 1 is analyzed in the first phase. After this follows a tentative theory. Next is a process in which this new theory will be tested in a process of error elimination, followed by a new problem situation 2. Each of these four phases will be explained in more detail.

The first step in this investigation was the determination of the research question. The research question and related subquestions have been discussed in chapter 1. The formulation of the research question is determined by the research objectives that the researcher is aiming for. According to Yin (1994), we can distinguish between three kinds of objectives: First is the exploration of a subject. Second is the description of a phenomenon. And finally, the explanation of what is observed. Exploratory research is applied in order to map the nature of certain problems. This type of research is especially suited to contextualize and define problems, for example when the researcher does not yet know which model applies and which characteristics and relationships are relevant. Descriptive research is applied to clearly structured research problems. The researcher knows what it is he wants to learn, but this knowledge is not yet available anywhere. Explanatory research, also referred to as causal research, is focused on questions with an obvious cause-and-effect relationship. This applies particularly to phenomena which are relatively familiar, but where one searches for the underlying reasons why certain phenomena occur and the causal links they are based on. Explanatory research often expands on preceding exploratory and descriptive research. The particular focus of this research is an exploratory investigation, which will give the initial impetus for a descriptive model regarding the way that the design process and the role of designers can be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function can be taken into account in a systematic manner.

The exploration of "problem situation 1" is divided in two parts. In chapter 3, it will be about a broad reflection on developments in the field of industrial design, discussing the background issues that influence the field of expertise, as can be recognized in the two very different definitions of the ICSID (see section 1.1.3). The focus of chapter 4 is much more narrow and is about the "design process" and about "design models", as discussed in section 1.6.5. In this chapter, existing design and innovation models are analyzed to determine in how far they provide the answers for the research question and subquestions as discussed in section 1.3. In order to structure this analysis, the various methods and models are arranged into four areas of expertise:

- Industrial Design Engineering
- Systems Engineering
- Sustainable Product Development
- Sustainable System Innovation

Together these models give an impression of the current status in the field of expertise of industrial design and some related fields of expertise that may be helpful in answering the research question. Besides the analysis of existing design and innovation models, chapter 4 will also discuss the conditions that an ideal design model must satisfy, in order to provide the insight as mentioned in the research question.

2.3 Research Phase 2: Tentative Theory

The analysis in chapter 4 will demonstrate that existing design and innovation models indeed offer valuable clues, but also that no single model is exactly suitable to help answer the research question. This is because existing models, particularly in the areas of industrial design engineering and systems engineering, are too often targeting the development of one single product or system. Because of this, the socio-technical and societal aspect mentioned in the research question cannot be dealt with in an appropriate manner. Other models, especially those in the area of sustainable systems innovation and transitions, handle an especially high abstraction level and in addition are of a more contemplative nature. Because of this, the product development aspect mentioned in the research question cannot be dealt with in an appropriate manner.

This is the reason that, based on the demands of the "ideal" design model that will be formulated in chapter 4 (see section 4.7, Table 4-2), in phase 2 of the research a modified design model will be developed in chapter 5, which will continue to build on the inventory of design models as discussed in phase 1. Therefore existing models will be transformed to a new multilevel design model, which may be considered as a tentative theory or conjecture, which will be evaluated on its merits in the next phase. When discussing the descriptive, explanatory and prescriptive aspects of this research, a distinction should be made about the research itself (which is an exploratory study, with an attempt to come up with a new, descriptive model), and the aim of the new design model, which in itself should have a certain descriptive, explanatory and even prescriptive element embedded in it (as discussed in section 1.6.5). To find out if this actually is the case, a number of testable propositions are formulated, which describe expectations about the way that the product design process can be interlinked with the course of socio-technical and societal change processes in a systematic manner, and the way that the new design model can possibly support this process. These propositions are being formulated in such a way that they contain a certain predictive value and can be tested through practical experiments. When the propositions are not refuted, this means that the multilevel design model has obtained a larger truth content or "verisimilitude" (Popper, 2002, 309). But even if the propositions are refuted by the outcome of the experiments, we have still learned something and the search can continue from 'problem situation 2'.

2.4 Research Phase 3: Error Elimination

2.4.1 Selection of research strategy

The new tentative theory will be evaluated in a process of "error elimination", which is phase 3 of the research. Although an effort will be made to come up with an objective, verifiable and testable model with accompanying propositions, falsifiability will not be tested, as would be the case if this research would be conducted totally from a critical rationalistic perspective. However, especially with regard to this phase, the socio-constructivist accent as mentioned in section 2.1.1 should be kept in mind. Instead of aiming at falsifiability, this phase is intended to test the internal consistency of the tentative theory and its functionality in describing what actually happens during the design process, possibly prescribing how this process can be performed and explaining the rationale of the process, in accordance with the definition of a design process as discussed in section 1.6.5.

The testing will take place either by means of a quantitative or a qualitative approach. A qualitative study focuses on getting a better understanding of the "how and why" issues. It is about finding out what are the relevant variables involved and developing the relevant research issues. The distance between the research subject and the researcher is generally smaller. Usually there's also a less formal structuring of the research approach (Cresswell, 2003). A quantitative study is focused on the degree in which certain phenomena occur, aimed at understanding the "how many", "how much" issues. The relevant variables have previously been identified and measured, and now the aim is to get a more detailed understanding of the relationship between these variables. This type of research is generally quite formalized and structured according to strict guidelines. The researcher often has good control over the subject matter and a comparatively large distance exists between the research subject and the researcher (Perry, 2002, 33). As the objective in this study is to develop more insight into the subject matter in a broad sense, the qualitative approach is best suited.

Several possibilities exist for the structure of a qualitative study, like experiments, surveys, archival analysis, histories and case studies. The choice for a certain strategy is determined by three questions (Yin, 1994). These are: (1) the form of research question, (2) the extent of control an investigator has over actual behavioral events and (3) the degree of focus on contemporary as opposed to historical events. Table 2-2 shows the different research strategies in relation to these three conditions. The "how and why" questions are vital in this study as opposed to the "how many, how often" questions. It is desirable that the researcher has control over behavioral events, and the study is focused on contemporary events. Table 2-2 indicates that in that case the best strategy is to use experiments.

Two possible research strategies that are compatible with this are the "design research" strategy and the "action research " strategy. When comparing both strategies, (Cole et al., 2005) arrive at the conclusion that they involve almost identical intervention processes, although the nature of the intervention differs. Action research focuses on the organization that is changing because of the researcher's actions, design research focuses on the development of a new product as a result of the researchers actions. Although within the area of design research several different strategies can be distinguished (Horváth, 2008), each of these have mainly been substantiated by examples involving the development of tangible products or artifacts. The development of new products is indeed an important focus of this study, but changes at the socio-technical or societal level play just as big a role. For this purpose, the action research strategy seems to be most suitable

Table 2-2: Possible research strategies (based on Yin, 1994, 6)

Strategy	Form of Research Question	Requires control of behavioral events?	Focuses on contemporary events?	Suitability for this research?
Experiment	How, why?	Yes	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes	No
Archival	Who, what, where, how many, how much?	No	Yes/No	No
History	How, why?	No	No	No
Case study	How, why?	No	Yes	No

The term action research was first used by Collier (1945), Lewin (1946) and Lippitt (1949). They describe it as a research method where the researcher actively interferes with the research subject. First of all as a means to effect change in a certain situation. Second, as a way to acquire new knowledge or theory about the way this takes place (Gilmore et al., 1986, 161). The method is an alternative to research that is strictly aimed at gathering theoretical knowledge as an objective in itself. In other words: "Research that produces nothing but books will not suffice" (Lewin, 1948, 202). The strategy can be considered as a combination of a case-study strategy and an experiment, with the difference that the researcher actively participates and influences the cases that are being investigated. The result of the action creates the case, as it were, that the research is based on. Action research is often used by "practitioner-researchers" who wish to improve their way of working in a systematic and scientific manner (Yen et al., 2002), so one could speak about "research undertaken by practitioners to improve their practices" (Corey, 1954, 375). where the ambition is to work on a "continuous interaction between theory and practice" (Baskerville and Wood-Harper, 1996, 240).

The reason for choosing action research is based on the fact that the research question is aimed at the way that the design process and the role of the designer can be described, in the light of socio-technical and societal change processes. In order to investigate this design process properly, it is desirable that the activities of the designer can actually be influenced and guided into a certain direction. In this way, the relevant variables can be influenced during the design process, to clarify whether a certain intervention has or does not have a certain result. A case study or "ex-post" archival study does not offer this option, whereas action research does.

During the research process, consecutive interventions are implemented, which are critically analyzed afterwards. The process begins by defining the problem or need. Next is an investigation of facts, in which the problem is explored in various ways. In the third step an action plan is developed, which is then carried out in practice. The effect of the action is studied, followed by an evaluation of the success or failure of the action. And finally, the action plan is adapted, after which the entire process can start again. The process can be represented by a cyclic model, where each cycle consists of the four steps: planning, action, observation and reflection (Lewin, 1948, 206). This process is shown in Figure 2-3. As we will see in chapter 4, this way of working fits well into the process that is being followed in many design processes, where the four quite comparable steps are named analysis, synthesis, evaluation and reflection.

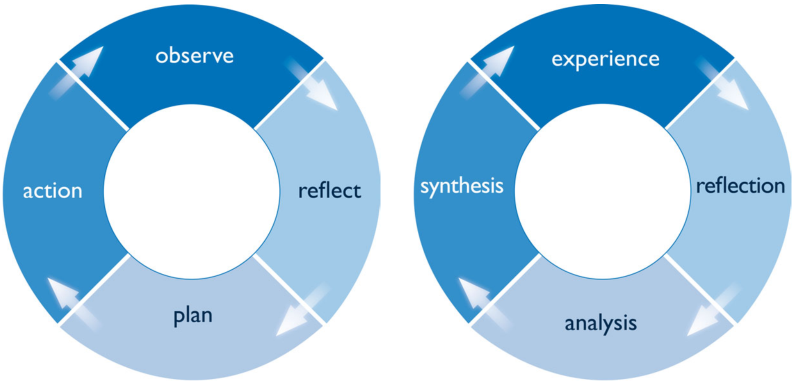


Figure 2-3 (left): Action research cycle (based on Kemmis and McTaggart, 1982)
Figure 2-4 (right): Typical design cycle (see chapter 4)

2.4.2 Selection of practical experiments

After having decided on the research strategy, the next step is the selection of the projects that will be the subject of investigation. This step is discussed at the end of chapter 5 and will result in the selection of two experiments. In order to select these projects, the following criteria are taken into consideration:

Criterion 1) Innovative products must be developed in the project
The research question mentions the "design process" and "the role of the designer" as one of the main issues to be studied. As this study takes place from the perspective of the industrial designer's field of expertise, whose objective is to develop innovative products or services, the projects must preferably involve the development of new products that are intended to be marketed commercially. It is not necessary to know at the beginning of the projects which products will be developed. However, it must be clear that secondary conditions are present to enable the development of new products as a result of the researcher's interventions. It must also be clear that existing products cannot offer satisfactory solutions for the problems at hand.

Criterion 2) A socio-technical or societal problem must be involved
In the research question, the "mutual relationship between new products and the socio-technical or societal context in which these products function" is being mentioned. This means that the experiments should include a relationship between new product development and a socio-technical or societal problem to be tackled. No specific preference exist to what kind of societal issue is the focus of the project. Having said that, a connection with the possible consequences of the growing application of communication and information technology, and the social questions that society faces as a result of this, would be an interesting research area. Initial studies in this area, for instance that of the Rathenau Institute into the effects of "Ambient Intelligence", are regularly focused on the added value of these technologies in the health sector (Schuurman et al., 2007). Therefore it appears desirable that at least one of the experiments will be conducted in this area.

Criterion 3) Availability of information
This criterion relates to the accessibility of information. The researcher must have access to detailed information and must be able to gain insight into the details of certain processes. Moreover it must be possible to closely follow the process over time, so that a causal connection between certain events can be identified: what happened first, what happened next, what is the

relationship between the events. For that reason it is important that the researcher himself is in direct contact with the parties involved in the design process and, if necessary, can ask them for more information about certain choices or events. Furthermore it is desirable that the projects will take place within a more or less specific timeframe, preferably with a clearly identified start and end date of the process.

Criterion 4) Influence of the researcher
Easy access to information is vital, but is not sufficient for the successful completion of the study. In combination with the choice for an action research approach, it is necessary that the projects can in fact be influenced by the researcher. He must be able to interfere in the design process, in order to effect change towards a certain direction. On the other hand it is not necessary that the researcher is in control of all activities in the project, as long as enough freedom exist to perform the necessary interventions. Based on the selection that will be made at the end of chapter 5, the actual design projects will be executed in order to test the new multilevel design model and the accompanying propositions, as will be described in chapters 6 and 7.

2.4.3 Evaluation of experiments, verification of propositions

After the practical experiments have been conducted, the practical experiments and the effects obtained by the researcher's interventions will be critically analyzed. This is discussed in chapter 8. By conducting a cross-case analysis, the results of the two practical experiments will be compared. This analysis consists of three parallel activities: (1) Reduction of the data, (2) presentation of the data and (3) drawing conclusions on the basis of the data (Miles and Huberman, 1994, 10).

Reduction of the data is about analyzing the available information and making a substantiated selection from this. In this way, the decision is made which information is relevant to answer the research question. This selection ensures that the information remains manageable and prevents the risk that one “cannot see the forest for the trees”. The results of this data reduction are presented in the project descriptions of chapters 6 and 7.

The following step relates to the logical presentation of the reduced data. This is necessary since people have trouble dealing with large quantities of information (Miles and Huberman, 1994, 11). In this study, the data is initially presented in a narrative, which includes a description of the course of the experiments over time. Furthermore, a selection is made from the most important situations in each project. These have been arranged in table format. This data is then converted into visual representations which are used in the analysis of chapter 8. The third step, processing the information, is about drawing conclusions and the verification of the results. Significance is given to the collected data by noting certain recurring patterns, declarations and assumptions. With the help of the previously drawn up research model, the previously formulated propositions will be tested in this step.

2.5 Research Phase 4: Reflection on Problem Situation 2

Finally in phase 4, a last reflection on the original analysis and research question will be conducted. This phase is discussed in chapter 9. Here the final answers to the research question and the research subquestions are being discussed. In addition, on the basis of this newly acquired knowledge, a last look will be taken at the recent developments and questions in the field of expertise of industrial design engineering and sustainable product development, in order to map the current situation of the research area. Also included at this point is a discussion of the consequences of this research for designers, entrepreneurs, government, education and societal organizations. In conclusion, a number of recommendations will be provided for possible supplementary studies, which will be able to build on the current results.

2.6 Validity, reliability and relevance

2.6.1 Validity

Validity relates to the relationship between the results of the study and a research question. Was this study designed and conducted in such a way that the acquired results indeed provide answers to the research questions? Is this study's conclusion valid, or is it based on a chance concurrence of circumstances? In quantitative research, validity can often be determined numerically through calculation of probability and statistics. However, this is usually not applicable to qualitative research. In qualitative research, a vital testing criterion for the validity of the research is the question whether another researcher, who would conduct a similar study, would also obtain comparable results. Based on (McNiff, 1992, 133) (McLeod, 1999, 101) (Cresswell, 2003) a number of criteria were defined for this, specifically

1. plausibility of the research,
2. credibility of the researcher,
3. available evidence,
4. contextualizing of the investigation,
5. the systematics and structuring of the research,
6. peer validation.

Concerning (1), the plausibility of the research, the results of the two practical experiments are quite plausible. A number of the results are so self-evident that they may be accepted without further foundation. What about (2), the credibility of the researcher? Does the author form a credible judgment on the research topic? How were mistakes and problems handled, and how did the relationship with the other actors in this study work out? The author can be considered as a credible researcher. He has almost twenty years of experience in the field of expertise of industrial design engineering and product innovation, working as a designer with several commercial companies as well as working as a researcher and consultant with the internationally renowned research organization TNO (Dutch Organization for Applied Scientific Research). The next criterion concerns (3), the evidence that forms the foundation of this study. Besides publications in trade magazines as well as popular magazines, sufficient other evidence is available for both cases. For example, physical artifacts were developed in both projects as a result of the conducted activities. In the project “Autonomous Elderly”, one example is the Guide Me system from the company My-Bodyguard BV, a GPS-GSM system for remote tracing of individuals. This product is commercially available. In the “Youth in Motion” project, an interactive game for children, the Make Me Move play floor, was developed by Colibri Interactive Innovations BV. The next item relates to (4) contextualizing the investigation. Is it possible to ascertain in which historic, social and cultural context the study took place? For both projects, exact details are provided of which organizations and which locations they were conducted. The cooperation with the housing and care organization “De Woonmensen” in Apeldoorn and the municipality of Eindhoven are presented in great detail. Concerning (5), the systematics and structuring of the research, both practical experiments progressed normally, within the often unpredictable reality of, for example, the internal reorganizations of the actors involved. Concerning (6), validation by third parties, most of the results of this study are accessible to the public. Concerning internal, confidential documentation or correspondence, these can be made available by the author on a confidential basis, if desired. Moreover, most of the directly involved actors have provided substantive comments on the way the results of the study were described and have provided supplementary information or corrections. Some information was modified, in relation to the internal interests of actors. For example, removal of the exact amounts of certain investments, or removal of the names of certain individuals involved. However, none of these modifications have affected the essence of the project description or had any direct relationship to the conclusions of this study.

2.6.2 Reliability

Reliability is related to the methodological basis of the study. The question in this is in how far the applied procedure would always provide similar results in similar circumstances. In action research it is not always possible to establish the reliability of the study in this manner, because specific circumstances can usually not be repeated and unique circumstances cannot be reconstructed at a later date (Seale and Silverman, 1997). Therefore we must look for other means to demonstrate reliability, since the methods and results of one study can frequently not be converted to a different situation (Badger, 2000). A vital criterion here is the degree to which the course of the study can be checked with the aid of documented notes. Discussion reports, interview reports, notes about observations, internal reports and other raw research data will then indicate reliability when judging the results of the study. In this study, reliability is guaranteed by the recording of various types of information that are compared with each other, also referred to as triangulation (Yin, 1994, 91). Data that form the basis of this investigation were recorded in written documentation. The majority of this information is available in digital form, although some information can only be accessed on basis of confidentiality through the author. These include, for example:

1. Internal notes of progress reporting, reports, presentations by the researcher and colleague researchers, who are involved in the described projects (e.g. Weterings et al., 2002, Eikelenberg et al., 2004, van der Horst et al., 2004, von Heijden, 2006)
2. Formal interim and final reports regarding the progress of described projects, discussion reports, memos, reports of meetings of the researcher and colleague researchers who are involved in the projects (eg. van den Berg et al., 2004, van Sandick et al., 2004, van Sandick, 2005, Jongert, 2005a).
3. Information about public meetings and congresses where the interim results of the described projects were presented by the researcher and by colleague researchers.
4. Scientific publications, papers and contributions to conferences where the interim progress of the project was presented (e.g. Joore et al., 2005a, Joore et al., 2005b, Joore et al., 2006, van Overbeek et al., 2005, van den Boogaard et al., 2007, de Vries et al., 2007)
5. The researcher's personal e-mail archive, containing more than 10,000 e-mail messages during the period 2002-2010. A considerable number of these messages, particularly during the period 2004-2008, are related to the described practical experiments.
6. Publications in public media, such as newspapers, magazines and company newsletters (eg. De Woonmensen, 2005, van Breukelen, 2007, De Telegraaf, 2005, Nuchelmans, 2007, Wijnen, 2007).

Another way to substantiate reliability of the study is to explicitly mention personal preferences and possible biases of the researcher, as was done in this study by recording a description of the researcher's professional background. Finally, an attempt was made to maintain a "follow the track" approach, where the study is described in such a way that another person can work out how the information was collected during the study, which steps were taken during the process and which choices were made during the study.

2.6.3 Relevance

Relevance of the study is related to the applicability and usefulness of the study. A study that is only interesting for a single person, for example the researcher himself, is not relevant. The societal relevance of the study emerges initially in the study's objective, namely to deliver a contribution to solving societal problems through the development of new products. Relevance for government is expressed in their financial support for the various projects. For example, in the "Autonomous Elderly" project, funding from the Ministry of Education, Culture and Sciences' basic funding made available to TNO, the TNO SME program and the support from the Small Business Innovation Research (SBIR) program. In the project "Youth in Motion" this applies to, among others, support from the Loosco foundation, the province of Brabant (GS Noord-Brabant, 2006), the Dutch Ministry of Health, the TNO SME program and the SBIR program (Oldeman, 2007b). The relevance of this study for companies is expressed in the direct or indirect involvement by a variety of Dutch companies in the described projects. The involvement of these companies varies from attending a few workshops to the investment of hundreds of thousands of Euros in the new systems that were developed during both of the research projects. The fact that these companies want to invest time and money in these projects for a longer duration, demonstrates that the subject is relevant for them. Relevance for other researchers is expressed in their involvement with the projects during this study. Another point that makes it obvious that this study is relevant for researchers, is the degree of support from the research organization TNO, which is in keeping with the research track focused on establishing sustainable systems innovations (Weterings et al., 2002) (van Sandick and Weterings, 2008). The relevance for product designers is in the expectation that the acquired knowledge can be applied in situations where they want to attain not only functional objectives, but at the same time societal objectives with their new products. The results of this study will indicate in how far designers, who enter this arena, can accomplish these goals. Involvement in the study by the Delft University Faculty of Industrial Design is an indication for the relevance of this study to this field of expertise.

2.7 Delimitations

The core of this study is in the field of expertise of industrial design. From this starting position, other knowledge areas are subsequently considered. The knowledge of developing new products is thereby the central point, from where the view is "from inside to outside" towards the way that socio-technical and societal change processes take place. The design engineer could remark that the discussion about the societal impact of new products is actually a subject for the "soft sector", and that he prefers to deal with the "hard facts". Unfortunately, making this distinction isn't that easy, because new products simply have an unavoidable effect on human actions and on society, as has already been concluded by many philosophers and sociologists (Heidegger, 1962) (Ellul, 1967) (Habermas, 1970) (Schuurman, 1977) (Callon et al., 1986) (Bijker et al., 1987) (Latour, 1987) (Achterhuis, 1995) (de Wilde, 2000) (Verbeek, 2005) (van Well, 2008).

Although this is definitely not the topic of this study, the nature of the research question is such that a brief discussion of this topic may be useful. Most engineers employ, consciously or unconsciously, a more or less "instrumental", "means-end" vision on the role of technology in the world. From this perspective, technology is a means that is employed in order to realize a certain objective. This instrumentality of technology is often viewed as the engine of progress: It enables people to create a world where hunger, disease and effort play a progressively smaller role. Various philosophers set a reversal of this means-end rationale against this, thereby creating a more deterministic vision of technology. It becomes an objective in itself and increasingly gets a tighter grip on our culture. Man is then only a component of the production machine of society (Jaspers, 1931) or useful as raw material, without intrinsic value (Heidegger, 1954). We are no longer the master of technology, but become its slave and victim (Ellul, 1967). The idea that technology steers an autonomous course is also referred to as the substantivist position (Verbeek, 2005).

These two extreme positions come about partly because engineers and philosophers have very little contact with each other. The engineers are too deeply focused on technology and the future ideals that are based on it, so that they did not have the time to occupy themselves with philosophical topics. For philosophers on the other hand, technology is not always that interesting, except when its influence on society can no longer be ignored. But even then it remains such an unmanageable topic that it is often viewed especially as a threat to humanity. "The optimistic and pessimistic views both lack an adequate perspective on technology. While the one view overestimates the cultural influence of technology, the other fails to appreciate the possibilities it offers" (Schuurman, 2003). A more recent approach is that of the "mediating" role of technology (Verbeek, 2005). People and technology are more or less equals in this, where technology mediates in the way people are present in the environment and the way they experience it. Although the latter approach definitely appears to provide valuable insights, this study will initially employ an instrumentalist, "engineer's perspective". The reason for this is that employing a relatively new philosophical perspective on the application of technology would generate so many new research questions, that an investigation of this topic would be better off in a separate study.

Nevertheless, chapter 9 will include a brief reflection on the extent to which the results and the progress of the study touch on the above-mentioned philosophical insights. Specifically, in section 9.4.2, we will come back on the issue of the "manipulability of society", and in section 9.3.2 we will discuss to what extent a "mediating" perspective on the relationship between man and technology" would have influenced the outcomes of this research.

2.8 Summary

With regard to the research philosophy that forms the basis of this study, this will be conducted as much as possible from a critical rationalistic perspective. The search for generally valid principles will however take place with the necessary restraint, considering the fact that design and innovation processes are directed by people whose behavior can only be captured in part by objective, refutable theories, as justifiably stated by socio-constructivists. Therefore the outcome can best be described as a critical rationalistic study with a socio-constructivist accent. This is a qualitative study, focuses on getting a better understanding of the "how and why" issues of the product development process, and developing more insight into the subject matter in a broad sense. It is based on a four-phase approach, as discussed in (Popper, 1999, 14). "Problem situation 1" is analyzed in the first phase. After this follows a "tentative theory". Next is a process in which this new theory will be thoroughly tested in a process of "error elimination", followed by a newly arisen "problem situation 2".

In order to explore "problem situation 1", the current knowledge situation is discussed in chapter 3 and 4. In chapter 3 this is about the broad area of "design", in chapter 4 it is specifically about design models and methods. To support the analysis process, a conceptual model is presented and four research issues are being discussed, together covering the "what", the "why", the "how" and the "who" issues of the subject under investigation. The first research issue is named "product and society" and is derived from subquestion 1. This is about the "what" issue, describing the relationship between product P and socio-technical or societal system S. The second research issue is named "problems and objectives" and is derived from subquestion 2. This is about the "why" issue, describing the functioning of the product as well as the functioning of the socio-technical or societal system, and the problems and objectives that are being met by means of this functionality. The third issue is named "design process" and is derived from subquestion 3. This is about the "how" issue, describing the way that the product design process takes place, comparing it to the way that socio-technical and societal change processes take place. The fourth issue is named "designer and actors" and is derived from subquestion 4. This is about the "who" issue, discussing the role of the designer and other actors.

Regarding the formulation of the "tentative theory", this is discussed in chapter 5 in the form of a new multilevel design model, which is based on the insights as discussed in the analysis of existing models. Regarding the process of "error elimination", this will be a qualitative research that is conducted by applying an action research strategy. Although an effort is made to define an objective, verifiable and testable model with accompanying propositions, falsifiability will not be tested, as would be the case in a real critical rationalistic research. However, here the socio-constructivist accent should be kept in mind. That means this phase is more about testing the internal consistency of the new model as compared to experience in real life. To select the design projects that will form the basis of this testing process, four criteria are presented that are used to select these projects. These criteria explain that (1) innovative products must be developed in the projects, that (2) a socio-technical or societal problem must be involved, that (3) the information about the design process must be accessible to the researcher and that (4) the researcher must be able to influence the content and direction of the design process. With regard to the conclusion to "problem situation 2", this will take place in chapter 9, in which also a discussion will take place regarding the consequences of this research for various actors, as well as recommendations for possible supplementary studies. All in all, this research can be summarized as follows:

- Research philosophy: critical rationalistic study with a socio-constructivist accent
- Research approach: Four phase model including "problem situation 1", "tentative theory", "error elimination", "problem situation 2".
- Research strategy: Qualitative study conducted by means of an action research strategy
- Research issues: The four main issues that will be subject of investigation, as derived from the four research subquestions: product and society ("what"), problems and objectives ("why"), design process ("how") and designer and actors ("who")

After discussing the research approach, the next two chapters describe into more detail the analysis of "problem situation 1".

3 *Chapter 3: New Products and a Changing Society*

3.1 Introduction

In chapter 1 the research question that is the subject of this study was described, leading to the question how the design process and the role of designers can be described, and potentially be structured, in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in systematic manner. In chapter 2, the way to find the answers to this question has been explained. In this process, the first step is the description of "problem situation 1". This chapter will reflect on this initial problem situation, taking a rather broad, philosophical approach, not directly aimed at answering the "narrow" research question. This reflection is necessary to put the subject in a broader perspective, explaining the "bigger" background questions that form the foundation for the more focused research question as discussed in section 1.3. When comparing this chapter to the next one, we could say that this one is about "design" as defined by the ICSID and discussed in section 1.1.3, while chapter 4 is about the "design process" and about "design models", as defined in section 1.6.5. Together they present the current status in the field of expertise of industrial design.

In section 1.1.3, two definitions of industrial design were presented, both from the International Council of Societies of Industrial Design. One definition was from 1959, the other one is being used in 2010. Comparing both definitions clearly shows that that the working area of the industrial designer has been considerably broadened during the last 50 years, shifting from a focus on the "materials, mechanisms, shape, colour, surface finishes and decoration of objects" (ICSID, 1959) to the design of "multi-faceted qualities of objects, processes, services and their systems in whole life cycles" (ICSID, 2010). And while the 1959 definition emphasizes the production of these products in industrial processes, the new definition explicitly mentions that it is not only about products that are produced by serial processes. After finishing this chapter, we should be able to understand what has happened between 1959 and 2010. But first, we will step back even further, looking into developments that occurred several thousands of years ago.

3.2 A new relationship between product and society

3.2.1 New products influence society

New products influence people and the development of society. Driven by the desire to make life more agreeable and livable, man has used his creativity for thousands of years to provide for his basic needs in a more effective manner, for example by developing agricultural tools for the cultivation of food. Such as about 8,000 years ago, when the Mesopotamians developed the first wooden plow (Podany and McGee, 2005). As a consequence it became possible for a single individual to cultivate food for a larger group of people than just his own family, so that others could expand into other activities. This also made it possible to find a permanent location for building a house, instead of having to wander during the hunt. The later development of metal tools allowed for building even more effective plow blades, first made of bronze and later of iron. For that matter, the discovery of metals, like so many other discoveries, was also used for the development of better weapons. As metal was scarce, plows were melted into swords in times of war and the reverse happened in peaceful times. That is most likely the origin of this statement in the Bible book of Isaiah, when he speaks of the day that the Earth will be judged and there will be peace between peoples:

> *"They will beat their swords into plowshares*
> *and their spears into pruning hooks.*
> *Nation will not take up sword against nation,*
> *and never again will they learn war." (Isaiah 2:4)*

For that matter, it is also the development of a new product that made it possible to read the Bible at all. Not until after the development of the printing press was it possible to print it in large numbers and for a reasonable price, so that many more people could learn the contents of this authoritative book. This in turn exposed certain social wrongs in society, which were previously maintained due to lack of knowledge. That's how the development of a new product led almost directly to a substantial social change, the Reformation. Innovation influences people and society. But ultimately it's people themselves who decide which products to develop and how to use them. Will they be swords or plows, that is the question. Both products are based on the same technology, but they serve radically opposing objectives. While plow blades serve as a metaphor for new products that make a valuable contribution to the world, swords represent the negative social effects that products can have.

3.2.2 Industrial revolution

While developments during the several thousand years of man's existence occurred rather slowly, a sudden surge took place approximately 200 years ago. The appearance of machines that run on fossil fuels changes the world in such a radical way that we speak of an industrial revolution (Toynbee, 1884). These developments make it possible to work the land in an even more effective way, household tasks can be simplified and products can be mass-produced. As a consequence there is a considerable increase in the yield per hectare of agricultural land, an increase in labor participation, new opportunities to communicate with each other, to travel larger distances in less time, in short, a tremendous increase in wealth among large parts of the population. Designers and companies are proud of these accomplishments, as demonstrated by an old company song of the Japanese company Matsushita:

> *"Let's put our strength and mind together,*
> *Doing our best to promote production,*
> *Sending our goods to the people of the world,*
> *Endlessly and continuously,*
> *Like water gushing from a fountain.*
> *Grow, industry, grow, grow…" (Time Magazine, 1962)*

The question is whether everyone is still just as excited about the unstoppable growth of industry, considering the ecological and social effects that are more or less related to it. And yet, the belief in the unstoppable growth of the economy still forms the basis of nearly all economic models. Industry must grow, in order to provide for the needs of people in an affordable way. For example, in the production of the legendary Model T Ford, one of the first mass-produced cars, where the principle of the assembly line is implemented for the first time. A principle, by the way, that was inspired by the way carcasses were transported in a slaughterhouse (Curcio, 2001, 205). Because of this sophisticated production process, the car can be sold for a mere $850, with the result that 10 years later half of all cars in the world are of this type. Ford's impact is so great that Aldous Huxley, in his book "Brave New World", even starts the new era of humanity in 1908, the year that the first model T Ford rolls off the assembly line. The novel takes place in the year 632 "after Ford", in other words 2540. In this beautiful new world, everyone is always happy, thanks to the never-ending opportunities provided by technological developments. In this new society, truth and beauty are subordinate to comfort and happiness. For that reason, science has been severely constrained, as have art and religion. After all, too much freedom for science could result in undoing its own good work. That's why researchers are only allowed to occupy themselves with solving short-term problems. Any other research is strongly discouraged and scientists who act too freely are banned from this ideal world:

> *"It's curious," he went on after a little pause, "to read what people in the time of Our Ford used to write about scientific progress. They seemed to have imagined that it could be allowed to go on indefinitely, regardless of everything else. Knowledge was the highest good, truth the supreme value; all the rest was secondary and subordinate. True, ideas were beginning to change even then. Our Ford himself did a great deal to shift the emphasis from truth and beauty to comfort and happiness. Mass production demanded the shift. Universal happiness keeps the wheels steadily turning; truth and beauty can't. And, of course, whenever the masses seized political power, then it was happiness rather than truth and beauty that mattered" (Huxley, 1932).*

Research, new technologies and new products influence society. And in its turn, society influences the direction and freedom of researchers, engineers and product developers. One of the most striking examples of such technological development still is the first lunar landing in 1969. Besides a technological breakthrough, it was also a trailblazing communication event, where the entire world could watch this occurrence live on television. Neil Armstrong's legendary words when he took his first step on the moon described a huge influence that a small change can have on the world: *"That's one small step for man, one giant leap for mankind"*. The impact of this space voyage is described in the report "Our Common Future" by the United Nations World Commission on Environment and Development. This Brundlandt report anticipates that the fact that we could see Earth from space for the first time during the 20^{th} century, may well have a larger influence on our body of thought then Copernicus' discovery that Earth is not at the center of the universe (Brundtland, 1987, 18).

Also in the 21^{st} century, space travel maintains its appeal. In January 2008, Virgin Galactic unveiled its "SpaceShipTwo", which was described by designer Philip Starck as *"the dawning of something new, something unique but accessible. Something far, but near" (Haines, 2006)*. On that occasion, entrepreneur Richard Branson points out that many astronauts returned to Earth as advocates for the environment. And precisely for that reason it would be really good if as many people as possible will make a space trip with Virgin Galactic's space ship, at "200,000 per trip:

> *"It is often claimed that the modern environmental movement can be traced back to the "Blue Marble" photograph of the Earth taken by the crew of Apollo 17 in 1972 and now one of the most widely distributed images of all time. Certainly, many astronauts of the past 45 years have returned to earth as confirmed environmentalists. We believe that the Virgin Galactic experience will have the same impact on many of those who travel with us, providing an important increase in environmental awareness and pressure for change." (Branson, 2008).*

Indeed, Dutch Space Shuttle astronaut, professor Wubbo Ockels, is a strong advocate of sustainable solutions (Ockels, 2000) (Ockels, 2001). The question is of course whether the heightened ecological awareness of the space travelers really offsets the thousands of liters of burnt-up kerosene by potential commercial space travel. In 1972, the same year that the famous "Blue Marble" photograph of Earth was taken, the Club of Rome warns that the supply of fossil fuels is limited and that we can expect huge shortages in the not-too-distant future. Taking a look at future scenarios that sketch out these developments, (Meadows et al., 2004) makes it clear that fluctuating oil prices, food shortages in large parts of the world, and global warming, are just the beginning of the dramatic changes we can expect.

Starck himself also does not appear to have an undivided positive view of the future. In an interview he describes the expectation that his son will be one of the space travelers who will be fleeing the expected catastrophe on Earth with the help of Virgin Galactic: *"We have some intuition in our DNA that we must escape before the world explodes. It is about the freedom and the* *democratization of space. My son, who is 11, will go" (Glover, 2007).* Apparently the renewed ecological awareness that will be created when everyone can make a space voyage is not enough to turn the tide. This alarming expectation about the future of Earth is in keeping with the analysis of the Brundlandt Report, which discusses the precarious condition of the earth:

> *"From space, we see a small and fragile ball dominated not by human activity and edifice but by a pattern of clouds, oceans, greenery, and soils. Humanity's inability to fit its activities into that pattern is changing planetary systems, fundamentally. Many such changes are accompanied by life-threatening hazards. This new reality, from which there is no escape, must be recognized - and managed." (Brundtland, 1987, 18).*

The report states that it all depends how one views the situation. Those who search for successes and signs of hope can certainly find them. Child mortality rates are decreasing, average life expectancy is increasing, the percentage of people who can read and write is increasing, more and more children attend secondary education, and the amount of available food is increasing faster than the world population. On the other side of the coin, the image is less positive. In absolute numbers, more and more people are starving than ever before, and their numbers are only increasing. The number of people who cannot read or write is also increasing, as is the number of people without safe drinking water, without a safe dwelling, or without the means to stay warm. The gap between rich and poor is only getting wider rather than smaller and it does not look like this process will be reversed (Brundtland, 1987, 19). This description dates from more than 20 years ago, but it's just as up-to-date today as it was then. New technology and new products influence the world, but unfortunately that influence is not always positive.

3.2.3 ICT revolution

After the first industrial revolution, which was based on the development of the steam engine, and the second industrial revolution, which was based on electricity and the combustion engine, we are well on our way to the third industrial revolution, involving information and communication technology. While the personal computer used to be a large piece of equipment that was only used in offices, the computer has now become so easy, accessible and natural that we are hardly even aware of it anymore. Mark Weiser describes the developments surrounding the constantly shrinking computer in his article "The Computer for the 21st Century" as follows:

> *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." "Such a disappearance is a fundamental consequence not of technology, but of human psychology. Whenever people learn something sufficiently well, they cease to be aware of it" (Weiser, 1991).*

In other words, this is not so much about the computer disappearing physically, but about the fact that it is present everywhere, so that one is barely aware of it anymore. In the same way we are not aware of written text in our environment, or traffic signs along the streets. They are simply there and they do what is expected of them. Weiser uses the term "Ubiquitous Computing", the omnipresent computer. Other terms to describe the emergence of the computer in daily products are "Pervasive Computing", used by IBM (Mark, 1999), which emphasizes that the computer permeates all areas of life, or "Ambient Intelligence", used by Philips, which indicates that man is surrounded by intelligent equipment. The result may be that, "within the next decade, we may find that any non-interactive objects or systems around us have been replaced by almost invisible, intelligent interactive systems - an 'Ambient Intelligence' that could soon form a natural part of our everyday lives" (Aarts and Marzano, 2003, 8). Combined with the incorporation of radio frequency identification (RFID) tags in many products (ranging from supermarket packaging to passports), some are talking about 'The Internet of Things" (Van Kranenburg, 2008). In turn, this increasing digitization affects the corresponding services. For example, internet businesses who sell products or services, such as booking a flight through the website of an airline company, or purchasing a book on the internet which is then sent to you by regular mail. And frequently it is not at all about physical products anymore, but purely about virtual services that are delivered, for example when buying a music file for your MP3 player in Apple's iTunes store. In this case it is only a matter of moving digital information and the physical equipment is merely the carrier of services delivered to the consumer.

One can frequently hear the expectation that applying this new technology will solve many of our society's problems. In the book "When Things Start to Think", Neil Gershenfeld, director of The Center for Bits and Atoms at the Massachusetts Institute of Technology, draws the parallel between the development of typography and the emergence of digital technology. The development of a new product, in this case the individual metal printing letter, made it possible to distribute texts quickly. This made it possible that the Bible, which was translated by Luther, could be reproduced quickly and affordably, which resulted in the Reformation and the liberation from the oppression by the Church. Gershenfeld expects that it will not be long anymore before a country can only be excluded from the world if the dome is built over it. The free exchange of information makes it more difficult to hide abuses, and knowledge of alternatives is more difficult to censor (Gershenfeld, 1999). While this thought may have been true a decade ago, recent developments with internet censorship in for instance China (Thompson, 2006) may render this vision outdated. As with any other innovation, the emergence of ICT appears to have a darker side. UNESCO expresses the fear that these developments may lead to an increasingly fragmented, "dissociated society", where everyone lives in his own world, but the communal world is distressingly empty (Unesco, 2000, annex p4). Incidentally, at the beginning of the 20th century it was not so much the ecological consequences, but rather the social effects of industrialization that were noticeably negative. The monotony of work, unemployment and poverty as a consequence of the increased efficiency of machines, are highlighted in the movie "Modern Times" from 1936. Ford's assembly line first appeared to be a bringer of so much good, but after a few years it turned out to be less than was thought. It is obvious that new products have an effect on the society in which they are used and vice versa. The question posed in this study is whether this mutual influence can only be identified after the fact, or if it is possible to shape this influence during the design process.

3.3 New problems and objectives for design

3.3.1 Social responsibility

What is actually the objective of all of these new products, services and systems that flow from product development? Is the world not good enough as it is, without human intervention? Whatever the answer to this question, the fact is that it is man's nature to change the world to his liking: "Through his actions, man is steering autonomous natural events in a new direction, chosen by him. A fundamental element in this is that man can collaborate with parts of his surrounding material reality, and can include it as instruments in his actions" (Roozenburg and Eekels, 1991, 51).

Man decides the direction. The question is which direction he is aiming for. For this, many socially concerned organizations refer to John Elkington's concept of the "Triple Bottom Line", also defined as the "triple P" of People, Planet and Profit. In his article "Towards the sustainable corporation: Win-win-win business strategies for sustainable development", Elkington emphasizes that it is important that companies are not only accountable for their financial success, but that they are also accountable for their ecological and social successes (Elkington, 1994). This approach is in keeping with the stakeholder theory (Freeman, 1983), which emphasizes that companies are not only accountable to their own shareholders for their interests, but also for the interests of other stakeholders. The foundation for this approach can be found in the "identification of moral or philosophical guidelines for the operation and management of the corporation" (Donaldson and Preston, 1995, 71). Consideration for Corporate Social Responsibility can be "defensive" in nature, for example if it is a matter of reducing environmental fees during production and the prevention of negative labor conditions for employees. The opposite would be the "offensive" approach, where embracing sustainability is considered a design opportunity that can provide added value to the products and services delivered by the company. Examples of this are products that carry the "Max Havelaar" fair trade certificate, such as coffee and bananas, Anita Roddick's Bodyshop and clothing brands such as Kuyichi that use ecological cotton (Audebrand and Pauchant, 2009). In these cases it is no longer just about the physical object that is delivered (the blue jeans or the coffee), but also about the way these were created and the underlying values involved. The exterior of the delivered product may be identical to a competitor's product, but it distinguishes itself in the context in which it was created. All in all, the emphasis on Corporate Social Responsibility stimulates companies to view their products in a broader, social sense. However, are the consumers of these companies actually interested in this social responsibility?

Various experts are of the opinion that the solution to social challenges cannot be guided. If "the market" wants it, it will appear by itself. And if "the market" does not want it, it just won't happen. As expressed by a unit manager of the supermarket chain Albert Heijn, who explains why ecological products are so slow to take hold: "Ultimately it is the consumer who decides. That's where the real power lies. We can't do anything other than fulfill the consumer's wishes as well as we can." (van Dinther, 2003) Unfortunately, at the crucial moment, people tend to be a consumer rather than a citizen, and they will choose economy over virtue. "The sad conclusion is that the consumer is two-faced. While his right hand is filling in a questionnaire about free-range meat, the left hand is filling his basket at the "Bargain Butcher", or other bargain grocery chains. It's not animal welfare, the preservation of our landscape, concern for our own farmers or sustainability that determine our approach to shopping, but it's the price. (van Dinther, 2003)"

We want to drive a car, but we also want to enjoy nature. To provide for the first we become a member of the Automobile Association, for the latter we become a member of Greenpeace. We want fewer traffic jams, so that we can drive faster on wide highways, and at the same time we want clean air, peace and space to live in. An essay bundle entitled "Citizens and Consumers -- between division and unity" explains that there are big differences between what people say they find important and what people do in practice. Apparently there are big differences between the attitude and the behavior of people, between the role of citizen and of consumer. It seems that people maintain a double moral standard: "In their role of citizen, it is believed, people are concerned and aware. But their consumer morals are considerably more crude" (Dagevos and Sterrenberg, 2003, 8). A more or less reverse discussion about the difference between consumers and citizens is discussed by Kandachar and Halme (2008b) when they describe the fact that more often than not, companies only consider poor people as potential consumers and don't perceive them as citizens at all. Although their specific research focus is on the relationship of business and poor people, the suggestions to see the poor as producers, not just as customers, and to emphasize the role of people as partners in business co-creation (Kandachar and Halme, 2008a, 2), may also be valid for "non-poor" people.

3.3.2 The influence of worldview

To find out what motivates people to make certain choices, we will take a short look at a "higher" level and consider the underlying worldview that is employed. The fact is that the way people view the world and themselves, apparently does have considerable influence on their behavior. John Grin emphasizes the influence that a person's worldview has on the way he evaluates his current situation and desired future situation: "Both evaluations of the past and expectations of the future reflect the values, worldviews and deep preferences of those who hold them" (Grin and Grunwald, 2000, 11). Josephine Green of Philips Design even compares the ambition for sustainability with the adherence of a religion, stimulating them to radically change their way of thinking and their way of being:

"Sustainability is not tame; it is a radical philosophy that, as with the great religions, asks people to

> *change their lives. Like those religions it is about radical change and transformation. A transformation of the way we think and the way we are, a personal transformation, which is often the hardest transformation of all but one that supports all the others. If we don't change ourselves we can't change the world" (Green, 2007, 62).*

In his book "The Religion of Technology: The Divinity of Man and the Spirit of Invention", historian David Noble argues that all innovation is primarily inspired by religious motives (Noble, 1997). This idea is not completely far-fetched, as can be seen in a story that is described in "State of the World 2003, A Worldwatch Institute Report on Progress Toward a Sustainable Society" (Starke, 2003, 165). This report describes how people's convictions have influenced attempts to clean up the river Ganges in India. This is one of the most polluted rivers in the world, caused by corpses of humans and animals, sewage water and soap from people who wash themselves in the river. The Ganga Action Plan (GAP) started in 1985, with the objective to clean up the river by 1993. Several Western purification plants were established, but these often stopped working due to power failures and lack of maintenance. The GAP initiative failed, and in 1993 the river was more polluted than ever before (Alley, 2002) (Stille, 1998). The user's worldview appears to play a big role in the way one looks at this situation. Hindus worship the river as a goddess, whose water can therefore be nothing but clean and pure. For that reason, tens of thousands of believers take a daily bath in the Ganges, to cleanse their inner soul. In addition, the ashes of cremated Hindus are scattered into the river so that the deceased will be liberated from this material world. When considered from this perspective, one is not just dealing with a river that drains melt water from the Himalayas, but with a source of eternal life. For that reason many Hindu priests blame the pollution of the Ganges not on the failing of the purification plants, but on the moral decay and a corrupt society in search of power and wealth. When seen from this perspective, the industrial purification plants are part of the problem, rather than part of the solution. Indeed, more than that, for many Hindus it is absolutely impossible to accept the fact that "mother Ganges" is polluted, since the holy river is pure by definition and does not need purification.

From a design perspective it appears to be an almost insurmountable task to integrate these two contrasting views of the world, the scientific and technological perspective on the one hand and the religious and cultural perspective on the other hand. And yet, that is exactly what Veer Bhadra Mishra, of Banares Hindu University (Ganguly, 1999) does in his attempts to clean up the Ganges. He has a good understanding of both views of the world, because beside his work in the Civil Engineering Department, he is also "Mahant", or high priest, of the Sankat Mochan Temple in Varanasi. Dr. Mishra compares the two competing views of the world as two perspectives which are inextricably linked: "Science and technology are one bank of the river," he explains, "and faith is the other... Both are needed to contain the river and ensure its survival." "With only one bank", he says, "the river would spill away and disappear" (Gardner, 2002, 37). By making a distinction between the physical purity and mental purity of the river, he manages to appeal to the concerned parties in a way that fits their specific worldview and its associated objectives and values. What this means in relation to the purification of the river is that alternative ways to clean the water are being utilized, which function better under local circumstances than the qualitatively outstanding, yet vulnerable hi-tech installations from the West.

A comparable example was described in Times Magazine, and is related to waste processing in Cairo, Egypt. In the summer of 2009 there was a global fear of Swine Flu, prompting the authorities to kill all 350,000 pigs in the country. Besides the fear of diseases, pigs aren't very popular in the primarily Islamic country of Egypt. The unexpected, or maybe not so unexpected effect appears later that year, when garbage accumulates in huge piles in the streets of the city. Although the city has an official waste collection system, based on a Western structure, using garbage trucks to collect refuse, the system apparently does not work. The fact is that for the past half-century, the central core of the waste processing system are the 70,000 "Zabaleen", the Egyptian Christians who collect refuse from the houses, extract the reusable items and feed the organic content to the pigs (Slackman, 2009a, Slackman, 2009b). John Ehrenfeld uses this example to indicate that it is important for designers to consider local knowledge and the complexity demanded by the development of socio-technical systems: "The informal system of the Zabaleen was self-organized and relied on local knowledge. I would imagine that it evolved over time with the actors learning as they worked. Trying to replace this system with a system that was developed in a vastly different culture ignores the complexity of socio-technical systems and is asking for failure from the start" (Ehrenfeld, 2009).

All in all it is becoming obvious that the product development process is not only about realizing the consumer's functional objectives, but also about fulfilling underlying values and needs that are closely related to the societal worldview of those involved. Man is more than just a "consumer" with only economic objectives, more than just a "user" with functional objectives and more than just a "citizen" with social objectives.

3.3.3 Societal problems and objectives

In spite of the limitations of the purely technological approach, expectations are high regarding the added value of research and development. In their program "socially responsible innovation" the Netherlands Organization for Scientific Research (NWO) states that the social potential of research and development is becoming more and more apparent, enabling the improvement of society as a whole as well as the improvement of the lives of individual citizens. Significant contributions are expected from technology and science in order to find solutions for global problems in food supply, health, safety, housing and transport, and to enhance sustainable economic development in general. Therefore this subject is high on the worldwide political and social agenda. Considering the solutions that technological and scientific knowledge can offer for social questions and problems, an exploration of the ethical and social aspects is required. This will lead to better innovation tracks and the optimal utilization of available opportunities. Opportunities will certainly be missed or misused without reflection on, and knowledge of these aspects (NWO, 2008, 5).

One of the organizations which is attempting to make a contribution in this area is the "Innovatieplatform" (Innovation Platform), a Dutch platform organization dedicated "to strengthen the Netherlands' capacity for innovation" *(Innovatieplatform, 2007).* One of the methods that is being used in order to define promising directions for innovation is the development of future visions that describe a desirable situation, to be achieved 10 to 25 years from now. An example can be found in the book "The Netherlands 2027. The future vision of the Innovation Platform". Under the heading "Health and the elderly: everybody active", we read:

> *"Opportunities of preventive care especially have increased considerably. Increased knowledge of the human body (genetics) has enabled a rich offering of made-to-measure activities, nutrition and (preventive) medications. The result of this elaborate attention — and opportunities — for health is that we can live longer in good health. Many diseases, as well as the pain and costs that accompanies them, are being prevented. Improved health and life expectancy make it possible for people to stay active longer" (Innovatieplatform, 2005, 15).*

Another set of societal objectives that many parties consider to be vital to strive for, are the eight United Nations Millennium Development Goals (UN, 2000) that have a target date of 2015: Ban poverty and hunger, accomplish universal basic education, realize equality between men and women, combat child mortality and maternal mortality, eradicate HIV/AIDS, malaria and other diseases, protect the environment so that everyone has clean drinking water, and develop worldwide cooperation towards development.

Incidentally, such an effort to sketch an ideal future is not new. Take for example the books "Utopia" by Thomas More (1516) and "The New Atlantis" by Francis Bacon (1627). Since that time it has been well established that such a top-down ideal world unfortunately does not always appear to be as ideal as intended (Achterhuis, 1998) and often results in an opposite "dystopia" nightmare scenario. An example of this is the book "1984" (Orwell, 1949), where an all-powerful authority uses a "telescreen", a TV with a built-in camera, to continuously keep track of everyone. This principle was inspired by Jeremy Bentham's "panopticum", which was then expanded in a philosophical sense by the French philosopher Foucault (Foucault, 1975). But there is nothing new under the sun, because even fairly recent technology, like the Global Positioning System (GPS), is being used to keep close tabs on employees, now in the form of location-oriented "geoslavery" (Dobson and Fisher, 2003, Joore, 2008). David Lyon also warns against this in his book "Future Society" (Lyon, 1984), in which he focuses on the possibility to keep an eye on everyone, everywhere and anytime, such as in the form of modern "panopticums" (Foucault, 1975), where everyone knows everything about everybody. And yet, why couldn't innovative products provide us with ultimate freedom instead of dictatorship? The "everybody happy"-scenario was developed in the introduction of the above-mentioned novel "Brave New World" by Aldous Huxley. In this scenario, everybody is always satisfied, their troubles and problems have been banned and everything is organized in such a way that there is never any reason for discontent. In order to stimulate the economy, one must even indulge at any time, and not to indulge is even considered unseemly. The remedy Soma (a kind of Prozac plus, but without the side effects) helps on the one hand to suppress possible indefinable emotions and on the other hand to arouse the most passionate emotions, when desired, with the help of the "Violent Passion Surrogate". This allows one to live the full spectrum of fear and anger once a month. *"Christianity without tears" — that is soma."* And yet, this ideal world of ultimate freedom and enjoyment does not appear to satisfy either, which is evident from The Savage's experience. This visitor can or does not want to conform to the rules of this new society in which he finds himself. In a discussion with government representative Mustapha Mond, he expresses his feelings:

> *"But I don't want comfort. I want God, I want poetry, I want real danger, I want freedom, I want goodness. I want sin." "In fact," said Mustapha Mond, "you're claiming the right to be unhappy." "All right then," said the Savage defiantly, "I'm claiming the right to be unhappy." "Not to mention the right to grow old and ugly and impotent; the right to have syphilis and cancer; the right to have too little to eat; the right to be lousy; the right to live in constant apprehension of what may happen to-morrow; the right to catch typhoid; the right to be tortured by unspeakable pains of every kind." There was a long silence. "I claim them all," said the Savage at last (Huxley, 1932).*

Claiming the right to be unhappy appears to be in contradiction with our logic and our image of an ideal future, such as in the example of the "Innovatieplatform". After all, this is where we prevent diseases and pain, so that we will all live happily ever after. Building an ideal world appears to be more difficult than was originally thought.

3.4 A new relationship between designer and other actors

3.4.1 The role of actors

Even if we take distance from the more far-reaching future ideals, the question remains, who is ultimately responsible for solving all of our societal problems. This investigation's viewpoint is especially from the perspective of the field of expertise of industrial design, but naturally the roles of government and other actors are also essential during this process. In the report "Innovation renewed. Opening in quadruplicate", the Scientific Council for Government Policy (WRR), in the Netherlands, takes a close look at the relationship between government and innovation, and concludes that one of the most important tasks of government is to promote cooperation between organizations (WRR, 2008). However, government is just one of many parties that give direction to the future of society. The above-mentioned study "Citizens and Consumers -- between division and unity", also mentions that government is less and less able to "enforce or independently realize political or policy objectives. Although appointing itself as the advocate of societal interests, in order to realize this responsibility for communal affairs it is at the same time dependent on other parties, both suppliers and demanders" (Dagevos and Sterrenberg, 2003, 12).

This analysis fits closely with some thoughts by the Dutch Minister of Social Affairs and Employment Opportunities, P.H. Donner, which he shared on the occasion of the opening of the academic year 2007 at the Theological University in Kampen. In this lecture he discusses the role of communal values, which are necessary in giving direction to social developments: "Because 'government' is nothing more than a capacity to order the members of a society, to entrust or to force, without gaining approval or even agreement from each individual. But that will have to be based on shared values; a shared perception of human value, of what is truth and what is good and evil. (...) However it's about more than shared values. Coexistence demands a communal view of our collective objectives and what we expect from each other" (Donner, 2007).

An example of a national initiative to move parties in a desired direction with the help of a coordinating manifest is the Urgenda, a manifest in which several organizations collectively sketch a sustainable vision for the future of the Netherlands. The signatories of the manifest have a need for wider views, substantial breakthroughs and structural modifications, in other words, the previously mentioned challenging, inspiring, visionary objective that all parties can agree to and can act upon. A vital aspect on the agenda concerns the relationship between a larger vision and concrete action: "The key is in creating links. To relate the macro-story to the numerous micro-stories; the visionary assignment to the small-scale experiments; the regime players in favor of change to the niche players; the long term to short term; and vision to action and decisiveness. Basically, to relate the undercurrent with the overcurrent" (Urgenda, 2007)

In short, this is all about making connections. Different parties must collaborate on radically new solutions. Technology, politics, economy and culture are inextricably linked and cannot function without mutual contributions. That means that experts from the area of design, business and culture need to work together, "in more intimate and more powerful combinations than ever" (Florida, 2002, 201). In "Vision 2050", the World Business Council for Sustainable Development emphasizes this need for more cooperation. They explain that there will be growing demand for those able to build and manage complex coalitions, made up of a number of different actors and areas of expertise – public, private, civil and academic sector individuals and organizations. These new structures will blend the best of each sector's knowledge, assets and capabilities in seamless partnerships at local, regional, national, and international levels. "They will be far more strategic and pervasive than the one-off, tactical relationships we have witnessed to date and as a result of the different development priorities of those involved, more likely to deliver both economic and social improvements" (WBCSD, 2010). Having said this, one must also conclude that very little research has been conducted on how different kinds of actors can actually work together in the innovation process: "While there is a growing literature stream on user-driven innovation there exists so far very little research on how innovation can be driven by other stakeholders besides users and consumers" (Hockerts and Morsing, 2008, 19).

3.4.2 The role of the designer

The question is, what is the role of the designer in this collective change process. If we go by books and exhibitions about the subject of design, we can quickly get the impression that a designer is some sort of gifted individual. Preferably he is so famous and respected that companies are honored to be allowed to take one of his designs into production. Somebody like Philippe Starck, well-known for his designs of kitchen utensils from Alessi, toothbrushes from Fluocaril, suitcases from Vuitton, office furniture from Vitra and even noodles from Panzani. His way of working is reminiscent of the image of an artist-designer, isolated from the outside world and only focused on his own inspiration:

> *"I work strictly alone. I live far from everything. I am a modern autist . . ." A modern artist? "No, a modern autist. I have no computer. My real job is dreaming. I have the same drawing paper, the same drawing pad I have used for 25 years. I do everything entirely alone" (Glover, 2007).*

This designer's objective appears to apply mostly to the expression of feelings and emotions from the subconscious, when, in the same interview, he tells about his motives during the design:

> *"I am driven by a powerful, sophisticated subconscious. And in my subconscious I am everything. It is my magma. I am a magma-former" (ibid.)*

The similarity to an artist becomes clear when we compare Starck's inspiration to the words of the Dutch poet Willem Kloos, who positions himself as ruler over his own inner soul, in his 1894 Sonnet. This indicates that art must be considered as the "utmost individualistic expression of the utmost individualistic emotions", art with intrinsic value:

> *"I am a God in the deepest of my thoughts,*
> *and I am enthroned in the center of my soul" (Kloos, 1894).*

Besides the odd designer who develops his unique creations like some kind of semi-artist, many more designers exist who collaborate closely with the patron company, and whose name and face will never become known to the users of their products. The collaboration with a producing company is in fact the most distinguishing criterion for the delineation of the industrial designer's working area. We saw this already in chapter 1 with Peter Behrens, who, exactly because of his narrow collaboration with AEG, is considered to be the first real industrial designer. Professor of Architectural History Adrian Forty emphasizes the role of the company during the design process, in contrast with the image of the autonomous designer who is solely responsible for the completed product. After all, it is the company who determines which of the various design variants, presented by the designer, will be refined and taken into production. Designers may appear to be the ruler in their own kingdom, but Forty describes this as a myth that must be dispelled as soon as possible, so that young designers will not be disillusioned and frustrated about the specialty they are making their own: "Although designers prepare designs, the responsibility for carrying them out rests with the entrepreneur; (…) It is the entrepreneur not the designer who decides which design most satisfactorily embodies the ideas necessary to the product's success, and which best fits the material conditions of production" (Forty, 1986, 241).

However, the tension that designers are confronted with goes deeper than the skill to combine the contrasting interests of various actors, towards a balanced design. The reason for this is that the designer in fact plays some kind of double role, described by Forty as the designer's paradox. On the one hand the direction of the design is determined by ideas and decisions of the patron organization, without any input from the designer. On the other hand, the design is the result of an autonomous and creative process where the designer is completely in control. In Forty's words: "To put the paradox in the most extreme terms, how can designers be said to be in command of what they do, but at the same time merely be the agents of ideology, with no more power to determine the outcome of their work than the ant or worker bee?" (Forty, 1986, 242).

So, is the designer some sort of autonomous artist, who creates a new product from his deepest emotions? Or is he merely a tiny cog in the great innovation process, executor of what the company's management orders him to do? Is the designer who occupies himself with social problems an idealistic visionary who spends his time dreaming up ideas that will never see the light of day? Or are designers, who don't dare to touch this, shortsighted doers who allow themselves to be governed by today's restrictions and are unable to see the larger picture?

One way for the designer to handle this troublesome double role is to choose, consciously or subconsciously, from one of the extreme positions within the design spectrum, and to ignore the other role entirely. Forty determines that many designers back away from the paradox by holding on to the "myth of their omnipotence" (Forty, 1986, 242), where they momentarily forget about their responsibility as representative of the company. For that matter it appears that holding on to that "myth of their omnipotence" is not so terribly unrealistic, but rather a necessary choice in order to successfully complete their own work. After all, a designer must be able to visualize a situation in front of him which is totally different than the current situation. To do this, it is necessary to free himself from the limitations and objectives of the short-term, and to focus on the opportunities for tomorrow and the day after instead of the limitations of yesterday and today. If the designer only extrapolates the current situation to tomorrow, the results will be predictable or plain bad designs: "Clearly, it is necessary for designers to believe, at least temporarily, in their own omnipotence in order for them to be able to create at all, but this does not mean, as they often assume, that everything they do is the result of their own conscious will and determination. The myth of the omnipotence is surely, like all such claims, a fantasy, but an attractive one: the myth of creative autonomy obliterates the problem of ideology as a determinant in design and releases designers from the uncomfortable prospect that they might be no more than actors in the theatre of history" (Forty, 1986, 242).

Yes, the designer is, like all of us, merely a puppet in the theater of history. But in order to fulfill this task successfully, he must, as a visionary, temporarily occupy the chair of the director, in order to improve or rewrite the play from that perspective. In fact the real work of the designer, as we just heard from Philippe Starck, is to dream of a better future. As he states elsewhere: "My job is to drive the philosophy, to keep the direction, to be the guard of the temple" (Glover, 2007). This necessary "naïveté" regarding one's own influence is also recognizable in Ezio Manzini's words when he explains why working on a sustainable future is necessary, even if the chance of success appears to be limited at first: "Indeed, we cannot act in a forward looking way if we are unable to imagine a state in which we could potentially live in a different and more attractive way than now" (Manzini and Jegou, 2003, 13).

In fact, this describes the essence of the work of a designer who is always occupied with mental creation of a new situation that will bring about an improvement of the current situation. Papanek labels the idea that the designer only has limited influence on his own work "The Myth of the Designers Lack of Control". Designers frequently excuse themselves by saying that "the marketing department, the sales department or the management are to blame". In fact, this is merely an excuse to shirk his responsibility, since "it is a fact that the designer often has greater control over his work than he believes he does…" (Papanek, 1985, 234) Forty will probably agree that the designer is allowed to temporarily enjoy the illusion of omnipotence. And agreed, the designer can play a significant intermediary role between a diversity of actors in and around the company. But, momentarily retaining the image of the theater, ultimately it's the company's management who are the director and decision-maker. There's only room for one boss. Or not?

Because what happens when it turns out that it's not just the company who are on the director's chair, and that they even turn out to be one of the many players on the larger stage? What if it is essential for the success of the company's new product, that another company, at the exact same moment, develops and markets another product? For example, in the development of various networked digital products, where the simultaneous involvement of multiple actors is essential for the functionality of the system. Is the company in that case still on the director's chair, or are multiple directors working side-by-side? Or perhaps we might even look at this as a number of theater stages, where performances are happening simultaneously, while closely interacting with each other? At that moment the playing field has become larger than one's own organization, and careful tuning between the various stages has become vital. Exactly this situation appears to be created more and more frequently by the above-mentioned change process of loose products and artifacts, towards the development of paired and networked products, services, and ultimately toward the design of complete systems where various components function in close relationship with each other. In nearly all cases, these various components are realized by a whole range of actors, where companies, government, interest groups and end users must collaborate in new ways. This means that the "design" as such, is no longer under the control of a single party, but demands a new collaboration effort from parties who, until now, could operate independently.

Must the designer still base his actions on the interests of a single party, or is there a need for a new role? Forty concludes that a simple answer to this question is not apparent. Both facts exist next to each other, no matter how uncomfortable this contrast may be: "There is no answer to this question: it is a fact that both conditions invariably co-exist, however uncomfortably, in the work of design" (Forty, 1986, 242).

3.5 Conclusion

The last item for discussion in this chapter is the question whether companies, government and designers actually need to worry about the effect that new products have on society. Why would we be concerned about the problems of this world? Perhaps it is better to stay inside, far away from the uncertainty and problems of the "real world", and withdraw behind the walls of our secure home or country? And then, when we try to create new products to improve the world, they turn out to have all kinds of unexpected side effects and "bite back" (Tenner, 1996) in an unexpected way. Some authors even suggest that it may be impossible to develop new products that do not have a negative effect on society and that industrial design is one of the most harmful professions that exist (Papanek, 1985). If this is true, it might be better if they stop designing altogether, to prevent so much misery. In "In the Bubble", John Thackara reacts to this suggestion that designing would indeed be the most damaging profession in the world. He writes that it is for sure that there are a number of designers who are self-centered and indifferent, but no designer is consciously homing in on destroying the planet or messing up our lives. The problem is that small actions can have large effects and that small actions can have big effects, which means that designers need to be incredibly sensitive to the possible consequences of any design step they take (Thackara, 2006, 7). And there is hope, because "if we can design our way into difficulty, we can design our way out" (ibid, 1). Papanek also provides an alternative for his own suggestion to completely stop designing. Better than not doing any more designing is to start working in a directed, positive way. In that way, designing can become a way in which design can contribute in a positive manner to the development of a changing society: "We can go beyond not working at all, and work positively. Design can and must become a way in which young people can participate in changing society. As socially and morally involved designers, we must address ourselves to the needs of a world with its back to the wall, while the hands on the clock point perpetually to one minute before twelve" (Papanek, 1985, ix).

Economist Ernst Friedrich Schumacher discussed the dilemma of big problems and small initiatives in the book "Small is Beautiful: A Study of Economics As If People Mattered". He makes a comparison between our efforts in this with a sailboat sailing on a quiet sea. No, we cannot change the world by ourselves. But we can make a contribution to the world at large. "Perhaps we cannot raise the winds. But each of us can put up the sail, so that when the wind comes we can catch it" (Schumacher, 1973). Perhaps the relation between small actions and big problems is best put to words by Nobel Peace Prize winner Agnes Gonxha Bojaxhiu, better known as Mother Teresa of Calcutta: "We ourselves, feel that what we are doing is just a drop in the ocean. But if that drop was not in the ocean, I think the ocean would be less because of that missing drop" (Spink, 1997) .

Having said all this, the question remains how to translate these ambitious goals into concrete action. What can designers actually do to make their own, albeit modest, contribution to society, to contribute their own specific "drop in the ocean"? To get somewhat closer to this rather elusive goal, it is necessary to first find out how the design process and the role of designers can be described in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a more systematic manner. Only then it may indeed become possible to structure the design process in such a way that the very commendable, but at the same time very challenging goals as formulated by the International Council of Societies of Industrial Design may indeed somehow be achieved. After this broad background chapter, the next chapter will take a more focused approach to determine the situation related to the four research issues that have been defined in chapter 1.

3.6 Summary

Chapter 3 reflects on the initial problem situation, discussing the broader developments in the field of design, which form the foundation for the more focused research question. When comparing this chapter to the next one, this one is about "design" as defined by the International Council of Societies of Industrial Design, while chapter 4 is about the "design process" and about "design models". In this chapter it is discussed how the development of new products and socio-technical and societal developments affect each other. It appears acceptable to assume that this mutual relationship nearly always exists, and that it affects the functioning of new products as well as the functioning of society as a whole. Examples of the mutual influence between new products and developments in society are, among others, the wooden plowshares of the Mesopotamians, which resulted in the emergence of an agricultural economy some 8000 years ago. Another example is the development of the Model T Ford, as forerunner of mass industrialization through the assembly line, including the ecological effects of this industrialization. The emerging consciousness surrounding this theme was inspired by the "Blue Marble" photograph of Earth in 1972, which in turn was made possible by the developments in space travel and photography. Related developments are the emergence of communication and digital technology, for example in the form of Ubiquitous Computing, and the development of medical technology, followed by the expectation that new products and new technology will soon eliminate all pain, suffering and related costs. This confirms the relevance of the first research subquestion, discussing the relation between (new) products and the socio-technical or societal system that they are a part of, and posing the question how this relation can be described in a systematic manner.

The various problems and objectives which influence this mutual relationship can be seen in the reforging of "swords to plowshares", which conveys the idea that the use of one product is more desirable than the use of the other. This value judgment is in turn closely related to the underlying worldview of the person, highlighted by the way the pollution of the river Ganges is handled in India. The way that people view the world may even determine whether they think there is a problem at all (after all, "mother Ganges" can't possibly be polluted). Also in the situation surrounding the waste processing by the Egyptian "Zabaleen", the divergent worldview of the various communities turns out to be an important source for the solution (waste processing, aided by pigs), as well as for the problem (slaughtering these same pigs because of their assumed uncleanness). Closely related to the value judgment of the current situation is the objective that is set for the future. The fact that these objectives cannot always be unequivocally defined, becomes clear in the example of the citizen-consumer, who says that sustainability is important, but when push comes to shove, he lets his decision be governed by the price of the product. This creates a difficult challenge for companies who occupy themselves with Corporate Social Responsibility, as they have to take into account the consumer's apparent double moral standard. Human beings are not easy to understand in any case, when we read how "the Savage" in Huxley's "Brave New World" explicitly does not choose for comfort and happiness, but for suffering, renouncing and pain. This desire seems to be totally opposite to the way that the Dutch Innovation Platform sees the future of healthcare, envisioning a future society in which most people can live longer in good health, as most disease and pain can be prevented. It appears that people's objectives cannot easily be placed in a framework, a conclusion that does not take away its importance. This confirms the relevance of the second research subquestion, discussing the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives which are being met by means of the functioning of a socio-technical system.

Even if we take distance from the more far-reaching future ideals, the question remains who is ultimately responsible for solving all of our societal problems. Here it becomes clear that different parties must collaborate to create radically new solutions. Technology, politics, economy and culture are inextricably linked and cannot function without mutual contributions, implying that experts from the area of design, business and culture need to work closely together. With regard to the role of the designer in this increasingly complex situation, this is not so evident. In fact, even where the regular product development process is concerned, the role of the designer is not that obvious. In fact, most decisions made regarding the introduction of new products are not made by the designer, but by the entrepreneur who decides which product to bring on the market and which one not. When looking to changes in society, this process is much more complicated, putting the designer in an even more modest position with regard to all other actors involved. This confirms the relevance of the fourth research subquestion, discussing the way that the (potential) role of the designer with regard to the product design process, as well as with regard to the way that socio-technical and societal change processes take place, can be described.

The fact that this contribution is not that self-evident is no excuse not to bother about the effects that design may have on society. Although some people may think that the potential negative effects of product development may be so bad that it may be better to stop designing at all, it seems reasonable to accept that it is possible to go beyond not working at all, and contribute positively to the challenges that society faces. Although the contribution that design can make may be modest, perhaps even comparable to "a drop in the ocean", if that drop was not in the ocean, "the ocean would be less because of that missing drop". Having said this, the question remains how to translate these ambitious goals into concrete action. This confirms the relevance of the third research subquestion, discussing the similarities and differences between the product design process and the way that socio-technical and societal change processes take place, discussing if it is possible to interlink both processes in a systematic manner. To find the answers to these questions, the next chapter will maintain a narrower focus when analyzing the way in which current design and innovation models and methods deal with these research issues.

4 Chapter 4: Inventory of Design and Innovation Models

4.1 Introduction

4.1.1 Four fields of expertise

Where the previous chapter looked at the relationship between new product development and developments in society from a broader perspective, in this chapter a more systematic analysis of the four fields of expertise as introduced in chapter 1 will be performed. These four fields of expertise are: (1) Industrial Design Engineering, (2) Systems Engineering, (3) Sustainable Product Development and (4) Sustainable System Innovation. The first two areas have a more or less "neutral" approach, the other two have an explicitly normative or sustainability focus. Another distinction is related to the degree that the emphasis is on the development of a single product or service (group 1 and 3), or on the development of composite systems (groups 2 and 4), (Table 4-1). Of course this description should be regarded as a simplification, as methods may converge and have a certain amount of overlap. However, structuring them is a necessary step to bring order into a complex reality.

Besides the analysis of existing design and innovation models, also included is a description of the conditions that an "ideal" design model must satisfy to ensure that it is suitable to help answer the research question. This desired model should preferable "cover" all of the conceptual model by combining elements of each of the fields of expertise that will be analyzed.

Table 4-1: Focus of the four fields of expertise

	Development of single products	Development of composite systems
Neutral focus	1) Industrial Design Engineering	2) Systems Engineering
Focus on sustainability	3) Sustainable Product Development	4) Sustainable System Innovation

4.1.2 Four research issues

Each of the four fields of expertise will be analyzed with regard to the way in which they deal with the four research issues that have been derived from the main research question.

Research question: How can the design process and the role of designers be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner?

In chapter 1, this research question has been divided in four subquestions, which briefly can be briefly be referred to as "product and society" ("what"), "problems and objectives" ("why"), "design process" ("how") and "designer and actors" ("who"). The analysis will look at each of those research issues consecutively, determining how the various fields of expertise deal with this subject. In the folowing sections, the four research issues are being discussed with regard to the way that the four fields of expertise deal with these issues. While these paragraphs will look at these issues in a rather detailed manner, the reader who wants to get straight to the point can skip paragraphs 4.2 to 4.5 and move immediately to paragraph 4.6, where the results of the analysis are being discussed.

4.2 Research issue 1: Product and society

Subquestion 1: What is the relationship between (new) products and the socio-technical or societal system that they are a part of, and how can this relationship be described in a systematic manner?

With regard to the relationship between "product and society" ("what"), the question is how the various fields of expertise deal with the relationship between the position of the product within the overlying socio-technical or societal system that it is part of. The question is how narrow or how wide the working area of the various fields of expertise is, in other words, what is the system boundary of each field of expertise. How do they distinguish between various kinds of elements within the overlying system and how are the reciprocal relationship between these elements handled?

4.2.1 Product and society -- Industrial Design Engineering

Models such as those implemented within the field of expertise of industrial design engineering are aimed especially at the development of one new product, en though the broader user context may indeed play an important role. One distinction that is being made is between the "physical product" and the "comprehensive product". The latter also includes - besides the physical artifact - packaging, users guide, distribution methods, advertising campaign, logistics, service, maintenance and possible recycling or return after use (Buijs and Valkenburg, 2005, 61). Other researchers emphasize more explicitly that products can be considered as complex systems and can themselves be part of larger systems. In the case of products, these elements are tangible objects, but systems can also be an assembly of symbols or concepts. "The system boundary is the conceptual boundary between elements that are, and elements that are not considered to be part of the system. A system boundary may or may not correspond with a physical boundary" (Roozenburg and Eekels, 1991, 85-86). Concerning the structure of these systems, Roozenburg and Eekels refer to the morphological method (Zwicky, 1967). This involves a search for those elements that are "essential" for all solutions, the parameters, after which for each element the theoretically possible realizations are mapped.

The Vision in Product design (ViP) approach (Hekkert and van Dijk, 2000) deals with the relationship of product and environment from the "context" within which the product functions. Three different aggregation levels can be distinguished in this, product, interaction and context. In turn, this context is made up of states, developments, trends and principles. States are factors that can only be changed slowly, such as infrastructure and legislation. Developments are factors in motion, in the field of technology as well as in economy, ecology, culture, politics or society. Trends relate to behavior, values and preferences of individuals and are subject to short-cycle changes. Finally, principles are more or less unchangeable factors, such as laws of nature and the psychological and physiological capacity of individuals. The significance of context is in the influence that it has on the product, which is the reason that this context must be chosen carefully and must be the starting point of each design project (Hekkert and van Dijk, 2001). Although the

ViP approach pays a lot of attention to the development of a "context vision", it is not the intent that this view of a possible new environment will actually be realized. This is mostly about a mental exercise, intended to inspire the creativity process.

With the development of "smart products", based on the application of information and computer technology, the importance of the context in which the product functions is an important topic of discussion. Three levels can be distinguished in this. First is the immediate context, in which individual and product communicate directly with each other. Second is the ecological context, in which various products communicate with each other. Third is the systemic context, where relationships exist within wider (technological and social) networks of products and people This is visualized in Figure 4-1. 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).

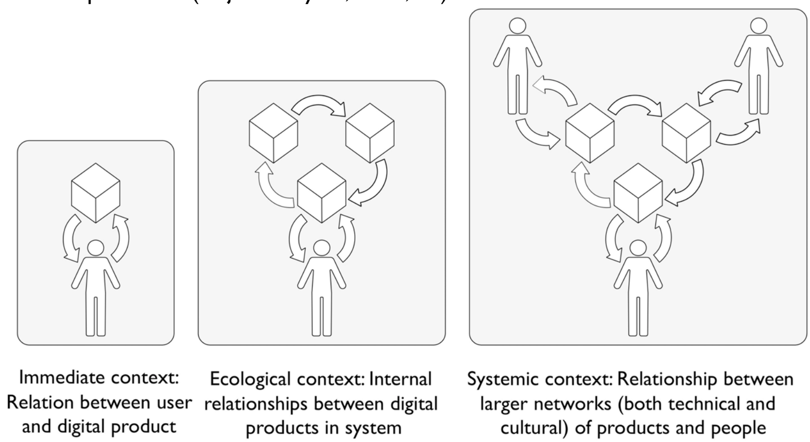


Figure 4-1: Immediate, ecological, systemic context of people and products (Andrews, 2003, 213)

4.2.2 Product and society -- Systems Engineering

The field of expertise of systems engineering is focused on the development of one new technical system. Furthermore it is emphasized that each system is an integrated whole, assembled from specialized structures and sub-functions. Functionality of the overlying system must be optimized during the development, whereby the objective is maximum compatibility of the components of the system (Chestnut, 1967, 3). Systems engineering is therefore also described as the "art and science of creating whole solutions to complex problems" (Hitchins, 2008, 91). The NASA "Systems Engineering Handbook" emphasizes the interdisciplinary approach that is required to 1) reach the technical objective, 2) organize this process, 3) translate the system into a "work breakdown structure" and 4) convey the information in such a way that management knows enough to be able to make the right decisions (NASA, 1995, 3). As for the system to be developed, it is about hardware, software, people, information, technologies, services, as well as all other supporting elements (INCOSE, 2000). System architecture is the hierarchical structure on which the system is built in elements, subsystems, assemblies, components and parts (Figure 4-2).

In order to divide the system into components, systems engineering makes use of a "Work Breakdown Structure" (WBS) approach. This approach was developed by the American army and described in MIL-STD-881 (Department of Defense, 1998). A WBS splits an object (like an aircraft, rocket, software system or a vehicle) into components, with the objective to clarify the mutual relationship between components as well as the relationship between the components and the entire system. This is done with the aid of a "family tree", in which the elements that make up the entire system are arranged. The tree structure can go as deep as is needed, but any outsourcing to third parties only occurs at the three highest levels of the system. Apparently the military organization does not want to be occupied with the "nuts and bolts" of an airplane, but is primarily focused on the functionality that should be achieved (Department of Defense, 1998, 4).

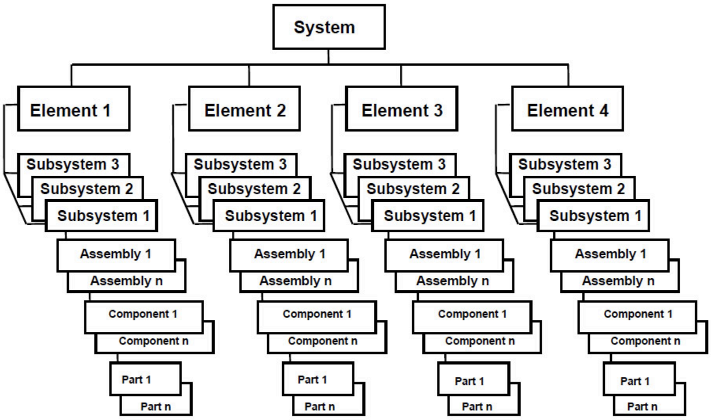


Figure 4-2: Hierarchy of System Elements (INCOSE, 2000, 12)

In order to divide the system into components, systems engineering makes use of a "Work Breakdown Structure" (WBS) approach. This approach was developed by the American army and described in MIL-STD-881 (Department of Defense, 1998). A WBS splits an object (like an aircraft, rocket, software system or a vehicle) into components, with the objective to clarify the mutual relationship between components as well as the relationship between the components and the entire system. This is done with the aid of a "family tree", in which the elements that make up the entire system are arranged. The tree structure can go as deep as is needed, but any outsourcing to third parties only occurs at the three highest levels of the system. Apparently the military organization does not want to be occupied with the "nuts and bolts" of an airplane, but is primarily focused on the envisioned functionality that should be achieved (Department of Defense, 1998, 4).

One of the most important design rules of the WBS is the "100% rule". This means that the sum of work that needs to occur at the sub-level must be identical to the work that is applicable at the overlying level. "The next level decomposition of a WBS element (child level) must represent 100 percent of the work applicable to the next higher (parent) element" (Haugan, 2001, 17). The rule is valid for dividing the physical object as well as for the division of organizational activities. Referring to Figure 4-2, this means that the combination of all the work that occurs at level 2 has to be identical to the work that must occur at level 1. And all the work that occurs at level 3 must again be identical to all the work that occurs at level 2. All parts together total exactly 100% of the activities to be completed. This division into subsystems also emerges in a visualization of the systems engineering process of the German Engineering Association (VDI, Verein Deutscher Ingenieure) (VDI, 1977, VDI, 1985), as shown in Figure 4-3.

Another model that is implemented in systems engineering is the V-model (KBST, 2004), also known as VEE model, V-Diagram or V-Cycle. It is used for structuring complex development projects of both software and hardware systems. Here too, the hierarchical structure of the system is emphasized. 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.

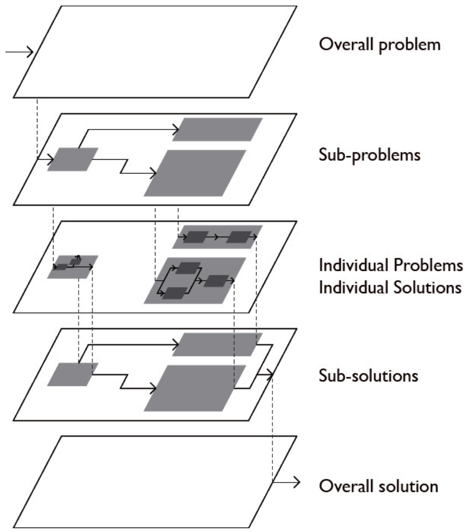


Figure 4-3: VDI view of problem decomposition and solution synthesis (Cross and Roozenburg, 1993, 328)

4.2.3 Product and society -- Sustainable Product Development

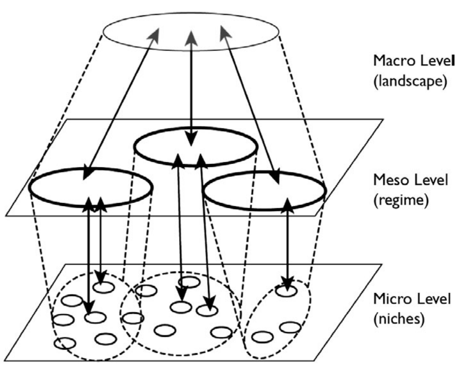
The field of expertise of Sustainable Product Development is especially focused on the development of one new product-service system, where the context of societal environment plays an important role. A wide variety of gradations can be applied between product and service, from "pure product" to "pure service". Between these two is a continuous scale which runs from "product-oriented PSS", "user-oriented PSS" to "result-oriented PSS" (Tukker and Tischner, 2006). When Papanek looks at the development of product-service systems, he relates the product to the system in which it functions, for instance when 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. (…) Problems are endless, and not enough breakthrough thinking is done" (Papanek, 246). In this he 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.

In spite of the realization that a system-wide approach is necessary in order to realize the envisioned sustainability improvement, the emphasis of these group of models is still on the improvement of physical products (Brezet, 2008). A commonly used tool during this process is the D4S Strategy Wheel, in which eight innovation strategies are placed side-by-side. In strategy 0, "product design review", the designer is encouraged to consider whether the interpretation of the function that the product fulfills could perhaps occur in a completely different way (Crul et al., 2009, 64). The realization that designers must focus on more than physical artifacts becomes apparent here, as "new methods are needed to enable designers to realize their strategic potential. Existing methods can be tailored to support a more strategic approach, beyond eco-redesign" (Bakker, 1996). This strategic approach is aimed for by the innovation method developed by Kathalys, in which initially a broad "innovation vision" is developed, which is then translated to concrete new products and services. During this translation from future vision to concrete product, an innovation paradox is encountered. The more groundbreaking the long-term ambition is, the less obvious it is what it will eventually look like. This makes it more difficult to assess the effects of the renewal: "in other words, we want to make big leaps, but the greater the leap, the less certain is the eventual outcome of the leap" (Brezet et al., 2001c, 37). In the HICS study (HICS, 2000), the relationship between product and societal environment can be recognized in the "specific context" and the "meta-context" that are taken into consideration. Within the HICS research the emphasis is on the development of "highly customerized solutions". The essence of such a solution is formed by the "solution platform", which forms the basis for the realization of a broad scale of "partner-based solutions". These are tailor-made solutions for various contexts of use. During the study, the concept "platform" gradually takes on a more conceptual character, instead of the more physical image that was originally envisioned. It turns out that the common ground between solution elements and platform is not so much material, but rather conceptual in nature, being "'a shared vision', 'a unitary language' and 'a group of rules for achieving compatibility between different elements and partners'" (Collina, 2004, 70).

4.2.4 Product and society -- Sustainable System Innovation

The field of expertise of sustainable system innovation employs the widest system boundary, since it is aimed at accomplishing changes at the socio-technical level. For instance, in the backcasting approach a sustainable future vision is developed with a time perspective of 10 to 15 years. Based on this, concrete steps required to achieve this ideal situation, developed by backwards reasoning, are presented in a roadmap which indicates how the envisioned future situation can be realized. The primary ambition is to realize changes at the level of socio-technical systems or at the societal level. The products and services that are a part of this are just some of the many building blocks necessary to accomplish this.

Experts in this field of expertise often make use of a multilevel innovation model. This describes the various system or aggregation levels where changes in society take place. 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 underlying micro-level consists of various niches (Schot et al., 1997), where small-scale changes take place (Figure 4-4).



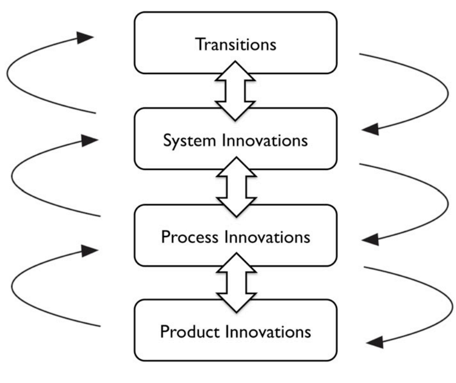


Figure 4-4 (left): Multilevel innovation perspective (Geels, 2001)

Figure 4-5 (right): Cascade of innovations (Loorbach, 2007, 94)

If experiments are conducted within these niches, one speaks 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. The experiments may be related to a technological renewal (for example, the introduction of a new means of transport), an institutional renewal (such as the introduction of new legislation), an innovation in the socio-cultural domain (for example, a specific behavioral change, causing people to choose a different means of transport), an organizational change (such as the founding of a new service), or an infrastructural change (construction of a new type of road). It is often a matter of a combination of several of these aspects, since, in the case of transitions and system innovations, it is primarily about the reciprocal relationship between the various components of the system. Experiments can lead to learning effects (Emmert et al., 2006) (van den Bosch, 2010). And that might even be the most important objective that any initiative by transition managers can accomplish. The fact is that a changed insight leads to changed actions, which is the first step on the way to a changed society. In paragraph 4.6.1, the conclusions about the research issue "product and society" are described.

4.3 Research issue 2: Problems and objectives

Subquestion 2: What is the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives which are being met by means of the functioning of a socio-technical system, and how can this relationship be described in a systematic manner?

In this framework we will examine the nature and extent of the problems and objectives that are the focus of the various fields of expertise. How are the technical, cultural, social, ecological, ethical and political interests and objectives being discussed, and how are they positioned relative to each other? Is a hierarchy applied to the various types of problems and objectives, and if so, how?

4.3.1 Problems and objectives - Industrial Design Engineering

The field of expertise of industrial design engineering is particularly focused on solving functional problems at the product level. It is not explicitly occupied with societal problems. The relationship between the more functional objectives and the underlying values is expressed in the means-end chain (Figure 4-6). This scheme clarifies that each product has specific characteristics, each performing a specific function. The need to perform this function is derived from the underlying values of the user. The design process follows this sequence in reverse (Figure 4-7), whereby backwards reasoning is applied from values to needs, function, characteristics and finally the form of a product. Reasoning from form to function can occur in a very 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 (Roozenburg and Eekels, 1991, 52). Perhaps that's why there is such a multitude of design methods, each trying to support this creative process in a systematic manner. After all, the ultimate scientific method to design will never come about. Designing is not a matter of finding objective and material "truth judgments", but of more subjective, personal "value judgments". As a matter of fact, these value judgments are quite essential, because they have a strong influence on people's actions. Each action is wedged, as it were, between two value judgments, which make value judgments the alpha and omega of acting, and thereby of designing (Roozenburg and Eekels, 1991, 63).

Backwards reasoning from function to form is even becoming a bit more complicated, since a product does not only have one function, but it performs a whole series of functions at the same time. 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, traveling 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's 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, 1991, 123). 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 and the designer must ask himself whether the respective means is complete or needs complementing. 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. In this way, the criteria can systematically be determined at a lower level, where they are generally more easily verified than the objectives at a higher level.

Figure 4-6: The functioning of a product

Figure 4-7: Designing a product

So what is the relationship between problems at the product level and problems at the business and societal level? As stated before, each product performs various functions. Where a solution for a user accommodates a specific functionality, for the manufacturing company it has a completely different, business-economic functionality and the employment opportunities that go along with this have a societal functionality. This "threefold functioning" of the product is schematically represented in Figure 4-8. The means-end chain ends in the area of values. Value conflicts between users, manufacturer and societal organizations are more often the rule rather than the exception. Environmental issues are clear examples of this (Roozenburg and Eekels, 1991, 58).

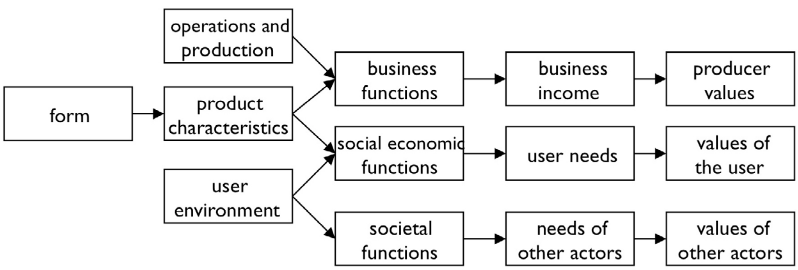


Figure 4-8: Threefold functioning of the product (based on Roozenburg and Eekels, 1991, 58)

A different approach with regard to the objectives to be achieved is the product lifecycle model (Eger, 2007). This model distinguishes between six stages that a type of product completes during its lifetime: (1) fulfilling a function, (2) optimization, (3) detailing, (4) segmentation, (5) individualization and (6) awareness. This division is somewhat compatible with Maslow's pyramid, which goes stepwise from fulfilling physical needs, to safety and security, social contact, appreciation and recognition, right up to self-development, where objectives are identified at an increasingly higher needs level (Maslow, 1987). Initially, new products are only aimed at fulfilling a specific function. This is optimized in the next stage of life, followed by further detailing. Once the product has matured, strictly fulfilling a function is no longer distinguishing in relation to competing products. Therefore further segmentation follows, where products become more and more distinct from each other. The last two phases are individualization and awareness. In the latter phase, the product is in the service of the mental development of the user. The aspect of awareness is related to problems that are located at a higher societal level, such as the worldwide environmental and social problems. This does not imply that attention for underlying values would only be relevant for a product's final stage of life, as a kind of icing on the cake. Eger also recognizes this when he writes that in the context of the individualization and awareness phases "some caution is called for in relation to the general validity of these phases" (Eger, 2007, 209).

4.3.2 Problems and objectives -- Systems Engineering

The field of expertise of systems engineering is focused on concrete, defined, technical objectives. For the onset of the design process, problem definitions must be refined in detail, where any vague or ambiguous objectives must be identified as early as possible. The underlying societal questions are not an issue in systems engineering. Why a specific objective must be pursued, is a matter for the client to determine. The various systems engineering models, such as the waterfall model, the spiral model and the V-model, subsequently serve to divide this objective into clearly defined components. With the help of the above-mentioned "Work Breakdown Structure" and the "100% rule", the system is divided into subsystems, each with its own specific functionality.

"Use cases" are often implemented when developing sub-problems. This is a description of the behavior of the system in reaction to an external action or request, where the events are described that lead to the system doing something useful (Bittner et al., 2003). The objectives at underlying system levels are indeed derived from the objectives of the entire system, but are in fact completely independent. An airplane is a system that has to fly, but the chairs in the plane need to provide a comfortable seat. In addition they have to be as light as possible, but in any case they themselves don't need to fly. Each of the components of the system must therefore be developed and evaluated at its own level. Only when a component completely satisfies the stated demands, can it be integrated as a part of the overlying subsystem, which can subsequently be evaluated on its own objectives. Systems engineering models have to our knowledge never before been applied to the change of societal situations or socio-technical systems.

4.3.3 Problems and objectives -- Sustainable Product Development

In the course of time, in the field of expertise of sustainable product development a shift has become apparent towards an increasingly broader perspective in relation to the objectives to be achieved. Rather than stepwise product improvements, the emphasis is increasingly on the realization of a "factor 4" or a "factor 10" reduction of the ecological impact of products and systems (von Weizsäcker et al., 1998). The realization of radical innovations is required to achieve this. The corresponding time horizon is therefore increased from less than a year to adapt an existing product, to more than 10 years for the adaptation of the societal system. The schematic in Figure 4-9 demonstrates that environmental gains are easily accomplished by improving a product, but remain limited as far as impact is concerned. This improvement is represented by the vertical axis of the graph. Functional and system changes can accomplish much greater gains but they do require more time, which is represented on the horizontal axis of the graph.

Papanek (1985) (1995) visualizes the relationship between various kinds of problems as a pyramid where most designers are only focused on the tip of the iceberg. He calls on designers to focus on the "real problem" instead of artificially created needs: "Design for the people's needs rather than for their wants, or artificially created wants, is the only meaningful direction now" (Papanek, 1985, 234). He indicates six areas where designers can play a relevant role: Designing for the third world, products for the handicapped, medical products, experimental research, products to support life in difficult circumstances and the development of "breakthrough concepts" (Papanek, 1985, 234-246). Here he defines six research questions in order to determine the most urgent societal objectives (Papanek, 1985, 340). What are the optimal circumstances for people to live on Earth? What are the limits to our resources? What are the human limits? What are the household rules for man's existence on planet Earth? And, not so trivial, what don't we know?

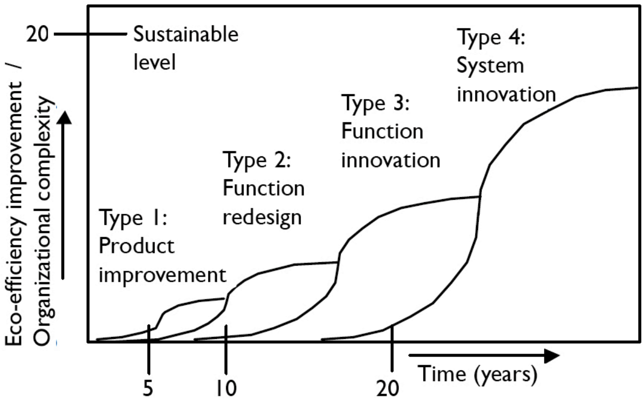


Figure 4-9: Eco-efficiency curves (Brezet et al., 2001b)

Comparable, fairly practical guidelines are provided in the book "Sustainable Everyday" (Manzini and Jegou, 2003). Manzini divides the recommendations into three categories. The first includes the general principles that a designer should consider before beginning his design activities ("think before doing", "promote variety" and "use what already exists"). The second relates to the quality of the context in which the solution will be implemented ("give space to nature", "bring people and things together", "share tools and equipment"). The third relates to the intelligence of the system in dealing with people and resources in a sensible way ("empower people", "develop networks", "use sun, wind, biomass" and "zero waste"). The Kathalys model (Brezet et al., 2001c, Luiten et al., 2001b) divides the innovation objectives across various innovation tracks, which define separate sustainability objectives, economic objectives, organizational objectives and objectives for the users. Work is not done based on the interest of one organization, but reasoning is based on the ecological objective to be realized. Therefore the process begins with an inventory at the societal level and becomes increasingly more concrete. The assumption here is that the ecological objectives can be achieved at a "high" societal level through the realization of concrete product innovations at a "low" product level.

The problems or needs that are the focus of the Solution Oriented Methodological Framework (Meroni, 2004) emerge especially in the "context of use" where the solution will function. The reference point in this is that the developed solutions are suitable for a broad scale of users in a specific context. The largest common denominator in these situations is defined as the "meta context of use", which can be viewed as the highest aggregation level in the model. The "specific context of use" describes a very narrow defined problem situation, where the eventual ambition is to be able to offer each user a unique solution, fitting his or her specific situation. This ambition can be compared with the concept of the "market of one", where each customer has access to his own unique product (Keenan, 2002). These use contexts are part of culturally determined needs and wishes, which in turn are part of global paradigms, with which we have arrived at the highest aggregation level (Lindsay and Rocchi, 2004). Visually this is represented in Figure 4-10.

Also in the SCORE! study (Tukker et al., 2008), a relationship is defined between societal objectives and concrete innovations. For a number of subsectors (mobility, nutrition and agriculture, surrounding structures), studies were conducted to see how concrete projects have contributed to the broader objective in the respective domain. For instance, for the theme mobility (Geerken and Borup, 2009), three societal objectives were defined: CO2 reduction, reduction of traffic jams and the reduction of accidents. Various case studies (e.g. working closer to home, free public transit, road pricing) then investigated in how far these indeed contributed to the three objectives at the higher system level. Similar studies were conducted in other areas as well (Lahlou 2010) (Tischner et al., 2010), where objectives at the societal system level are linked to objectives and activities at more concrete project, socio-technical or product-service levels.

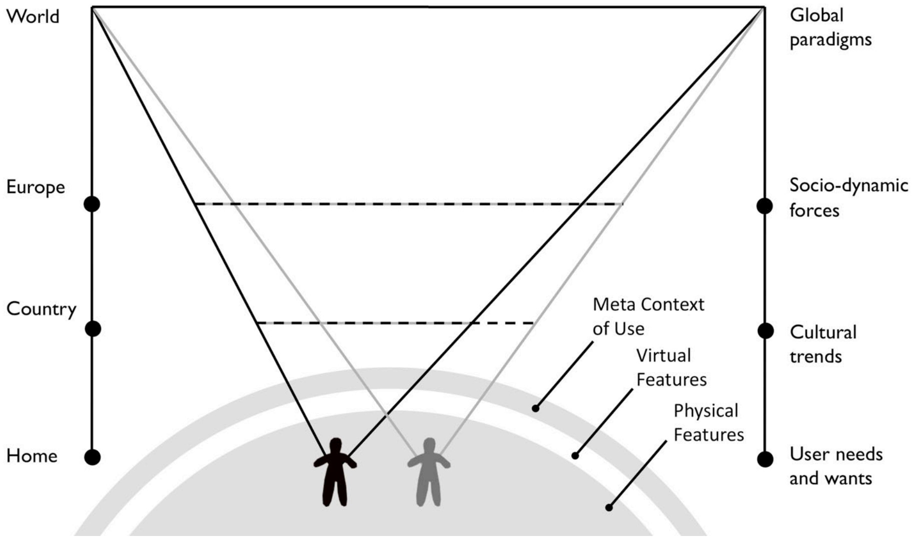


Figure 4-10: Context of use and meta-context of use (Lindsay and Rocchi, 2002, 18)

4.3.4 Problems and objectives -- Sustainable System Innovation

Sustainable system innovations are aimed at providing a positive influence on the future of society. In this, one can distinguish between "likely futures", "possible futures" and "desirable futures" (Quist, 2007, 17). Others use the terms "plausible futures", "potential futures" and "normative futures" (Dunn, 1994, 195). In the backcasting approach, the objective is to realize a desired or normative vision of the future, which thus incorporates an explicit value judgment. This is in contrast with studies of the future that attempt to determine, based on a more neutral attitude, with the future might look like, for example by extrapolating from the current situation (Stead and Banister, 2004). "The major distinguishing characteristic of backcasting analysis is a concern, not with what futures are likely to happen, but with how desirable futures can be attained. It is thus explicitly normative, involving working backwards from a particular desirable future end-point to the present" (Robinson, 1990).

A vital central point in sustainable system innovations is the learning effect that can be achieved by certain activities. In 1st-order learning, or "single loop learning", it is about knowledge of the primary action to be executed and the primary objective that is targeted. In 2nd-order learning, also known as "higher order learning" or "double loop learning", discussion also takes place about the thought framework on which actions are based. This includes discussions of the way the problem is framed and the way the solution of the problem is being approached (Fischer, 1980) (Fischer, 1995) (Hall, 1993) (Grin and van de Graaf, 1996) (Argyris, 1976) (Argyris and Schön, 1978) (Brown et al., 2003). If the learning process is compared with the functioning of a heating system, then "single loop" learning is comparable to the thermostat which switches on and off in order to modify the temperature. "Double loop" learning asks whether it is perhaps possible to modify the entire heating system (Argyris and Schön, 1978, 2-3).

Vergragt and Brown (2004) (2006) (2007) focus on the "level of discourse" of various actors and divide these into four levels. The "problem solving level" is aimed at solving problems within a well-defined framework. At the second level, the "problem definition in relation to a specific technology-society coupling", the target objectives are determined. The broad outline of the problem is framed, but still within a previously determined umbrella reference framework or value system. The third level deals with the "dominant interpretation framework". Here it is determined how data is interpreted and assessed. Here it is decided what is considered important, and why. The fourth and highest level concerns the "worldview" that one maintains. This concerns the fundamental preferences related to the way society is structured. This level is based on the ultimate values that one maintains and relates to political, cultural and religious preferences, among others. In paragraph 4.6.2 the conclusions about the research issue "problems and objectives" are described.

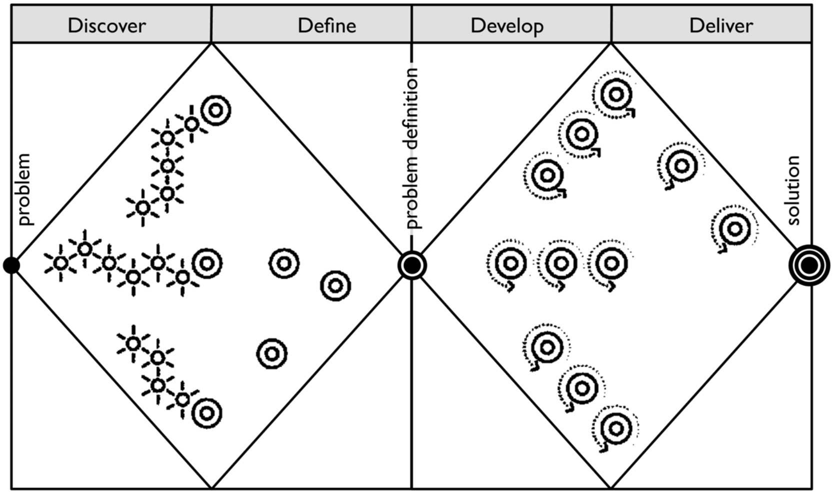


Figure 4-11: Double Diamond design process (Design Council, 2007)

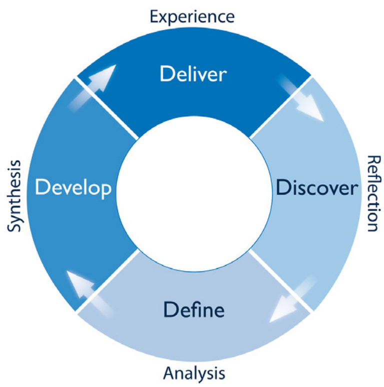
4.4 Research issue 3: Design process

Subquestion 3: What are the similarities and differences between the product design process and the way that socio-technical and societal change processes take place, and how can these processes be interlinked in a systematic manner?

This includes an analysis of how the various fields of expertise view the way that the design process develops. Are the models only aimed at the development of single products, are they focused at the change of socio-technical or societal systems, or both? Does one distinguish between various innovation tracks, and if so, which? How does the process develop and what steps are distinguished along the way? Are the models more descriptive or contemplative in nature, or are they instead more prescriptive guidelines that dictate "how it's supposed to go"?

4.4.1 Design process -- Industrial Design Engineering

Within the area of industrial design engineering, the emphasis is on prescriptive design models which are intended to structure the design process in a stepwise manner. For instance, Simon (Simon, 1969) describes designing as a form of "rational problem-solving". Each design can be divided into sub-problems with an objectively measurable quality. This rational approach appears quite usable when a design problem is strictly defined. In "The Reflective Practitioner", Donald Schön (Schön, 1983) describes the design process as an unstructured process, a kind of reflective dialogue between designer and design. Most models follow a somewhat more structured process, where the phases of analysis, synthesis, experience and reflection can be recognized. A pioneer in the development of design methods is Bruce Archer, who was one of the first to set-up a systematic method for designers (Archer, 1965), splitting up the design process in various stages. Archer defined design as a combination of the intuitive and the cognitive, and attempted to turn the design process into a science by formalizing the creative process. Based on an analysis of several design methods, the British Design Council comes up with a four phase method, the "double diamond" (Design Council, 2007). It is based on four phases, that can be recognized in almost any design process, which they call "discover", "define", "develop" and "deliver" (Figure 4-11). A cyclic version of this model is presented in Figure 4-12, in which they are compared to the phrases we will use in this research: "reflection", "analysis", "synthesis" and "experience".



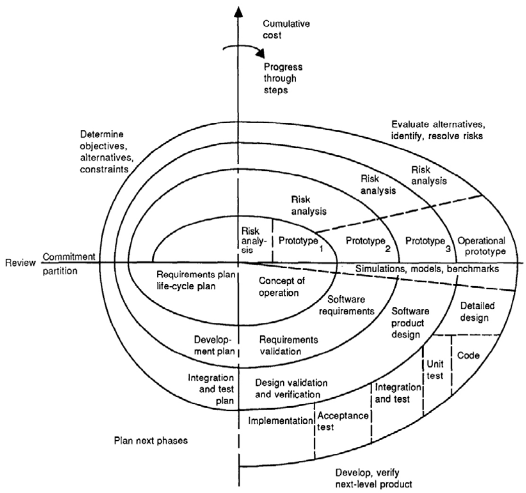
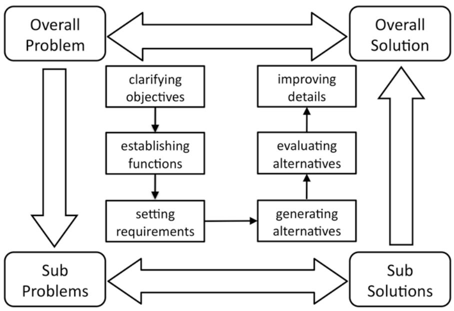


Figure 4-12: Double Diamond (Design Council, 2007) presented as a Design Cycle

Figure 4-13: Spiral model of the software development process (Boehm, 1988)

The starting point for a design process is always a "problem", which can be considered as a (negative) value judgment of a specific, existing situation. This is the result of a reflection phase ("discover"). This is followed by a phase where the new situation to be realized is defined. This analysis phase ("define") or target definition leads to a description of an envisioned, new situation. Next is a synthesis phase ("develop") which results in a design for a new situation. Subsequently this situation is realized and a new situation with new characteristics comes about ("deliver"). This can then be evaluated, followed by a new value judgment discover). If this value judgment turns out positive, the process stops; if it is unsatisfactory, a new process follows. In Figure 4-11 the "Double Diamond" is shown as a cyclic process. In Figure 4-21 and Figure 4-22 two design models (Roozenburg and Eekels, 1991) (Buijs and Valkenburg, 2005) were converted to the four innovation steps mentioned. Cross and Roozenburg (1993) describe the design process as solving an "overall problem" that can be divided into "sub-problems" through a decomposition process. In the same way, the "overall solution" is made up of various "sub-solutions" (Figure 4-14). A somewhat comparable process is being followed in the ViP process. In the deconstruction phase, existing ideas about the product and context in which it functions are "dismantled", so the design process can start with a clean slate. The second step is the creation of a new context. In between is the interaction vision, where a vision is developed of the desired interaction in the new context. This in turn becomes the basis for the development of the new product vision, as a basis for the development of a new product. This method is schematically represented in Figure 4-15, which shows the "deconstruction" taking place on the left from bottom to top. The vision formulation and design process takes place on the right, from top to bottom.



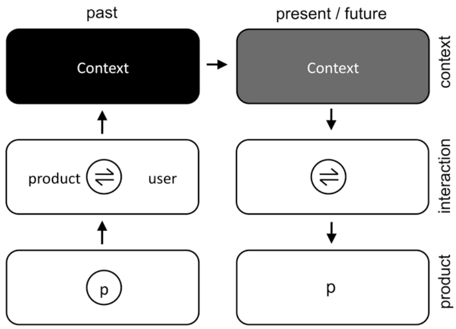


Figure 4-14 (left): The engineering product design process (Cross and Roozenburg, 1993)

Figure 4-15 (right): Vision in Product Design (ViP) model (Hekkert et al., 2003).

4.4.2 Design process -- Systems Engineering

The models within the field of expertise of systems engineering are also more prescriptive in nature, where the development process begins from the overlying system and subsequently descends, step-by-step, to the lower aggregation levels. Each subsystem is again divided, down to the level of the "nuts and bolts" (in case of hardware development), or "ones and zeros" (in case of software development). One of the models which is applied within systems engineering is the waterfall model (Royce, 1970) (US Department of Defense, 1985), also known as the "Linear-Sequential Model" (NASA, 2000, 3), the "System Development Life Cycle Model", or the "Classic Life Cycle Model". Design demands in this model are strictly defined, after which they are fixed for the entire process. Possible problems or ambiguous demands only become visible again at the end of the process, when the design work is finished. Cadle and Yeates (2008, 71) describe the V-model (KBST, 2004) as a variant of the waterfall model, because the described development process still proceeds in a fairly linear path. The left side of the V represents the design or decomposition process, where the product is being developed, from top to bottom, at an increasingly detailed level. On this side the demands of the system and the demands of the underlying subsystems are translated into a design of each of the components. The right side of the V represents the integration and testing process, which takes place from bottom to top. When all of these various components are developed and tested at one specific level, they can be integrated into the overlying subsystem. This can in turn be developed and tested as a whole. This process continues until the functioning of the total system can be compared to the stated demands.

The iterative aspect of the design process receives more emphasis in "A Spiral Model of Software Development and Enhancement" (Boehm, 1988), where each iteration cycle starts with the design objective and ends with an evaluation by the client. The model describes a cyclical process, where each cycle is divided into four quadrants. It starts at the center of a spiral, after which it moves towards the outside. The objectives are determined and the alternatives to achieve this objective are mapped in the top left quadrant. This can sometimes require a new design, but it is also possible to use an existing product, component or software program. The various alternatives are evaluated in relation to each other and the risks for each variant are mapped in the second quadrant. At the end of this phase, a choice is made for a concept design, represented in the form of a more or less developed prototype. The prototype becomes more detailed in each cycle, until an operational prototype is developed after several cycles. This is a description of the component or system to be developed, which at that point still needs to be programmed or further detailed. The actual development always takes place in the bottom right quadrant. This phase corresponds with the process as described in the more linear models. This is where real programming takes place and the details of the design are worked out. The ultimate result is a developed and implemented system. In the fourth quarter this system is subsequently applied in practice, and a possible follow-up phase or iteration stroke is always prepared. Here too, the four quadrants again follow the broad outline of "analysis, synthesis, experience and reflection".

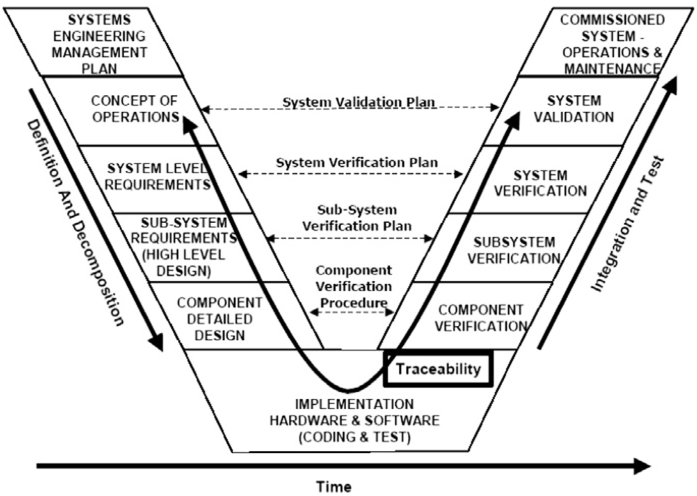


Figure 4-16: Systems Engineering V-Modell (Peterfeso, 2005)

The approach of the spiral model and the V-model appear to be similar in the sense that the overlying objectives and later the sub-objectives are established first. As for the implemented visualization, both models provide a complementary view. In the spiral model it is emphasized that the first design phases can often be worked through fairly quickly (the short cycles in the middle of the spiral), while later in the project time and cost for each phase usually increases (the outer layers of spiral). The radial distance of the spiral represents the cumulative costs required to complete a specific step, which creates the characteristic egg shape of Boehm's model. Some steps require more energy and budget, while other steps are relatively inexpensive. In the V-model, the width of the V represents the size of the respective system level. The top side covers the entire system, and the narrow bottom represents the smaller components, where no relationship exists with the required time and costs.

4.4.3 Design process -- Sustainable Product Development

The societal aspect is more prominent in the area of sustainable product development. When discussing this, Papanek speaks of the "general case" and the "special case". The "general case" is aimed more at the societal perspective, whereas the "special case" is aimed at the development of one product *(Papanek, 1985, 305)*. Sometimes the designer starts with a specific design problem and subsequently works towards the broader needs area where the problem occurs, after which he returns to the problem where he started, comparable to a diamond shape (Figure 4-17, left). It is also possible to work from a general problem towards a specific design challenge, and to subsequently place this again in the broader problem context, a process comparable to a butterfly shape (Figure 4-17, right). Ideally one completes an alternating convergent and divergent process (Figure 4-18), where the problem is viewed alternately from a broad or a narrow perspective.

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Figure 4-17: Left, design process from "special case" towards "general case". Right, design process from "general case" towards "special case" (Papanek, 305).

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Figure 4-18: A series of cyclical design "events" (Papanek, 306).

Kathalys (Brezet et al., 2001c) (Luiten et al., 2001a) as well as Hics (Verganti, 1999) (Manzini et al., 2004) begin with a long-term vision of the societal system. The initial steps take place at the system level, where sustainability problems in society are investigated by means of a number of "quantitative explorations" (van der Koijk, 2000, Alfers et al., 2001). On the basis of this analysis, concrete innovation projects are set in motion, targeting the realization of concrete components of the envisioned system. In the Solution Oriented Partnership Methodological Framework (Manzini et al., 2001) (Manzini et al., 2004), parallel work is done on the development of the envisioned solution, on the context of use and on the development of the consortium that must realize the solution. The developers emphasize that the model does not need to be worked through in a linear fashion, but that it can be applied in an intuitive manner: *"Progresses generally occurs from left to right, but the succession of actions that correspond to each cell is not necessarily linear. (…) Revisiting of previous actions is usually necessary when new information, new ideas, or new actors appear" (Meroni, 2004).* The question remains whether developments can be guided "top-down" in a specific, desired direction at all. An approach that reasons in reverse is that of the "creative communities" (Manzini et al., 2006) (Meroni, 2007) (Jegou and Manzini, 2008), where one looks at the local level for examples of a new way to organize society. In that case the designer does not necessarily have the role to invent these patterns, but to identify them and reinforce them if possible. This shares common ground with the way one thinks of "niches", where likely initiatives are created on a small scale which is subsequently broadened, deepened and enlarged.

4.4.4 Design process -- Sustainable System Innovation

Sustainable system innovations particularly involve describing models, which are suitable to analyze societal developments after the fact. For instance, the dynamic multilevel perspective (Figure 4-19)shows that changes at various aggregation levels influence each other. Developments at one level thus exert "pressure" on developments in the adjacent level. The arrows which point from bottom to top indicate a large quantity of innovations. Apparently, innovations always start in "niches" (Schot et al., 1997) (Geels and Kemp, 2000, 19). Subsequently they must do some upwards "infighting" in a socio-technical regime. Successful innovations can then influence the development of the socio-technical system through a "fit-stretch" pattern (Hoogma, 2000). In this case the solution "fits" seamlessly into the 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 entirely 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 (Hoogma et al., 2002) (van den Hoed, 2004). The question is now how all this knowledge can be used to study developments, not only after the fact ("ex post"), but to guide them in a desired direction ahead of time ("ex ante") (Kemp and van den Bosch, 2006, 39).

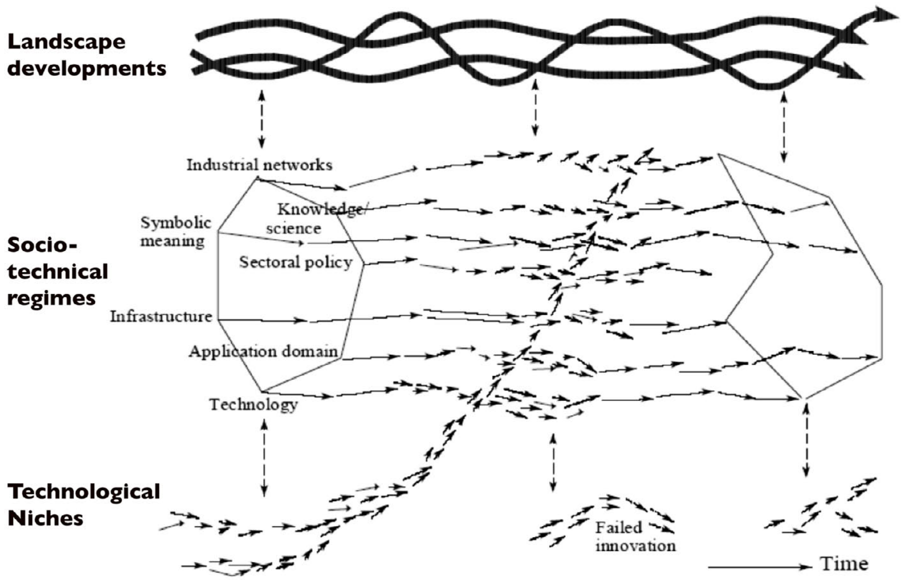


Figure 4-19: Dynamic multilevel perspective on technological transitions (Geels, 2001)

In order to accomplish this, a transition cycle is implemented (Figure 4-23) where initially a transition arena is established and the problem is defined. This is followed by the development of transition coalitions, the definition of the transition agenda and the corresponding transition paths. Step three includes the establishment of transition experiments and the mobilization of transition networks. Step four is the monitoring, evaluation and learning of the transition process. This approach is comparable with the backcasting approach where one develops a sustainable future vision and subsequently reasons in reverse towards the steps which are necessary to achieve this future. Here too, development of a "follow-up agenda" and mobilization of actors is essential (Quist, 2007, 28). For that matter, especially active "backcasting" - stepwise reasoning in reverse from the future vision towards the present - is the least certain part of the method: "The backcasting step has been less well elaborated in terms of prescriptive methods and tools than the other steps. Often this was done in an intuitive and non-formalized way" (Quist, 2007, 234).

A vital aspect of these initiatives concerns the learning process of the actors involved. The four-phase model by Kolb (1973) is often implemented to describe this learning process, where the steps experience, reflection, abstract conceptualization and active experimentation are completed consecutively. In fact, similar processes are involved in the design process and the learning process, as Kolb himself determined when he compared his learning cycle (Figure 4-24) with the problem-solving process. Designing is also a special form of solving problems (Eekels, 2002, 623), in other words the analogy is evident. In paragraph 4.6.3 the conclusions about the research issue "design process" are described.

4.5 Research issue 4: Designer and actors

Subquestion 4: How can the (potential) role of the designer with regard to the product design process, as well as with regard to the way that socio-technical and societal change processes take place, be described in a systematic manner?

This includes an examination of the way the role of the designer emerges, among others related to the role of other actors involved. One of the questions in this is whether the designer works from the position of one specific organization, or that he has a specific responsibility with regard to the interests of other actors involved. Another question that is considered is who is viewed as the problem owner or client during the innovation track. Here the issue is how one views the collaboration between the various types of organizations and what role is being considered for the designer in this process.

4.5.1 Designer and actors -- Industrial Design Engineering

The field of expertise of industrial design engineering is based on one discernible client who gives an assignment to the designer. The role of the client is that of the final decision-maker who determines the design demands and who judges the developed concepts. *"No assignment, no design"* (Buijs and Valkenburg, 2005, 78). The designer dreams up the design, but the entrepreneur decides which design is the best fit with the company's objectives. Societal developments and questions are merely environmental factors where the company chooses whether to take them into account or not. This becomes clear in the Delft Innovation Steps Model (Buijs and Valkenburg, 2005, 168), because the interior of the innovation cycle represents "the company", or rather one's own perspective. The exterior of the cycle is "the environment", or all other parties and factors that are relevant to the design process. As for the objectives of organizations that are not primarily focused on profit, such as a hospital, fire department or university, it is established that these organizations have societal tasks. "These tasks are actually determined at a higher level than the organization itself" (Buijs and Valkenburg, 2005, 62). The role of the client becomes clear in the description of the development of a new train. This product consists of a large number of components from different suppliers. Apparently it's impossible to develop a concept for the train with so many actors, after which the client himself establishes a principal solution for the design of the train (Buijs and Valkenburg, 2005, 326). Only after this has happened is it the turn of the designers who develop the various elements, one by one. The question is of course in how far such a "top-down" approach can also be implemented with innovations where it is no longer about one physical, discernible artifact and not one party can be identified who can make the decision. In the case of developments where decisions have to be made jointly by various parties, one speaks of "multi-criteria decision problems". With these kinds of problems, making assessments is extra complicated because "the decision-maker" is not an individual, but a heterogeneous group of actors, who do not share the same objectives (Roozenburg and Eekels, 1991, 245). Because methods for multi-criteria group decisions are complicated and cumbersome, they are seldom implemented in product development practice (Roozenburg and Eekels, 1991, 277).

Instead of the complexity of multi-actor innovation processes, other researchers place considerably more emphasis on the creative freedom of the individual designer (Hekkert and van Dijk, 2000). It is then not a matter of having to achieve an authentic and original result, where nothing is allowed to stand in the way of the designer's creativity. Employing a societal or ecological objective in advance would only restrict this freedom, no matter how beneficial such objectives may be. However, also with ideas that are developed in this way, the company ultimately determines the eventual realization of the developed ideas, as "a designer should strive for maximum freedom and should be driven as little as possible by competitors or product-related needs of supposed users" (Hekkert and van Dijk, 2001).

4.5.2 Designer and actors -- Systems Engineering

Systems engineering is based on a strictly defined client-contractor relationship. For example, the 624 pages thick users guide for the "V-Modell XT®" of the German "Koordinierungs- und Beratungsstelle der Bundesregierung für Informationstechnik in der Bundesverwaltung" (KBST, 2004) describes in detail who must do what and when during the development of a new ICT system. The model even knows two variants: the version which is based on the client's perspective, and the version where one applies the method as a contractor. In other words, one discernible client must always be identifiable and there must always be one contractor who coordinates the design process and who is responsible for the various sub-activities. And yet, systems engineering emphasizes the integral, interdisciplinary and generalist approach of the field of expertise: "On large-scale-system problems, teams of scientists and engineers, generalists as well as specialists, exert their joint efforts to find a solution and physically realize it" (Goode and Machol, 1957, 8)

However, this cooperation is focused on actors who are directly involved with the new, technical system. For instance, the spiral model is developed for internal use within organizations (Boehm, 1988, 70). The most important individuals or organizations who are involved with the development of the product are consulted after each spiral cycle, in order to evaluate the achieved result. The objective of this step is that the parties involved can agree to the approach for the next phase. In the case of a simple system component, this analysis can be done by the designer himself. However, complex system components will require elaborate evaluation sessions with developers, clients, users and managers of the new system.

4.5.3 Designer and actors-- Sustainable Product Development

In the area of sustainable product development the emphasis is on the societal interest, instead of the interest of one specific company. Here it is impossible to identify one deciding party during the design process, thereby constantly requiring parties to enter into collaboration agreements. And this in turn signifies a new role for the designer, who is no longer commissioned by one organization, but who must play an active role in establishing the necessary coalitions. The position of the various actors is represented as a cycle by Manzini and Vezzoli, where each party makes his own contribution to a specific element of the solution, with the designer at the center of it all. Elements jointly form a common system Figure 4-20.

Setting up collaboration agreements between organizations gets a lot of attention at Kathalys and HICS. At the beginning of an innovation track it is not known which organizations are part of the network of actors, which leads to an "innovation paradox": joint vision development must take place with external parties, but once this vision is developed, it often turns out that entirely different parties are required to realize them (Brezet et al., 2001c, 49). The other risk entails that reasoning is entirely based on the initial consortium, whereby the envisioned ecological objectives disappear from sight (Eikelenberg, 2000). In addition, one encounters a difference in innovation horizon. The realization of a radical vision requires an extended period of time. Government and research organizations can afford this time, but companies cannot. Therefore one must always be looking for other parties and for small, intermittent successes (Brezet et al., 2001c, 67).

In HICS the collaboration agreements are driven by "Platform Providers", industrial parties who, together with "Specific Partners" form a "Solution Oriented Partnership". Some tools to describe the role of the partners are the "Stakeholders Motivation Matrix", the "System Organization Map", the "Interaction Storyboard" and the "Solution Element Brief" (Jégou et al., 2004). The multi-partner design process, which is necessary to form product-service combinations, remains a relatively undeveloped area in spite of these tools: "A PSS is usually put on the market by a network of firms. But tools and methods for finding the right partners and organizing the new co-operative arrangements efficiently are still largely missing" (Tukker and Tischner, 2006, 371).

To become entirely independent from companies, Papanek propagates avoidance of industrial parties by designing in such a way that end users can manufacture a product themselves. This approach could be viewed as a kind of "open source" design approach, for example made concrete in the form of a home-built radio based on a tin can, of which many thousands have been fabricated, according to the author (Papanek, 1985, 225). In addition, he is a great proponent of working on a small-scale and he believes that changes can only come about on a surveyable scale. Large-scale initiatives and ambitions are doomed to fail in most cases.

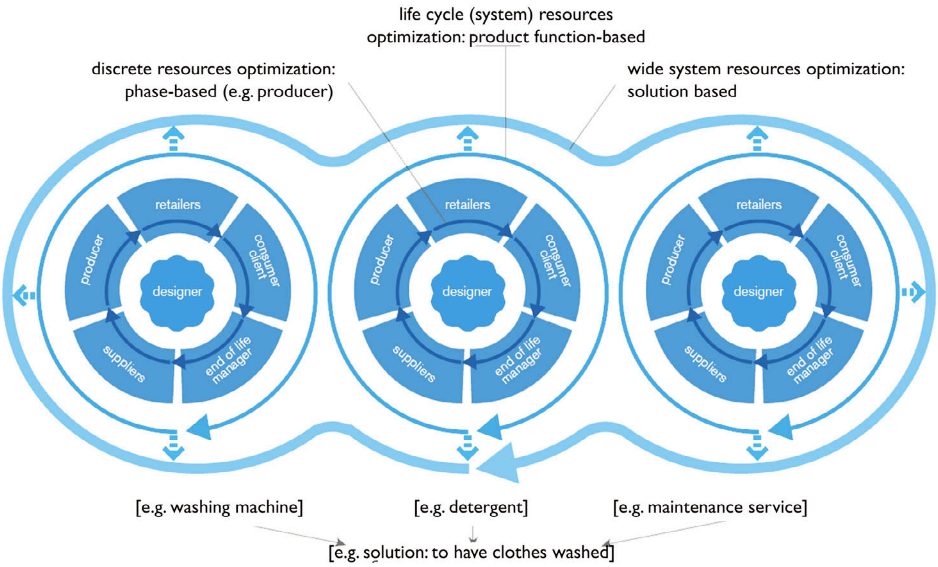


Figure 4-20: Actors in a product-service combination (Manzini and Vezzoli, 2002)

4.5.4 Designer and actors -- Sustainable System Innovation

Within the field of expertise of system innovation, "society", more or less, is considered as the owner of the problem, often represented by government who subsequently has to mobilize other parties. Since no actual client-contractor relationship exists here, one searches for other ways to motivate actors, for example through the development of a joint future vision, an enticing perspective that leads companies in a specific innovation direction. This ensures a change in the mental framework (Grin et al., 1997), thereby enlarging the room to maneuver for the actors involved. One will be more receptive, as it were, for new solutions that fall outside the existing thought and work framework (Grin and van de Graaf, 1996). And in turn, this freedom to act is a prerequisite to bring about the desired sustainable system innovations which, after all, will be considerably different from the existing order. If the vision also comes about in a participative or collective process, also referred to as "collective value learning" (Wynne, 1995), then the effect is that much greater (Grin and Grunwald, 2000).

In order to get the process started in the direction of societal changes, Rotmans speaks of a "transition arena" which consists of innovative parties who are prepared to take new initiatives and to develop alternatives for the current state of affairs, a process where the government especially should stay out of as long as possible (Rotmans, 2003, 75). Therefore an independent "transition manager" is introduced, instead of government, who is responsible for protecting and monitoring the process (Rotmans, 2003, 97). Which role the transition manager has in the actual design or synthesis process is not perfectly clear. It's also not clear how the contradictory demands and interests of the various actors are woven into an integral unit. One may sometimes get the impression that an integrated "design", in the form of a trailblazing future vision or enticing perspective, more or less comes about by itself, as long as the maximum number of parties possible are involved in the joint discussions.

Once the development of such a trailblazing vision has succeeded, then the next challenge is the realization of this future vision. How parties can get to the point where they indeed begin to make the short-term steps which are envisioned, is an important sticking point in backcasting as well is in transition management. Although ideally this is a "bottom-up, self-organizing" process (Quist, 2007, 235), one actively searches for ways to stimulate this, for example with the help of a joint innovation agenda. Another essential aspect concerns the mobilization of those players who can set an example, the "key stakeholders" or "vision champions". Realization of the established objectives is not easy, because the involvement of actors develops during the course of the experiment (Quist, 2007, 242). For that matter, it is also apparent that commercial parties in particular are involved to achieve certain short-term interests, while government is often aiming at achieving long-term changes (Hoogma et al., 2002, 202). In paragraph 4.6.4 the conclusions about the research issue "designer and actors" are described.

4.6 Conclusions

4.6.1 Conclusions research issue 1: Product and society

The various design and innovation models differ in relation to the system boundaries that are adhered to. This system boundary defines, as it were, the subject working area. For instance, the field of expertise of industrial design engineering is in practically all cases aimed at the development of one concrete, new product or service. The environment is taken into account, only for as much as the context within which the product functions, exerts influence on the functioning of the product. Occasionally an attempt is made to bring this societal context up for discussion during the design process, but this appears to be intended more to stimulate the creativity of the designer then that it is aimed at the actual realization of this new environment (ViP). Sustainable product development is also primarily focused on the development of one new product or service, although the societal context plays a more prominent role here, especially with regard to the subject of ecological sustainability. Occasionally work is done on the development of a group of product-service combinations aimed at various contexts (HICS), but usually the models are aimed at bringing about one new product-service system. Systems engineering is also aimed at the development of one technical product or system, where the way the system is structured is more expressly discussed. Finally, the field of expertise of sustainable system innovation is not focused on the development of single new products, but on the way that broad societal changes or transitions take place. When seen from this perspective, a product is just one of the many building bricks of the entire societal or socio-technical system.

All in all, one could state that there is a need for a design model which employs a wider system boundary than what is currently used within industrial design engineering, sustainable product development and systems engineering. Points of departure for this are in the field of expertise of sustainable system innovation, since this area is more focused on that way that changes on a socio-technical and societal level occur. The desired model should in that case establish the relationship between developments at the socio-technical and societal level and the development of new products. Summarized:

- Industrial Design Engineering: Targeting development of one new product or service, within the wider environment context
- Systems Engineering: Targeting development of one new technical system, including subsystems
- Sustainable Product Development: Targeting development of one new product-service system, within the context of the societal environment
- Sustainable System Innovation: Analyzing change of the socio-technical and societal situation. Products are limited building blocks of the whole.
- Desired model: Provide insight into the development of one new product in relation to developments that occur on the socio-technical and societal level

Although none of the presented models appear to meet this requirement to position the development of one new product in relation to the way that socio-technical and societal changes take place, the various models offer clues to creating this relationship. This is particularly present in the distinction of various aggregation levels where the design process takes place. Some of the classifications that are used are:

- Physical product, comprehensive product, environment
- Product, man-machine system, environment
- Product, interaction, context (itself divided into Principles, States, Developments, Trends)
- Immediate Context, Ecological Context, Systemic Context
- Pure product, product-service combinations, pure service
- System, element, subsystem, assembly, component, part
- Micro-, meso- , macro-level
- Niche, regime, landscape

When looking at the classifications as they are employed in industrial design engineering, sustainable product development and systems engineering, it appears that these are particularly aimed at a physical classification of the levels. The macro or landscape level is only explicitly present in the field of expertise of sustainable system innovation. From this perspective, the product is only a part of the micro-level or niche level. No single classification satisfies the stated objectives as such, but a combination of the various levels appears to be possible.

4.6.2 Conclusions research issue 2: Problems and objectives

The four fields of expertise examined are different with regard to the type of problem and the size of the problems that they are focused on. Put simply, the field of expertise of industrial design engineering is aimed at singular, functional problems. Systems engineering is possibly even more strictly limited and is aimed at the development of one, exactly predefined technical product or system. The objective that this system serves, must be precisely defined before the design process begins. Systems engineering experts do not occupy themselves with the question whether the respective product (e.g. an airplane) is the best way to fulfill a certain function (provide transport from A to B), but only get to work after the specifications of the system to be developed have been determined. Models in the field of expertise of sustainable product development are primarily focused on the sustainability objective that one wants to achieve, namely limiting the negative ecological or social effects of products. Driven by the desire for large-scale, radical improvements, experts within this field of expertise are becoming more and more convinced that the "real problem" is not at the product level, but at the level of the socio-technical and societal system that the product is part of. With that we have arrived at the field of expertise of sustainable system innovation. This field is aimed at changes occurring in the socio-technical and societal system, with a timeline of several years. The target objectives in this are usually aimed at long term policy measures, and because of that are relatively far removed from the more short-term commercial objectives of most design projects. From this can be concluded that, to answer the research question, there is a need for a design model where the realization of short-term, commercial and functional objectives can be combined with the more long-term, socio-technical and societal objectives. Summarized:

- Industrial Design Engineering: Targeting operational problems and satisfying functional objectives.
- Systems Engineering: Targeting realization of strictly defined, technical objectives.
- Sustainable Product Development: Aimed at limiting the negative ecological impact of products, within the broader socio-technical and societal context.
- Sustainable System Innovation: Targeting socio-technical or societal problems, operating from policy and political objectives
- Desired model: Provide insight into the relationship between operational problems and societal problems

When looking at the various objectives that the design and innovation models are focused on, a number of aggregation levels can be distinguished, from solving concrete, defined, technical and functional problems on the one hand to solving more abstract socio-technical and societal questions on the other. Some of the classifications that are used are:

- Means-end chain: Form, Characteristics, Function, Needs, Values
- Evolutionary Model: Fulfilling a function, Optimization, Detailing, Segmentation, Individualization, Awareness
- Eco-Design: Product improvement, product redesign, function innovation, system innovation
- HICS: Context-of-Use, Meta Context-of-Use
- Social paradigm: User needs and wants, Cultural Trends, Socio-dynamic forces, Global paradigms
- Kathalys: Product-service combination, system definition, factor 4 environmental improvement
- Learning levels: Single-Loop learning / First-order learning, Double-Loop learning / Higher order learning
- Levels of discourse: Problem solving according to predetermined objectives, Problem definition in relation to a specific technology-society coupling, dominant interpretive frame, worldview.

In order to realize a specific objective it is usually necessary that derived sub-objectives are realized at a "lower" aggregation level. The realization of these sub-objectives subsequently contributes to the realization of the overlying objective from which they were derived. When reasoned in reverse, each objective can be viewed as a means to achieve a "higher" objective. For instance, in the case where the realization of certain innovative products can make a contribution towards fulfilling a certain socio-technical or societal function.

4.6.3 Conclusions research issue 3: Design process

When analyzing the actual course of the design process, it is particularly important for this study how the relationship between the product design process and changes at the societal or socio-technical level can be described. In spite of the large differences, a fair number of similarities can be identified between the design and innovation processes that have been discussed, which in its most elementary form can be described as a cyclic process consisting of four steps. First is a reflection based on a certain experience, after which a value judgment can be created about this situation (the problem). Next is an analysis phase, where it is determined what a possible new situation should look like (the objectives). Next is a synthesis phase, where this new situation is made concrete (the design). Concretizing this will lead to a new situation where new experience can be acquired, after which the entire process starts again. This design cycle can be completed at the product level (Figure 4-21 and Figure 4-22), or at the technical system level as in Boehm's spiral model (Figure 4-13) or from the perspective of the transition management process (Figure 4-23) or from the perspective of Kolb's learning process (Figure 4-24). It seems that a similar process can be identified, whether this is about new products or about societal changes.

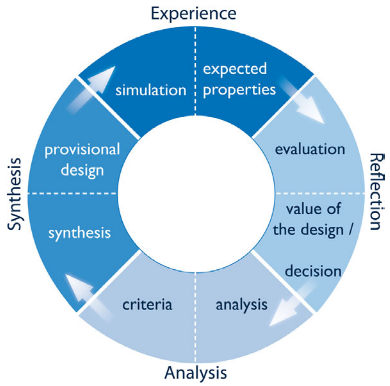
Having said that, there is a big difference between the degree of controllability and the manipulability of the system that one is focused on. Industrial design engineering and systems engineering are focused on systems which are clearly defined and which can ultimately be developed, integrated and tested as a single unit. Sustainable system innovation is studying changes where the socio-technical or societal system as a whole cannot physically be defined within exact limits and cannot be designed in a "top down" manner. Another major difference concerns the relationship between the big system and the smaller subsystems. Where systems engineering is employing the "100% rule" -, which indicates that the various subsystems are not allowed to overlap in any way - subsystems at the societal level on the other hand appear to be influencing each other in a more organic manner in a kind of symbiotic interrelationship.

The approach of the design and innovation process in the different areas can be summarized as follows. In the field of expertise of industrial design engineering it is usually about prescriptive models, which target the development of one new product or service. The context in which this happens plays a role, but only as much as it influences the development of the actual product. Systems engineering also employs prescriptive models, which work up to one new technical system through various aggregation levels. The demands for the system must be strictly defined beforehand and without ambiguity. Societal questions only play a role in the background at best, but are not part of the design process itself. With sustainable product development on the other hand, the societal aspect most certainly plays a prominent role. The overlying sustainability objective is leading these processes. Because the development of these product-service systems often requires various actors, these models place a lot of emphasis on how cluster forming and cooperation by the various parties can be stimulated. Sustainable system innovation is aimed at the broadest innovation perspective and its objective is to tackle complex societal questions. This usually involves the implementation of a fairly descriptive and policy oriented approach, where the researcher analyzes from a distance, as it were, how certain changes take place. And yet, also on this level there are more prescriptive models. An example of this is the transition cycle, which tries to structure the process to set socio-technical and societal developments in motion. Finally, the desired design model would have to be a combination where change can be described at the level of the socio-technical or societal system, as well as at the level of concrete new products. Summarized:

- Industrial Design Engineering: Prescriptive models, especially targeting the development of one new product or service.
- Systems Engineering: Prescriptive models which work up to one new technical system through various aggregation levels.
- Sustainable Product Development: Prescriptive models that work towards one new product-

service system, emphasis on cluster forming by actors.

- Sustainable System Innovation: Descriptive and analytical process, aimed at solving socio-technical or societal questions, especially on the basis of political strategy.
- Desired model: Provide insight into the course of the product design process as well as the course of socio-technical or societal change processes.



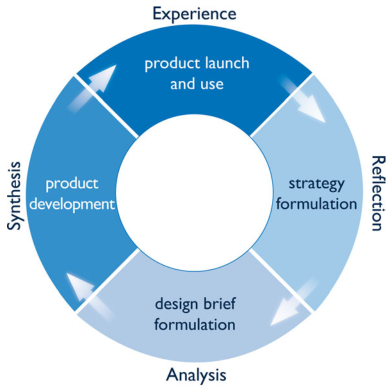
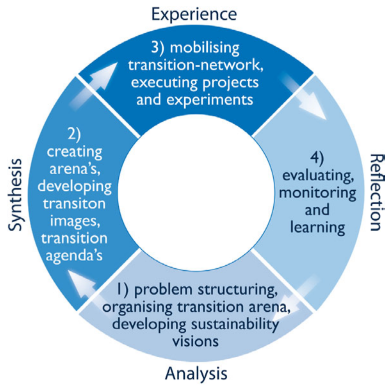


Figure 4-21 (left): Basic Design Cycle (based on Eekels, 2002)

Figure 4-22 (right): Innovation Cycle (based on Buijs, 2003)



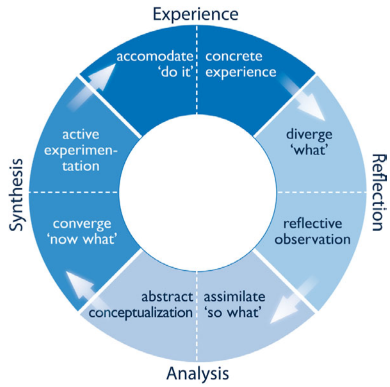


Figure 4-23 (left): Transition Management Cycle (based on Rotmans, 2005, 53)

Figure 4-24 (right): Kolb Learning Cycle (based on Kolb, 1973, 15)

4.6.4 Conclusions research issue 4: Designer and actors

The fields of expertise of industrial design engineering and systems engineering assume that the designer always works for a discernible client. This client ultimately is responsible for each decision to be taken. Obviously he may delegate or outsource some of this to other parties, but eventually these parties are again accountable to the primary client. This works well in design processes, where all components of the system to be changed lie within the sphere of influence of one party, and if this party wields enough money or power to hold onto all other parties. However, with the development of more complex societal or socio-technical systems it appears impossible to exactly identify the role of the designer, as well as a single individual organization that can serve as a client to take all decisions. Although government is often looked to for this, certainly in a democracy, government has limited powers.

I appears that that solving complex socio-technical and societal problems is dependent on the actions of actors whose primary interest is not in solving the respective societal question. Because the activities of these actors cannot be guided "top-down", other mechanisms are needed to influence their actions, for example by developing a joint vision of a desired future. And yet, in order to subsequently realize this vision it is again a matter of mobilizing parties in the here and now. And there it is, at least with commercial companies, mostly about short-term objectives such as the development of profitable new products. The question is now whether these two objectives (development of profitable new products and solving complex societal questions) can be combined effectively.

As for the process to set these two objectives in motion, again two extremes can be identified. On one side is the basic assumption that there must always be one party who decides, and that the possible network forming always has to emanate from one organization, which therefore has to be identified from the beginning of the process. This party is then the seed, as it were, which forms the basis for a possible collaboration. This manner of working seems to be efficient, since the interested and deciding party is at the table from the start. However, the question is whether changes in society will ever take place at all when this approach is used, as it is nearly impossible to identify parties which have a direct interest in solving societal questions. Most organizations are not at all interested in changing the societal system in which they function, since they are optimally adapted to this very system. For that reason they will often adopt a waiting attitude when it involves questions that play out in the long-term. From this perspective, these issues only become important when government gets involved, for example in the form of regulations and legislation.

The other approach, on the contrary, takes the viewpoint that as many parties as possible must be involved in the societal change process, in the form of a so-called "transition arena". In this process, organizations which are not (yet) part of existing societal structures think along about potential new solution directions. In this case it appears that formulating an inspiring future vision might be easier, but that the realization of this vision is difficult. After all, at the start of the thought process it is not known which elements and which actors should become part of the new envisioned societal system. Therefore a way must be found to motivate these actors to make a contribution nonetheless. More than that, organizations who are indeed interested in bringing about change of the societal system, often are not the parties who can actually bring about these changes. For example, government is usually able to put items on the agenda, but is dependent on other organizations for the execution of ideas.

The position of the designer is more or less linked to both of these extreme approaches. At one in the spectrum is the designer who doesn't do anything without getting his assignment from a specific client. In this case the most important task of the designer is to bring together conflicting interests and demands of one party into the design of one new product or service. At the other end of the spectrum is the designer who acts as intermediary between the parties. In this case the most important task of the designer (or "transition manager", if it is about societal changes) is to bring together conflicting interests and demands of various parties into the "design" of a new societal or socio-technical system which is made up of several elements, such as products, services, infrastructural, cultural or social renewals. Summarized:

- Industrial Design Engineering: Targeting one individual company; designer is commissioned by company.
- Systems Engineering: Designer is commissioned by one client.
- Sustainable Product Development: Targeting innovations by clusters of companies; designer as

accelerator of innovation that brings parties together.

- Sustainable System Innovation: Targeting the involvement of as many actors as possible, to be mobilized through "innovation agenda" Transition manager as intermediary, who brings parties together.
- Desired model: Provide insight into the potential role of the designer, in relation to individual companies as well as in relation to different societal actors.

4.6.5 Mapping the fields of expertise on the conceptual model

In Table 4-2, the way that the four research issues are related to the four fields of expertise. To visualize the outcome of the analysis, the emphasis of each of the four fields of expertise has been "mapped" on the conceptual model as presented in section 2.1.2. With regard to the field of expertise of industrial design engineering, the accent is mainly on the level of the existing and new products, and the problems and objectives related to the functioning of these products. This emphasis is indicated in the top left picture of Figure 4-25. With regard to the field of expertise of systems engineering, the emphasis is on the reciprocal relationship between the bigger (technical) system and the elements (like products) that are part of this system. This emphasis is indicated in the top right picture of Figure 4-25. With regard to the area of sustainable product development, the emphasis is on the product level as well as on the societal context in which these products function.

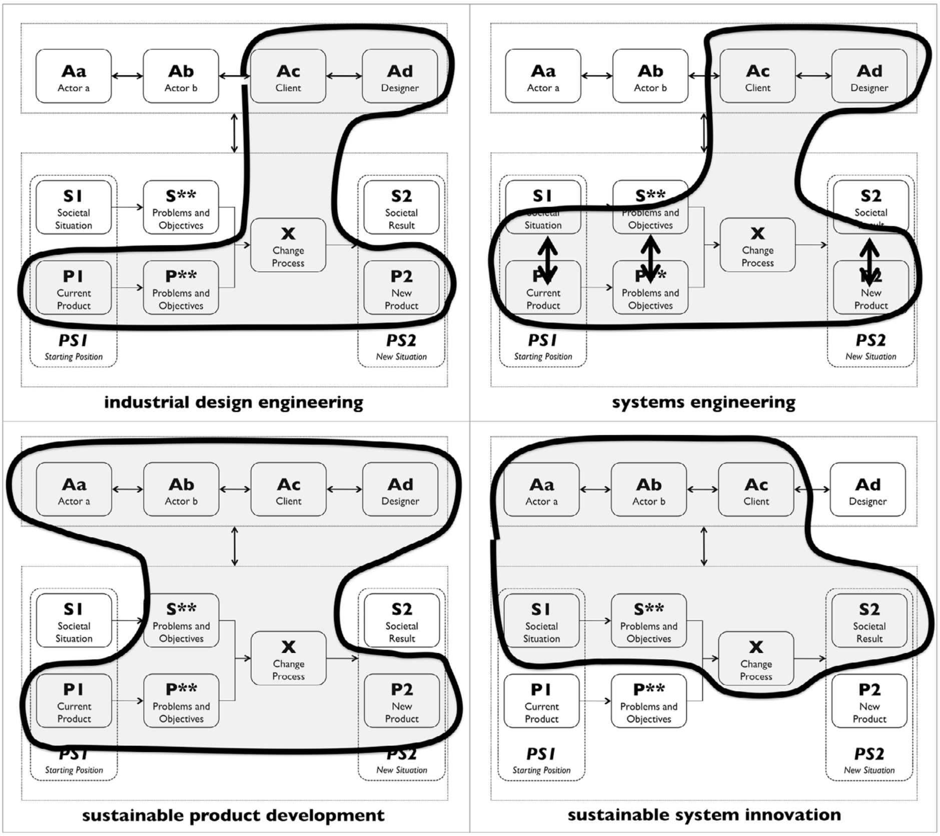


Figure 4-25: Emphasis of four fields of expertise in relation to the conceptual research model

Table 4-2: Overview fields of expertise and research issues

Research issue: Field of expertise:	Product and society Chapter 4.2	Problems and objectives Chapter 4.3	Design process Chapter 4.4	Designer and actors Chapter 4.5
Industrial Design Engineering	Targeting development of one new product or service, within wider environment context	Targeting operational problems and satisfying functional objectives	Prescriptive models, especially targeting the development of one new product or service	Targeting one individual company; designer is commissioned by company
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	Designer is commissioned by one client
Sustainable Product 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 product-service system, emphasis on cluster forming by actors	Targeting innovations by clusters of companies; designer as accelerator of innovation that brings parties together
Sustainable Systems Innovation	Analyzing change of the socio-technical and societal situation. Products are limited building blocks of the whole	Targeting socio-technical or societal problems, operating from policy and political objectives	Descriptive and analytical process, aimed at solving socio-technical or societal questions, especially on the basis of political strategy	Targeting the involvement of as many actors as possible, to be mobilized through "innovation agenda" Transition manager as intermediary, who brings parties together
Desired Design Model	Provide insight into the development of one new product in relation to developments that occur on the socio-technical and societal level	Provide insight into the relationship between functional (product related) objectives and socio-technical and societal problems	Provide insight into the course of the product design process as well as the course of socio-technical or societal change processes	Provide insight into the potential role of the designer, in relation to individual companies as well as in relation to different societal actors

However, when looking at the actual design process that is followed, the actual innovation that is being achieved is mainly focused on the new products itself, and less on the realization of societal change processes. This emphasis is indicated in the bottom left picture of Figure 4-25. With regard to the field of expertise of sustainable system innovation, this is mainly focused on development that take place on the socio-technical or societal level, where the development of new products is only of limited interest. This emphasis is indicated in the bottom right picture of Figure 4-25. With regard to the desired design model, this would preferably "map" the entire model, instead of only a part of it, as current models appear to do. In the next chapter, we will find what such a model could potentially look like. The question what such a desired design model may look like is discussed in the next chapter.

4.7 Summary

In chapter 4, four fields of expertise are discussed: "industrial design engineering", "systems engineering", "sustainable product development" and "sustainable system innovation". For each of these areas an analysis is made how they deal with the four research issues: "product and society", "problems and objectives", "design process" and "designer and actors". With regard to the research issue "product and society", models such as those implemented in the field of expertise of industrial design engineering are especially targeting the development of one new product within the broader user context. Systems engineering appears to be particularly targeting the development of one new technical system, including the corresponding subsystems. Sustainable product development appears to be particularly targeting the development of one new product-service system, within the context of the broader societal environment. Sustainable system innovation appears to be targeting the changes of the socio-technical or societal level, implying that new products are merely considered to be limited building blocks of the whole.

With regard to the research issue "problems and objectives", the field of expertise of industrial design engineering is particularly focused on solving operational problems and achieving functional objectives. Sustainable product development is aimed at limiting the negative ecological impact of products, within the context of the wider socio-technical and societal situation. Systems engineering is aimed at the realization of strictly defined, technical objectives, where the societal context does not play an explicit role. Finally, sustainable system innovation is aimed at dealing with complex societal problems, operating from policy and political objectives. Here, objectives at the level of products are only relevant here if they contribute to these higher objectives.

With regard to the research issue "design process", in the case of industrial design engineering it is particularly about prescriptive models, which target the development of one new product or service. In systems engineering it is also about prescriptive models, which systematically work up to one new technical system through various aggregation levels. Sustainable product development is aimed at prescriptive models that work towards one new product-service system, while cluster forming by actors is often an explicit aim during this process. Sustainable system innovations particularly involve describing models, which are suitable to analyze socio-technical and societal developments after the fact. Here it is particularly a matter of policy processes and hardly about processes that are aimed at the development of new products and services.

With regard to the research issue "designer and actors", industrial design engineering is particularly focused on developments by one individual company, where the designer is commissioned by that company. Systems engineering is also focused on technical developments, where the designer is contracted by one client. Sustainable product development is aimed more expressly at processes involving collaborations by clusters of companies. Here the designer is frequently viewed in this as the accelerator of the design process, who is responsible for getting various parties to cooperate towards a new product-service system. Sustainable system innovation is often aimed at involving as many actors as possible, to be mobilized through an "innovation agenda". Here an independent "transition manager" is sometimes seen in this as the intermediary, who brings parties together.

As for the desired design model, this should preferably provide insight into the development of one new product while interlinking it with developments at the socio-technical and societal level ("product and society"), provide insight into the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives that are being met by means of the functioning of a socio-technical system ("problems and objectives"), provide insight into the course of the product design process as related to the course of socio-technical and societal change processes ("design process") and provide insight into the potential role of the designer, in relation to individual companies as well as in relation to other societal actors ("designer and actors"). The question what such a desired design model would look like is discussed in the next chapter.

5 Chapter 5: A Multilevel Design Model

5.1 Introduction

In the previous chapters it became clear that the environment in which product design takes place is changing rapidly, and there is a need to describe the design process and the role of designers in a new way. This led to the formulation of the following research question, discussing the way that the design process and the role of designers can be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner.

As indicated in chapter 2, the process to find an answer to this question is divided into four phases. The analysis of existing design and innovation models concluded phase 1 of the research. An overview of the four fields of expertise in relation to the four research issues is presented in Table 4-2. Next is the formulation of the tentative theory, phase 2 of the research approach. As a start for this, we can look at the bottom row of Table 4-2. Here the prerequisites of a possible "ideal" design model are described. Such a model should make it possible to describe the design process in such a way that the mutual relationship between the development of new products and the socio-technical and societal context in which this development occurs is taken into account in a systematic manner. Moreover it is desirable that the model, besides a more descriptive function, potentially can serve in a more prescriptive manner, so that it can be an aid in structuring the design process in practice.

From the analysis in chapter 4 it has become apparent that no single design or innovation model offers the desired insight. A number of models, especially those in the area of industrial design engineering and systems engineering, are too often formulated around the development of a single concrete product or system, such that the societal aspect is not sufficiently dealt with. Other models, particularly those in the area of sustainable systems innovations, employ an abstraction level which is too high. These models are often more of a contemplative nature, where the aspect of concrete product development is not sufficiently dealt with. The conclusion is that none of the existing design models offer the insight that were looking for. Therefore, a modified design model will be developed in this chapter, which may be considered as a new tentative theory, and which in turn must be critically scrutinized. This new design model will continue to build on the relevant aspects of the models that were studied in chapter 4.

5.2 Hierarchical system structure, "the architecture of complexity"

In the conceptual model as discussed in chapter 2, only two innovation levels are distinguished, that of the product and that of the socio-technical or societal system. However, when studying the various design and innovation models, it appears that a more detailed distinction between the various aggregation levels may be an effective way to provide the desired insight. To make a substantiated choice with regard to the system levels used, the analysis as described in "The Architecture of Complexity" (Simon, 1962) may be of use. This includes a description of a widely applicable systems theory, suited for material, biological as well as social systems. Simon explains that all systems are hierarchical and consist of interrelated subsystems, which in turn are also hierarchical in nature. Eventually these subsystems cannot be subdivided further, when we will have arrived at the elementary building blocks of the respective system. In physics this concept is often referred to as "elementary particles". In order to identify the basic element of a certain system, Simon introduces the term "nearly decomposable system". These are subsystems that cannot be broken up or divided further. To this end he employs two propositions:

A) "In a nearly decomposable system, the short-run behavior of each of the component subsystems is approximately independent of the short-run behavior of the other components."

B) "In the long run, the behavior of any one of the components depends in only an aggregate way on the behavior of the other components." (Simon, 1962, 474)

The structuring of the subsystems is determined by the degree of interaction or attraction between the elements it is made up of. Each subsystem has strong internal bonds, where a high degree of interaction exists between the elements that make up the subsystem. In contrast, the interaction or connection with other subsystems is very low. For example, at the atomic level the force between atoms is relatively low compared to the force that keeps the atom itself together (just try and split one!). When viewed from the higher level of molecules, however, it is the force that keeps the atoms together which is extremely high, compared to the relatively minor force between molecules. Therefore the structure at each aggregation level is determined by the degree of "decomposability", or "divisibility" of the components that make up the system. When a subsystem can no longer be split without influencing the fundamental properties of that system, then we have reached the boundary of that system level. The choice of boundary depends on the specific objectives of the researcher. For some research objectives, atoms may be considered as elementary components, while other researchers may indeed look at them as complex systems. In other research, for example in certain branches of astronomy, entire stars or even solar systems may function as an elementary system. So the question here is, which system level should be maintained considering the objective of this specific study.

5.3 Selection of aggregation levels

Which levels can be implemented in this study? To determine this, we'll review the aggregation levels as described in chapter 4. An overview of these levels is presented in Table 5-1, Table 5-2 and Table 5-3. Several models use only three aggregation levels, whereas others employ four or more levels. So what is a suitable number? As the main subject of this research is the development of new products, we will use this as the basis of the model. Based on the analysis of chapter 4, the previously combined socio-technical and societal system will be separated in two separate levels. In between the socio-technical level and the product level one more level can be distinguished, that of product-service systems. Thus we arrive at four aggregation levels, as presented in the left column of Table 5-1, Table 5-2 and Table 5-3. Level P is defined as the product-technology system. Level Q as the product-service system. Level R as the socio-technical system. Level S as the societal system. The four aggregation levels are visually represented as icons in Figure 5-1. The "cube icons" indicate the different kinds of elements that make up the structure of the system at each level. Please note that the cube icon from level P recurs at all overlying levels and that the characteristics of the respective product do not change between the levels. Ultimately there is only one reality, no matter how we look at it. What does change between aggregation levels, is the specific function of the product in relation to the other elements at that level.

To explain this point, the comparison to a lens can be used. At the bottom level one looks at the world through a microscope, as it were, at the highest level through a wide-angle or fish-eye lens. The design models that were discussed in chapter four could possibly be compared with a camera that has a fixed, unchangeable lens, so that it can only photograph from one single perspective. One might compare the desired model with a zoom lens that helps the photographer to change the perspective very quickly. This comparison also indicates the limitations of each design model: After all, a good photographer can take beautiful pictures with a simple camera, while an amateur with the most complex equipment will only produce unattractive shots. This comparison also makes it clear that the choice for four levels will always remain arbitrary. One photographer has a need for a 30-80 mm zoom lens in order to photograph objects from close up, while another always uses a 120-500 mm zoom lens to see objects from far away. And there will always be photographers who choose to work with fixed lenses.

In other words, the four design levels presented in this study are not the "correct" ones. The point being made is that the appropriate assignment of various aggregation or system levels could be a relevant addition to the "toolbox" that is being used during the design process. However, one could wonder whether it is necessary to add a level "under" the product level (which would be a strictly technological level). The choice was made not to do that at this time, as the main subject of the research question is about the relation of products and society, where the technological aspect seems to be of limited influence. After the research we will evaluate whether this was a sensible choice.

Table 5-1: Aggregation levels in different design and innovation models (1/3)

System Level	Industrial design	VIP model	Intelligent products	Product-service systems	Systems Engineering	Multilevel approach
S: societal system		authenticity and originality of the designer	Rethinking values	Sustainable Society		Landscape
R: socio-technical system	Environment	Context Principles States Developments Trends	Systemic Context		System Subsystem	Socio-technical regime
Q: product-service system	Compre-hensive product Man-machine System	Interaction	Ecological Context	Product-service combination	Element	Niche
P: product-technology system	Physical product / Artifact	Production	Immediate Context	Pure service Pure product	Component Component	

Table 5-2: Aggregation levels in different design and innovation models (2/3)

System Level	Means-end chain	Evolutionary model	HICS	Social paradigm	Learning levels	Levels of discourse
S: societal system	Values	Awareness Individualizing		Global paradigms	Double Loop learning / Second-order learning	Preferences relative to social order
R: socio-technical system	Needs	Segmen-tation	Meta-context of use / Meta Solution	Socio-dynamic forces		Dominant interpretive frame
Q: product-service system	Functions	Detailing Optimization	Specific Context or Use / Specific Solution	Cultural needs and wants /		Problem definition for particular technology society coupling
P: product-technology system	Character-istics Form	Function implemen-tation	Solution Elements	User needs and wants /	Single Loop learning / First-order learning	Problem solving

Table 5-3: Aggregation levels in different design and innovation models (3/3)

System Level	Cross	Papanek	Sustainable System Innovation	Kathalys	Backcasting	Transition management
S: societal system		The "real problem"	Sustainable society	"Factor 4" environment enhancement	Sustainable society	Transitions
R: socio-technical system	Overall problem	General case	System innovation Function innovation	Innovation-vision System definition	Normative vision of desired future	System innovations
Q: product-service system			Product redesign	Product-service combination	Innovation agenda	Process innovations
P: product-technology system	Sub-problems	Special case	Product improvement			Product-innovations

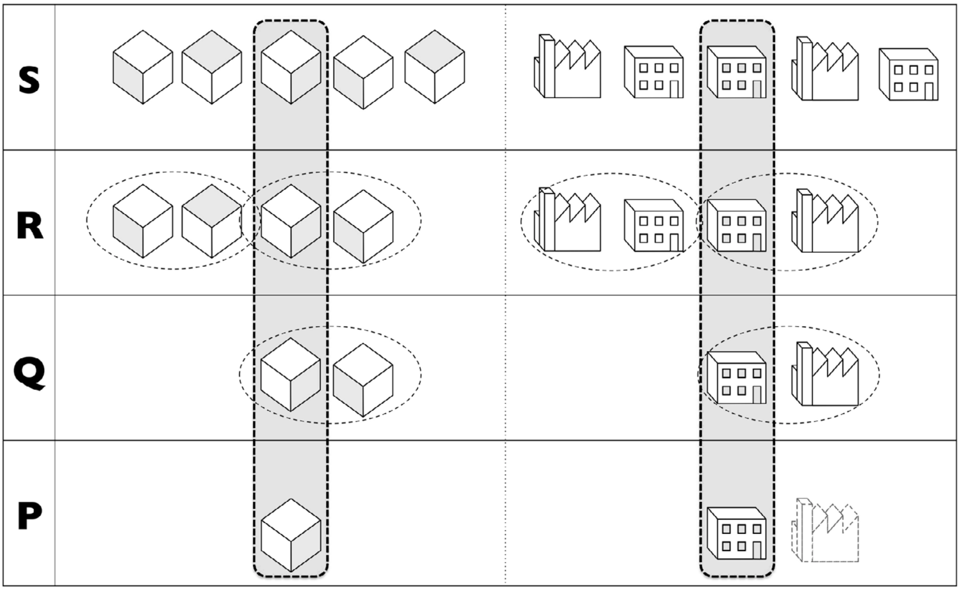


Figure 5-1: Four aggregation levels visually explained

5.4 Description of aggregation models

Before the new multilevel design model will be further explained, we will first conduct a closer examination of the four chosen design levels, exploring the structure, the type of problem which is solved at each level, the way that the design process takes place at each level, and the role of the designer and other actors at each level. A summary of this description is presented in Table 5-4. Examples from the transport sector will be utilized to illustrate the descriptions. The choice to use examples from this domain is based on pragmatism. On the one hand, the field of transport is complex enough to visualize the various aspects of the study. On the other hand, it is a field that the reader will clearly recognize from his own world of experience. This in contrast with, for example, the food sector or the domain of energy supply, where many of the discussed processes are invisible to the consumer.

5.4.1 Level P: Product-Technology System

Concrete products form the basic level of the multilevel design model. In chapter 1 a product was defined as "a physical object that originates from a human action or a machine process". This is indicated by the single cube icon at level P in Figure 5-1. These form, as it were, the elementary components of the model. Together with all the other elements (like services, infrastructure, other products) they are comparable to the "nuts and bolts" of a technical system, or the "ones and zeros" of a software system. Products are also small systems themselves, made up of technical components. The complete name of Level P is therefore "product-technology system", but to improve readability we will generally refer to this as "products". Products refer to tangible, inextricably linked technical systems, physically present in place and time. With most of these artifacts, you could "drop them on your toes", although with "smart" products based on continuously shrinking computer technology, this may not always be so evident. Product-technology systems generally fulfill one clearly distinguishable function. A system dysfunction occurs as soon as one or more technical components are missing. As for the involvement of actors and designer, at level P it is generally a matter of a limited group of actors who are in direct contact with the product. In most cases, one organization can be identified that delivers the product, which is indicated with the organization icon on the bottom row of Figure 5-1. The manner in which the design process progresses at this level, appears to be mostly in keeping with the various models in the areas of industrial design engineering and system engineering. Although the product-technology system can be divided in smaller subsystems, for the purpose of this study this level is exact enough. Model precision could undoubtedly be increased by splitting towards lower levels, but the accompanying increased complexity would not be desirable or necessary to answer the research question.

An example of a product-technology system is the physical artifact "car". The car is discernable in place and time and fulfills a clearly defined primary function aimed at transporting people or things. As soon as certain technical components are missing the car ceases to function as such, for example with a flat tire or an engine that's out of order. The direct relationship with the car as a product-technology system is limited to individual persons, such as the driver, passengers and the maintenance mechanic.

5.4.2 Level Q: Product-Service System

The second level of the multilevel design model is formed by product-service systems. In chapter 1 a product-service was defined as "a mix of tangible products and intangible service designed and combined so that they jointly are capable of fulfilling final customer needs". A product-service system was defined as "the product-service including the network, infrastructure and governance structure needed to "produce" a product-service" (Tukker and Tischner, 2006, 24). This level is more or less comparable with the concept "comprehensive product" from product development or the concept "novelty", as used in transition management. Naturally various sub-categories and levels exist even within the category of product-service systems, and an overlap exists between the various levels. If the delivered service is limited to, for example, selling the physical artifact, then a substantial overlap exists between level P and level Q, as the particular product-service combination will consist primarily of delivering one specific product-technology system.

A product-service system is built up of physical as well as organizational components, which form a united and cohesive whole that together fulfills a specific function, usually definable in time and place. In Figure 5-1 these are indicated by two encircled cube icons at level Q. The second cube is an abstract presentation of the other products or services which, together with the product at level P, form a joint product-service system. The system fulfills 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. The relationship with actors is restricted to a limited number of parties who are usually in a formal or legal relationship, for example as consumer-supplier or as formally cooperating partners. This is indicated in Figure 5-1 by two encircled organization icons at level Q, which indicates a more or less formal cooperation between the various parties. The manner in which the design process progresses at this level, appears to be mostly in keeping with the various models in the areas of sustainable product development, as these models have a rather strong focus on the organizational aspect.

An example of a product-service system is a taxi service, which is made up of technical as well as organizational components. If, for example, the taxi driver is missing, the system no longer works. The product-technology system "car" may still be able to function perfectly well, but the product-service system "taxi service" ceases to function. Good roads and corresponding traffic regulations are indeed necessary to perform the service, but these do not form an inseparable component of the service. It varies where precisely the boundary is between elements that are or are not components of the product-service combination. For example, until several years ago, railway infrastructure in the Netherlands was an inseparable component of railway service. More recently, the organization providing railway infrastructure services was detached from the organization responsible for the running of trains. By separating these responsibilities, a continuous discussion was created whether train delays are created by problems with the physical trains or by problems with the infrastructure.

5.4.3 Level R: Socio-Technical System

The third aggregation level of the model is defined as the socio-technical system. In chapter 1 such a system was defined as "a cluster of aligned elements, including artifacts, technology, knowledge, user practices and markets, regulation, cultural meaning, infrastructure, maintenance networks and supply networks, that together fulfill a specific societal function" (Geels, 2005). It can be compared with the concept "environment" from regular product development, the "developments" and "trends" from the VIP method, the "systemic context" from ambient intelligence and the "meta-context" from the HICS study. Some researcher consider the socio-technical level as the highest aggregation level of the technology (Geels and Kemp, 2000, 3). Changes that take place at this level are often referred to as a "system innovation", which was defined in chapter 1 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). However, as this research is not only about large scale transformations, but also about more modest changes that may occur, we will use the more descriptive term "socio-technical change process".

At this level a large number of components are combined that are not necessarily formally related to each other, but that do have a narrow, substantive, joint relationship. For example, a socio-technical system can consist of a combination of various product-service systems, accompanying infrastructure, government legislation, cultural and social aspects, and the specific knowledge which exists in this area. All of these elements form a joint system which fulfills a combination of functions that have a narrow, joint relationship with each other. In Figure 5-1 this is represented as four cube icons at level R, which are linked in pairs. This indicates that various independent product-service systems and other elements function at this level that exhibit a substantive coherence. In contrast to the levels described above, the system continues to function if one or more elements are missing, and elements may even assume each other's function. Agreements between actors can be formalized collectively, for example in the form of legislation, regulation, or collective standardization. This is represented in Figure 5-1 as two pairs of coupled organization icons at level R. The way in which change processes progresses at this level, appears to be mostly in keeping with the various models in the field of sustainable system innovations and transitions. Here it is usually a matter of slowly progressing and difficult to direct developments, so the question is of course whether it is at all possible to speak about a "design process" at this level. However, even if may be impossible to "design" systems at this level in a top down manner, it may indeed be possible to describe the changes that take place in such a way that they resemble the design process followed on the lower aggregation levels.

In this way, "road transport" can be considered a socio-technical system, where private cars, rental cars and taxis meet each other on public roads. They are joined there by buses, pedestrians and cyclists. Other elements which are part of this system are the roads that are used to move around, traffic rules, the insurance that a driver must have, the license required by a taxi driver, the service stations that provide gasoline, diesel or liquid petroleum gas, 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. In case one of these subsystems fails, its function can 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. The way in which the relationship between competing systems develops, is strongly determined by the societal context, for example when the authorities decide to make parking in the inner city more expensive, in order to stimulate public transit. These examples already demonstrate that these kinds of changes often take more time and have a greater societal impact than changes at the level of product-service systems.

5.4.4 Level S: Societal System

If the socio-technical system described above is indeed “the highest level of technology”, then what is the level above it? In this study this level is referred to as the “societal system”. In chapter 1, society was defined as “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. The level of the societal system overlaps with the “states” from the VIP model and can be compared with the “landscape” of the dynamic multilevel innovation model. 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” (Rotmans et al., 2000, 11). However, this research is not only about structural, large scale societal change, but also about more modest, small scale changes that may occur. And while the term “transitions” is used often in the field of expertise of sustainable system innovations, in the area of design the phrase is hardly known. That is why the more descriptive term “societal change process” will be used.

While the socio-technical system can more or less be defined, 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 defined. Also the societal system does not fulfill one distinct function, but is made up of functions which are not necessarily related. The influence of the system extends to all sorts of parties which do not maintain any deliberate relationship with each other, but become implicitly related as developments touch several sectors of society. This is indicated in Figure 5-1 by utilizing the same cube icons and organization icons at level S as on the other levels, but omitting the mutual separation between the various subsystems. This indicates that at this level, all subsectors are considered in mutual association. At this level it is usually a matter of slowly progressing and difficult to direct developments, so the question is of course whether it is at all possible to speak about a “design process” at this level. However, even if may be impossible to “design” systems at this level in a top down manner, it may indeed be possible to describe the changes that take place in such a way that they resemble the design process followed on the lower aggregation levels.

An example of development on the society level is the influence of the socio-technical system “road transport” on other sectors. Noise pollution and toxic emissions as a consequence of road transport affect the health of people, also when they are not part of the transport system. The transport system can function perfectly, even when everybody who lives 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.

Table 5-4: Description of the four system levels

Area of attention / Aggregation level	System structure, product and society	Problems and objectives	Design process	Designer
Societal System (S)	System is made up of a wide range of material, organizational, policy, legal, social, cultural and infrastructural elements. It cannot be defined in time and place	The system fulfills various functions, which are not formally related but can exert mutual influence, across the boundary of several influence spheres	Slow changes, which appear to be only moderately controllable, discussions about manipulability of society	Influence extends to actors who don't have a formal or functional mutual relationship, yet acquire that relationship at this level
Socio-Technical System (R)	System forms organizational coherent entity. Policy, legal, social, cultural and infrastructural elements are inseparable components of the system	System fulfills various, substantively related functions. Elements of the system can take over each other's function	Fits in with processes in the area of sustainable system innovations and transition management, transition cycle: deepening, broadening and scaling up transition experiments	Large, but still demonstrable and identifiable group of actors. Cooperation can be collectively formalized through legislation, regulation or collective classification
Product-Service System (Q)	The system forms a mutual coherent entity, made up of physical and organizational elements. In keeping with policy, legal, social, cultural or infrastructural elements, without these being part of the system	The system fulfills one or more operational functions. The system no longer functions as such when a technical or organizational component is missing	In keeping with methods in the area of sustainable product-service systems, relatively structured process is possible	Limited number of actors Organizations may be formally or legally related, for example as consumer-supplier or as organizations in a joint venture
Product-Technology System (P)	System made up of material, technical components Physically discernable, coherent and inextricably linked technical entity	System fulfills one or more operational functions. It no longer functions when certain technical components are missing	In keeping with methods in the area of industrial design and systems engineering, thoroughly structured process	Limited group of actors, who are in direct contact with the system

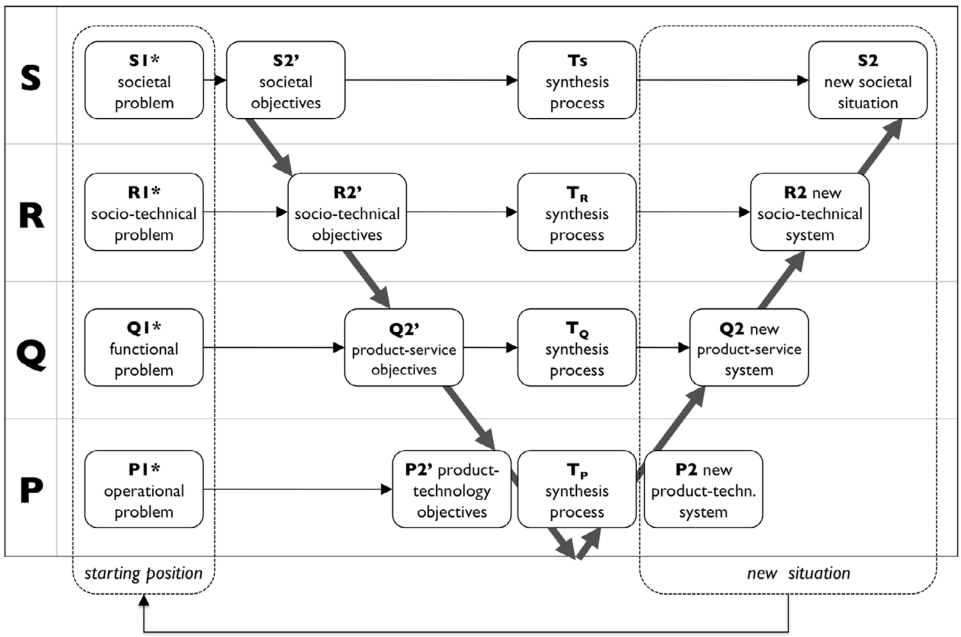


Figure 5-2: Multilevel Design Model

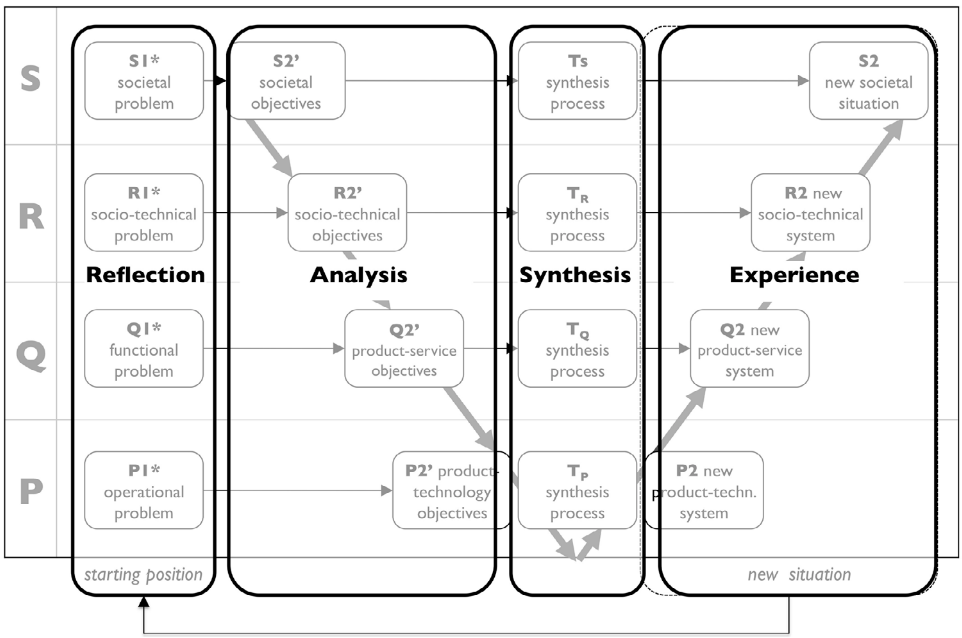


Figure 5-3: Multilevel Design Model and the four phases of the design cycle

5.5 The Multilevel Design Model

To develop the new multilevel design model, two steps will be taken. First, a more or less generic design process has been selected, as discussed in chapter 4. This design cycle is made up of the four phases experience, reflection, analysis, synthesis. In Figure 5-4, this cycle has been visualized for both the development of products, as well as the societal change process. Next, this generic process is combined with the four aggregation levels as described in the previous section (Table 5-4). To accomplish this we can describe this process separately for each of the four different aggregation levels. In symbol form this can be described as:

$$S1 \rightarrow S1^* \rightarrow S2' \rightarrow Ts \rightarrow S2$$
$$R1 \rightarrow R1^* \rightarrow R2' \rightarrow Tr \rightarrow R2$$
$$Q1 \rightarrow Q1^* \rightarrow Q2' \rightarrow Tq \rightarrow Q2$$
$$P1 \rightarrow P1^* \rightarrow P2' \rightarrow Tp \rightarrow P2$$

If these four processes are combined and presented in a graphical way, we arrive at the model as appears in Figure 5-2, presenting the new multilevel design model. For this study the choice was made to maintain a linear representation of the process, where the cyclic model of Figure 5-4 can be kept in mind. As a manner of fact, in chapter 9, an effort is made to present the same model in a more "cyclic" manner.

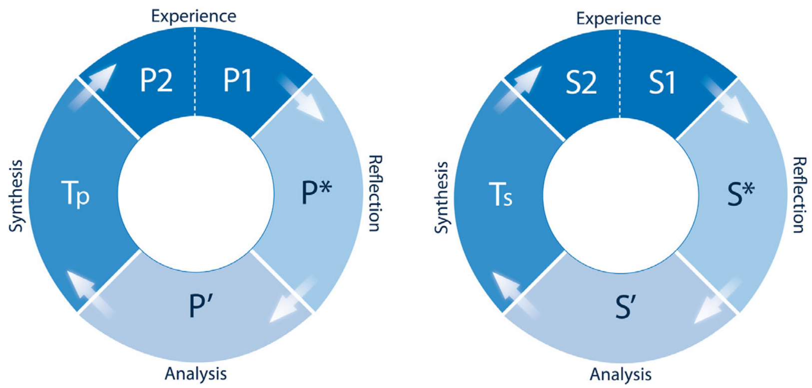


Figure 5-4: Design cycle for new products (left) and changing society (right)

Table 5-5: Legend multilevel design model

Symbol	Meaning
P1,Q1, R1, S1	Characteristics of the system in starting position
P1*, Q1*, R1*, S1*:	Value judgment relating to this situation, problem definition
P2', Q2', R2', S2'	Objectives, criteria for new (sub-)system
Tp, Tq, Tr, Ts	Synthesis process, resulting in design of new (sub-)system
P2, Q2, R2, S2	Characteristics of new (sub-)system
P2*, Q2*, R2*, S2*:	Value judgment relating to the new (sub-)system

Looking at Figure 5-4 and Figure 5-2, the starting situating (P1, Q1, R1, S1) is evaluated in the "reflection phase" and a value judgment is made, indicated as (P1*, Q1*, R1*, S1*). This is the most left box of the multilevel design model. If the value judgment is positive, the situation appears to be in order and the process stops. If the value judgment is negative, then there is a "problem" and the analysis phase is entered. Here, the objectives at the various levels are determined, indicated as (P2', Q2', R2', S2'). Next follows a synthesis process (Tp, Tq, Tr, Ts) where new ideas and concepts are developed, resulting in the design of a new situation (P2, Q2, R2, S2). These can then be subjected to value judgment (P2*, Q2*, R2*, S2*), after which the process repeats itself. The meaning of the symbols used in the multilevel design model is explained in Table 5-6.

The horizontal arrows of Figure 5-2 indicate the progress of the various development processes. The vertical arrows indicate the mutual relationship between developments at the four design levels. The returning arrow at the bottom of the diagram indicates that the acquired result is again being evaluated. The reason for only a single representation of this feedback loop is to indicate that the system as a whole is being evaluated. In fact, a similar feedback loop could be indicated at each of the four levels, but these have been left off in favor of legibility. To emphasize the difference in size or dimension of the system at the various levels, the model resembles a V-shape. On each level an identical process is presented in the model, only the width of the various layers differs, creating the characteristic V-shape. Off course, the model represents a gross simplification of the complex manner at which these changes take place, certainly at the higher aggregation levels (but as well on the level of regular product or service development). By applying a gross simplification, the intention is to recognize and describe the similarities and differences of the processes at the various system levels, and the way that these processes potentially influence each other. That means that the simplification applied is an intentional effort to describe and possibly structure this change process in a more systematic manner and should not be considered as an attempt to "catch" or confine reality to this simple model.

5.6 Relationship with other models

5.6.1 Differences compared to conceptual model

The multilevel design model is closely related to the conceptual model as discussed in 2.1.2. However, although the concepts discussed in both models are similar, they are certainly not exactly identical. The starting situation of the conceptual model does not appear separately in the multilevel design model, as the starting situation (P1, Q1, R1, S1) is combined with the new situation (P2, Q2, R2, S2) in a cyclic manner. The single variable "problems and objectives" (P**, S**) of the conceptual model is split in two different entities, separating the problems (P*, Q*, R* S*) and the objectives (P', Q', R', S'). This can be seen in Figure 5-4 and Figure 5-3. In the conceptual model, the variable X indicates the change process that takes place between the starting position and the new situation. Within the multilevel design model, the box indicated with T is specifically about the synthesis step of the design process. So the variable explaining the change process that takes place between the starting position and the new situation (box X of the conceptual model) should be more or less "covered" by the multilevel design model, as is explained in Figure 5-5.

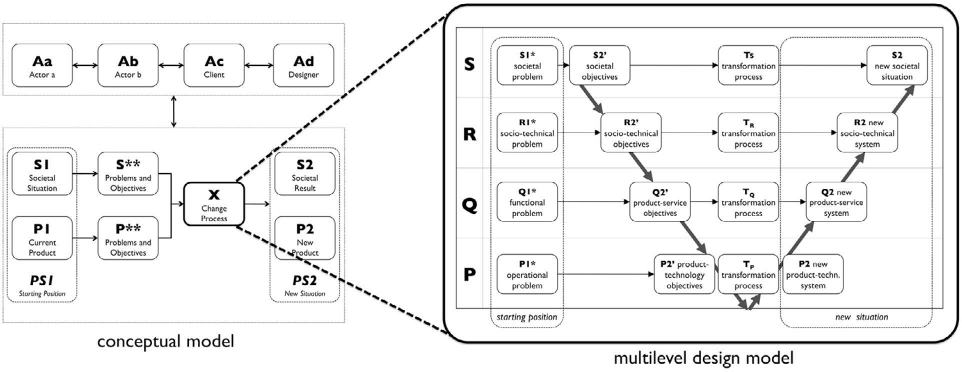


Figure 5-5: Relationship conceptual model and multilevel design model

5.6.2 Differences compared to systems engineering V-model

Even though the new multilevel design model looks very similar to the familiar V-Model () from the field of expertise of systems engineering (KBST, 2004) (Cadle and Yeates, 2008), there are some distinct differences. In systems engineering, the objective of the design process is strictly delimited and meticulously defined. With these technical systems, it is possible to direct the design process "top down", as a fixed process that progresses from left to right. In the systems engineering V-Model the specification and design phase passes through the left side of the V, starting at the top and moving down. In this process the system is divided into smaller subsystems, which can each be developed and tested independently. If these subsystems function well, they can then be integrated at a higher level into a larger system, which can be tested in turn, until ultimately the entire system can be developed, implemented and evaluated. This integration and test process forms the right side of the V-shape. Although the representation of the new multilevel design model may suggest a comparable systematic process, this linearity is not the intention of the multilevel design model. The essential difference compared the V-model used in systems engineering is the fact that socio-technical and societal issues are explicitly part of the model. Simply said, the "height" of the multilevel design "V" is much higher than the systems engineering "V". That means that one of the research issues may indeed be whether such a systematic design process is at all possible at all at the socio-technical and societal system level.

5.6.3 Differences compared to dynamic multilevel model

Another model which shows a certain similarity to the new multilevel design model, is the dynamic multilevel model such as applied in the field of expertise of sustainable system innovation (Geels, 2005). However, these levels are not identical. The concepts applied in the dynamic multilevel model emphasize the "location" where changes take place, hence the terms "landscape" and "niche". Within such a niche area, changes can take place at the product level as well as product-services level or at the socio-technical system level. If local legislation is adapted in order to stimulate a certain transport system, then this change may indeed take place within a defined niche, but from the perspective of the new multilevel design model it is a change at the socio-technical system level, since a number of independent organizational and policy elements are changing. On the other hand, within the multilevel design model it makes no difference whether a new product has very few sales or if millions are sold. In the dynamic multilevel model, an upscaling of that type would mean that the new product is working itself "up" from the niche towards the regime level or even the landscape level. In the new multilevel design model, this shift towards the higher levels of the model takes place, independent of the degree of acceptance of the new product or system. A product that changes the world in a dramatic way, still remains a product. And a socio-technical change that happens only in a niche situation, still is a socio-technical change. Both aspects are of course related to each other. For example, no new legislation or infrastructure will be introduced for one individual consumer who is starting to use a new, super-fast reclining bicycle. But if a lot of people start doing this, it may prove necessary to modify legislation or infrastructure in this area.

5.7 Propositions

As discussed in the introduction, the multilevel design model can be considered as a tentative theory, which subsequently needs to be tested thoroughly. To enable this, it must become clear which explanatory and predictive value the model could have. This is done by the formulation of five propositions, which can be confirmed or refuted. The propositions are closely related to the research question, however each research issue may be related to more than one proposition. The exact relationship between propositions and research issues is shown in Table 5-6.

5.7.1 P-01: Design process takes place at different system levels

P-01: "The design process can be described and organized at various system or aggregation levels. The steps that are taken during this process are comparable at each of the various system levels."

This proposition articulates the basic assumption on which the multilevel design model is based, namely that design processes occur at various aggregation levels. The expectation is that the multilevel design model is not only suitable as an analytical instrument for subsequent study of design processes, but also that it can contribute as a more prescriptive means to structure the design process in practice. In order to test P-01, the following will have to be demonstrated:

- A) The design process can indeed be described with the help of the four system levels.
- B) The design process can indeed be organized at each of these four levels.
- C) The steps that are taken at each of these levels are indeed comparable.

As for question A, a substantial analysis of historical cases would perhaps be sufficient to answer this question. It will be necessary to conduct an experiment in order to find an answer to question B and C. Only by actively executing and directing a design project in practice, will it become apparent whether the model is indeed applicable as a prescriptive means to support the design process. This will have to be demonstrated by the execution of the practical experiments. During that research it could also be shown that the model is only useful as a descriptive instrument, for after-the-fact analysis of design projects. The worst-case scenario is that it could be apparent that the model is not at all compatible with reality. However, the latter is not very likely, considering the fact that the model is quite compatible with various existing and thoroughly investigated models, as described in chapter 4.

5.7.2 P-02: Systems at various aggregation levels influence each other's functioning

P-02: "Design processes can be described and directed at various system or aggregation levels. Systems at various aggregation levels affect each other's functioning, in both a "top-down" as well as a "bottom-up" direction."

This proposition indicates the expectation that functioning at the various system levels does not take place independently, but that there is a mutual influence between them. The functioning of the higher system levels influences functioning at the lower system levels, and vice versa. In order to test this proposition, the following must be demonstrated:

- A) The functioning of systems at the various aggregation levels influence each other in a "top-down" direction.
- B) The functioning of systems at the various aggregation levels influence each other in a "bottom-up" direction.

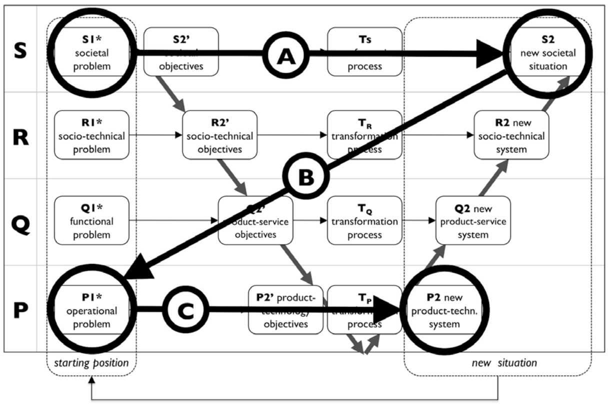


Figure 5-6: P-02 – Functioning of socio-technical or societal system influences functioning of product

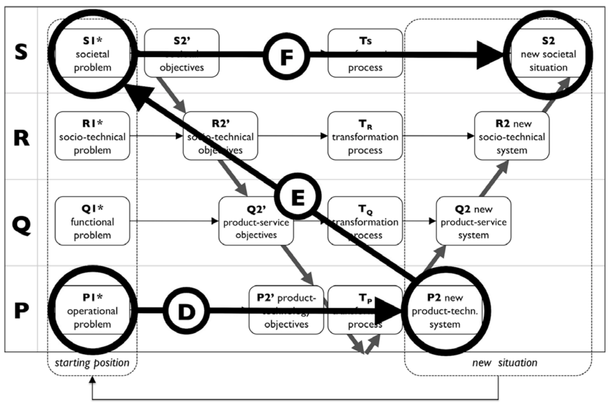


Figure 5-7: P-02 – Functioning of product influences functioning of socio-technical or societal system

The first issue is related to influence in a "top-down" direction and is visually represented in Figure 5-6. Arrow A indicates that the function of a certain socio-technical or societal system is changing. This influences the functioning of the products that are part of this system (arrow B). The subsequent change that these products may or may not undergo, is shown by arrow C. The second issue is related to influence in a "bottom-up" direction, and is shown in Figure 5-7. A new product is developed here (arrow D), which influences the functioning of the current socio-technical or societal system (arrow E). The subsequent change that these socio-technical or societal systems may or may not undergo, is shown by arrow F.

The introduction of the car that was previously used as an example, demonstrates how various design levels influence each other. The new product influenced the position of horse and wagon, but also led to the development of new roads, service stations and traffic rules. This is an example of a “bottom-up” influence, where the new solutions are developed first, necessitating changes in the design of the overlying system. The reverse, “top-down” legislation in the area of transport, such as the introduction of the Zero Emission Vehicle program in California in 1990, or the toll levy for visitors of London's inner-city in 2003, can lead to design changes at the product level, either to satisfy the new rules, or to circumvent them.

5.7.3 P-03: Functioning of product depends on the system that it is a part of

P-03: “The functioning of a system influences the functioning of the elements that it is composed of. The functioning of a product is therefore dependent on the product-service system, the socio-technical system and the societal system that it is a part of.”

The multilevel design model assumes that products can be viewed as product-technology systems that are part of larger product-service systems, socio-technical systems and societal systems. As already stated in P-02, a mutual influence exists between the various design levels, but no further pronouncement was made about the effect of this influence. In P-03 the expectation is expressed that the functioning of a product is dependent on the function it fulfills within the larger system that it is a part of. This place in the larger system is therefore an important factor in determining the successful functioning of a product. In order to test this proposition, the following must be demonstrated:

- A) Each product can indeed be viewed as an element of an overlying product-service, socio-technical or societal system, which functions at a higher aggregation level.
- B) The functioning of this larger system indeed influences the functioning of the respective product in a positive as well as the negative manner.

In fact, this proposition describes the way in which many new products are now being developed, where the environment in which the product will be functioning is mapped at the outset and the new product is designed in such a way that it is as compatible with the environment as possible. Similarly, new cars must fit on existing roads, they must satisfy legislation applicable to new cars and they must make use of existing conventions concerning the interaction with the user. If they do not comply, they are often not allowed to be sold. But even if such a car would be allowed to get on the road, it would quickly encounter problems with the authorities or the user. For example, an employee of the rental company “Greenwheels” once told the author that the company fairly regularly gets phone calls from panicked renters, because they cannot find a handle to open the car windows. Such a handy little button to open them electrically appears to be quite a leap forward for some users. The conclusion of this discussion was that this was one of the reasons that this car rental organization consciously avoids the more technical vehicle innovations, such as the use of electrical propulsion. The innovation of the company is the rental concept and the rest of the system must remain identical as much as possible. On the other hand, the fact that a new product fits perfectly within an existing system does not automatically mean that it will be a commercial success. In fact, a certain departure from the existing is often a condition for success, provided that the modification is not too dependent on the change of other elements of the system that is part of.

The proposition can be clarified with the help of Figure 5-8. This figure illustrates the hierarchical structure of systems at the four defined aggregation levels. The shape of this model is the exact opposite of the V-shape in Figure 5-2. The V-shape in Figure 5-2 shows that the dimensions of the system become progressively larger at the higher aggregation levels. Figure 5-8 indicates that one large system can be divided into quite a few subsystems. The lower the level, the more sub-subsystems can be identified and the wider the model becomes. For example, societal system S1 is made up of various subsystems R1.1, R1.2, R1.x. Socio-technical system R1.1 is in turn made up of various subsystems, among which product-service system Q1.1.1, infrastructural system Q1.1.2, etcetera.

Please note that, for example at level Q, it is not only a matter of a collection of product-service systems, but that also the other types of components that make up the socio-technical system R, have been placed at the same level. This is also the case for level P of the product-technology systems, displayed as P1.1.1.x. After all, other individual system elements can be found at this lowest level, such as a specific infrastructural component, an individual service, an individual law. These form, as it were, the elementary components that make up the system. The exact location of the boundary of such a "decomposable system" is dependent on the specific situation, as was discussed previously in the system theory of Simon (1962). In order to indicate that products themselves can be viewed as hierarchical systems, they in turn are made up of assorted technology components T1.1.1.1.1 up to and including T1.1.1.1.x. However, no extra system level was introduced for this. As mentioned previously, model precision could undoubtedly be increased by splitting towards lower levels, but the accompanying increased complexity would not be desirable or necessary to answer the research question.

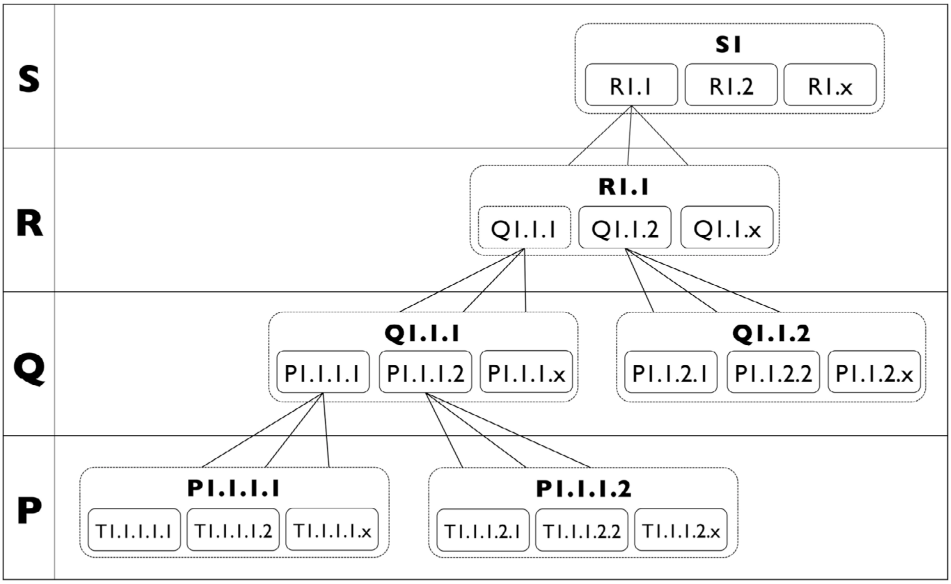


Figure 5-8: Hierarchical system structure

5.7.4 P-04: New products can help to achieve societal objective

P-04: "Each socio-technical or societal system is made up of subsystems. Change of a subsystem, as takes place in the introduction of a new product, influences the functioning of the entire system. Therefore the development of a new product which is a component of an envisioned future socio-technical or societal system, will hasten its realization."

P-02 includes a description that the socio-technical or societal system and the underlying product-technology systems, exert a mutual influence on the way that they function. P-03 includes a closer examination of the "top-down" effect experienced by products as a part of larger systems. In P-04 we go deeper into the possible "bottom-up" effect that new products can have on the development of societal systems. P-04 states that it is possible to give careful direction to the effect that new products have on the socio-technical or societal system, such that an envisioned future situation will come one step closer.

Figure 5-6 indicates how such a process can occur. The first assumption in this proposition is that objectives at the level of the societal system can indeed be defined (arrow G). This objective (S') can subsequently be split into sub-objectives (R') at a lower system level, which in turn can be converted to sub-sub-objectives (Q') and sub-sub-sub-objectives (P') at the underlying aggregation levels (arrow H). The realization of these sub-objectives (arrow I) subsequently contributes to the realization of the overlying objective from which they were derived (arrow J). The development of new products which are relevant components of an envisioned future socio-technical or societal system, can in this way contribute to the realization of that new system. And this is the essence of P-04. In order to test this proposition, the following must be demonstrated:

- A) The socio-technical or societal system can indeed be considered as a collection of subsystems and sub-subsystems among which are products.
- B) The introduction of a new product can indeed influence the functioning of a socio-technical or societal system.
- C) The development of carefully chosen new products can indeed hasten the realization of an envisioned socio-technical or societal system.

A familiar system puzzle in the field of transport concerns the presence of loading locations for vehicles which utilize alternative energy sources. For example, electric vehicles or hydrogen vehicles. This is how Amsterdam journalists, who enthusiastically took a test ride with the electric rental scooter Novox, discovered that recharging locations in the city are few and far between. Subsequently they go in search of alternative solutions: "Coffeeshop owners react with surprise to the question if the scooter could be recharged for a few moments. "Do you have an extension cord with you? Because you can't take this inside of course." And "what is that going to cost, two hours of electricity?"" (Beusekamp and Huisman, 2009).

The prediction that can be derived from P-04 is that the introduction of the electric rental scooter as a product-service system will be accelerated once more recharging locations are available in the city. Although individual users of electric scooters will manage to find their way to the sympathetic coffeeshop owner with an electrical outlet, for the transport system as a whole it will be necessary that recharging locations are introduced in the city on a wide scale. The capacity to recharge scooters is a derived objective of the umbrella objective, the introduction of a rental system for electric vehicles. The proposition expresses the expectation that the development of such system elements (in this case the recharging locations), can accelerate the realization of the system (the electric scooter rental system) as a whole.

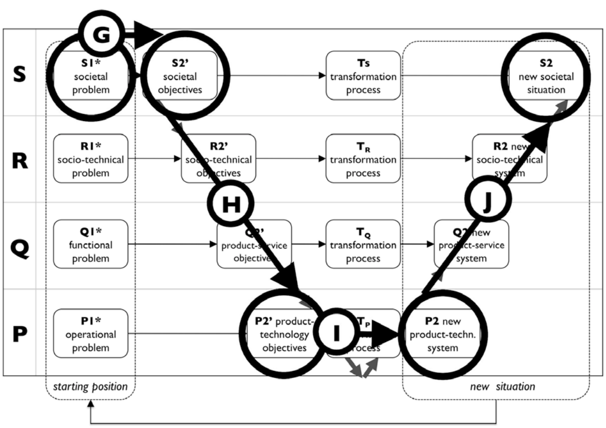


Figure 5-9: P-04 - New products influence development of socio-technical or societal system

5.7.5 P-05: Contribution from the designer varies by system level

P-05: "Design processes take place at various system or aggregation levels. The nature of the system to be developed is different at each of these levels. A logical connection exists between the respective aggregation level, the system to be developed and the contribution from the designer during this process."

This proposition is related to the role of the designer involved in the design process. The assumption is that this contribution will vary at each design level, and that the identification of the various system levels can help clarify the designer's contribution to this process. There is a certain amount of "chicken and egg" discussion in this. The question is how to research whether the activities of a certain type of expert are changing. The statement that the role of the designer does not change can be defended with the reaction that designers who expand into other activities, in fact stop being a "real" designer at that point. After all, they no longer do the "normal" work of the designer, but do other things. In the reverse scenario, the person who wants to defend that the designer's activities are definitely changing, can look at all of these situations that are created by this "other" activity. These situations can easily be found, so that it may be argued that "therefore" the role of the designer has to change.

In order to make a substantiated judgment about the contribution of the designer, the choice was made to define this design role to the actual synthesis process, where several possibilities are combined in a new way into a "design" of a new situation. The next assumption is that the party who creates that design, can be defined as "the designer". It is therefore possible that, in some situations, the designer does not formally use this title on his or her business card, but is certainly fulfilling this role. It is also possible that this is not about one single individual, but about a group of actors who collectively fulfill the role of "designer". The assumption is that the nature of this design varies between system levels. If that is the case, then logically the designer's contribution will also vary between levels. In order to test P-05, the following must be demonstrated:

- A) The nature of the system to be developed varies between various system levels.
- B) There is indeed a logical connection between the various system levels, the nature of the system to be developed and the designer's contribution during this process.

The proposition can be clarified by comparing the design of a car, a taxi service and a regional transport system. The designer of a bumper or a seat in this car must know everything about materials, production processes, draft angles and other technological details. The designer of the car as a whole will be more focused on design, the character of the vehicle and the emotional value that the user will place on the product. In the development of a taxi service, vehicle has suddenly become part of a "transportation experience". At each of these levels it is still a matter of generating a design, however each time at a different aggregation level. In the case of the designer of the seat or the bumper, it is much more about detailed engineering skills, while with the development of a "transport experience", it is about an "experience design" (Shedroff, 2001) (Goulden and McGroary, 2004). 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. It seems obvious that the designer who is skilled in designing the details of a bumper, does not necessarily require the same qualities as the designer who is skilled in the development of a "unique experience" or a future vision aimed at what mobility will look like in the year 2020.

Table 5-6: Relationship between propositions and research question

	Research question	Research issue 1 Product and society	Research issue 2 Problems and objectives	Research issue 3 Design process	Research issue 4 Designer and actors
P-01: The design process can be described and directed at various system or aggregation levels. The steps that are taken during this process are comparable at each of the various system levels					
A) The design process can indeed be described with the help of the four system levels	X	X			
B) The design process can indeed be directed at each of these four levels	X			X	
C) The steps that are taken at each of these levels are indeed comparable	X			X	
P-02: Design processes can be described and directed at various system or aggregation levels. Systems at various aggregation levels affect each other's functioning, in both a "top-down" as well as a "bottom-up" direction					
A) The functioning of systems at the various aggregation levels influence each other in a "top-down" direction	X			X	
B) The functioning of systems at the various system levels influence each other in a "bottom-up" direction	X			X	
P-03: The functioning of a system influences the functioning of the elements that it is composed of. The functioning of a product is therefore dependent on the product-service system, the socio-technical system and the societal system that it is a part of					
A) Each product can indeed be viewed as an element of an overlying product-service, socio-technical or societal system, which functions at a higher aggregation level	X	X			
B) The functioning of this larger system indeed influences the functioning of the respective product in a positive as well as the negative manner	X		X		
P-04: Each socio-technical or societal system is made up of subsystems. Change of a subsystem, as takes place in the introduction of a new product, influences the functioning of the entire system. Therefore the development of a new product which is a component of an envisioned future socio-technical or societal system, will hasten its realization					
A) The socio-technical or societal system can indeed be considered as a collection of subsystems and sub-subsystems among which are products	X	X			
B) The introduction of a new product can indeed influence the functioning of a socio-technical or societal system	X		X		
C) The development of carefully chosen new products can indeed bring the realization of an envisioned socio-technical or societal system closer	X		X		
P-05: The nature of various systems to be developed is different at each system level. A logical connection exists between the respective aggregation level, the system to be developed and the contribution from the designer during this process					
A) The nature of the system to be developed varies between system levels.	X				X
B) There is indeed a logical connection between the various system levels, the nature of the system to be developed and the designer's contribution during this process	X				X

5.7.6 Relationship between propositions, research question and research subquestions

The relationship between the propositions and the research question and research subquestions is shown in Table 5-6. In the top row of the table are the research question and the four research issues, side-by-side. In the left column of the table, one below the other, are the five propositions. At each proposition the criteria are indicated which are important to test the respective proposition. The relationships between the research questions and the propositions are indicated by "X" symbols in the body of the table. This overview makes it clear that research sub question 1 pertains to five propositions. Subquestion 2 especially pertains to P-03 and P-04. Subquestion 3 pertains to P-01 and P-02. Subquestion 4 pertains to P-05. All points together provide an answer to the entire research question.

5.8 Verification of the new model, project selection

So far, the new multilevel design model has been discussed and five propositions were formulated. This new model now needs to be thoroughly tested. As explained in chapter 2, this is phase 3 of the research approach: the error elimination. One might ask why supplementary practical experiments would still be necessary, and whether the explanation and examples in this chapter are "proof" enough for the propositions. Why spend even more time and effort on an extensive action research that will take several years, if the examples already make it clear that the new model corresponds well with reality? The reason is in the formulation of the research question, which is about the way that the design process and the role of the designer can be described, and possibly be structured in a systematic manner. Therefore this is not about the new products themselves, but about the way they were developed. To facilitate researching this aspect, it must be possible to take real-time control of the design process, to investigate while working, which specific actions yield what results. Therefore it is necessary that the activities of the process to be investigated can actually be influenced and guided, in order to discover through experience what does or does not work and why. This aspect returns in the four criteria which are used to select the practical experiments for this study.

Choosing these projects can be viewed as an arranging process, ultimately resulting in the two selected projects. In chapter 2, the four criteria for selecting the practical experiments are explained. The outcome of this selection process is shown in Table 5-7. If a potential project satisfies a criterion, it receives a "+" assessment, if not, then it will be a "–" assessment. The projects that score a "+" on all criteria will remain.

Criterion 1) Innovative products must be developed in the project
This criterion is not very distinctive, since there are hundreds if not thousands of projects in which new products are being developed. These few thousand possible projects form the starting point of the selection process.

Criterion 2) A socio-technical or societal problem must be involved
Using this criterion will immediately reduce the size of the "mountain" of possible projects. But there are still hundreds of projects remaining that operate under the labels of "sustainable product development", "sustainable product-service system", "societal responsible innovation" and "corporate social responsibility".

Criterion 3) Availability of information
This criterion creates a considerable reduction in the number of suitable projects, depending on the interpretation of the criterion. After all, as soon as a project is described in scientific literature it can be said that the information is "available". If we only consider the various research reports

of the Design for Sustainability Group in Delft, then, for example, several studies of the application of fuel cell technology (van den Hoed, 2004) (Hellman, 2007), or the study of the application of new technology in products (Poelman, 2005) could be eligible. Other research that could possibly be relevant is the study of new forms of mobility, such as (Meijkamp, 2000) or (Berchicci, 2005). However, in most cases the desired information is not available, since an information shift has already been applied by the respective author on the basis of the specific research question. The latter study (Berchicci, 2005), could perhaps be an exception, since the author himself was project leader of a large part of the MITKA project, analyzed by Berchicci. That means the author has access to the majority of the relevant research data, including some that did not appear in Berchicci's thesis. And yet, the Mitka project was not selected for further analysis in this study, because of the following criterion: the ability to guide the design process.

Criterion 4) Influence of the researcher

The fourth criterion is related to the degree to which the researcher can interfere in the design process. If the author had started this study in 1999, the Mitka project would have been a perfect research topic. However, the start of this study is in the period around 2004 and the author's involvement with the Mitka project was only minimal at that time. The opportunity for actively interfering was past, more or less, making it unsuitable for this study.

Table 5-7: Selection of practical experiments

Selection criterion: / Potential practical experiment:	1) Innovative products must be developed in the project	2) Socio-technical or societal problem must be involved	3) Availability of information	4) Influence of the researcher
Large amount of regular product development projects	+	--	--	--
Large amount of sustainable product development projects	+	+	--	--
Previously documented design projects, for example DUT-DfS research reports	+	+	+/-	--
Mitka project	+	+	+	--
Projects that the author is involved in at TNO (Rapid Manufacturing, Wearable Sensor Systems, Systems in Foil Polymer Electronics)	+	--	+	+
Project “Autonomous Elderly”	+	+	+	+
Project “Youth in Motion”	+	+	+	+

All in all, no “existing”, previously published projects remain to base this study on, so the author had to search for new projects that satisfied all of the four previously mentioned criteria. As a project manager at research organization TNO, there were several innovation projects that had the potential to form the basis for this study. However, with many of these projects the socio-technical or societal issues are not so much a subject that is part of the research, so these projects are also not suitable for this study. Two projects form an exception here. The first is entitled “Autonomous Elderly” (chapter 6) and is aimed at the societal challenge as a consequence of the increasingly aging population and the question what contribution can new products bring to this problem. The second project is entitled “Youth in Motion” (chapter 7) where the underlying societal problem is the accelerating growth in the number of youth with obesity.

It must be noted that the projects are not so much perfect because they were selected on these criteria after the fact, but also because the researcher himself was able to guide the projects in a certain direction. In addition, in both experiments it is not about one solitary project, but about a cluster of formally separated projects, that have a mutual, strong, substantive or programmatical relationship. The author, in his role as project manager with the Dutch Organization for Applied Scientific Research TNO, is directly or indirectly involved with all projects and subprojects. Although the described projects as a whole were not explicitly designed to answer the question of this study, the projects offered the researcher sufficient freedom to guide these projects in a direction desirable for the study. On the other hand this does not mean that the author was able to steer the projects, as it were, exactly in a certain direction. A substantial part of the developments took place autonomously, another part was explicitly set in motion on the basis of the research objective of this project.

5.9 Summary

From the analysis in chapter 4 it has become apparent that no existing design or innovation model can describe the design process and the role of designers in such a way, that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner. However, when studying existing models, it appears that distinguishing between various system levels may be an effective way to provide the desired insight. Based on that conclusion, a modified design model is presented which is based on these aggregation levels. To make a substantiated choice with regard to the system levels used, the analysis as described in "The Architecture of Complexity" (Simon, 1962) is applied. Simon explains that all systems are hierarchical in nature and consist of interrelated subsystems, which in turn are also hierarchical in nature. When these cannot be subdivided further, we have arrived at the elementary building blocks of the respective system. At this level, a system can no longer be split without influencing its fundamental properties. The choice of boundary depends on the specific objectives of the researcher. For some objectives, atoms may be considered as elementary components, while in other cases they may be considered as complex systems, while in other cases again, entire stars may function as the elementary components of the system that is being studied. To determine the system levels that should be maintained considering the objective of this specific study, the aggregation levels as applied in other design and innovation models (as discussed in chapter 4) are used as a reference point. Thus we arrive at four aggregation levels: Level P is defined as the product-technology system. Level Q as the product-service system. Level R as the socio-technical system. Level S as the societal system.

The product-technology level (P) refers to tangible, inextricably linked technical systems, which in most cases can "drop on your toes" (although with "smart" products based this may not always be so evident). Product-service systems (Q) consist of a mix of tangible products and intangible service, designed and combined so that they jointly are capable of fulfilling a final customer need (Tukker and Tischner, 2006, 24). Socio-technical systems (R) are defined as clusters of aligned elements, including artifacts, technology, knowledge, user practices and markets, regulation, cultural meaning, infrastructure, maintenance networks and supply networks, that together fulfill a specific societal function (Geels, 2005). Changes that take place at this level are often referred to as a "system innovation", describing large scale transformations in the way societal functions are fulfilled (Elzen et al., 2004, 19). However, in this research it is not only about large-scale transformations, but also about more modest changes that may occur. Therefore the term "socio-technical change process" is used. The society, or societal system (S), is defined as "the community of people living in a particular country or region and having shared customs, laws, and organizations" (Oxford dictionaries). Changes that take place at this level are often referred to as a "transition", which are gradual, continuous processes of societal change, where the character of society undergoes structural change (Rotmans et al., 2000, 11). However, this research is not only about structural, large-scale societal change, but also about more modest, small-scale changes that may occur. That is why the term "societal change process" is used.

To develop the new multilevel design model, two steps are taken. First, a more or less generic design process is selected, based on the analysis of chapter 4. Next, this generic process is combined with the four aggregation levels as described in the previous section. The generic design cycle that forms the basis of the new model is made up of the four phases experience (X1), reflection (X1*), analysis (X2'), synthesis (Tx). This process can be described separately for each of the four system levels, which in symbol form looks like:

- Societal System: S1 → S1* → S2' → Ts → S2
- Socio-technical system: R1 → R1* → R2' → Tr → R2
- Product-service system: Q1 → Q1* → Q2' → Tq → Q2
- Product-technology system: P1 → P1* → P2' → Tp → P2

If these four processes are combined and presented in a graphical way, we arrive at the new multilevel design model. On each level an identical process is presented, only the width of the various layers differs. This is done to emphasize the difference in size or dimension of the system at the various levels, creating the characteristic V-shape. Off course, the model represents a gross simplification of the complex manner at which these processes take place, certainly at the higher aggregation levels (but as well on the level of regular product or service development). However, this simplification is an intentional effort to describe and potentially structure these processes in a simplified and systematic manner, and should certainly not be considered as an effort to "catch" or confine reality in any way. To be able to verify the new multilevel design model, five propositions are presented, which indicate the potentially explanatory and predictive value of the model. These are:

- *P-01: "The design process can be described and organized at various system or aggregation levels. The steps that are taken during this process are comparable at each of the various system levels."*
- *P-02: "Design processes can be described and directed at various system or aggregation levels. Systems at various aggregation levels affect each other's functioning, in both a "top-down" as well as a "bottom-up" direction."*
- *P-03: "The functioning of a system influences the functioning of the elements that it is composed of. The functioning of a product is therefore dependent on the product-service system, the socio-technical system and the societal system that it is a part of."*
- *P-04: "Each socio-technical or societal system is made up of subsystems. Change of a subsystem, as takes place in the introduction of a new product, influences the functioning of the entire system. Therefore the development of a new product which is a component of an envisioned future socio-technical or societal system, will hasten its realization."*
- *P-05: "Design processes take place at various system or aggregation levels. The nature of the system to be developed is different at each of these levels. A logical connection exists between the respective aggregation level, the system to be developed and the contribution from the designer during this process."*

The five propositions are not linked to the four research issues on a one-to-one basis, but together they cover all aspects related to the research question. The new model and corresponding propositions can be considered as the "tentative theory", which can now be critically tested in a process of "error elimination". The initial step of this verification process is the selection of the practical experiments to be conducted. Two projects emerge from this selection, namely the project "Autonomous Elderly" and the project "Youth in Motion". The next step is the actual carrying out of both practical experiments, which will be described in chapters 6 and 7.

6 *Chapter 6: Autonomous Elderly*

6.1 The societal challenge – "Autonomous Elderly"

6.1.1 Aging in the Netherlands

This chapter describes a project which has taken place in the period 2002 to 2010, with emphasis on the period 2004 to 2007. The societal context which is the focus of this experiment carries the working title "Autonomous Elderly". The elderly in Holland are doing well, according to the Social and Cultural Planning Bureau (SCP) (e.g. de Boer, 2006). Their life expectancy is high and they occupy a favorable socio-economic position, allowing them to live a long and active social life. This is confirmed in a report by the Dutch Scientific Council For Government Policy under the title "Reconsidering the welfare state" (WRR, 2006). According to this report, The Netherlands is a country with good care, and income of the elderly is well organized (Bussemaker, 2007). However when looking from a demographic perspective, the fact is that the amount of elderly people is rapidly increasing in numbers. This has substantial consequences for society. In the next few years, the number of senior citizens in The Netherlands will grow from nearly 2.2 million in 2000 to at least 3.2 million in 2020, an increase of 49% (van den Berg Jeths et al., 2004, 57).

6.1.2 Government vision on the elderly

A vision on the way that Dutch society should handle this fact is described in the government report "Policy on the elderly in the perspective of an aging population" (Ministerie van VWS, 2005), which includes a description of the basic values of government with respect to the elderly population. The most important value that is highlighted here is the awareness that the elderly are sovereign and valued citizens, also when at some point in time important resources for an independent existence are removed. The report also mentions the expectation that product innovation and technological developments can help the elderly to stay healthy and live independent for a longer time. That is why the responsible ministries promote, among others, the use of home automation technology to enable people to remain living independently (Ministerie van VWS, 2005, 57) (van Kammen, 2002).

6.1.3 Reflection – Organizational context of this project

This section outlines the societal context in which this experiment takes place. Apparently policy makers expect that new products can indeed help the elderly to function independently longer in society. Of course the designer has no direct influence on the developments described here, they mainly serve as input or inspiration for the design related initiatives to be taken. Here the question is how this societal context has influenced practical activities of the designer and other actors involved. Therefore we switch to the organizational context of the author at the time of this research, who is then project manager at the Product Development department of the "Industrial Technology" institute of TNO in Eindhoven, The Netherlands. In this position, he is a project member cooperating in a TNO wide research project in the area of sustainable system innovation in which the societal issue of the aging of society (along with several other societal issues like nutrition, mobility, water management and chemistry) is being connected to the knowledge base of the TNO organization. When looking to the multilevel design model of chapter 5, one could say that the aim is to connect the top level of the model (where societal challenges are being defined) is being connected to the lowest level of the model (related to the development of detailed technological knowledge).

6.2 New Initiative Sustainable System Innovation

6.2.1 Approach: "Sustainable System Innovation Method"

In TNO's strategy memorandum 2003-2006, a number of "new initiatives" are introduced, aimed at cooperation and integration of knowledge across the entire organization. One of these is the "New Initiative Sustainable System Innovations" (acronym "NIDSI"). These sustainable system innovations are defined as a "vital renewal of products, processes and production systems, targeting the realization of a substantial enhancement of ecological, economic and social sustainability" (Weterings et al., 2002, 2). At the core of the NIDSI project are five pilot projects, targeting complex societal questions in the area of elderly, nutrition, mobility, water management and chemistry. This description only focuses on the subproject related to elderly people. Concerning the name of the project, within the NIDSI project one speaks of the subproject Multifunctional Center (MFC) (van Sandick et al., 2007). In this chapter, the name "Autonomous Elderly" is maintained, since it covers the perspective from the MFC project as well as the wider perspective of the not formally related innovation projects. The NIDSI project aims at the realization of so-called "Societal Innovation Experiments", in which innovations are tested in a small-scale practical environment (van Sandick and Weterings, 2008). The project approach is quite similar to the back-casting method (Quist, 2007), following a retrospective process from a desired future perspective towards the steps necessary to actually realize this future. Five consecutive steps are being taken (van der Horst et al., 2003) (van Sandick and van den Berg, 2004), namely 1) domain exploration, 2) system definition, 3) system design, 4) system specification, and 5) practical experiment.

In step 1, the domain exploration, the societal issue is explored and combined with TNO's current knowledge in this area. This results in a number of innovation opportunities for the respective domain and a decision on what TNO can possibly contribute to this. It also provides a first view of which parties should be involved. This is presented together in a so called "Open System Concept", a future vision which is sufficiently concrete and challenging to appeal to relevant actors and which at the same time is sufficiently open to leave room for specific customization. In step 2, the system definition, partners are approached with whom the developments in the respective area are again examined, but now with specific focus on the interests of these parties. Based on this, future scenarios with a horizon of 5 to 10 years are drawn up, outlining the boundaries of the project to be implemented. In step 3, based on these scenarios, a concrete "end view" is developed, sketching the ideal view of the new situation 5 to 10 years ahead in time. This end view is then translated to short term innovation steps, with which this future ideal can be realized one step at a time. The technique is becoming more concrete in this phase and a program of requirements is drawn up for the technical design that will subsequently be realized and tested in practice. Step 4, the system specification, is where technology development and product development takes place and a plan is drawn up for the practical experiment to be conducted. Step 5 is related to the actual execution of the "societal innovation experiment" itself.

When the TNO Board of Directors approves the program proposal for the NIDSI project in March 2003, much preparatory work has been completed. A preliminary vision for a multifunctional center for elderly is presented, including a foretaste of the technical opportunities that come along with it (Weterings et al., 2002, 39). This multifunctional center meets daily needs, such as residences, teleworking, shopping, education, relaxation and short distance transport (van Sandick, 2003). The expectation is that these needs can be met on the basis of innovative, high quality technology, available at TNO and others. With this initial vision for the upcoming multifunctional center, the first step of the system innovation process is finished. The next step in the project is the search for compatible partners who can identify with the developed vision and with whom a potentially fruitful cooperation can be established.

6.2.2 Reflection – Preparing the New Initiative Sustainable System Innovation

In the preparation stages of the project, an effort is made to find out which current TNO knowledge could potentially assist in solving the societal challenges related to the aging of society. More concretely this is about establishing a connection between the specific knowledge available within the TNO organization, with the apparent needs of the envisioned multifunctional center. The department where the author is employed is at that moment has a lot of expertise about the development of "personal intelligent devices" and also has a lot of experience in the area of roadmapping, so a proposal is made to include those aspects in the project. Other institutes come up with their own specific expertise, among others in the areas of safety, climate control and health and care monitoring. The following emails give an indication of the communication process surrounding this 'puzzle', connecting the big picture to the knowledge base that the various departments have to offer.

June 18, 2002, from project manager NIDSI-MFC, to TNO researchers. Subject: Goals
Dear colleagues, Attached are the goals we have formulated following the workshop Sustainable System Innovation of last week Wednesday. Please provide us with answers to the following three questions:
1. Which technologies from your Institute could fit into the initiatives?
2. In how far would working on these goals be compatible with pre-existing projects / initiatives that you know about, both internal to TNO, as well as external?
3. Do you have any supplementary ideas that would enhance these ideas?
On Friday we would like to make a selection, based on your supplementary information. Best regards.

Friday, June 21, 2002, from department manager TNO Industrial Technology, to project manager NIDSI-MFC. Just before the closing date I still succeeded to put my reaction on (digital) paper, see attached table. Due to scheduling conflict it was impossible to consult with Peter Joore, who will react separately. Apart from that, the service/technology roadmapping can be implemented somewhere in the process within each objective, so I have not mentioned that in each case. Success with the compilation.

6.3 Cooperation with De Woonmensen, Apeldoorn

6.3.1 Cooperation between TNO and location Apeldoorn

To further develop the "Open System Concept" regarding the Multifunctional Center, a suitable project partner needs to be found. To that end contacts are made with three locations which all fit within the initial vision of the project. There are various contacts with municipalities that are working on a multifunctional complex, combining facilities around care, housing and other services. In the end it appears that the relationship with several organizations in the city of Apeldoorn provides the best opportunity for cooperation. In the previous years, the municipality has developed a vision about the way that the city wants to deal with housing circumstances (Gemeente Apeldoorn, 2002). Apeldoorn has a relatively large number of elderly inhabitants, as its location in the middle of nature area "De Veluwe" makes the city an attractive location for care institutions. In addition, the municipality is working towards a fundamental change in care, placing it more and more in the city and in the neighborhoods. For this purpose the municipality stimulates the introduction of "assisted living zones". These are neighborhoods where care is delivered 24 hours a day and where all services and opportunities for self-development, self-determination, safety and mobility are present (Gemeente Apeldoorn, 2002, 24).

Figure 6-1: Special Woonmensen Magazine regarding Hubertus-Drieschoten (De Woonmensen, 2004)

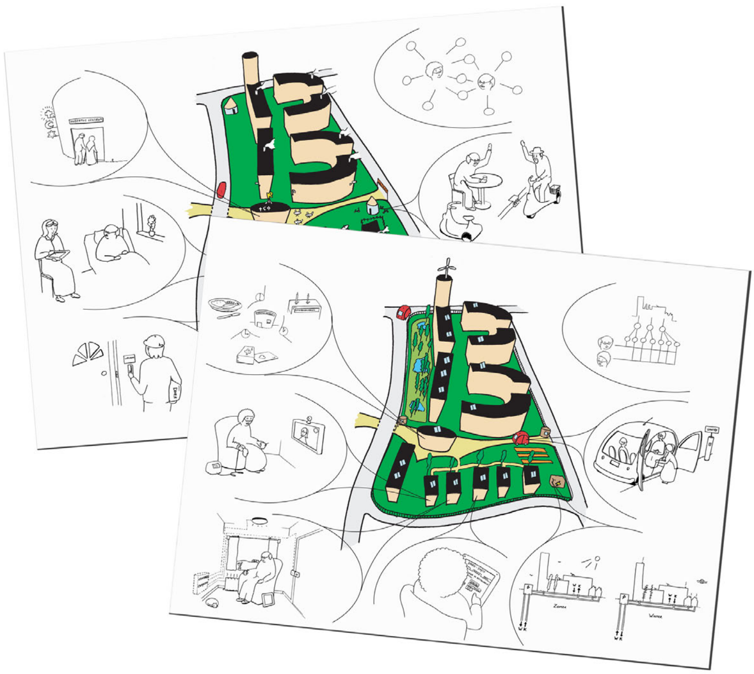


Figure 6-2: Scenarios "Freedom and Custom Care" and "Living Together and Carefree"

6.3.2 Development of assisted living center Hubertus-Drieschoten

A concept that fits perfectly within this vision for "assisted living zones" is being developed by housing and care organization "De Woonmensen", located in Apeldoorn and employing approximately 450 people including 200 volunteers. Of all the possible project partners, this organization appears to be the most enthusiastic about collaborating with TNO. They also have concrete questions already about the application of innovative technologies in the assisted living center they are planning to build. Moreover, the time perspective of both initiatives fit well together, since the expectation is that the new center will become reality in 2006, exactly within the timeframe of the TNO study.

The particular project concerns the renovation of an area called "Hubertus Drieschoten" in which small-scale independent housing for seniors and other households will be developed, with an emphasis on the prospective independence of the future residents. The project is located in the neighborhood Kerschoten and has a surface area of approximately 3.3 ha (8.1 acres). The plans for the site include 72 residences for families, independent living as well as assisted living for elderly, a church, a meeting room, a children's playroom, a physiotherapy practice, a home care organization, a restaurant, a store and a hairdresser. These services are also accessible to the residents of the surrounding neighborhood, with a total of 200 to 250 households. The vision is that the new complex does not look like a traditional seniors home, but that it will look like a regular street, fitting perfectly in the existing environment. However, care, welfare and services are always within reach and can, if necessary, be delivered at home, made-to-measure. During development, there is close contact with many related actors among which are the municipality of Apeldoorn, the local community center, the children's day care center, a foundation for home care, a physiotherapy organization and the residents of the neighborhood.

6.3.3 Reaction to the future visions

6.3.4 Reflection – MFC as a socio-technical system

From the perspective of the multilevel design model, the development of the Multi-Functional Centre in Apeldoorn can be considered as the design of a local socio-technical system which fulfills a specific societal function (providing housing and care for elderly people). In the new center, a combination of a physical space (the building) and possible technical solutions (e.g. home automation) are being combined with accompanying services like medical care and a physiotherapy center. All of these elements have to function within the government policy guidelines, for instance related to financing and insurance regulations. Based on the initial vision, the design process for the new center has started. Having said that, the design of the multifunctional center doesn't just begin when TNO gets involved, as De Woonmensen has a rather clear vision and objectives to be reached with their new center. It's clear that they themselves are in the lead, and the new TNO initiative is a good opportunity for them to strengthen this ongoing initiative.

6.4 Future scenarios and future visions

6.4.1 Future societal scenarios

At the end of 2003, the collaboration between TNO and De Woonmensen is taking further shape, among others by means of two workshops on November 5 and 24, 2003 (Gouverneur, 2003). Here a number of future scenarios about the way that the care system in the Netherlands could look like 5 to 10 years ahead are being discussed. The scenarios are based on two uncertainties. The first uncertainty concerns the degree to which the organization for care, housing and welfare will be open, demand-driven and flexible, or rather closed, standardized and supply-driven. The second uncertainty concerns the relationship between government and marketplace, indicating the degree to which society is organized publicly or privately. In order for the scenarios to appeal to the imagination, each scenario is labeled with a musical metaphor. The scenario Open/Public gets the title “Flute Player on the Mountain” and sketches an image of small-scale care, financed with public funds. The scenario Open/Private is also based on small-scale care, but more from a self-organized perspective, hence the title “Jazz Improvisation”. “Russian State Orchestra” is the title for the Closed/Public scenario, which offers more large-scale, standardized care. The “Andre Rieu Orchestra” scenario is indeed organized on a large-scale, but from a self-directing, commercial perspective. The future scenarios are not necessarily intended as a design sketch, but as possible extremes within which a possible future can occur. Parallel to the development of the scenarios, an initial sustainability scan is also completed in this period, which maps the opportunities for energy conservation, for example, in the new multifunctional center (Tempelman, 2003).

6.4.2 Future Visions

The next step in the research process is the development of several “desired future visions” or “ambitious visions”. Here an image is sketched of what the new neighborhood would ideally look like in 15 years. The four societal scenarios are now applied to more elaborated future visions of the multi-functional center (van Sandick et al., 2004) (van Sandick, 2004) (van Sandick and van den Berg, 2004). In future vision “Freedom and custom care”, the emphasis is on the individual responsibility of the residents. The organization of Hubertus Drieschoten is characterized in this perspective by openness and free market processes. In the second future vision “Living together and carefree” , the emphasis is especially on the collective aspect of the solutions. In the visualization of the two future visions, an indication of possible related products is given. The contrast between the individual and the collective is a clearly distinguishing criterion for potential products to be applied. For example in the vision “Freedom and custom care”, transportation of the residents is arranged with the help of individual scooters. In the vision “Living together and carefree” this happens with the help of collective shuttle buses that take people anywhere on the site, using automated vehicle guidance. This contrast is not as explicit for all components, as for instance a system that monitors residents in their dwelling fits perfectly in both future visions. Particularly the organization and financing of the system will be different in each case; the technical aspects will be mostly identical.

In order to find out about the opinion of possible future residents, a number of in-depth interviews are held with current and potential residents of the new neighborhood (Dries and Hoving, 2004). The comments on the presented future visions can be arranged into the three subjects, “health, well-being and safety”. It appears that the theme sustainability is not very high on the agenda. In order to map the opinion of professional parties, a workshop is organized on May 26, 2004 with about 25 representatives of companies, care organizations and government. To support this process, a vision booklet is designed, in which the various ideas surrounding the multifunctional center are visualized (see *Figure 6-3*). The booklet includes a roadmap indicating the potential roadmap for the development of various ideas. The reactions on the future visions indicate no clear preference for either the individualistic, or the collective future vision. The most important aspect appears to be freedom of choice, with a good balance between individual and collective solutions. Based on the feedback results of the workshop, the problem definition is adapted and defined as:

> *“How can elderly in 2015 remain living independent longer, with a higher quality of life, at acceptable costs?”. We believe that this can be achieved by integrating technological, organizational and social systems, while paying attention to living, care, wellbeing and safety. We aim at achieving a situation that will both be sustainable from an economical, a social and an ecological perspective.” (van den Berg et al., 2004, 6)*

Figure 6-3: Vision booklet "Inspiration for Housing, Care and Well-Being of Elderly" (TNO, 2005)

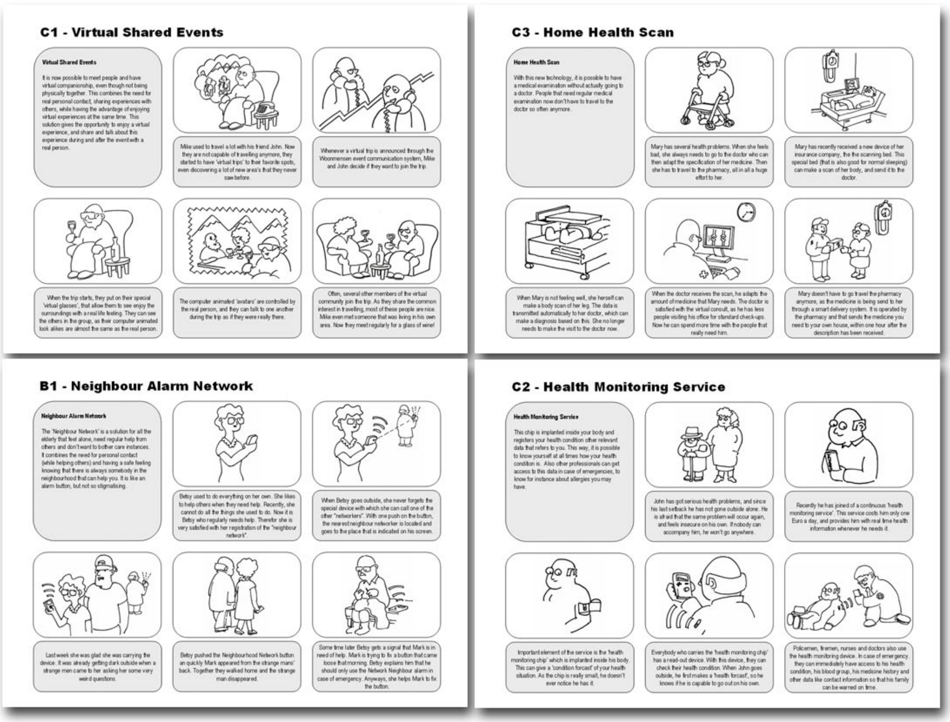


Figure 6-4: Solution scenarios within the subsector telemonitoring (Joore et al., 2004)

6.4.3 Reflection – balancing the whole system against the parts

Based on the new problem definition, the question is how to get more concrete about the details of the future visions. Which technology will be developed to be applied in the new assisted living center? Early 2004, the research team evaluates the developments up to that point. This process highlights the tension that exists between the somewhat “product or technology-oriented” expertise of several TNO-experts involved (including the author), as opposed to the more “process-oriented” experts within the project. In addition, the more organizationally-oriented solutions (as opposed to technological innovations) seem to be the most urgent point of attention for De Woonmensen. It appears more difficult than was first thought to discover common ground between the quite diverse areas of technology that are taken into account. Synergy advantages from the parallel development of, for example, heat pump technology, care services and mobility solutions seem to come across somewhat forced. The technology-oriented experts (including the author) indicate that it is necessary for them to get more into the finer details of the solutions that are envisioned, so it is possible to “really get to work”. On the other hand the more process-oriented experts indicate that the broad multidisciplinary focus of the project must remain guaranteed. Apparently the relationship between the broad vision and the narrowly defined subsectors is not that simple.

A closely related discussion is about the role of the various actors involved, including TNO itself. In the project meetings of February 12 and March 8, 2004, it is discussed how new companies can become involved in further developing the future visions discussed. One question seems to be in how much detail a certain concept should be explored, before it is interesting for companies to step in. TNO has no desire to be some sort of broker who brings together the supply and demand of companies and care institutions. And it is certainly not the intention that the NIDSI project is seen as an easy way to collect subsidies. A related issue is the manner in which intellectual property rights are handled and the question whether companies will want to openly and jointly develop new products. After all, there's always the risk that one's own ideas will simply be taken over by others. Furthermore, the risk emerges that companies will only cooperate with the project to ensure that competition remains outside, without actual interest in contributing to the success of the project. The proposed joint adventure should be a vital point of interest, where some parties will gladly join together in one single consortium, and others may refuse. To support this process, it is proposed to profile De Woonmensen as “launching customer” and potential client for the companies involved, with the new neighborhood as a beckoning perspective on the horizon. The role of TNO is defined as “system architect and process leader of a system innovation” (van den Berg, 2004).

In the multilevel design model presented in chapter 5, this tension apparently is related to the “crossing” of the border between the higher level of the socio-technical system (the multifunctional center) and the lower levels of the elements that this system consists of (the detailed products, the innovative technology). This tension between the “big picture” of the multifunctional center, and the “small elements” that form part of the new center, can be recognized in an email discussion about the content of the Vision booklet. One of the possible ideas mentioned in the workshops is an implanted chip to monitor people’s health or location. Although this concept can be considered very promising from a product or technological perspective, it is not yet clear if the concept will be considered as attractive from a “higher” point of view.

> *From: Project manager NIDSI-MFC, Monday, February 21, 2005*
> *Dear everyone, as most of you know we are making a booklet for De Woonmensen in which our vision is explained. Could you please give your comments on the texts of the booklet.*
>
> *From: Peter Joore, to project manager MFC, Monday, February 21, 2005*
> *I would like to suggest that the heading “Chip implant” be removed from the roadmap. I believe this is a very controversial idea (obviously to get the discussion going), and that it should not be presented as*

something you want to work towards. Unless you indeed want to stimulate discussion about these kinds of controversial end views, but in that case the other ideas should perhaps also be more extreme.

On top of all it turns out that none of the actors involved in the project appear to have a direct interest in the aspect of ecological sustainability, unless this is paired with financial advantages for the organization. Apparently the more overlying, society-wide sustainability interest is not being represented by the various actors. The only one who does appear to be concerned about this is the representative of the “Sustainable Construction” department from the municipality of Apeldoorn, who, besides existing legislation and regulation, has limited means available to influence the direction of the project's development. It seems there is no one “onboard” to properly represent this interest. On the other hand, the issue of social sustainability (health, safety and wellbeing) appears to fare much better, as it is directly related to the care services of De Woonmensen. When looking to the multilevel design model, it appears that the objectives to be reached by the various actors are defined by the system boundaries they apply. In this case, this is mainly about the new living center. Only when the aspect of sustainability “crosses the boundaries” of this system, the issue becomes relevant to take into consideration (for instance from the perspective of costs or comfort of the users). As long as it remains a “societal issue” (outside of the boundaries of the direct environment of the actors), the issue is apparently not that big an issue.

6.5 Subsector telemonitoring

6.5.1 Splitting the future vision into subsectors

In order to meet the apparent need for more technological depth, the project is divided into several sub-areas, which will allow for more technological depth when looking into specific solutions. The first subsector relates to “housing, care and safety”. This in turn is divided into two sub-areas. The first one is the development of “sensor and networked technology in personal alarms”. The second is the area of “telemonitoring”, which is aimed at the development of systems where the user and the care providers get feedback about the physical well-being and behavior of the user. Work in the subsector “constructing the environment” involves the inclusion of cold and heat technology in buildings. Increasing comfort and energy conservation by the application of home automation and sustainable construction at the neighborhood level fall under this theme. The subsector “mobility in the neighborhood” has to do with the development of innovative mobility concepts for transporting persons and goods within the neighborhood. This thesis focuses specifically on the topic of telemonitoring. In an initial orientation on this subsector (Eikelenberg et al., 2004) the working area is defined, the relevant actors and financial structures are mapped and a review is done of current technical and organizational developments.

6.5.2 Reflection – Looking for the “Egg of Columbus”

The choice to zoom in on the subtopic telemonitoring is related to the specific focus of the Product Development department at which the author is working at the time of the project. In this period, the research focus of this department focuses on the application of sensor technology in small and wearable products.

In the next phase, the concrete development of new products is pushed more expressly by the author, finding ways to translate the broad vision of the MFC project into the concrete development of new products. Several hands on initiatives are being taken to get this process started (e.g. Joore and van Gestel, 2004), among others by initiating a student design project at the faculty of Industrial Design at the TU/e (Loh et al., 2004), by means of a workshop with about 80 attendants in which even more new concepts and ideas are being generated (Garcia Lechner and Joore, 2004), and by means of the development of a new future vision, focusing on the sub-area telemonitoring (Joore et al., 2004). However this new future vision still turns out to be quite wide-ranging, even when only considering the sub-area telemonitoring. To support the choice for one specific product, the project team is making an attempt to search for a so-called "breakthrough element". Such an element would then be a strategically crucial innovation that signifies a large step forward in enabling elderly people to remain living independent longer, with a higher quality of life, at acceptable costs. This effort turns out to be in vain, as there doesn't seem to be one single "egg of Columbus", that serves as the key to achieve this goal. In reality it appears to be about a very wide range of solution elements, each in itself bringing the desired future closer, step by step.

6.5.3 Concept development within subsector telemonitoring

In the next period, several telemonitoring concepts are being designed by the department of Product Development, among which the "contact television", for a grandparent to communicate with the grandchildren, an "SMS picture frame" or "SMS ring", allowing people to receive SMS messages without having to handle a complex mobile telephone, an "alarm ring" as a miniaturized variant of a fall-detection system, which is usually carried around to neck stop listening, a "smart diary", which indicates when medication has to be taken (Joore and van Gestel, 2004). Together with TU/e, a symposium entitled "Smart Care Solutions" is organized by TNO on October 20, 2004. This is attended by more than 80 care institutions, companies and designers, to brainstorm about new solutions in the care domain. Concrete care applications are discussed in the workshops, led by theme experts coming from the relevant care sectors. The day results in even more new ideas which are compatible with the subsector telemonitoring (Garcia Lechner and Joore, 2004).

6.5.4 Future vision subsector telemonitoring

In order to organize the large number of ideas, even within the subsector telemonitoring, an attempt is made to transform the earlier developed future visions to this subsector. However, the contrast between the individual scenario ("Freedom and Custom Care") and the collective scenario ("Living Together and Carefree"), which was used earlier in the future visions, does not appear to have a distinguishing effect for the subsector telemonitoring. Therefore two new future visions are developed. The first version is entirely focused on technological solutions, the other entirely on organizational solutions. This is followed by a search for a balance between the two extremes, where the positive aspects of both solutions are combined (Joore et al., 2004). A list of 35 "solution elements" is made up on the basis of both visions and the technological and economic feasibility is investigated for each of these possible solutions (Joore et al., 2004, 25-39). All in all, there are still a huge amount of possible new products and other solutions, even within the telemonitoring subsector. For sure there are too many to develop them all, so the question is how to proceed.

6.5.5 Guide Me development by student team

From January 2004 on, one of the ideas, the Guide Me system, is being further designed in a 3 month project at the faculty of Industrial Design of the TU/e. Here the concept is put before potential users and their relatives who are visiting with a so-called Alzheimer Café. Some progress is also made with the technical development of a system which is based on a combination of GSM and GPS technology. The reaction of end-users is being analyzed by doing a user study based on the "Wizard of Oz" technique. This includes a simulation of the functionality of the new product-service combination, without actually requiring the product to be developed. Reactions from the potential end-users and their relatives are rather positive (Loh et al., 2004). Some respondents would like to purchase the system as soon as possible. The reason for this interest is the fact that in the current care situation, even people with early symptoms of Alzheimer cannot be left alone in their own home. Many times, these people start wandering outside, resulting in caregivers having to go out and look for them, sometimes for hours. In many cases, a simple solution is used

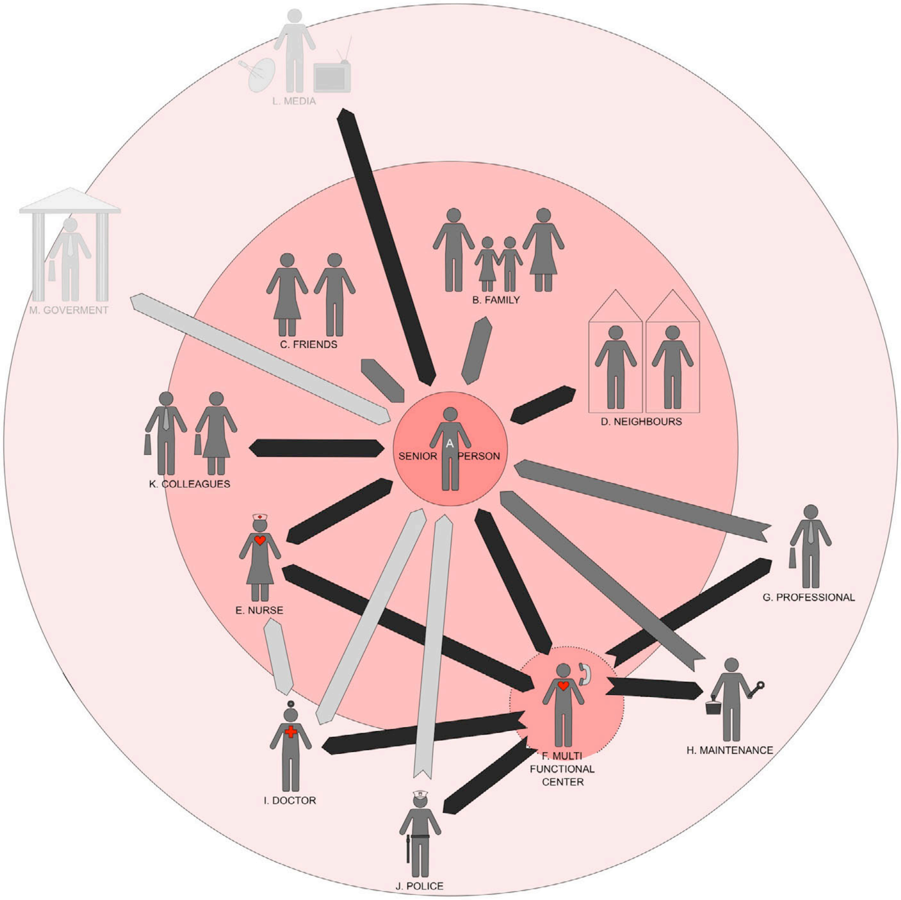


Figure 6-5: Who communicates with whom in the multifunctional center? (Joore et al., 2004)

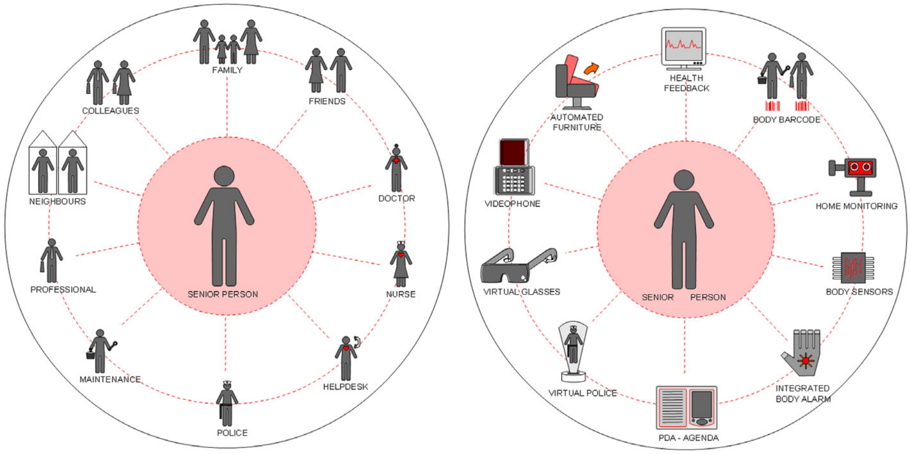


Figure 6-6: Left, telemonitoring scenario on the basis of relationship; right, scenario on the basis of technology (Joore et al., 2004)

by locking the doors of their homes. This way, patients can't get out at all. In many of those cases the patients have to move to a closed care situation, which indeed contradicts to the earlier mentioned government goal that is aimed at enabling elderly people to remain living independent for a longer time (as mentioned in paragraph 6.1.2).

6.5.6 Reflection – Some delay along the way

During the project it appears that different actors have different time frames in mind regarding the development of new products. While the application of much commercially available technology is already quite revolutionary and trailblazing for housing and care organization De Woonmensen, the TNO institutes involved would like to develop even newer technology, with an implementation horizon considerably further into the future. The development of the new center as a whole has its own planning issues. Although construction of the new neighborhood is planned for 2006, the specifications will need to be ready at a much earlier stage. When defining the specifications of their new center, it is not desirable for De Woonmensen to specify technology which is not yet commercially available and has not yet proven to be functionally viable.

During the course of the project it becomes clear that the start of construction is being pushed back further and further. Ultimately the first pile for the new complex is put into place in 2009 (De Woonmensen, 2009, 16), but that is not yet known at that time. It is becoming clear however, that the realization of the multifunctional center will fall outside the horizon of the three-year TNO project, since it will terminate at the end of 2006. It appears that the chance of actual implementation of a large-scale multidisciplinary experiment during the course of the project is getting smaller. That means a direct link (at least in time) between the development of the bigger socio-technical system of the new multifunctional center, and the development of the potential new products that could be part of this center, appears to be rather difficult. However, the cooperation with De Woonmensen could still be valuable from the perspective of new product development.

In his search for the development of concrete new products, the author is trying to connect the various ideas mentioned in the previous section, with commercial partners that would be interested in developing these products together with TNO. Perhaps by looking at the cooperation with De Woonmensen from the other side could put things in a new perspective. Looking to the multilevel model one could say that instead of trying to define "top down" what new products would be useful for the multifunctional center, the perspective could also be looking "bottom up" at the way that the new multifunctional center or the cooperation with De Woonmensen could be useful for a potential new product (for instance with the new center as an potential testing area). One of the companies the author gets into contact with during this period is My-Bodyguard BV, a small company from the east of The Netherlands.

6.6 Guide Me and My-Bodyguard

6.6.1 My-Bodyguard BV

In 2002, the same year that the TNO NIDSI project is started, the owner of company 3SP in the Dutch city of Haaksbergen is jolted by an event in his environment (My-Bodyguard BV, 2003). In Ahaus, just across the German border, a little girl fails to come home after rollerblading. This is big news in the region and an extensive search over several weeks takes place in the German and Dutch border region. Weeks later she is found in the forest by playing children. The girl apparently was taken away not far from her home, abused and left for dead in the forest. The manager of 3SP can see the anxiety of parents in the area and he is wondering how he can protect his children against such a crime. Could it be possible, he wonders, to send an emergency signal with a simple push of a button, without the attacker realizing it? While developing his idea, he is becoming convinced that other target groups can take advantage of such an alarm system (My-Bodyguard BV, 2007). Together with his business partner, they search the Internet to see if something similar already exists. To their amazement it appears that very little is available. "Something new must be possible" is their conclusion.

One year later they have developed "My-Bodyguard". A business plan is written which is the foundation for attracting private investors. After the project got underway at 3SP, it is later housed in the new company, My-Bodyguard BV. Initially the system is primarily targeting people with a speech impediment, caused by aphasia, which prevents them from using a regular phone to call the 112 alarm number. Starting January 2003, work is progressing towards a test with 120 aphasia patients, who get to use the system at no cost. Besides this application, the company is looking to other markets, for example for the protection of VIPs or tracing of vehicles. Agreements are entered into with police and the Ministry of the Interior and Kingdom Relations about the transmission of emergency calls to the 112 call-center (the equivalent to "911" in some other countries) of the National Police organization (KLPD) in Driebergen. The equipment is officially recognized as an alarm system and in December 2003, Dutch minister Remkes gives the green light for national distribution of the system (AVN, 2003) by symbolically transmitting the first emergency call (Remkes, 2003). Production gets going during 2004 and sales can begin.

The My-Bodyguard system consists of a device with two buttons, the size of a package of cigarettes. It is activated by holding down the two buttons simultaneously for three seconds, after which the device will make contact through the nearest telephone network with the 112 call-center, or with a private agency. Once My-Bodyguard is activated, it will continue to call the alarm number until the preprogrammed message has successfully been transmitted. The device then automatically reports: "I am a person in danger. Please notify the police. My position is ... East and ... West". If necessary, personal data such as medical information can be added to the preprogrammed text.

6.6.2 Reflection – making connections

The author contacts My-Bodyguard BV in May 2005, in order to gather more information about their mobile alarm system. Because there appears to be a lot of overlap between some of the ideas from the NIDSI project and the products of My-Bodyguard, a meeting is planned to get better acquainted. In the meantime, the previously mentioned student project "Guide Me" was wrapped up, resulting in rather positive reactions from potential end users. To communicate the idea with potential business partners, a leaflet is designed representing the concept. The author explains to the management of My-Bodyguard about the collaboration with De Woonmensen. During the conversation, the idea is discussed to conduct a user's test with its residents. This appears to be a good opportunity for My-Bodyguard to further widen the reach of its products. Cooperating with "the big TNO organization" can certainly offer opportunities, and approaching a new group of potential clients through De Woonmensen seems attractive.

A meeting takes place between De Woonmensen and My-Bodyguard BV on June 29, 2005. On the agenda is a discussion of the outcome of an earlier users study, as well as the idea of a small-scale users study based on the idea of the Guide-Me system combined with the existing system of My-Bodyguard. (Schietecat, 2005) (Eikelenberg, 2005). Everyone is enthusiastic about conducting the test, which can get started very soon. The following email discussing gives an impression about the discussion regarding the way that the connection is being made.

Thursday May 26, 2005, from Peter Joore to management of My-Bodyguard BV. Dear sirs, I really enjoyed visiting your company yesterday and enjoyed seeing how you develop the various localization products. I was also glad to hear that the project we are planning appears to be compatible with your ideas."

Monday, June 20, 2005, from Peter Joore to management of My-Bodyguard BV. Subject: Appointment about users study My-SOS, June 29, Apeldoorn. "Dear sir, the appointment on June 29 is at 15:30 in Apeldoorn. The appointment is with the manager Building Development and his assistant from De Woonmensen. I will be there myself representing TNO, along with my colleagues, a project leader and a user's study expert.

Wednesday, July 6, 2005, from: TNO project leader to My-Bodyguard BV, De Woonmensen, Peter Joore. Subject: meeting notes De Woonmensen, My-Bodyguard, TNO, dated June 29, 2005
Ladies, gentlemen, Please find attached the meeting notes of our meeting of last week Wednesday. (...) A summary of the action items from the notes is listed below, for the speed readers. Meanwhile I have also arranged to omit the alarm function in the first test, and to focus the test purely on taking the device along for fixing locations. (…) Action items: 1) I will write a one-pager (A4) to recruit caregivers / participants and sends this to De Woonmensen on Thursday, 2) De Woonmensen will ensure that feedback will be on A4 by the end of week 27, 3) I prepare the plan for the users test, 4) My-Bodyguard sends system + users guide for My SOS and Palm/internet to TNO, 5) when the A4 is approved and planning + global script is approved, De Woonmensen will recruit caregivers and residents, 6) TNO user researchers set up, test and modify the script (if necessary)."

Looking from the perspective of the multilevel design model, apparently a connection is being made between the socio-technical level of the assisted living center, and the product-service level of the mobile alarm system. The fact that there is an already functioning system available is rather helpful in creating this connection, as it is now possible to "really get things done". Having said that, the interpretation of "really getting things done" apparently differs. From the perspective of researchers that have an interest in developing fundamentally new technology, the alarm system of My-Bodyguard is not very relevant. After all, it is based on existing technology (so nothing new needs to be developed). On the other hand, from the perspective of De Woonmensen, the introduction of such a mobile alarm system is very new indeed, as it could radically influence the way their organization functions. Simply said, the exact same device can be "old news" from one perspective, while being "hot news" from another perspective.

6.6.3 Users study Guide Me system

To enable the user test, My-Bodyguard modifies the software and buttons of five existing products, based on the specifications that result from the discussions with TNO and De Woonmensen. Among others, a new user interface is implemented, so that caregivers can not only follow the location of residents on a fixed computer, but also on a mobile device. This way the system can be implemented in a user test at an existing location of De Woonmensen. The investigation takes two weeks. During this period the system is used by three residents and three accompanying caregivers. The choice of compatible residents for the test turns out to be a rather difficult. The Guide Me is intended for (early onset) Alzheimer patients, but in the current situation they live in a closed environment. Therefore it appears to be pointless to do a user's test with these residents, since they will always be in the same place, namely in their residence. Therefore the choice is made to conduct the study with reasonably healthy, mobile residents. Residents and caregivers each maintain a journal to record their experiences with the system. Extensive interviews follow after the conclusion of the study, in order to discuss their experiences and possible improvements of the system. The message that the product is intended for residents with early onset dementia, or those who tend to go astray, appears to backfire. None of the residents can identify with this profile and they indicate that the product is "therefore not intended for them". And yet, one of the test users is so positive about the system that he would prefer to purchase it immediately, which is unfortunately impossible. Management of De Woonmensen indicates that this is a point of interest for a subsequent test. They would rather not be raising expectations that cannot be met, thereby disappointing residents. The next time they would rather study a product that can immediately be implemented by the organization, if the results are positive.

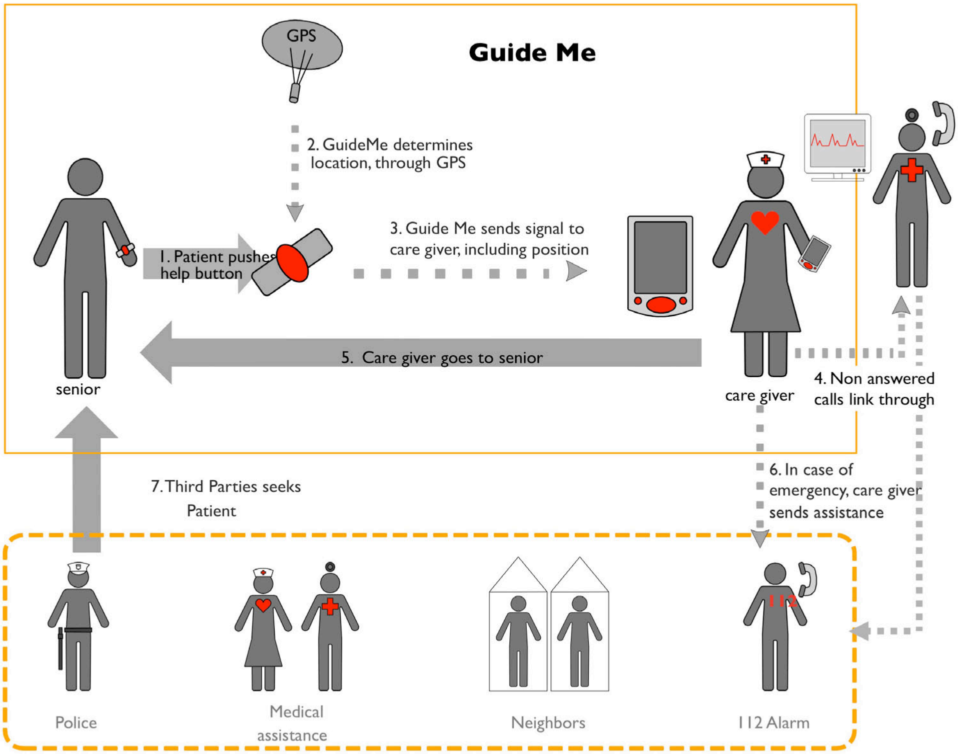


Figure 6-7: System map of the Guide Me system

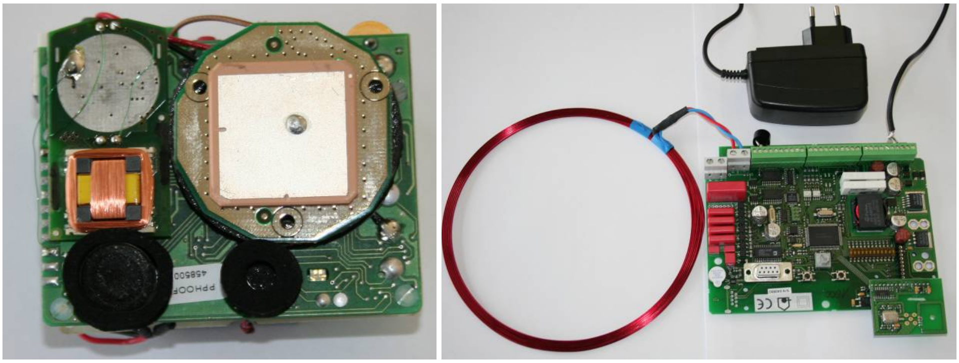


Figure 6-8: Sensor assembly and door module of Guide Me system (Siemerink, 2006b)

For the caregivers it is particularly the logistics surrounding the system that play a role. This is based on the often changing shifts by caregivers. This means that responsibility for residents is constantly transferred to another caregiver. This is not a problem in this short-term test, but it is an important point in case of a wider implementation of the system. Ultimately it is agreed that the establishment of a 24-hour reporting center is the appropriate way to deal with this. This center can, if necessary, call the available caregivers. Another point of interest is related to the responsibility for the residents. The caregivers are not formally responsible for residents if they choose to go outside. And yet, a moral responsibility is felt to search for a straying resident. With the introduction of the Guide Me system, this responsibility is perhaps even less clear; after all, the location of a resident would now be known at any time.

6.6.4 Reflection – moving at different speeds

A more detailed discussion of the social aspects of localization systems can be found in (Joore, 2008). Although the system is intended to potentially make it easier to find straying residents, it may well have the opposite effect. The reason is that it he introduction of the system may well be accompanied with new tasks and responsibilities for caregivers which did not previously exist. This means that new care protocols are necessary, should the new system be implemented (Kok et al., 2005). Although it is clear that quite a few problems will have to be solved before the Guide Me system can be widely implemented, all parties have the impression that the system is promising. So now it's a matter of dotting the i's, which requires a closer look at the (technical) details of the system. From now on, the project description will focus solely on the development of the Guide Me system by My-Bodyguard BV. Although the relationship with De Woonmensen proved to be a valuable experience for the company, they need to focus on their regular business. From the perspective of My-Bodyguard, De Woonmensen is only one of the many potential clients for their alarm system, and the company cannot depend on only one potential client to base their business on. As it turns out that the decision to actually adopt the system on a larger scale in Apeldoorn will take some time, the company "moves on" to other clients.

From the perspective of the multilevel model of chapter 5, it seems that developments at the various innovation levels each have their own momentum. Although they may mutually interact, they apparently are not totally dependent on each other. My-Bodyguard doesn't "wait" for De Woonmensen to decide if they want to adopt the Guide Me system or not, but takes its own route. Looking from the other side, De Woonmensen is not "dependent" of My-Bodyguard either. As will be described in section 6.8.1, they end up adopting a competing system of the local alarm organization "Paraat", instead of the system of My-Bodyguard.

6.7 Detail development Guide Me

6.7.1 Reflection – supporting the development of the Guide Me

At this stage of the project, the author finds himself facing the question what role he is supposed to play within this process. As mentioned in section 6.4.3, TNO has defined its own role as "system architect and process leader of a system innovation". Looking from that perspective, in this particular track one could consider the role of TNO successfully finished. The link between different organizations is made and innovative technology is being applied. This result can, on a micro level, be considered as a "vital renewal of products, processes and production systems" (which is, as described in section 6.2.1, one of the goals of the NIDSI project). Of course one could question if this relatively small innovation actually contributes to a "substantial enhancement of ecological, economic and social sustainability" (which is the other goal of the NIDSI project), but at least a concrete step is made.

On the other hand, the preliminary Guide Me system is based on an existing alarm system of My-Bodyguard. A lot of development work still needs to be done to actually resemble the concept of the Guide Me system as envisioned in the original design. For instance, the current device of My-Bodyguard consists of a rather big, black "box" which isn't really suitable to be used by elderly people. During this period, the author is moving to a new TNO department, which is focused on the technological theme "rapid manufacturing". For product developers this offers opportunities for customizing products, where they are adapted to the individual wishes of the user. Combining this knowledge with the rather "basic" casing design of the existing My-Bodyguard device, it soon becomes clear that this new knowledge could possibly be interesting if applied by My-Bodyguard.

EDWIN SIEMERINK, MY-BODYGUARD BV:

'We kunnen lekker snel schakelen'

My-Bodyguard bv was een van de zeven bedrijven die door TNO werd benaderd voor het project 'Guide Me'. Uiteindelijk werd het ook het bedrijf waarmee TNO in zee ging voor het ontwikkelen en vermarkten van het systeem, bedoeld om mensen met Alzheimer te kunnen traceren. De start was in november 2006 en de ontwikkelingen en successen volgen elkaar in rap tempo op.

Tekst: Adrie Beyen

'Een krantenberichtje over de vondst van het lijk van een vermist meisje was aanleiding om ons te verdiepen in personenalarmering. We bedachten dat een simpel GPS-alarmeringssysteem dit waarschijnlijk had kunnen voorkomen. Een speurtocht op internet maakte duidelijk dat er op dit gebied weinig was, en wat er was kon beter. Zo werd het idee voor My-Bodyguard geboren, een klein alarmeringskastje ter grootte van een sigarettendoosje dat een noodoproep met GPS-positie naar 112 verzendt. We schreven een businessplan, voerden een proef met 120 afasiepatiënten uit, testten met politie en ANWB, en maakten afspraken met 112. In december 2003 werd My-Bodyguard officieel erkend als 112-alarmeringssysteem en kon de productie starten. Inmiddels hebben we drie producten: My-Bodyguard, My SOS en X-trace. Hiermee bedienen we klanten in de zorg, de beveiliging en objectbewaking. Samen met onze distributeurs zetten we het systeem in de markt. Het vergt veel voorbereiding en begeleiding om de verkoop in een nieuw land op gang te krijgen. Wij leveren de distributeur het systeem en de kennis om het in de markt te zetten. Samen zoeken we er de telecomprovider, alarmcentrale en het beveiligingsbedrijf voor de opvolging bij. En daarna is het aan de distributeur om de verkoop te realiseren.'

Validatieplan

'In 2005 werden we door TNO benaderd voor een project bij Stichting De Woonmensen in Apeldoorn. TNO was bezig met de ontwikkeling van "Guide Me", een volgsysteem voor Alzheimerpatiënten. Wij hebben een aantal Alzheimerpatiënten uitgerust met My SOS. Binnen enkele dagen was al duidelijk dat GPS werkte – dat was dus niet het probleem, maar wel: hoe zorg je voor meer draagcomfort? We kwamen tot de conclusie dat een apparaat specifiek voor Alzheimerpatiënten welkom zou zijn. TNO stelde voor techniek te ontwikkelen waarbij het systeem in een speciaal voor de gebruiker ontworpen behuizing kon worden gedragen, in een voorwerp waaraan iemand zó is gehecht dat hij het altijd bij zich heeft. Maar de productie hiervan is ongelooflijk ingewikkeld. Daarop hebben wij voorgesteld om een kleiner kastje te ontwikkelen. TNO schreef een tender uit, waarop wij een haalbaarheidsonderzoek mochten uitvoeren. De uitkomst was een validatieplan dat tegelijk de projectomschrijving is. Ook de uitvoering is ons gegund. We hebben in het plan aangegeven dat "Guide Me" niet alleen is voor mensen met Alzheimer, maar voor alle patiëntengroepen en ouderen die er gebruik van willen maken. Dat het apparaatje kleiner moet en zeer eenvoudig te bedienen. Dat het zoeken en vinden van de drager zeer eenvoudig moet zijn en de interface zo toegankelijk mogelijk. En ook dat je moet kunnen detecteren of iemand binnens- of buitenshuis is. Dit laatste is met GPS niet mogelijk, want als iemand in een flat op de derde verdieping woont, krijg je als laatste positie van die persoon de voordeur van het flatgebouw op de begane grond. De technologie die we hiervoor hebben ontwikkeld, draait momenteel al. Deze wordt bijvoorbeeld ingezet voor alleenwerkers, waaronder mensen die solo in een chemische fabriek werken. Als zij een chemische stof inademen en op het toilet onwel worden, kunnen ze snel getraceerd worden.'

Valdetectie

'Ook hebben we een valdetectie ontwikkeld. We maken hiervoor gebruik van een combinatie van technieken, waaronder hoekverdraaiing en G-kracht. In 95 procent van de gevallen kunnen we dagelijkse activiteiten onderscheiden van een val. We hebben dit getest in samenwerking met het Epilepsie Instituut.

Door de samenwerking met TNO zijn onze ontwikkelingen in een stroomversnelling geraakt. Als je binnen TNO de weg weet, kun je heel snel schakelen, mensen heel snel bij elkaar brengen, technieken overhevelen, noem maar op. Het is natuurlijk ook een kennisinstelling. We kunnen goed sparren met TNO; de discussies maken al snel duidelijk of je op de goede weg zit. Wij hebben TNO ingeschakeld bij de ontwikkeling van het volumeconcept van het kastje. Ook kennis op het gebied van productietechnologie, ergonomie en elektronica hebben we goed kunnen gebruiken. Er zijn modellen gemaakt met rapid prototyping, dat werkt heel verhelderend. Nu onderzoeken we of we een horloge kunnen ontwikkelen dat samen met "Guide Me" werkt en bijvoorbeeld de enkelband van gedetineerden kan vervangen.

Ik ben superenthousiast over TNO. Ik kan me voorstellen dat MKB'ers zich soms afvragen hoe ze binnen moeten komen en wat ze er dan aan hebben. Ik kan ze verzekeren, dat als je eenmaal binnen bent, je toegang hebt tot ontzettend veel kennis. Peter Joore weet voor ons alle kennis die we nodig hebben te mobiliseren. We kunnen met hem lezen en schrijven.'

DE TNO EXPERTISE

Ir. Peter Joore

'Om een bijdrage te leveren aan brede vraagstukken in de maatschappij hebben we een methode ontwikkeld om langetermijnproblemen te vertalen in innovatiekansen waarbij onze technologie een meerwaarde biedt. Met behulp van Maatschappelijke Innovatie-Xperimenten (de MIXT® aanpak) is gewerkt aan het thema vergrijzing, waarbij is ingezoomd op de wens van ouderen – in dit geval mensen met Alzheimer – om langer zelfstandig te blijven wonen. Dit heeft geleid tot de ontwikkeling van het "Guide Me"-systeem, dat verder is ontwikkeld door My-Bodyguard met ondersteuning van de SBIR- (Small Business Innovation Research) regeling. Het bedrijf betaalt zelf de kosten voor het commercialiseren en vermarkten van het product.'

Info: peter.joore@tno.nl

DE RELATIE

Edwin Siemerink is een van de twee directeuren en verantwoordelijk voor businessdevelopment.

My-Bodyguard bv in Haaksbergen is actief in de personenalarmering en tracking & tracing van objecten. Het bedrijf ontwikkelt en verkoopt een systeem voor signalering, positionering, alarmering en opvolging. De klanten bevinden zich in de zorg, beveiliging en objectbewaking. Het bedrijf is lean and mean ingericht; dat betekent dat voor ontwikkeling en productie wordt samengewerkt met andere bedrijven. Samen met distributeurs wordt het My-Bodyguard concept in de markt gezet. My Bodyguard komt voort uit 3SP (Special Parts, Special Products, Special Projects) dat bedrijven helpt bij het realiseren en vermarkten van ideeën.

TNO magazine juni 2008 · Industrie en Techniek · Industrie en Techniek · juni 2008 TNO magazine

Figure 6-9: Article TNO Magazine, interview Edwin Siemerink, My-Bodyguard BV (Beyen, 2008)

Figure 6-10: My-Bodyguard Website (www.my-bodyguard.eu , viewed May 2010)

Several opportunities exist within TNO to support the transfer of knowledge to small and medium sized companies (SME's). As My-Bodyguard perfectly fits this description, the author takes the initiative to introduce the company to the TNO "SME program" and the TNO "Small Business Innovation Research" program (TNO SBIR). The intent of this program is to reduce the gap between knowledge development and the application of this knowledge, the so-called knowledge paradox (Oldeman, 2007b). The program consists of a feasibility phase and a valorization phase. The following two emails indicate one of the actions by the author to "connect" My-Bodyguard to potential funds within the TNO organization. It also shows the parallel way that these processes occur. While on the one hand there is communication about an ongoing technological research in the area of electronics of the Guide Me system, at the same time the opportunity for new funding is being discussed. The third email is dated almost a year later, indicating that My-Bodyguard successfully finished the feasibility study regarding the Guide Me system, and intends to present a follow-up proposal regarding the valorization of the system.

Thursday, November 17, 2005, from Peter Joore, to manager My-Bodyguard BV. "Dear sir, I recently spoke with you about TNO's "Small Business Innovation Research" program, see http://www.tno.nl/sbir. The Guide Me project is one of the cases that may be eligible for registration. I believe this is an interesting opportunity for you, since 25,000 Euro could potentially be available to investigate the feasibility of the Guide Me, based on a proposal you need to submit before December 1. In the following phase, as much as 300,000 Euro may become available. See attachment for the SBIR program, the application and the confidentiality agreement. Please let us know soon if you would like to register for this. With kind regards, Peter Joore P.S. when do you think you can send the information related to the electronics? I would like to start working on this next week."

Thursday, November 17, 2005, from manager My-Bodyguard BV to Peter Joore "Dear Peter, I've received your information and will take a closer look at this. As for the electronic components, can you please indicate in what format you would like to receive them? Then we can deliver them the way you want them. Regards"

June 30, 2006. From: Manager of My-Bodyguard BV to TNO Project Manager SBIR Program. "Dear sir, please find attached our report for the SBIR feasibility study. This proposal includes the details of the feasibility study. The technical innovation directions were investigated, as well as the market analysis for the feasibility of Guide Me. Conclusions from the feasibility study are:
- The technical innovation directions are mostly feasible
- The patient groups we talked to in the market scan have reacted very positively to the Guide Me project.
- The three distributors of My-Bodyguard have also reacted very positively to the development of Guide Me.
With these three above-mentioned items, the conclusion of the feasibility study can simply be put as follows: The Guide Me project is very interesting for My-Bodyguard BV and we will submit a valorization plan for a follow-up approach."

6.7.2 Cooperation between My-Bodyguard and TNO

The initial detailed development of the Guide Me system takes place starting in June 2005. A project entitled "innovation small-scale production of synthetic casing" (Joore and Eikelenberg, 2005) is approved in September 2005. It is aimed at modifying the casing of products through customization, adapting the products to individual client wishes. The earlier mentioned "black box" of the My-Bodyguard device is one of the products taken into account. During the project, various casings are developed to scale with the help of TNO expertise in the area of Rapid Manufacturing Technology (Joore et al., 2005a, Joore et al., 2005b). In December, My Bodyguard submits a project plan to conduct a SBIR feasibility study for the Guide Me system (Siemerink, 2005). After an independent commission has judged the proposal positively, the company gets approval in April 2006 to implement the plan, in which a number of technological innovation tracks are investigated and the commercial feasibility of the concept is tested. Based on the outcome of the feasibility study, My-Bodyguard draws the conclusion that the project is indeed very favorable, and in August 2006 they submit a supplementary proposal for the execution of a valorization project (Siemerink, 2006b). Within three years of completion of the valorization project, sales of the Guide Me are anticipated to be between 20,000 and 30,000 pieces, provided that the conditions for acceptance by the care insurers are satisfied (Siemerink, 2006a). On October 2, 2006, My-Bodyguard's management makes a presentation to the SBIR commission, who judge the project positively. Later that month they receive formal confirmation that the valorization project can go ahead.

6.7.3 Cooperation of My-Bodyguard with other partners

My-Bodyguard is part of a broad network of partners, that each take their own specific role during the development and commercialization of the Guide Me system. There is a close collaboration with Brunelco Electronic Engineering who is responsible for all software and hardware development and who is established in the same building as My-Bodyguard. Other partners are the distributors of the system, among which are Xmark, Chubb Security and My-Freedom BV, a subsidiary of Meyra Nederland BV. Another partner is Proline BV, who manages a system for receiving and transmitting alarms. As for the alarm centers involved, the company collaborates with, among others, Security Monitoring Centre (SMC), a component of UTC Fire & Security. Other partners include the supplier of the casing of the wearable device a, a plastic vacuum molding company. With regard to this casing, some design work is being done by design agency Smool. Regarding the subject of fall-detection, a research project is being conducted with medical institution Kempenhaeghe and the related company Hobo Heeze. With regard to the application in the care sector, discussions are being conducted with various patient organizations, among which the Dutch Aphasia Association, the Alzheimer's Association, the Epilepsy Association, TV for the Deaf and the Heart Association. Last but not least, the acceptance of the Guide Me system by care insurance companies is an important factor for the successful adoption of the system, which turns out to be a rather slow process which apparently cannot be influenced easily.

6.7.4 Detailed development of the Guide Me system

With regard to the detailed design of the Guide Me system, seven technological innovation tracks are being taken into consideration:

1. Link with health alarm
2. Intelligent on and off switching
3. Inside/outside residence detection
4. Addition of alarm function
5. Attractive casing
6. Interaction with caregiver or companion
7. Miniaturization

When linked to a health alarm, medical devices analyze the physical condition of the individual and pass this information on to an alarm center by means of the Guide Me. To facilitate intelligent on and off switching of the Guide Me, an active "tag" in the device detects when it's in the neighborhood of a loop near the door, so the device can turn itself off when it is inside the wearer's residence. The effect of this is that the batteries do not have to be recharged as often. Research is being done in the area of fall-detection, as many existing devices have problems being either too sensitive (giving false alarms) or not sensitive enough. Concerning the casing, the emphasis is on portability and comfort, where it is important that the product does not have any stigmatizing characteristics. Especially for use by elderly people it seems to be important to miniaturize the device, thereby increasing wearing comfort (Siemerink, 2006a). All in all a wide range of innovation themes are taken into consideration, among which is a new, favorable development regarding indoors localization with the help of ZigBee beacons. In 2006 this development was hardly predictable, but it appeared to be an unexpected success. When the various cooperation projects with TNO are finalized with a presentation on September 10, 2008 (Oldeman, 2008), most of the planned development lines are finalized as planned and in total more than 600,000 Euro is invested in the development by the company and its partners.

With regard to the commercial perspective, sales in the care market remain lower than the expectations of two years earlier. In spite of very positive reactions during a number of pilot programs and test deployments, actual orders are few and far between. It appears an important reason for this seems to be the compensation by care insurers, a central point that was already identified in 2006. But also in a wider sense, the "care environment" appears to be characterized by slow decision-making, where technology is also not very high on the list of priorities for many decision-makers. However, sales of the system in a totally other market segment emerge strongly. The device is actively adopted by security organizations, enabling them to track their employees during their daily routine. From a commercial perspective, this application surely can be considered as a success. The question is if the same is true looking from the societal perspective. After all, the original idea behind the Guide Me system was to enable elderly people to remain living independent at home for a longer time.

6.7.5 Reflection – direct involvement is finished

During the course of the project, the role of the author is shifting. Initially this role could be described as a kind of idea generator in the area of telemonitoring. Next the role shifts to being a kind of intermediary facilitator between My-Bodyguard and De Woonmensen. Next, the author seems to fulfill a mediating role again, now between My-Bodyguard and the available knowledge within TNO. In time there is less need for such a mediating contribution. The development of the Guide Me system is well under way, and the technological contribution of TNO with regard to this development turns out to be relatively limited. At the end of 2006 it is becoming increasingly obvious that My-Bodyguard is solely responsible for the development of their new system. Although the link with the wider system innovation project is reflected by a presentation of My-Bodyguard at TNO's symposium of 30 November 2006, titled "How system innovation creates opportunities for new ways to look at living and caring in an aging society" (TNO, 2006a), the new position of TNO with regard to My-Bodyguard resembles more that of a regular consultant or contract research organization, rather than a mover and shaker of new initiatives. Apparently, the initiating role of the author with regard to the development of the Guide Me system is more or less over. This fact becomes clear in an email exchange between the author and strategic design agency Solutioning Design in Brussels, whichis involved in developing some more user scenarios related to potentially new innovation tracks surrounding the Guide Me system.

During the email exchange it becomes clear that the company has decided not to take on any more initiatives, but to focus on current developments. As said before, the input of the author in the Guide Me project appears to be no longer needed.

> *Friday 3 November 2006, from director Solutioning Design, to Peter Joore. Subject Tentative scenario's 2.0, "Dear Peter, Please find an update of the tentative scenarios with a proposal for the visualizations. If you agree with this, we could start right away on their realization. All best"*
>
> *Wednesday 20 December 2006, from Peter Joore, to director Solutioning Design. "We used the scenarios in a meeting and they work rather well, it works almost like a kind of video the way that you have done it. I actually put all the scenarios after each other, creating a kind of 10-minute video we showed in a larger meeting where we presented the whole Multifunctional Center project. With regard to the content, through the scenarios it becomes clear that several functionalities very much resemble a "one touch mobile phone". In discussions that we had with the company that is realizing the Guide Me concept, they emphasized that they actually expect their product to move further away from the mobile phone concept in the future (as of course the mobile phone arena is very competitive). The*

> *more specialized functionalities related to emergency and health will probably be the niche focus for the future. So, regarding the work you have done: I think these scenarios now are the final work of you within our project. The project is being continued by the company itself, so we will from now on be more bystanders in the development process. Well, that's the life of an advisory organization I guess. I will keep you updated about the developments that will take place. Probably in 2007 the main development will be regarding electronics, so not very interesting from a scenario design perspective. But, there are always other projects in the future.... Best regards, Peter"*

Looking from the perspective of the multilevel design model, during the description of the project we have descended from the top level of the model (the societal challenge regarding the aging of society), to the socio-technical level of the assisted living center in Apeldoorn, to the product-service level of the Guide Me system, to the detailed product level of the casing and electronics that are part of the hardware of this system. In the next section we will take a last look at the developments at the new assisted living center in Apeldoorn. In other words, we will ascend again in the multilevel design model to the socio-technical level of the new Hubertus-Drieschoten center and reflect on the way that innovative technology (including the Guide Me system) has, or could potentially, influenced this initiative.

6.8 De Groene Hoven

6.8.1 Implementation of innovative technology by De Woonmensen

What has happened in the meantime with the development of assisted living center Hubertus Drieschoten? And what has happened with the original ambitions related to the application of innovative products and technology to allow people to remain independent longer? While initially the expectation was that the entire center would be realized in 2006, during the course of the project it turns out that the development takes more time than originally planned. This is particularly because of regular struggles involved in restructuring a city neighborhood, such as zoning plans that must be modified. Under the heading "It looks like nothing is happening!!", the Woonmensen Magazine explains the situation in December 2005. A lot of work is done behind the scenes and in September 2005 the architect gets the go-ahead to design the new buildings, but the process takes longer than planned. The article ends with the conclusion that it will take some more time till actual construction will start (De Woonmensen, 2005, 3).

Another reason for the extended preparation period has to do with regulations related to the type of Alzheimer patients that are allowed to live in the new home. Besides the 75 care dwellings, destined for, among others, those with moderate dementia, 30 "small-scale housing" units are planned. Initially the organization assumes that moderate dementia patients will be living there, but during development it appears that government compensation for this category is insufficient for a healthy financial situation. Only people with medium to severe dementia are now eligible for the 30 units, which will require a greater square footage. That means that drawings have to be modified, which is one of the reasons for the mounting project delay (Provincie Gelderland, 2009, 6). As for the implementation of innovative technology like home automation, financing appears to be the biggest sticking point in this as well. So it appears that De Woonmensen will provide for the basic infrastructure, and the residents, if they wish, can obtain specific services themselves. During this period, TNO is still conducting various studies into the possibilities of applying technology in the new multifunctional center. In a report of the Province of Gelderland, 10 regional projects are being described in which home automation is being used to support care organizations that focus on people with dementia. Although the interview states that De Woonmensen expects to save money by using home automation, it is not exactly clear how much of the technological possibilities will actually be implemented:

Figure 6-11: Impression of the Guide Me system in use.

Figure 6-12: Impression design sketches for casing of Guide Me product (Smool Designstudio, 2006a) (Smool Designstudio, 2006b)

> *APELDOORN, July 2008 – Domotics for light dementia patients appears to be no option in Apeldoorn. The drawings had to be redone. "Sensors to prevent the washbasin from overflowing; a chip which reports to the care station that someone is wondering too far from the residence; fall detection; a sound sensor or even a camera that allows the care station to view the scene, allowing the partner of a demented person to take a break; a light that automatically switches on when the person wakes up; 'light simulation" throughout the day presumably has a purifying effect; blocking the door...", Gerard Brugman reads from a TNO report from last year about domotics and dementia, specially written for De Woonmensen, the organization Brugman works for. "We still have to deal with this report internally. Consultants are busy developing several items." (Provincie Gelderland, 2009, 6).*

As for the new multifunctional center, the first pile is being driven in late 2009 (De Woonmensen, 2009, 16). Sale of the yet to be built houses begins in February 2010. The project has meanwhile been rechristened to "De Groene Hoven" (The Green Courtyard). The project's website indicates that modern technology is "implemented and applied to support the independence and self-coping of residents" (De Groene Hoven, 2010). According to an article in the regional newspaper De Stentor, there is a lot of interest and a long waiting list exists for the rental houses in De Groene Hoven (Felix, 2010). Basically, the new project appears to become a big success.

6.8.2 Implementation of mobile alarm systems

For that matter, during the course of 2008, an outdoor alarm system is being introduced at other care locations of De Woonmensen, which is quite similar to the alarm system from My-Bodyguard. It is introduced by local alarm organization "Paraat" which has approximately 1200 inhabitants in the city of Apeldoorn and surroundings connected to it. Up to that moment they only supply an alarm system that functions indoors. From that point on, the new product "Mobielparaat" introduces an alarm system that works outdoors as well (De Woonmensen, 2008). Perhaps Mobielparaat has received some inspiration from My-Bodyguard, considering the slogan on the website which reads *"with the mobile Paraat you will always have a little bodyguard with you" (Mobielparaat, 2010)*. For this purpose, they use the "PeopleTracker-1202" device sold by MobileTrack BV in Rotterdam. When being asked about the success of the mobile alarm system in 2010, the organization explains they have about 50 systems in use, but have stopped promoting the new system. The localization functionality of the system turned out to be not precise enough when an alarm was given. Also, many of the elderly users have a hard time remembering to recharge the device every day.

And yet, this assessment does not mean that the implementation of tracking systems, like the Guide Me system, could not have any added value in the care sector. The Institute for Revalidation Questions (iRv) conducts a study in 2006 into the implementation of personal localization systems, including the system from My-Bodyguard. The conclusion is that the application of GPS technology in cases of moderate dementia can have a positive effect on the independence of residents (Rasquin et al., 2006). Other studies appear to confirm these conclusions (Miskelly, 2005) (Shoval et al., 2008) (Oswald et al., 2010). Having said that, when closely reading the article called "The use of technical devices to support outdoor mobility of dementia patients" (Rasquin et al., 2007), the conclusions happen to be based on several interviews and one practical experiment with one patient couple, that have used a localization device for one day. Apparently the conclusion is that more research is needed to be able to really make a substantiated estimation about the potential benefit of tracking devices to support the independence of elderly people.

6.8.3 Reflection - national situation on aging

Now what about the national situation regarding the aging of society? Has independence of elderly worsened or improved in 2010? And has the development as described in this chapter contributed anything to it? Or is it impossible to give a sensible answer to this question at this time?

Figure 6-13: North West side of De Groene Hoven in progress (source google streetview, retrieved October 25, 2010)

Figure 6-14: North West side of De Groene Hoven when finished (source www.degroenehoven.nl , retrieved October 25, 2010)

Without a doubt, the theme "aging" will remain high on the political agenda in the next 20 years, since the post-war baby boomers will pass the age of 25, starting in 2010. That's how 2011 will be the first year that more people will leave the labor market than that young people will enter it. In other words, the real challenge is yet to begin. The "complex societal question" is not even close to being solved, but that should not be surprising. After all, it's not for nothing that it's called a complex societal question. Concerning the impact of the new alarm system that has been developed during the course of this research, one could say that it is impossible to measure the impact of this product on the societal problem of an aging society. Concerning the impact of the new alarm system on the new multifunctional center De Groene Hoven, the impact is also very small. However, on this level is does appear possible to measure the impact of the new system in one way or another. After all, 50 mobile alarm systems have been implemented here (even though they are made by a different company than the one that the author has cooperated with, and even thought the results turned out to be not very positive), so some kind of impact seems to be present here.

When looking to the multilevel design model once more, one could say that a direct connection between new products can only be made up to the level of the socio-technical system, in this case with regard to the new multifunctional center. The way that these interventions will in turn influence large scale societal developments appears to be beyond the designer's horizon. Although also on this level change certainly takes place, to actually influence the way that these societal developments occur by means of new products seem to be out of reach when looking from the design-oriented perspective of this research.

6.9 Summary

Chapter 6 includes a description of a practical experiment under the title "Autonomous Elderly". This project focuses on the societal challenge related to the aging of society, due to demographic developments. It is executed within the context of a TNO project under the heading "New Initiative Sustainable System Innovation". During this project, a close cooperation of TNO with housing and care organization De Woonmensen in the Dutch city of Apeldoorn is set up. This organization is restructuring an area of approximately 3.3 ha (8.1 acres) while developing a new assisted living neighborhood under the name Hubertus-Drieschoten. When looking from the perspective of the multilevel design model of chapter 5, this new neighborhood can be considered as a socio-technical system in development. Within the project, several future scenarios are being developed, based on two uncertainties. The first uncertainty concerns the degree to which the organization for care, housing and welfare will be open, demand-driven and flexible, or rather closed, standardized and supply-driven. The second uncertainty concerns the relationship between government and marketplace, indicating the degree to which society is organized, either publicly or privately. The combination of those issues creates four possible combinations, which are not so much intended as a design sketch, but as extreme scenarios in which a possible future can occur. Based on these scenarios, two future visions for the new neighborhood are being developed. The one entitled "Freedom and custom care" emphasizes the individual responsibility of the residents. In the second future vision, called "Living together and carefree", the emphasis is especially on the collective aspect of the solutions.

In a parallel process, innovative technology that potentially can be used in the new neighborhood is being developed, working simultaneously on the bigger system (the new neighborhood) and the elements that potentially can be a part of it (new products and technology). To make this concurrent development more manageable, the project is being split up in several sub-areas of development. In this study, specifically the area of telemonitoring is being analyzed, as this is the area that the author has been able to influence directly. It turns out that even within this smaller area, there still remain too many options for new products to be developed, with not one "Egg of

Columbus" or Holy Grail among them. When looking from the perspective of the multilevel design model, the "crossing of the border" between the bigger societal and socio-technical vision of the new living area, and the smaller product-service and product-technology elements to be developed by commercial companies, turned out to be a major barrier to be taken. This chapter describes several "design interventions" that the author initiates, among others in the form of student projects in which some of the possible ideas are being translated to more elaborated concepts.

In the study, the development of one of these concepts, the product-service system Guide Me, is discussed. Based on the results of the various design interventions by the author, the actual development of this personal alarm system is taken up by a company called My-Bodyguard. This company has been working on the design of a mobile alarm system that is quite similar to the Guide Me concept and they are very interested of linking their initiative to the broader TNO initiative involving the new assisted living area. A user test is being conducted with De Woonmensen, based on a modified alarm system of My-Bodyguard. Based on the positive results of the user test, the Guide Me system is further being developed by My-Bodyguard, in cooperation with a wide range of other actors and with support from TNO's Small Business Innovation Research (SBIR) program. At this stage, the direct involvement of the author decreases and the company further develops the system on its own.

When looking from the perspective of the multilevel design model, one can consider the project as a design process that has taken place, descending from the societal level (the aging of society) to the socio-technical level (the assisted living center Hubertus-Drieschoten in Apeldoorn) to the product-service level (the Guide Me system) to the product-technology level (the hardware elements of the Guide Me system). During that process, their appeared to be something of an "invisible border" between the socio-technical level of the assisted living center, and the product-service level of the Guide Me system. However, linking both levels turned out to be useful from both perspectives. For De Woonmensen, the Guide Me system could serve as one of the potential building blocks of their new assisted living center, while for My-Bodyguard it is valuable to test the Guide Me alarm system in a real life environment. When ascending upwards again (when looking from the multilevel perspective), the new neighborhood (renamed De Groene Hoven) is almost finished in 2010 and seems to be rather successful in attracting new inhabitants. Although new technology is certainly being used in the new center, it is not the exact same technology as being developed during the TNO project. For instance, with regard to mobile alarm systems, not the Guide Me but a competing system under the name "Mobiel Paraat" is being implemented. Regarding the societal level (the aging of society), this seems to be out of reach to be directly influenced by means of new products, at least when looking from the design perspective that forms the basis for this research.

7 *Chapter 7: Youth in Motion*

7.1 Societal Challenge - Youth in Motion

7.1.1 Healthy moves

This chapter describes a practical experiment, conducted in the period 2005 to 2010, with emphasis on the period 2006 to 2008. The societal challenge which is the focus of this experiment is “Youth in Motion”. An ever-increasing number of children in the Netherlands are overweight or obese. The percentage of young people with problems in this area has more than quadrupled between 1980 and 2005, from 4% to 15% (Jongert, 2006). This is not even because children eat more, which would increase their energy intake. As long as energy intake is balanced with energy consumption, no problems arise. However, energy consumption in young people is steadily decreasing because they move less and less. While in 1974, on average children as young as six years old went to school by themselves, in 2003 this average age has risen to nine years (Fietsersbond, 2001). The “backseat generation” is sitting still too much and is therefore not spending enough energy.

Young people are not only sitting still on the backseat of the car, but also in front of the TV or computer. A Dutch study indicated that nearly 40% of the children watched more than two hours of television the previous day (Renders et al., 2004). And American research shows that young people watch TV or play video games an average of 4.5 hours per day (Roberts and Foundation, 1999). A researcher quoted in Time Magazine even compared the obesity problem with an epidemic that is like a tsunami, “heading toward the shore” *(Walsh, 2008)*. Sitting still in front of a screen even has a double negative effect, because on the one hand you move less (Robinson et al., 1993) (Tucker, 1986) and at the same time more fatty snacks are being consumed. Moreover, there are a lot of commercials on TV for mostly calorie-rich food, which have an additional negative influence on the eating habits of children (Taras et al., 1989) (Wolf, 1997) (Wong et al., 1992).

7.1.2 Children in priority neighborhoods

Besides the attraction of television and computer games, the arrangement of the neighborhood that one lives in plays an important role in the physical activity behavior of young people. The influence of the neighborhood was examined more closely in the study “Children in priority neighborhoods: physical (in)activity and obesity (de Vries et al., 2005). In this study, commissioned by the Dutch Ministry of Health (VWS) and the Dutch Ministry for Social Building, Regional Planning, and Environment Administration (VROM), TNO examines the influence of the neighborhood on the physical activity behavior of children. The study is focused specifically on young people in a number of “priority neighborhoods”, neighborhoods that are slated for restructuring, so that the before and after data can be compared after the change. Of the children studied, at least 31% turn out to be overweight. This is substantially higher than the national average. Only 4% of boys and 3% of girls meet the NNGB, while the usual assumption is that approximately 80% of elementary school students in the Netherlands meet this norm. Eating behavior, i.e. energy consumption, of the studied children did not appear to deviate from the national average. This appears to justify the conclusion that the high percentage of overweight children is because of insufficient energy consumption, in other words due to lack of physical activity. That is why the researchers come up with the following advice:

> *"It's important to stimulate children into more physical activity. One of the measures that can contribute to this is 'movement friendly' (re)design of urban neighborhoods" (de Vries et al., 2005, 5).*

The recommendations of the report include concrete guidelines for the design of the neighborhood. For example, children must be able to use formal play areas as well as informal play areas such as lawns and sports fields. In addition, play areas must be suitable for young children - who like objects such as teeter-totters, slides or swings - and for older children, who probably need a skating track, soccer field or a place to hang out. Larger, easy-to-get-to and well-designed play areas apparently attract more children and moreover, they reduce the chance that the larger children shut out the smaller ones (Karsten et al., 2001). One of the ideas to enlarge the informal play area is the construction of wider sidewalks. Another idea is to combine the attraction of computer games and the need for informal play areas. Before expanding on this possibility in section 7.3, let's first explore the organizational context of the practical experiment, thereby defining the "playing field" within which the project has played itself out.

7.2 Organizational context

7.2.1 The government, NOC*NSF

Government stimulates and subsidizes various activities which promote movement. The Ministry of Health encourages municipalities, sports associations and provinces to pursue a more active sports policy (Ministerie van VWS, 2001). For example through special sports programming for specific target groups, or by supporting local sports clubs. In the prevention memorandum "Live Healthy Longer" (Ministerie van VWS, 2003), the Cabinet's objective is to put a stop to the increasing incidence of obesity. Agreements were formulated in the National Action Plan for Sport and Activity to combat lack of movement, in order to reduce the incidence of obesity (Ministerie van VWS, 2008). Besides the government, there are various other organizations actively engaged in promoting physical movement, such as the Netherlands Institute for Sport and Physical Activity (NISB), the Netherlands Olympic Committee*Netherlands Sports Federation (NOC*NSF), the IOS as umbrella organization for 12 provincial sports councils, the Dutch Institute for Local Sports and Recreation and the National Institute for the Promotion of Health and Prevention of Disease (NIZG). All of these organizations are focused on promoting, in one way or another, activity behavior among the Dutch population (van de Wert et al., 2004).

A much-used yardstick to help these organizations to strive for objective goals to be achieved, is the Dutch Standard for Healthy Physical Activity (NNGB, Nederlandse Norm Gezond Bewegen) (Giesbers and Frenken, 2008). According to this norm, youth up to the age of eighteen must be involved in at least one hour of relatively intensive activity per day. Above the age of eighteen, people should be physically active at least five days a week for half an hour a day.

7.2.2 Reflection - TNO Sport, Stichting Sports and Technology

When looking from the perspective of the multilevel design model presented in chapter 5, the previous sections describes the characteristics (S1) of the "societal system" in the area of youth obesity. Apparently, government considers this situation as a problem (S1*), and comes up with goals and objectives (S2') to be achieved (like the NNGB), in order to improve the situation. The discussion about the importance of city neighborhoods connects the societal level with the level of specific socio-technical situations.

One of the players that are active in the area of activity and health is TNO. The projects described in this chapter are primarily based on initiatives that originated within this organization, or on initiatives that are directly related. Within TNO, the "Quality of Life" institute and the "Prevention and Health" department in Leiden are important players. During the period that the main events of this project take place (2004-2008), the author is employed at the "Health and Sports" department of TNO Science and Industry. He is the project manager of several of the projects mentioned in this description, and a member of the project team in a number of other projects. In this function, he collaborates within the "TNO Sport" program. This program was started in 2002, combining the efforts of various departments within the organization (TNO Sport, 2005) (Binnendijk, 2006). Within the program, the problems and objectives of the sports domain, are connected to the detailed knowledge that is available within the TNO organization. These broad needs are, among others, defined in a study entitled "Innovation for gold", which is conducted in cooperation with NOC*NSF (NOC*NSF en TNO, 2004). In this research, "roadmaps" are drawn up which indicate current standings of sports in the Netherlands and future objectives in the areas of products, services, technologies and knowledge in the area of sports innovation. When looking from the multilevel design perspective as presented in chapter 5, within the TNO Sport program a connection is made between the "larger" problems and objectives that take place on the level of society, and the "smaller" knowledge area's that are available within the TNO organization and in other organizations.

Important actors from the perspective of this research are the TNO Sport manager, and the project manager in the Prevention and Health department of TNO in Leiden. Together they try to set up new innovation projects, related to the area of "youth and activity" and "sports promotion". On October 11, 2004, the activities in this area become widely known through the conference "Sports and Technology". The 355 attendees can choose from 17 workshops, among which the theme "Obesity, activity and sports". Introduced at the conference is the Stichting Sports and Technology, a center for business creation and acceleration (Sports and Technology, 2004). A similar conference is organized in September 2005. This time, the workshop that is related to youth and activity is labeled "More Sports in Less Space"' (Jongert, 2005b) and is focused on the opportunities offered by gaming to get young people more active: "There are good examples of games which stimulate sports. In this session we will explore the opportunities offered by gaming. But the reverse is also conceivable: what opportunities does gaming offer to make the sometimes dull hours of training of the sportsman (virtually) more appealing or more effective? " (Sports and Technology, 2005). Before going into these possibilities, we will first finish describing the organizational context of the project.

7.2.3 InnoSportEU, InnoSportNL, InnoSport Brabant

In order to expand the activities in the area of sports innovation even further, TNO and a number of national and international partners conduct the research project "InnoSportEU" between February 2006 and January 2008, a two-year project, sponsored by the European Union, with a budget of 1.45 million Euro. During that same year, TNO and NOC*NSF establish the Institute InnoSportNL as a "program for demand-oriented knowledge development for promoting sports". This ambitious collaboration is made possible by a contribution of 15 million Euro from the Ministry of Health (RVD, 2006). "Innovative Approach in Sports Promotion" is one of the five areas that Innosport is focused on, in addition to the themes nutrition, training, sports equipment and facilities. The sports complex in Eindhoven is mentioned as an important partner in this theme (NOC*NSF and TNO, 2005, 37).

In 2007, in order to provide sports development in Brabant with an additional push, the province of Brabant provides a subsidy of 393,000 Euro to the Stichting Sports and Technology towards the implementation of the project "Exploration InnoSport Brabant" (GS Noord-Brabant, 2006), expressly linked to the opportunities offered by InnoSportNL. The exploration is aimed at the support of seven field labs, focused on hockey, gymnastics, soccer, bicycling, swimming, equestrian sports and recreational sports/sports promotion. The latter is established at sports complex Eindhoven-North. Here, the Brabant project helps to start the creation of a so called "Sport Promotion Field Lab" (von Heijden, 2006), which is further discussed in section 7.4. Two years later, this results in the start of the company "Embedded Fitness", which is opened on January 28, 2008 (Scholten and van Krieken, 2006) (Embedded Fitness, 2008) (presented in section 7.7), and the founding of a new Play and Activity Square (presented in section 7.8) which is officially opened at the Sports and Technology conference of October 30, 2008 (Gemeente Eindhoven, 2008c).

So much for the organizational context of the project. The lines are drawn, the playing field is known. So let's return to the societal challenge. Is it possible to actually get the TV-watching and gaming youth moving? And can new products help in this?

7.3 Make Me Move

7.3.1 Computer technology: opportunity or threat?

Can more computer technology only lead to more passivity and less activity? Or is it possible to implement this technology in such a way that it helps promote the health of young people? As the old saying goes, "if you can't beat them, join them". Moreover, the necessary computer and sensor technology is rapidly becoming available for small-scale applications. Is it perhaps possible to create a fruitful combination from the attraction of computer games and the desire for more informal playing space, for example on the sidewalk? That idea inspires the TNO Prevention and Health project manager to start thinking about an alternative use of the currently available outdoor space. But who could develop something like that? The department of Prevention and Health may be good at researching the behavior of young people, but knows nothing about developing new products.

This idea to implement computer technology in such a way that it stimulates people to move more is the background of the Make Me Move student project, a collaboration between TNO and the faculty of Industrial Design of the TU/e (Eindhoven University of Technology). In the first round of this project the students develop an interactive kite, the "Interactive Kite Experience". This is a computer simulation where the behavior of a virtual kite on a computer screen can be controlled by pulling on real cables (Ahn et al., 2004). In June 2005, TNO Prevention and Health receives a subsidy from the Loosco fund for the development of a stimulating environment that invites children in elementary school to move spontaneously (Jongert, 2005a). The project is targeting children in elementary school, between the ages of 5 and 12. These children should be physically active with reasonable intensity for at least 60 minutes per day. The objective of the project is formulated as follows: "To transform an ordinary outside area into an interactive space that motivates children to start moving." (van Overbeek et al., 2005)

7.3.2 Reflection – Start of the Make Me Move cooperation

How did the author actually involved in this project? The project manager of TNO Prevention and Health in Leiden is interested in working with TNO Science and Industry in Eindhoven, and also wants to work with students from the faculty of Industrial Design of the TU/e there. As the author at that time takes care of the cooperation between TNO and TU/e Industrial Design, he gets connected to the Make Me Move project. This process is shown in the following email communication.

From: Project manager TNO Prevention and Health, Monday 30 may 2005, to manager TNO Sport. We have received a subsidy from the Loosco fund to engage in a study regarding the Make Me Move *project, encouraging children in cities to become more active. We want to determine the issues that are important for the activity behavior of children in city neighborhoods, and come up with a program of demands and a first prototype of a play unit that encourages children to move. It is a follow up of a project that we have conducted with students Industrial Design. Now we would like to include you (TNO Science and Industry) in the project. We would like to work with students of Industrial Design again, and we would like to include a play equipment producer from the start. Best regards.*

From: Manager TNO Sport, Monday 30 may 2005, to project manager TNO Prevention and Health. Great that this project can start. Some remarks:
1. Do you already have a location where this project should land? I know that the city of Eindhoven most certainly is interested and perhaps has some budget to support the project.
2. We have several contacts with companies. How many parties do you want to be involved, and what could be there role?
3. Regarding Industrial Design, we discussed internally that Peter Joore will take care of those contacts. So hereby I send this mail to Peter.
Best regards.

From: Peter Joore, Tuesday 31 May 2005, to project manager TNO Prevention and Health. Regarding the cooperation with the TU/e, I think this project fits perfectly in the TU/e unit that is focused on the area of Health. Practically speaking, new projects will start from August on. I will propose this project to the unit manager, so we can start immediately after the summer. Can I use the project documents that you have attached, or do they contain confidential information? Best regards.

7.3.3 Make Me Move project

In the startup phase, the program of requirements for the new play environment is drawn up on the basis of a literature review, focus group interviews and in-depth interviews. Some of the obstructing and stimulating factors that are highlighted by this are social security, traffic security, recreational facilities, green space, accessibility of facilities, surrounding structures and public (play) areas (Boer et al., 2005) (de Vries et al., 2005). The most important points from the program of requirements for the play equipment are (van Overbeek et al., 2005, 30-33):

Reference points:
- The play equipment must offer several possibilities, for example a menu which offers the choice of three games.
- The play equipment must be adjustable so that the tempo can be increased, which in turn increases the participants' level of exertion.
- The duration of the game must be at least 5 to 10 minutes. This must be followed by a "reset", where the same participants can choose a higher level (for example by increasing the speed), another game, or they may switch with other participants.
- When the children have made use of the equipment for a total of 4 x 15 minutes, they must be alerted in a playful way that they have passed the NNGB (for example traffic light colors switching from red to orange to green, accompanied by sound effects).
- The play area must be freely accessible to children in the 4 to 12 age group, regardless of the time of day.
- The play equipment must be suitable for individual as well as group use.
- The number of children (estimated) that can make use of the play area at the same time must be from 10 to 15.

Activities:
- The play equipment must demand a physical effort from the participants of at least 5 MET (a physical effort which for youth is comparable with walking, bicycling or walking stairs).
- The play equipment must make a demand on the power, flexibility and coordination of the participants, for example by
    - Incorporating a play element, comparable to the game Twister, which makes a demand

on coordination and flexibility and/or
- Incorporating the necessity for jumping, so that the aspect of power is also taken care of;
- Other options, such as dancing steps, or alternating movement forms such as jumping, hopping, running, squatting and stretching;
- Activities must be supported by light and/or sound effects, so that an interaction exists between the participants and the physical environment.

- The game must contain an "addictive" and a competitive element, in order to motivate children to improve their own score and to allow two groups of participants to play against each other at the same time.

Wishes in relation to atmosphere and character:

- The play equipment must preferably be located in a spot where children already meet frequently (a "natural" meeting place);
- The play equipment must have a futuristic feel;
- The play equipment must be "approachable". In other words, when a child happens to walk or bicycle nearby, he or she will be tempted to try it out by the looks of the equipment.

7.3.4 Reflection – Student project Lighting Tiles

The scope of the Make Me Move project was a topic of discussion between the author and the project manager of TNO Prevention and Health. Should it be about a broad search for new ways to design the way that city neighborhoods are being arranged, or should it be about a focused effort of one specific playing device? Whereas the earlier student project had a fairly broad foundation, its results were not elaborated on. As the intention was to get something "really working" this time, the choice was made to create a much narrower design assignment for the students. One of the undeveloped sketches from earlier student projects was based on a concept of "smart tiles", and the TNO Prevention and Health project manager would like to see this idea developed further. On the basis of his explanation, an initial computer visualization is created (see Figure 7-1). Although initially the students complain that the project may be too "narrowly defined", they soon get to work enthusiastically. When viewing this discussion in light of the multilevel design model of chapter 5, it appears that the "broad" scope regarding the redesign of the city neighborhood is more about the product-service or even socio-technical level of design, whereas the "small" scope of the play tiles is on the product-technology level. To get things "really working", it is apparently necessary to limit the scope of work, as was done by restricting the design freedom that the students had in this project. On the other hand, this allowed them to create a working model of the play floor, which would most probably not have been the case when they would have been allowed to explore all of the available design space.

7.3.5 Development of the play floor

In a few months the students develop a working model of the play floor. After first having tried it out using a "wizard of Oz" method (Stuyfzand et al., 2005, 16), the six students develop their concept and name it "Into the Living Lights" (op 't Hof et al., 2005) (Cursor, 2005). The play floor is made up of square tiles that are 30 x 30 cm. This allows the tiles to be easily installed in play areas, schoolyards, or a simple sidewalk, since they are the same size as the most commonly used sidewalk tiles. The tiles can light up and can signal, with the help of a pressure sensor, when they are being touched. Different games can be played, each game intended to get the children to move more. For example, in the game "tag", the children must chase and tag a constantly moving lighted tile before it turns off again and the next tile lights up. And in the game "fill it up", all tiles must be tagged so that the entire playfield is lit up. This requires speed because a lighted tile will turn itself off after a few seconds. The game will also recognize the level of the player and adjust itself accordingly. This will allow children to play an increasingly higher level, making it suitable for various age groups.

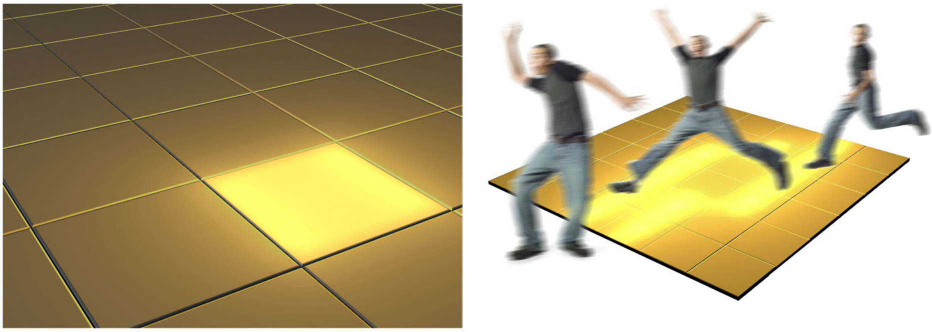


Figure 7-1: Initial artist impression of the Make Me Move floor

Figure 7-2: First user test in play center Eindhoven (op 't Hof et al., 2005).

7.3.6 Use of the play floor

The Make Me Move prototype is tested in a children play center in Eindhoven Woensel. Observations are made of how the children interact with the lighted play tiles. The manager of TNO Sport introduces the project team to the area manager of Sports Complex Eindhoven-North. He is enthusiastic about the play tiles and pledges his cooperation to the experiment. On December 9, 2005, a new play floor is tested for two days in the play center in Eindhoven with the help of interviews and camera observations. It appears the children need to get used to the way various games can be turned on or off, but the overall effect is positive. In spite of the fact that there is competition from play pillows, swimming balls and trampolines (see Figure 7-2), some children are playing on the floor for more than 45 minutes, nonstop (op 't Hof et al., 2005, 56).

Besides this study, TNO itself conducts a more technical study of the energy consumption of children on the play floor. To do this, users are equipped with an oxygen measuring device, with which they then play a number of games. Measuring the oxygen consumption during play allows the determination of the MET (metabolic equivalent) value of the play tiles. This measurement unit indicates how much energy is used relative to energy consumption while at rest. An average individual uses approximately 3.5 mL of oxygen per minute for each kilogram of body weight. This quantity represents one MET (Wendel-Vos and van Gool, 2008). With relatively intensive movement, such as walking or bicycling, five times as much oxygen is used (5 MET). With intensive movement, such as running or playing soccer, oxygen use and energy use is more than eight times as much (8 MET). With regard to the Make Me Move floor, the game "tag" has a MET value of 7.23 ± 0.96 MET, and the game "fill it up" has a value of 7,14 ± 0.91 MET (Jongert, 2006).

7.3.7 Reflection – Creating publicity around the subject

After the December 2005 presentation, the Dutch morning newspaper "De Telegraaf" prints a photograph of the product under the heading *"Losing weight on the play floor"* (De Telegraaf, 2005). As a result of this article, the author is approached by the management of play equipment company Kompan, with whom an initial orientation meeting is held on December 20. It seems that the play floor is a good fit with new products that Kompan is developing in Denmark under the label "Bodygames" (Kompan, 2005) (Lund et al., 2005). Enthusiasm about the possibilities of the play floor appears to be contagious. The subject of youth in motion is becoming more and more relevant for TNO's Prevention and Health department. The cooperation with the more technically-oriented designers of TNO Science and Industry and the faculty of Industrial Design of the TU/e in Eindhoven appears to be a favorable match. The manager of Stichting Sports and Technology and the area manager of Sports Complex Eindhoven-North are both enthusiastic about the idea to bring the theme to the attention of a wider public. Subsequently, plans are made for a meeting under the title "Sport Promotion Field Lab - experimental garden for innovative activity concepts" (TNO, 2006b). The following emails give an indication about the communication regarding this event. Looking from the multilevel perspective, here a connection is established between the "small building blocks" of the play floor, and the "big picture" of the regional development in the area of sports promotion.

> *"From: Peter Joore, Wednesday December 7, 2005, To: project manager TNO Prevention and Health, manager TNO Sport. Please find attached a first approach for our symposium "sports promotion". Your comments please. The objective is to gather support, to refine the definition of the recreational sports field lab, and to make the next move towards its realization. The trigger is the lighting tiles concept, which we developed with TU/e and the Loosco fund. Regards, Peter"*
>
> *"From: Manager TNO Sport, Thursday, December 8, 2005, To: Peter Joore, project manager TNO Prevention and Health,* manager Stichting Sports and Technology. *Hello Peter, Excellent initiative. I think it's a good idea to place this in a broader framework (no incident, but it's a step towards structure)! Framework:*
> *1. Field lab development Eindhoven-North for sports promotion. As I've indicated before, there probably are financial opportunities for a definition phase/feasibility study for the creation of a sports promotion field lab in Eindhoven-North. The municipality of Eindhoven could finance this. It might also be handy to involve the Stichting Sports and Technology.*
> *2. Harmonizing with the development of a national network of field labs and new initiatives in sports promotion (InnoSport NL). In other words I think it's a good idea to actively involve NOC*NSF as well!*
> 3. *In addition, the province of Brabant is also a good candidate to contribute to the foundation and development of field labs which fit in Brabant. Sports promotion field labs (in larger cities, but also in the countryside) as an experimental plot for innovative approaches to tackle social or societal problems*

and to utilize economic opportunities, are a perfect fit in this!! I have already made contact with the province about this and they are quite enthusiastic. (...) That's it for some quick ideas, regards, Manager TNO Sport"

The event takes place on March 21, 2006. For this purpose, the prototype of the play floor is disassembled and then reassembled at the site of the meeting. Just before the meeting the last electrical wires and sensors are soldered back together and the prototype is back in action. The project manager TNO Prevention and Health and the author present the theme from the perspective of TNO, to an audience of companies and organizations that occupy themselves with playing and activities in public areas. Subsequently, a professor and researcher from the TU/e explain what possibilities are offered by interactive play objects. Finally, the area manager of Sports Complex Eindhoven-North discusses the opportunities of a "field lab". The question what actually is a field lab will be discussed in the next section.

7.4 Sports Complex Eindhoven-North

7.4.1 Sports and recreation in Eindhoven

In the "Sport and Recreation Memorandum" (Gemeente Eindhoven, 2003), the municipality of Eindhoven describes its objectives to increase the activity of its residents. They recognize that the health value of sport is becoming increasingly important and therefore their target is that at least 72% of residents will participate in sports. The Sports Complex Eindhoven-North is situated between neighborhoods in North Eindhoven, with a total of approximately 100,000 residents. It covers a surface area of more than 32,000 m^2, 28 sports and recreation facilities, 50 sports clubs and three educational institutions. It is one of the three large-scale facilities to practice sport in the city and it receives more than 1.5 million visitors annually. In the Sports Memorandum 2008-2015, the area is defined as the ultimate experimental area for sports innovation in the city: "Sports Complex Eindhoven-North is the most important pilot project in Eindhoven. New sports activities are started here, after which they are implemented across the city and in some cases across the whole country." (Gemeente Eindhoven, 2008b, 19)

The memorandum includes ten ambitions that the municipality wishes to focus on in the near future. One of these ambitions concerns the strengthening of knowledge developments by means of field labs. These field labs collect and analyze, with the help of the latest technologies, information about top sportsman and recreational sportsman, in order to improve results and develop new products. The city has three of these. First is the National Swimming Center "de Tongelreep", the training location for, among others, Olympic champion Pieter van den Hoogenband. Second are the training fields of soccer club PSV at "de Herdgang". The third field lab is aimed at recreational sports. The 2008 memorandum states in this regard: "The Field Lab Sports Promotion at Sports Complex Eindhoven-North tries to get children more active with the help of the latest technological play and activity equipment. TU/e develops this equipment in cooperation with TNO. The data collected is used as input for further knowledge development in this area" (Gemeente Eindhoven, 2008b, 31).

7.4.2 Sports Promotion Field Lab Eindhoven-North

What precisely is the Sports Promotion Field Lab and how did it come about? The field lab concept is used by TNO Sport for locations where practical tests of technological innovations are conducted on location. For example, ice skaters in the Thialf stadium in Heerenveen are using suits that allows three-dimensional tracking of their movements, and soccer club PSV uses shirts during training, that allow tracking the positions of players on the field on a monitor. Everything is focused to enhance the results of the sportsman or sportswoman. Although in recreational sports or sports promotion it's not a matter of establishing records, conducting a study in a field lab can be important, for example, to allow low-level testing of new products.

Because these kinds of field labs are considered to be important for the regional sports infrastructure, on October 3, 2006, the Province of Noord Brabant grants a subsidy to the Stichting Sports and Technology for the project "Exploration Innosport Brabant": "This project envisions economic strengthening in Brabant by the realization of so-called field labs: these are on-site research environments for innovation in sports. To that end the further development of already existing potential locations will be fast-tracked." (GS Noord-Brabant, 2006). The developments in Eindhoven-North are the closest fit with this vision in relation to sports promotion. A project team and steering committee is formed by Stichting Sports and Technology, the municipality of Eindhoven and TNO, who will jointly have to give further shape to the field lab. On November 15, 2006, the developments surrounding the Sports Promotion Field Lab are presented at the 3rd Sports and Technology conference (Sports and Technology, 2006).

7.4.3 Reflection – Setting up the field lab initiative

The following email of the manager of Stichting Sports and Technology confirmed that provincial funding for the Sports Promotion Field Lab was on its way:

> *"From: Manager Stichting Sports and Technology, Wednesday, October 4, 2006, To: Area Manager Sports Complex Eindhoven-North; manager TNO Sport, project manager TNO Prevention and Health, Peter Joore and several others. "Hello everyone, I have just received a telephone message that yesterday the Provincial Council of the Province of Brabant approved the project 'Exploration Innosport Brabant'! It has taken some time, but all doubt has now been removed. All of us had already started with the projects, but now we can continue in full swing (...) With kind regards. Manager Stichting Sports and Technology".*

In the period between October 2006 and the end of 2007, the author is part of the steering committee in which the course of action for the field lab is being discussed. One of the items being worked on is a business plan for the long-term establishment of the field lab (von Heijden, 2006). At the same time the search is on for a number of likely projects that fit with the objectives of the field lab and that can be accelerated by means of a financial impulse. In this way the project is actually being built up of a wide range of subprojects, all focused on the same target, to get youth to move more. One of the projects being supported is the project 'Xperience Area', where students of the faculty of Industrial Design of TU/e are working on innovative products to get youth more active, (discussed in section 7.5). Other projects that are being supported in this period are the Playground of the future project (discussed in section 7.6), the start of the E-Fitzone (discussed in section 7.7) and the development of the Sport, Play and Activity Square (discussed in section 7.8).

When looking from the perspective of the multilevel design model, the Sports Promotion Field Lab can be considered as an initiative at the socio-technical level, spurring "smaller" sub-initiatives at the product-service level. Each of these sub-projects has its own organizational structure, and is formally independent of the "bigger" Sports Promotion Field Lab. Most of them would also have come about without the field labs support, but perhaps it would have taken a little longer or the shape of the project would have been slightly different. However, because the project "fit" in the vision of the field lab, the steering group has an interest in supporting the seeing the commencement of these projects, preferably at location Eindhoven-North.

Figure 7-3: Sports Complex Eindhoven-North including E-Fitzone (29) and Sports, Play and Activity Square (31)

Figure 7-4: Brochure Sports, Play and Activity Square concept (Yalp, 2010)

7.5 Xperience Area and Design for Movement

7.5.1 Xperience Area

On Monday, September 11, 2006, approximately 30 students of the TU/e start on their new design assignment with the title "Xperience Area". The objective of the project is to develop an interactive environment that will stimulate young people to move. The location where this environment would have to be realized is Sports Complex Eindhoven-North.

> *"In this second year project the design goal is to transform an ordinary location into an interactive space that stimulates children into playful and healthy movement when they enter it. The implementation of the innovative area should take place in Sports Complex Eindhoven-North situated in an area of Eindhoven that has a lot of young children as inhabitants." (TU/e, 2006)*

The students are getting to work enthusiastically and on Monday, December 21, 2006 they finalize the project with the presentation of their ideas: The GameWall, the Gumby, the Drawing Wall, BodyBeats, LightCubes, Takid Door Bell and Flash Poles. In their projects the students are happy to make use of scientific knowledge available at TU/e regarding the way in which computers can influence social interaction of children, or about the subject tangible interaction which is aimed at physical ways of controlling computers (Bekker et al., 2007) (van den Hoven and Eggen, 2008) (van den Hoven et al., 2007) (Bekker et al., 2009). Vice versa, the researchers in turn can profit from the practical results of student projects and from the opportunity to test their scientific ideas in a practical environment.

7.5.2 Design for Movement

In order to present the concepts to interested companies and other organizations, the ideas are presented during a mini-conference with the title "Design for Movement". At this conference, a professional jury judges the students' ideas. This meeting takes place on January 15, 2007 in the Blue Room of TU/e, and is led by Hans van Breukelen (former keeper of the Dutch soccer team, and now manager at Stichting Sports and Technology). The day before the meeting he discusses the Promoting Sports Field Lab in his regular column in daily newspaper De Telegraaf. Under the title "Back to the playground", he discusses the cooperation between the different parties:

> *"Researchers monitor what is and what isn't successful. They share this knowledge with manufacturers of play equipment, electronics and games. They in turn can develop products that will be available in the playground of the future, a place where young and old together can have fun, in a relaxed and cozy atmosphere, while looking after their health." (van Breukelen, 2007)*

TERUG NAAR DE SPEELTUIN

DE KWESTIE

door Hans van Breukelen, directeur Stichting Sports & Technology

EINDHOVEN, zondag

Jong en oud moeten meer bewegen. Onze huidige stijl van leven gaat ten koste van onze gezondheid en zal ons op termijn heel veel belastinggeld en verzekeringspremie gaan kosten.

Een juiste constatering, maar hoe zetten we deze woorden om in daden en krijgen we mensen daadwerkelijk aan het sporten? Kunnen we dit jaar voor een doorbraak zorgen op dit gebied en wat moeten we hier voor doen?

Onbewust komen mijn jeugdherinneringen van onze buurtspeeltuin naar boven, waar gelukkig ook ruimte was om te voetballen. Voor mijn gevoel was dit de speel- en ontmoetingsplaats voor jong en oud. De jongeren speelden en de ouderen keken veelal toe.

Zulke plekken zijn verdwenen. Ze hebben plaats gemaakt voor "trapveldjes" en de Johan Cruyff Courts. Je ziet er veelal voetballende jeugd, maar daarmee houdt het helaas op. En als je niet oppast geldt vaak de regel survival of the fittest op zo'n veldje. Maar wat moeten we dan doen om de computer en televisie te 'verslaan'?

Om te beginnen moeten we als volwassenen eens stoppen om oplossingen te bedenken voor onze jeugd. Jongeren zijn heel goed in staat een eigen keuze te maken. Laten we eerst eens serieus gaan onderzoeken wat hen echt uitdaagt.

In Eindhoven (Woensel) is een prima initiatief gestart. Gemeente, bedrijfsleven, onderzoeksinstituten als TNO en de Technische Universiteit Eindhoven slaan de handen ineén en creëren een omgeving die mensen van alle leeftijden via allerlei technologische en innovatieve ideeën tot bewegen aanzet. Onderzoekers monitoren wat wel en niet aanslaat. Die kennis delen ze met fabrikanten van speeltoestellen, elektronica en games. Die kunnen op hun beurt producten ontwikkelen, die straks terug te vinden zijn in de speeltuin van de toekomst. Een plek waar jong en oud, in een ontspannen en gezellige sfeer, samen lekker bezig zijn met hun gezondheid. Op deze wijze krijgt bewegingsstimulering concrete inhoud en kan het een aanzet geven tot meer sporten. En dat laatste heb ik in mijn eigen leven als zeer plezierig ervaren. Vroeger als kind, later als professional en nu als recreant.

Daarom voel ik mij bevoorrecht om namens de Stichting Sports & Technology (www.sportsandtechnology.com), als schakel te fungeren tussen al die partijen, die samen de sleutel in handen hebben om dit tot een groot succes te maken.

• Hans van Breukelen

REACTIES: DEKWESTIE@TELESPORT.NL

Figure 7-5: "Back to the playground" (van Breukelen, 2007)

This cooperation between the various parties is also expressed in the composition of the jury, which is made up of representatives from the University, TNO, the company Yalp and the municipality of Eindhoven. Together they represent the business community, knowledge institutions, education and government. The concept 'Lighting Poles', a series of interactive lighted pillars that turn on and off when they are "tagged" by children, is selected by the jury as the best of the presented concepts (Nuchelmans, 2007) (TU/e Online, 2007).

Telegraaf 15 december 2005

Afvallen op speelstoep

• Dolle pret op de speelstoep die de Eindhovense universiteit ontwierp in opdracht van TNO. Spring op en neer en de stoep begint vrolijk te knipperen! Kleurig oplichtende stoeptegels op het schoolplein moeten basisscholieren meer in beweging brengen.
Vandaag presenteren studenten van de Eindhovense universiteit de teststoep. Zo wil het instituut voor toegepaste wetenschap overgewicht onder schoolkinderen bestrijden. Ruim een derde van de kinderen is te zwaar.
„We willen de kinderen achter de computer vandaan halen", zegt Lisa van 't Hof, teamleider van zes tweedejaarsstudenten Industrieel Ontwerpen, die de tegels met lichtjes ontwierpen.
„We bekijken op het moment wie de tegels in productie kan nemen", zegt TNO-medewerker Tinus Jongert. „Bovendien werken we aan meer manieren om jongeren te laten bewegen, onder andere met computerspelletjes."

FOTO: JOHN CLAESSENS

Figure 7-6: "Losing weight on the play floor" (De Telegraaf, 2005)

TU/e-studenten in actie tegen overgewicht

Ontwerpen moeten te zware jeugd in beweging zetten.

door **Lucas Nuchelmans**

EINDHOVEN – Zet jongeren met nieuwe spel- en speeltoestellen aan tot meer bewegen om overgewicht tegen te gaan. Dat was in het kort de studieopdracht voor tweedejaars studenten van de faculteit Industrial Design van de TU/e. In het kader van het project Design en Movement presenteerden de studenten gistermiddag in het auditorium van de TU/e voor een breed publiek – naast medewerkers en studenten van de TU/e, de gemeente Eindhoven, TNO en bedrijven – de resultaten van de opdracht. Door een samenwerking tussen de faculteit, TNO en andere partners worden er door TU/e-studenten steeds meer concepten ontworpen die interessant zijn voor het bedrijfsleven.

De Flashpoles werden met goed gevolg getest op De Hasselbraam

Tweedejaars studenten ontworpen de afgelopen maanden de zogeheten flashpoles als speeltoestel om overgewicht bij de jeugd tegen te gaan. foto **Vincent Wilke**

„Het is een win-winsituatie", zegt Antonio Atjak van de faculteit Industrial Design. „De studenten kunnen voor hun studie aan de slag terwijl ook het bedrijfsleven kan profiteren van de gemaakte ontwerpen. Die zijn in een aantal gevallen goed genoeg om verder ontwikkeld en eventueel geproduceerd te worden."

Atjak was gistermiddag voorzitter van een jury die de zeven gepresenteerde ontwerpen beoordeelde. „Ontwerpen van een hoge kwaliteit en creativiteit", loofde hij de studenten. Winnaar werd het ontwerp 'Flashpoles' van de studenten Kim Böhre, Joran Damsteegt, Erik van Erp, Jabe Pitere Faber en Frank de Jong. Flashpoles zijn twee meter hoge palen met oplichtende kleuren die op tientallen manieren gebruikt kunnen worden. „We hebben eerst tientallen speeltoestellen bedacht die aan een aantal criteria moesten voldoen zoals tot beweging uitnodigen, aantrekkelijk en betaalbaar te produceren", vertellen de vijf tweedejaars. „Uiteindelijk bleef er één concept over dat we de afgelopen maanden hebben uitgewerkt." De Flashpoles werden met goed gevolg getest door leerlingen van basisschool De Hasselbraam.
Andere gepresenteerde ontwerpen waren de Body Beats, waarbij op het lichaam bevestigde sensoren lichaamsbewegingen omzetten in muziek. De Experience Area is een groot, uit kubussen opgebouwd speeltoestel. De oplichtende kubussen zijn bespannen met elastieken waar kinderen tussendoor kunnen kruipen. De knuffel Gumbie kan gebruikt worden als een soort personal coach bij het kennismaken met allerlei sporten. Dat het bedrijfsleven interesse heeft voor de bedenksels van de studenten bewijst een vorig jaar gepresenteerd concept dat momenteel door een bedrijf verder wordt ontwikkeld.

Figure 7-7: "TU/e students in action against obesity" (Nuchelmans, 2007)

7.5.3 Reflection – Intellectual property rights

Another idea that appears to receiving a lot of positive feedback is the concept 'BodyBeats'. This consists of a number of sensors that can be attached to the body or to a piece of clothing. Each sensor reacts to the movements of the wearer and converts this into a sound. In this way the user can make rhythmic music by means of movement, without the use of a musical instrument. The designers of this concept get the opportunity to continue development of the 'BodyBeats' , with support from the Sports Promotion Field Lab, in an internship at the company 2M Engineering. This leads to a discussion in the steering committee of the Sports Promotion Field Lab about the property rights of the developed ideas. Do they belong to the students, the university, TNO, or to nobody? The discussion ends open-ended and the conclusion that none of the concerned parties wants to appropriate the design at any cost. In other words, the students are free to run with the idea in any way they wish. The students develop the concept a bit further during their internship, but the idea seems to stagnate after that, except for a website displaying a short film on the concept (www.bodybeats.org, 2007). The following email shows the way this discussion occurred:

From: Peter Joore, Monday, February 12, 2007: To: Manager Stichting Sports and Technology. Again the question about who would actually be the owner of the BodyBeats concept after the project is finished by 2M. I discussed this with the TU/e, but they too don't really know how to handle this. It's not clear to me whose idea this is going to be. Is it going to belong to "us" (the field lab working group, the municipality of Eindhoven, Stichting Sports and Technology, or TNO?), and will we therefore receive all the results of the internship? (…) Regards, Peter

From: Manager Stichting Sports and Technology, Tuesday, February 13, 2007, To: Peter Joore. Dear Peter, My understanding is that it isn't possible to patent anything, also because it was created publicly; the idea is "as free as a bird". In other words, it appears unnecessary to ask whose concept it is. I would suggest that we think along the lines of our activities, namely that eventually our target is business creation and that it's up to the students and 2M to decide what to do with it. So in fact, the party that invests money in the concept becomes the owner of the concept. I do not think that our money and our function as accelerators are legitimate reasons for a claim. I don't think that the municipality, the project group, TNO or TU/e has any ambition to act as entrepreneur, so I would say leave it up to the students and 2M, and other potential parties who will invest in it... Give the entrepreneurs some room... Naturally we must make sure that they will present the results through the field lab, in order to keep the process going. But in fact, we already have that cooperation (verbally).

When looking from the perspective of the multilevel design model, this discussion relates to "crossing" the border between the socio-technical level of the Sports Promotion Field Lab and the underlying levels of the product-service and product-technology systems. At the higher level, it appears to be mainly about the application of products and services that are being exploited by other organizations (even though in this case, they are supported with some financial help). When new concepts are being initiated at the higher system level, this discussion about commercial value and intellectual property rights appears to be not so relevant to the involved actors, as they are mainly interested in using the functionalities that are offered by those products and services (and not in making a living from them). However, when looking from the lower product-service and product-technology level, this discussion about intellectual property rights suddenly becomes extremely relevant, as these new products and services are now being considered to be "core business", instead of just smaller elements of the bigger system.

Figure 7-8: (left) invitation to seminar "Playground of the future" (TNO, 2007)

Figure 7-9: (right) invitation to E-Fitzone opening (Embedded Fitness, 2008)

7.6 Playground of the future

7.6.1 Evaluation of six innovative playgrounds

The "Playground of the future", already referred to by Hans van Breukelen, is also the title of a TNO study in which an evaluation of six Dutch playgrounds is conducted: a "Sprankelplek" by Jantje Beton, a "Cruyff Court", a "Zoneparc" school yard, a "Richard Krajicek Playground", a playground with elements from the company KOMPAN and a playground with elements from the company Nijha. In the study it was determined in how far the playgrounds contribute to 1) the intensity and the degree of physical activity, 2) motor development, 3) integration, 4) the children's pleasure to move, 5) the degree of use and 6) the degree of attraction of the playgrounds (Bakker et al., 2008, 3). Based on this evaluation, a "program of requirements" is drawn up - related to legislation, safety and effectiveness - for the ideal play area, the "Playground of the Future" (Bakker et al., 2008, 5). Initially the researchers considered developing the ultimate requirements for the "ideal playground". This ideal playground would combine all the elements that make an optimum contribution to the necessary physical activity and related energy consumption, the development of motor skills, mutual integration as well as the joy of playing. However, it soon becomes clear that this objective is not only unrealistic, but also undesirable. After all, each child is different, each play environment is different and the needs of the neighborhoods where the playgrounds are placed are usually dissimilar as well. Therefore the choice is made to take a broader view in the form of different future visions which indicate what a playground of the future might eventually look like.

7.6.2 Playground of the far-away future

Inspired by the results of the student project Xperience Area, the parties involved decide to set up a comparable follow-up project. For the TU/e this is again about research into the development of tangible and physical interaction, specifically targeting use by children. TNO expresses the desire that the project will more explicitly target the outside environment, in order to make it compatible with the research project for the Ministry of Health as mentioned in section 7.1.2. In other words, not so much "moving" in a broader sense, but more aimed at "moving in the public space", but then with the help of innovative technology. In the period from February to June 2007, another six groups of students get to work (TU/e, 2007), each with their own unique approach to the problem area. In TNO's final report, the five designs are presented as a "visionary finger exercise", meant to enable a view of what playgrounds could look like in the near future, viewed from the perspective of a group of promising young designers, who let themselves be inspired by the opportunities of new technology in the form of computer games, sensors and "ambient intelligence" (Bakker et al., 2008, 183). The students develop the Stack It, The Sphere, Weeping Willow, Funky Fountain, Lock Blocks and the B-Plane (Bakker et al., 2008, 183-196). The authors of the book express the hope that the designs will serve as inspiration for designers, manufacturers, civil servants and policy makers, who worked together on the future play environment of young Dutch children.

As a matter of fact, one of the developed products, the B-Plane, is not presented to the outside and is also not mentioned in the TNO report. The reason for this is that the students have dreamt up an innovative activity concept that may potentially be eligible for patent. Because a public presentation of the idea could potentially wipe out that opportunity, the choice is made to keep this idea in-house for the time being. Apparently the intellectual property issue as discussed in section 7.5.3 has had its effect.

Figure 7-10: Artist impression of the Weeping Willow (van den Broek et al., 2007)

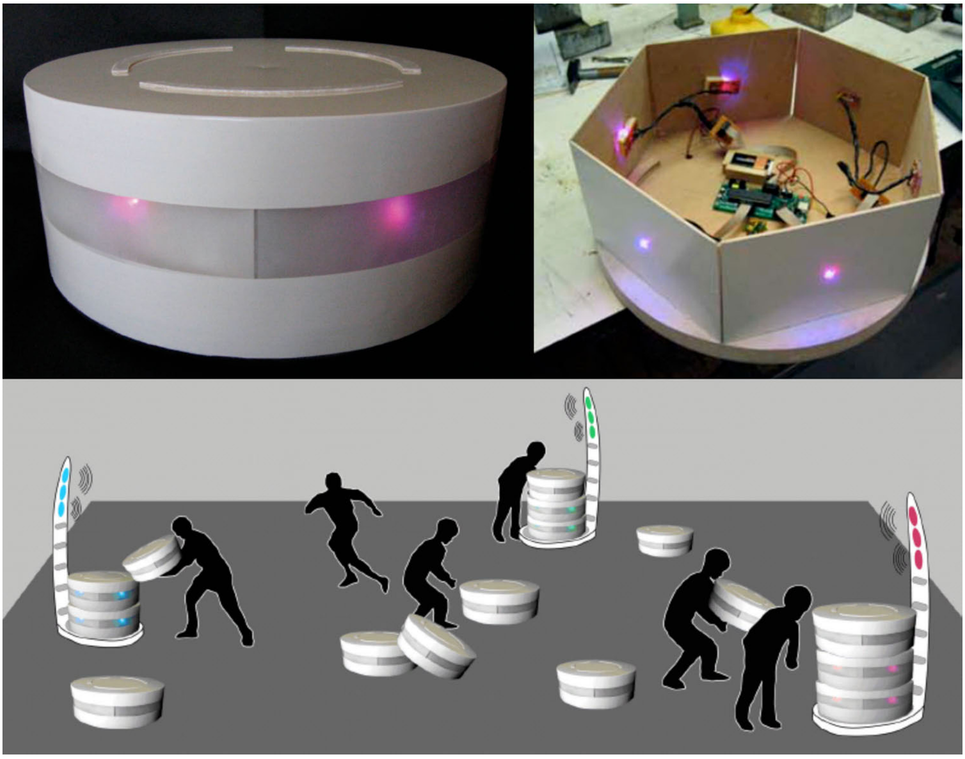


Figure 7-11: Visualization and technical model of the StackIt! system (Hur et al., 2007)

The results of the student projects are presented on June 18, 2007 in "De Zwarte Doos" in Eindhoven, in the form of a design contest, and the "Weeping Willow" (Figure 7-10) emerges as the winning design (TNO, 2007, Wijnen, 2007). This design is presented at the Sports and Technology Conference on September 27, 2007. Under the title "Playground of the Future" it is right next to presentations from other companies such as Electronic Arts, Nijha and Yalp.

7.6.3 Reflection – Criteria for success

The TNO final report is presented at the symposium "Playground of the Future" of March 11, 2008 (TNO, 2008). One important conclusion is that the success of a play area does not depend on the products that are located there, but on the support available on-site: "Broadly speaking, the success of a play area is in the support. Activities must be available, something must be organized and there must be guidance and supervision. Then the children will come and they will all get busy." (Wolthuis, 2008)

Apparently the available on-site support is more important for the success of a playground, than the physical products that are used. When looking to the multilevel design model, this can be described as follows. The playground can be considered as product-service systems, and the physical products are only part of that system. Although they may be the most visible elements, the value judgment regarding the success of a certain playground apparently depends on the "highest level" (in this case the product-service system) that is taken into account. And seen from this level, the on-site support appears to be at least as important, or more important than the available products.

This is for instance recognized by the Richard Krajicek Foundation (responsible for one of the playgrounds that had been studied by TNO, see section 7.6.1), an organization with the mission to "stimulate sports activities, in a safe social environment, for youth that live in neighborhoods in which opportunities are limited" (www.krajicek.nl, retrieved November 15, 2010). One of the explicit demands of this organization to "adopt" a certain playground is the fact that a sports coordinator is present for at least 20 hours a week. Apparently the conclusion that the support surrounding a playground is at least as important as the physical artifacts that it exists of.

7.7 Embedded Fitness

7.7.1 Moving with computer games

Besides design projects by students, the theme "moving and gaming" is increasingly used in the business community. For example, new products appear on the market place during 2006 and 2007, such as of the DanceDanceRevolution, the Nintendo Wii and the Apart Game. In February 2007, TNO presents a proposal to the steering committee of the Sports Promotion Field Lab to investigate a number of these games in relation to their activity intensity and energy consumption. Initially the idea is to study a number of the games that were developed by the students. However, these products turn out not to be available on time. Therefore the choice is made to monitor products that are actually available in stores. The play equipment is installed in Sports Complex Eindhoven-North in June 2007, and data collection can begin. It includes an investigation of the intensity of activity of six different kinds of computer games: the Xerbike, Lasersquash, the ApartGame, DanceDanceRevolution, the EyeToy and the Nintendo Wii. Besides energy consumption, amusement experience by the children and degree of equipment use is also being monitored.

Figure 7-12: Investigation the energy used while gaming (photo by author)

The results of the study are presented in the TNO report "Moving with computer games" (van den Boogaard et al., 2007). Where energy consumption is concerned, especially the Xerbike, Lasersquash and the ApartGame score high, with values above 9 MET, well within range to be labeled as a relatively intensive physical activity (5-8 MET) and as such contributing to meeting the NNGB standard. The Wii scores lowest with a value of 4.4 MET. As for the amusement experience, Lasersquash, Apartgame and the Wii score highest. Reasons for considering a game as the most amusing are: the movements that are required to play the game; the degree of intensity; the novelty of the game; the degree of difficulty; the challenge of the game. A game is considered to be stupid if the degree of difficulty is too high, if there is not enough of a challenge, or the operation or adjustment is too complicated. Ultimately the report concludes that computer games Xerbike, Lasersquash, Apartgame and DanceDanceRevolution can make a positive contribution to meeting the NNGB standard and can be used to stimulate activity.

Having said that, the fact remains that these four games are not nearly as popular compared to the Nintendo Wii, of which apparently more than 70 million units have been sold worldwide between 2006 and 2010 (Gamespot, 2010). So one could argue which product will potentially have a bigger impact on the activity of citizens. In a good way, or in a risk related manner, as can for instance be seen in the article "White-Out From a Wii: Traumatic Haemothorax Sustained Playing Nintendo™ Wii" (Peek et al., 2008). It includes a description of how a 55-year-old woman gets seriously hurt by falling against her couch while playing a game of tennis on her Nintendo Wii. While playing she swings so hard with her arm that she falls and ends up in hospital. The authors of the article were especially alarmed by the fact that the accident happened during a computer game: "The authors wish to highlight the severity of the injury sustained by this patient, especially when considering she was playing a computer game, which would normally be considered a sedate activity" (Peek et al., 2008). Another research in this area concludes that, "as interactive systems such as the Wii increase in popularity, health care providers must be increasingly prepared to recognize and treat game-related injuries" (Sparks et al., 2009). In spite of the risk of injuries it appears clear that playing computer games can make a relevant contribution to promoting activity of young people. This notion forms the basis for the Embedded Fitness initiative, which will be presented in the next section.

7.7.2 E-Fitzone by Embedded Fitness

The emergence of innovative activity games is the reason for the founding of Embedded Fitness. In June 2006, this organization is introduced by the Stichting Sports and Technology at the steering committee of the Sports Promotion Field Lab. The company wants to establish the first fitness center for interactive gaming in Europe, aimed at young people in the 8 to 18 age group. It's not intended to be a game hall, but a serious activity space, where gaming, entertainment and fitness come together and where young people, just like at a sports school, can work through activity programs under professional guidance. The objective of Embedded Fitness is that the establishment in Eindhoven will be the first of a series of comparable concepts in other locations, and that it will function as a "laboratory" in the area of interactive gaming. To that end they wish to use the Trazer, DanceDanceRevolution, Gamebike Sensamove, Makoto, Wii, Laser squash, Wellpoint, E-fit bicycling, Expresso bicycling, Silverfit, C2 Rower, Lightspace and Sportwall, among others (Embedded Fitness, 2010).

The steering committee decides to give the initiator a helping hand. A business plan (Scholten and van Krieken, 2006) is drawn up and the new company is invited to set up shop in Sports Complex Eindhoven-North. On January 28, 2008, Erica Terpstra, chair of the NOC*NSF, officially opens the "E-Fitzone" (Embedded Fitness, 2008) (Trouw, 2008). This event is at the same time the opening of Sport Year 2008 for the municipality of Eindhoven. Following that event, the company continues the work and develops, among others, a mobile E-Fitzone which is implemented at a number of secondary schools around the country. An E-Fitzone is opened in Bergen op Zoom in 2009 (Hopmans, 2009) and in February 2010 an E-Fitzone is opened in Nijmegen (Gemeente Nijmegen, 2010). Interactive games for indoors remain hot news and are apparently an attractive way to get people to move. The next question is whether such innovations are only valid for games that are played indoors, or if they can be useful outdoors as well. This item comes up for discussion during the development of the Sports, Play and Activity Square.

7.8 Sports, Play and Activity Square

7.8.1 Development of the Sports, Play and Activity Square

Partly inspired by the study of the Playground of the Future and the promising ideas of the TU/e students, starting at the end of 2006 the municipality of Eindhoven develops a vision for an outdoor "Sports, Play and Activity Square". A proposal is submitted to the then recently founded InnoSportNL (see section 7.2.3) to jointly develop this location further. The municipality has set aside a substantial budget for the project and would like to multiply it by cooperating with external parties. In February 2007 a project proposal entitled "Sporting Xperience Area" is submitted to InnosportNL for comments. In March 2007, Innosport indicates that they want to focus their efforts on the theme "sports promotion", excluding the more general theme of "activity promotion". After several discussions it is concluded in October 2007 that at that moment, a joint initiative is not attainable. Well before that time, the municipality of Eindhoven decides not to wait for others any longer and takes the initiative to develop the innovative Sports, Play and Activity Square. Developments keep coming and several companies indicate that they would like to test their most innovative products at the Sports Promotion Field Lab, in order to profit from the pioneering role which Eindhoven is expressly trying to adopt.

7.8.2 Reflection – Cooperating or going alone?

Looking from the multilevel perspective of chapter 5, the Sports, Play and Activity Square can be considered as a product-service system, with clear organizational and physical boundaries. In this case, the municipality of Eindhoven is the owner of the project, who decides who to cooperate with and who not. Although they actively pursue partnerships with other actors, the continuation of the Sports, Play and Activity Square doesn't depend on them. When InnosportNL decides that they don't want to join the initiative, the municipality goes ahead with the project anyways. During that process, other actors join in, among others several companies that want to place their products in the new activity square. The following emails give show some of the communication regarding this issue. The first one showing that InnosportNL more or less indicates that the aims of the Sports, Play and Activity Square don't fit their purposes, the others indicating that several companies are very interested indeed.

> *From: Program manager InnosportNL, Wednesday, April 4, 2007, to: Peter Joore, project manager Prevention and Health Subject: Sporting Xperience Area. This past Friday we started an internal discussion at InnoSport regarding sports stimulation, aimed at fine-tuning our vision (…). The current vision is that we are targeting sports promotion and not activity promotion. Sports can be described as all of the activities that are aimed at improving physical performance / fitness by means of training and competition. Training refers to a planned, regular activity. Competition refers to competition. My personal view is that it can be about existing sports and sport variants ("new sports" still to be discussed). It will be obvious that this vision has consequences for the acceptance or rejection of projects which are offered to InnoSportNL. (…) Regards.*

> *From: Peter Joore, Monday, July 2, 2007, To: Area Manager Sports Complex Eindhoven-North; project manager TNO Prevention and Health;* Manager Stichting Sports and Technology. *Dear all, This past Friday I received a call from the director of Kompan. They have finished their new series of play equipment for teenagers and older, with a fair amount of electronics in the equipment. (...) The directors question was about the field lab, whether this could be a suitable location for installing the equipment. The installation would constitute the first publicity surrounding the new products. Their precondition is that the equipment will be used intensively and that there will be some form of*

monitoring of their use (how much, by whom, etc.). Ordinarily they would look for a location in a busy downtown area, but since we have already been in discussions with them, they would like to consider the option of the field lab in Eindhoven. (…) Regards, Peter

From: Manager Stichting Sports and Technology*, Monday, July 2, 2007, to: Peter Joore, area manager Sports complex Eindhoven-North; project manager TNO Prevention and Health. Dear everyone, Good news, the area manager of sports complex Eindhoven-North will of course need to indicate the possibilities and preconditions but it does show that the field lab "is going to work" (...) Regards.*

From: project manager TNO Prevention and Health, Thursday, July 5, 2007, to: Peter Joore; Area Manager Sports Complex Eindhoven-North, Manager Stichting Sports and Technology. Dear all, What a great question. I feel it's desirable that this will be realized, so that we will have a real field lab setup. (...) From TNO Prevention and Health we could implement the same research methodology as was used in the playground study. This includes monitoring of which kids make use of it, how long, how intensively they move, what they enjoy, etc. Regards.

From: Area Manager Sports Complex Eindhoven-North, Monday, July 9, 2007, to: Peter Joore. Dear Peter, I am busy making contact with the director of Kompan, in order to make an appointment about the installation of the play equipment in Eindhoven-North. Regards.

7.8.3 Realization of the Sport, Sports, Play and Activity Square

In March 2008, the municipality reports: "Sports Complex Eindhoven-North radical renovation" (Gemeente Eindhoven, 2008d). Part of this renovation is the rebuilding of the velodrome, to enable automatic time recording with the help of the "TimePoint" system from the company ChampionChip. It also includes the construction of four fenced-off sports fields which are equipped with a "Multiturf" artificial grass cover from Ten Cate, suitable for soccer, volleyball, basketball and other sports. There is a separate play area where interactive outdoor play equipment is placed, such as the Icon system by Kompan and the Sona and Smartus systems by Yalp. The company Candelled developed a modern version of the old game "stoeprandje butsen" (bouncing a ball off the curb), incorporating LED lighting in the concrete curbs, which reacts when a ball is bounced off the curb (Gemeente Eindhoven, 2008a). Another product that gets its trial run at the Sports, Play and Activity Square is the "Light Finder" system where 20 streetlamps react to passers-by who carry a "LiFi" device. Each user gets his own route from the system and the streetlamps indicate with colored lighting which way to go. In this way, commercially developed products, but also test installations that may never be admired anywhere else, are being used at the complex. The Sports, Play and Activity Square is officially opened on October 30, 2008, during the Sports and Technology conference (Sports and Technology, 2008) (Gemeente Eindhoven, 2008c) (Gemeente Eindhoven, 2008d) and in 2010 it is still intensively used at Sports Complex Eindhoven-North.

7.8.4 Reflection - Some things take time

At the end of 2008, the authors leaves TNO for a new job in the North of the Netherlands. Developments in the area of Sports Stimulation continue their way. Even the connection with Innosport ultimately appears to be getting off the ground, albeit a few years later than originally envisioned. The municipality of Eindhoven announces at the end of 2009 that the Eindhoven Sports Promotion Field Lab and InnoSportNL will be paired up starting in 2010, forming one single "national innovation center for recreational sports" (Sportcomplex Eindhoven Noord, 2009). The partners are NOC*NSF, NISB (Netherlands Institute for Sport and Physical Activity), the Stichting Sports and Technology, InnoSportNL and the municipality of Eindhoven. The official opening of the new Innosportlab takes place on June 23, 2010 (Gemeente Eindhoven, 2010). The following email discussion shows the link between the development at the Field Lab Sports Stimulation, and the activities of the author.

De E-fitzone in Eindhoven is niet zomaar een sportschool. Het is de eerste interactieve sportschool in Europa die gaming, entertainment en fitness combineert.

De heersende gedachte dat kinderen dagelijks achter de computer zitten en te weinig bewegen vormde de aanleiding om de sportschool met game-elementen te beginnen. En het slaat aan. Inmiddels zijn op diverse plaatsen E-fitzones gestart voor naschoolse sportactiviteiten. Maar ook ouderen en revalideren-den maken deel uit van de doelgroep. Het afgelopen jaar heeft een mobiele game- en fitnessunit bij verschillende verzorging- en verpleeghuizen gestaan. Gamen zonder stil te zitten, dat is waar het om draait. Wie op de elektronische dansmat staat, merkt dat het energieverbruik vergelijkbaar is met reguliere sporten. Het leuke is dat je de vermoeidheid vergeet tijdens het gamen.

Gamebike

De gamebike is een hometrainer die gekoppeld is aan een PlayStation 2. Door te fietsen en te sturen met de fiets, kan de game – bij voorkeur een racespel – worden gespeeld. Het vraagt veel concentratie en beheersing om goed op de weg te blijven en niet te crashen. Van het fietsen tegen een collega of vriend word je natuurlijk extra fanatiek.

Dance Dance Revolution

De Dance Dance Revolution Arcade 2 mat is een populair videodansplatform dat je speelt met je voeten. Je staat op een dansplatform en springt, danst, glijdt op een favoriet dansnummer. Hierbij moet je de pijlen op het scherm volgen en die met de voeten exact nadoen. In Noorwegen is deze interactieve game zelfs een nationale sport.

Sportswall

Een interactieve muur met led-verlichting erin, dat is de sportswall. Gebruikers kunnen op vele niveaus oefeningen en spellen doen, zoals tennis oefenen, ballen gooien en estafette.

Lightspace

De interactieve vloer Lightspace bestaat uit programmeerbare, drukgevoelige led-tegeltjes. Elk 4 inch tegeltje bestaat uit een aantal pixels dat elke kleur, beeld of patroon kan aannemen. Het oppervlak is in staat om de locatie, dichtheid of beweging van de spelers te detecteren. Zo kun je touwtje springen, 'stoelendans' spelen en 'ga niet op de bal staan'.

Meer info: www.e-fitzone.nl

Figure 7-13: Fit Cool – Magazine Article about E-Fitzone (Computer Idee, 2010)

'Sportpark van de toekomst' geopend

EINDHOVEN, 31 OKT. Jongeren vermaken zich op Sportcomplex Eindhoven-Noord, waar gisteren het 'sportpark van de toekomst' officieel openging. Op deze locatie lag eerder het veld van de voetbalclub Woensel. Het vrijgekomen terrein, in beheer bij de gemeente, is nu een hightech speelplaats, voorzien van allerlei technische snufjes. Zo kunnen kinderen op het zogeheten sport-, speel- en beweegplein een sprintje trekken op een hardloopbaan. Hun prestaties worden onmiddellijk digitaal vastgelegd. Scores op 'interactieve' speeltoestellen zijn te zien op internet, wat wedstrijdjes mogelijk maakt met jongeren op vergelijkbare toestellen elders. In totaal heeft de speeltuin anderhalf miljoen euro gekost, waarvan gemeente en bedrijfsleven allebei de helft hebben betaald. Het complex is gedeeltelijk in gebruik bij de sportopleiding van het nabijgelegen ROC. Buiten schooltijd is het toegankelijk voor het publiek. Ook is het te huur. Foto WFA

Figure 7-14: Sport park of the Future officially opened (NRC Handelsblad, 2008)

From: Peter Joore, to: Interim Manager Field Lab Sports Promotion, Wednesday June 16, 2010. Hello, I heard that next week is the opening of the Innosport Sports Promotion Lab in Eindhoven. Sounds good to me. I am still in the process of writing my thesis, which includes a discussion of the Sports Promotion Field Lab in Eindhoven, so I'm quite interested in the progress. Maybe you could send me an invitation. I am not sure if I can make it, but I'm certainly interested to find out how things are going. Peter

From: : Interim Manager Field Lab Sports Promotion, to: Peter Joore, Wednesday, June 16, 2010. Hi Peter, Hey, nice to hear from you. Enclosed is the invitation, would be nice if you can be there! Everything is okay here, this month I am transferring my field lab management duties to the new InnoSport Lab manager.

From: Peter Joore, to: Area Manager Sports Complex Eindhoven-North, July 5, 2010, How are things in Eindhoven? I heard that the opening of the Innosport Lab took place recently. Unfortunately I could not be there, but it's good to see how our cooperation is still effective a few years later! As you might know, I've been working on finalizing my thesis for the last little while. One of the projects I'm using in my story is about youth and motion, and is based on the work surrounding the Sports Promotion Field Lab and the Make Me Move play tiles. My question for you is whether you could read the chapter I have attached and possibly supply some comments. (...) Thanks in advance for your reaction! Peter Joore

From: Area Manager Sports Complex Eindhoven-North, to: Peter Joore, July 8, 2010. Hello Peter, nice piece! Good overview of everything that has happened. No comments. Attached are a few more recent pictures and articles. Perhaps they'll come in handy. When your thesis is done, we (InnoLabmanager Sports Promotion and I) would gladly receive a copy. Best regards.

7.9 Small Business Innovation Research - SBIR

7.9.1 Feasibility study Make Me Move play tiles

And what has happened to the Make Me Move play floor in the meantime, one of the product ideas that started it all in 2005? Parallel to the above-mentioned developments of the Sports Promotion Field Lab, the E-Fitzone and the Sports, Play and Activity Square, work was also done on the development of the interactive play tiles. The concept of the Make Me Move play tiles is included in the "Small Business Innovation Research" program of TNO in September 2006. Proposals can be submitted until November 2006 for carrying out a feasibility study of the concept (TNO SBIR, 2006) (Oldeman, 2007b). More than 10 companies submit a proposal that are judged by an external commission. Based on that feedback, two proposals are submitted for acceptance to the TNO Board of Directors. Starting in January 2007 the selected companies start their feasibility study for which TNO supplies them with a financial contribution. The companies must present the results of their research in early April, and they decide on the basis of these results if they also wish to submit a proposal for a "valorization process". Both companies do this and present their ideas to the assessment commission in May 2007. The outcome is that one of the two companies, NPSP from Haarlem, is also awarded the assignment for the valorization process, for which they receive a contribution from TNO again (Oldeman, 2007a).

7.9.2 Valorization of the Make Me Move play tiles

NPSP is a specialist in the handling of composites but has no experience with the development of play equipment or the development of electronics. For that purpose they elaborate with the company Tedac EMC, who are specialized in electronics development. Design agency Vormdrift in Dordrecht is responsible for the design of the tiles. The organizations involved jointly establish the company Colibri Interactive Innovations BV at the end of 2007. The first prototype of the play tiles is presented by the project team in Dordrecht on March 25, 2008 and an improved version is presented on May 29, 2009 during the inaugural speech of the project manager TNO Prevention and Health, who is now a part time professor ("lector") in the area of Innovative Activity Stimulation and Sport at The Hague University of Applied Sciences. The development appears to be more troublesome than expected, but the first fully functional play tiles, which in the meantime have been renamed "Twinkle Tile", can be admired at an elementary school in the Dutch village of Oud-Beijerland at the end of 2009. The formal SBIR valorization project is formally finalized in February 2010, and the new tiles are finally presented at October 27, 2010 in Delft, more than five years after the idea originated in May 2005, as discussed in section 7.3.2.

The fact is, that during the course of the project competing tiles were marketed, such as the Pebbles play tiles from competitor Boer Playground Equipment. On October 10, 2009 they install the first Pebbles Play Tiles in a shopping mall in Heemstede (Gemeente Heemstede, 2009). For that matter, these tiles are not primarily aimed at stimulating activity. In contrast to the objectives behind the Make Me Move tile, the games of the Pebbles tiles are primarily educational and instructional in nature, aimed at memory training, math skills, cognitive skills and social skills (Pebbles, 2010). In other words no healthy movements. But wasn't that what started it all, those "Youth in Motion"…?

7.10 Reflection - Societal impact

What is the current situation regarding the original societal challenge that was the focus of the project "Youth in Motion"? What was the contribution to this complex societal question by means of the development of innovative play products? Or in other words, do the products developed in the project indeed make a contribution to the objective of increasing the activity of young people, so that a higher number will meet the Dutch Standard for Healthy Physical Activity?

The Make Me Move play tiles, while invented in 2005, are commercially available by the end of 2010. That means that it is not yet clear whether they can have any significant impact on the activity behavior of children. The first challenge is to turn them into a commercial success. And that will be quiet some work, since several competing products with a similar functionality have in the meantime become commercially available.

Concerning the impact of the E-Fitzone and the Sport, Sports, Play and Activity Square in Eindhoven-North, the results are somewhat more visible. Certainly at the local level, these initiatives have a discernable impact on the activity behavior of youth, and in the case of E-Fitzone the concept also appears to spread on a national level, through installations at several secondary schools in The Netherlands. The Sports Promotion Field Lab Eindhoven still exists and in early 2010 it is renamed to "National Innovation Center for Sports Promotion". The municipality of Eindhoven has formally designated the site as its dedicated test location for innovative sports development. Furthermore, the concept behind the Sports, Play and Activity Square is also being promoted by the company Yalp at other locations (*Figure 7-4*), where the Eindhoven experience is used as inspiration for similar initiatives elsewhere. The area manager of Sports Complex Eindhoven-North, is cited in the Yalp brochure when he says: "you can tell it's working; everybody is gathering here" (Yalp, 2010).

And what about the national view? Are a youth enough in motion? At 6 October 2010, TNO presents their bi-annual Trend Report Activity and Health 2008/2009 (Hildebrandt et al., 2010). Among youth in 2008-2009, only 22% meets the Dutch Standard for Healthy Physical Activity (NNGB), while in 2006 this figure was 27%. It is evident that the complex societal challenge regarding the activity behavior of young people has not yet been solved, but that should not be surprising. After all, it's not for nothing that it's called a complex societal challenge...

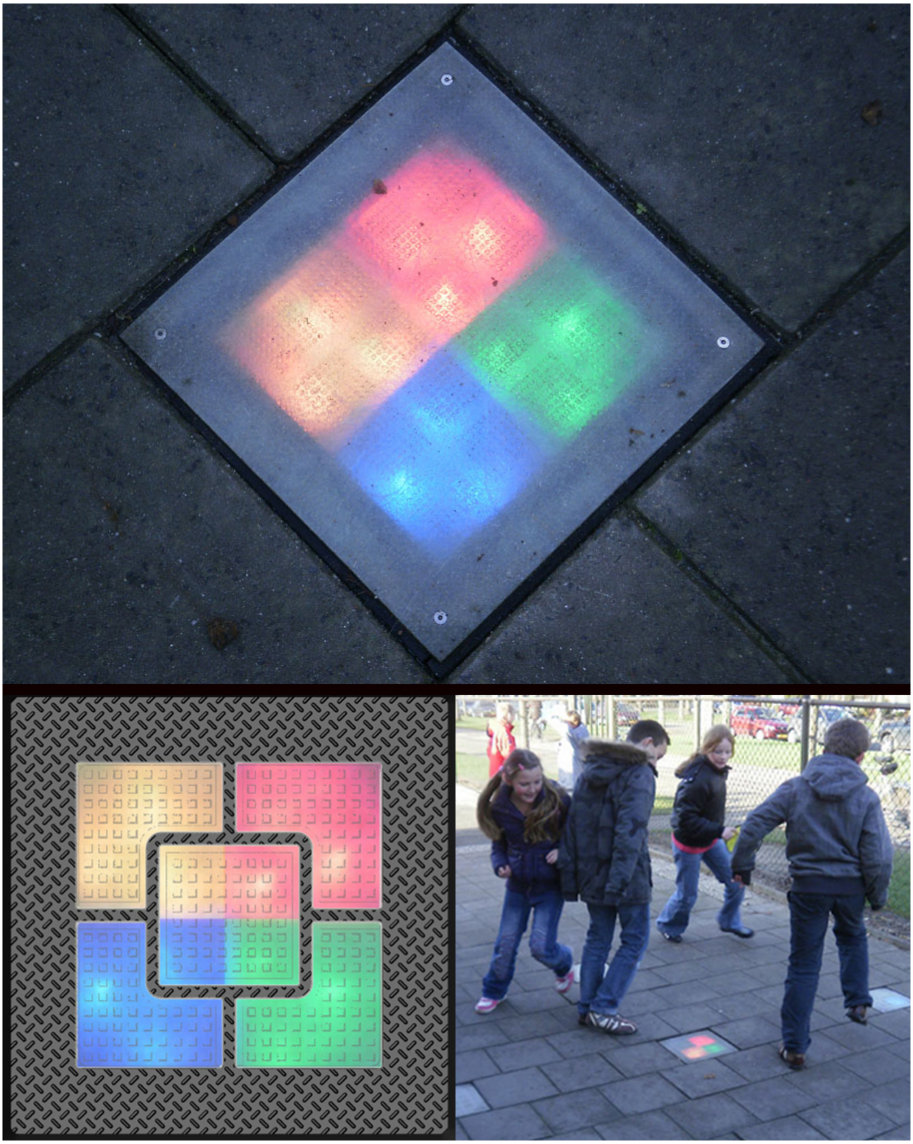


Figure 7-15: Twinkle play tiles (photograph Colibri Interactive Innovations)

Figure 7-16: Pebbles play tiles from Boer Playground Equipment (website www.boerplay.com)

7.11 Summary

Chapter 7 includes a discussion of the project "Youth in Motion". The societal challenge that is the focus of this project is the assessment that many young people are overweight or obese. The cause of this does not appear to be so much in excessive eating, but rather in a lack of activity. This appears to be due to the fact that children are attracted to TV and computer screens, more than that they are attracted to move outside. And this may again be caused by the way that city neighborhoods have been set-up, discouraging children to play on the streets. Several organizations try to improve this situation, ranging from government, the Netherlands Olympic Committee NOC*NSF and TNO. This research takes the perspective of the author, who works at the TNO Science and Industry Institute in Eindhoven. During the project, a close collaboration with the department of Prevention and Health in Leiden is conducted, as well as with the Eindhoven University of Technology (TU/e), the Stichting Sports and Technology and the municipality of the city of Eindhoven. The collaboration takes off in 2005, when TNO Prevention and Health receives a grant of the Loosco fund for the development of a stimulating environment that invites children in elementary school to move spontaneously. This leads to the development of the interactive Make Me Move play floor, combining the apparent attractiveness of computer games, with the need for young people to be more active. The Make Me Move prototype is tested in a children play center in Eindhoven Woensel and a study of the energy consumption of children on the play floor is measured, allowing the determination of the MET (metabolic equivalent) value of the play tiles. The play tiles are tested at the Sports Complex Eindhoven-North, a 32,000 m2 Sports Complex receiving more than 1.5 million visitors annually. During the project, a "Field Lab Sports Promotion" is set up at this location to collect and analyze information about people's activity behavior, with the help of the latest technologies. The field lab also stimulates other initiatives in the area of sports promotion, among which are the project Xperience Area, Design for Movement, Playground of the Future, Embedded Fitness and the Sports, Play and Activity Square.

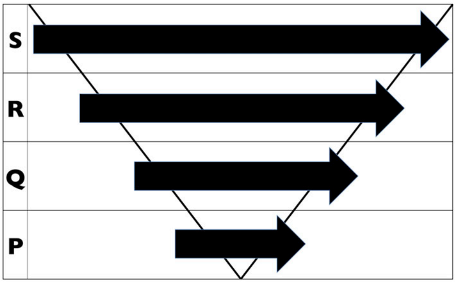
In the student design projects entitled "Xperience Area", "Design for Movement" and "Playground of the Future", several student teams of the TU/e develop new products that encourage young people to be more active. These new products carry inspiring names like the GameWall, Gumby, Drawing Wall, BodyBeats, LightCubes, Takid Door Bell, Flash Poles, Stack It, The Sphere, Weeping Willow, Funky Fountain, Lock Blocks and B-Plane. Playground of the Future is also the name of a study conducted by TNO to evaluate six Dutch playgrounds, a "Sprankelplek" by Jantje Beton, a "Cruyff Court", a "Zoneparc" school yard, a "Richard Krajicek Playground", a playground with elements from the company KOMPAN and a playground with elements from the company Nijha. One of the conclusions of this research is the fact that the success of a play area does not so much depend on the products that are located there, but on the on-site support. Activities must be available, something must be organized and there must be guidance and supervision. Besides design projects by students, the issue of activity games is increasingly used in the commercial gaming industry. New products appear on the market place during 2006 and 2007, such as of the Xerbike, Lasersquash, ApartGame, DanceDanceRevolution, EyeToy and Nintendo Wii. Supported by the Field Lab Sports Promotion, TNO conducts a study regarding the intensity of activity of these computer games, concluding that several of them can make a positive contribution to meeting the Dutch Standard for Healthy Physical Activity. This fact inspires the founding of Embedded Fitness, aiming at the establishment of a fitness center for interactive gaming, aimed at young people in the 8 to 18 age group. As a result, on January 28, 2008, Erica Terpstra, chair of NOC*NSF, officially opens the "E-Fitzone", a location where gaming, entertainment and fitness come together and where young people, just like at a sports school, can work through activity programs under professional guidance.

Parallel to this development, starting at the end of 2006 the municipality of Eindhoven develops a vision for a so called "Sports, Play and Activity Square", which is officially opened on October 30, 2008. This includes a velodrome with automatic time recording, four sports fields which are equipped with a "Multiturf" artificial grass cover, suitable for soccer, volleyball, basketball and other sports. There is a separate play area where interactive outdoor play equipment is placed, such as the Icon system by Kompan and the Sona and Smartus systems by Yalp. All in all, commercially developed products, but also test installations that may never be admired anywhere else, are being used at the complex. With regard to the Make Me Move tiles that initiated the collaboration between the various actors involved in the project, they are being developed with support of the TNO Small Business Innovation Research (SBIR), a program aimed at knowledge transfer to small and medium sized companies. The development takes quite some time, and the new tiles are finally commercially available by the end of 2010, more than five years after the idea originated in May 2005. With regard to the societal impact of all these initiatives, it is not possible to say anything yet about the Make Me Move tiles, as they are just recently commercially available. Concerning the impact of the E-Fitzone and the Sport, Sports, Play and Activity Square in Eindhoven-North, the results are somewhat more visible. Certainly at the local level, these initiatives have a discernable impact on the activity behavior of youth, and in the case of E-Fitzone the concept also appears to spread on a national level, through installations at several secondary schools in The Netherlands. The Sports Promotion Field Lab Eindhoven still exists and in early 2010 it is renamed to "National Innovation Center for Sports Promotion".

8 Chapter 8: Analysis of Experiments

8.1 Introduction

The previous two chapters included discussions of the projects “Youth in Motion” and “Autonomous Elderly”. In this chapter you will find an evaluation of the experiences from these two projects, by means of the multilevel design model as described in chapter 5. A check will be done in how far the new model and the corresponding propositions are confirmed or refuted by practical experience. This chapter does not yet include a discussion of the broader consequences that the results of this evaluation may, as this is discussed in chapter 9.



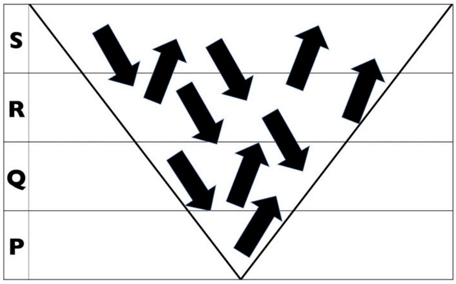
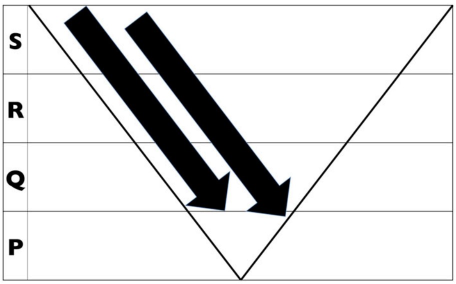


Figure 8-1 (left): P-01 - Design process at different system levels

Figure 8-2 (right): P-02 - Mutual influence between system levels



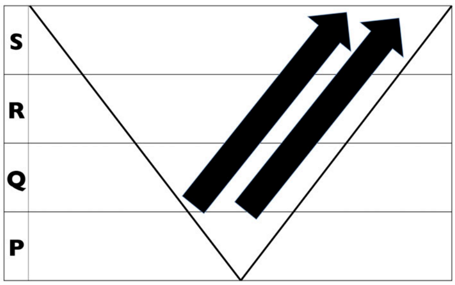


Figure 8-3 (left): P-03 – Top down influence

Figure 8-4 (right): P-04 – Bottom up influence

The multilevel design model establishes the relationship between societal, socio-technical, product-service and product development by the introduction of various system or aggregation levels. The evaluation of P-01 will be examined to see if it is indeed possible to consider the design process as a process that takes place at various aggregation or system levels. This can be displayed graphically as in Figure 8-1, where the “horizontal” process is visualized at the four system levels. P-02 indicates the expectation that the functioning at the various system levels exert a mutual influence, which is graphically shown in Figure 8-2. The expectation is that the multilevel design model can also provide insight into the way that the functioning at the various system levels influences each other. This item comes up for discussion with P-03 and P-04. With P-03 it's about the "top-down" influence of the larger system on the functioning of the individual product, graphically represented in Figure 8-3. With P-04 it's about the "bottom-up" effect that the introduction of a new product can have on the functioning of the broader product-service, socio-technical or societal system, graphically displayed in Figure 8-4. With P-05 we will see how the role of the designer is related to the various aggregation or system levels.

8.2 P-01: Design process takes place at different system levels

8.2.1 Introduction

P-01: "The design process can be described and organized at various system or aggregation levels. The steps that are taken during this process are comparable at each of the various system levels."

In order to test proposition 01, three subquestions will be considered on the basis of the two practical projects:

- A) In how far can the design process indeed be *described* with the help of the four system levels?
- B) In how far can the design process indeed be *organized* at each of these levels?
- C) In how far are the *steps* that are taken at each of these levels indeed comparable?

To enable us to answer these questions, the events that took place in both projects were clustered and positioned at the four aggregation levels of the multilevel design model. The criteria as described in chapter 5 (table 5-4) are used as a guide for this classification. Next is a structuring of the events, according to the steps that can be distinguished during a typical design process, as discussed in section 5.5:

$$S1 \rightarrow S1^* \rightarrow S2' \rightarrow Ts \rightarrow S2$$
$$R1 \rightarrow R1^* \rightarrow R2' \rightarrow Tr \rightarrow R2$$
$$Q1 \rightarrow Q1^* \rightarrow Q2' \rightarrow Tq \rightarrow Q2$$
$$P1 \rightarrow P1^* \rightarrow P2' \rightarrow Tp \rightarrow P2$$

Based on the starting position (P1, Q1, R1, S1), a value judgment is made indicating which problem exists on the various aggregation levels (P1*, Q1*, R1*, S1*). Next, (P2', Q2', R2', S2') indicate the objectives that are defined for the envisioned future situation. (Tp, Tq, Tr, Ts) indicate the synthesis process, resulting in a design for the new situation (P2, Q2, R2, S2). This new situation can then be subjected to a value judgment again (P2*, Q2*, R2*, S2*), after which the process repeats itself.

Table 8-1: Legend for the multilevel design model

Symbol	Meaning
P1,Q1, R1, S1	Characteristics of the system in initial situation
P1*, Q1*, R1*, S1*:	Value judgment relating to this situation, problem definition
P2', Q2', R2', S2'	Objectives, criteria for new (sub-)system
Tp, Tq, Tr, Ts	Synthesis process, resulting in design of new (sub-)system
P2, Q2, R2, S2	Characteristics of new the new (sub-)system
P2*, Q2*, R2*, S2*:	Value judgment relating to the new (sub-)system

8.2.2 Evaluation P-01 on the basis of "'Autonomous Elderly" project

Appendix A includes a table listing of all events of the project "Autonomous Elderly". Based on this overview, a division was created of the various design levels that can be distinguished in the project. The left column of the table indicates the chapter where the respective event is described, the middle column describes the specific event, and the right column indicates the design steps that were completed at each system level, according to the multilevel design model.

First we will look at developments that can be considered as occurring at the societal level. This level includes, among others, political and demographical developments with a more national character, aimed at the question of how aging in the Netherlands should be handled. The scenarios for the future of care, developed by TNO, were also placed at this level, since they were drawn up from a more universal perspective, not yet aimed at a specific, defined situation. This table shows that the starting position is the aging situation in the Netherlands (S1), which leads to a value judgment (S1*) as described in the report "Policy on the elderly in the perspective of an aging population" (Ministerie van VWS, 2005). An attempt to come up with demands for a possible new societal situation (S2') is generated within the TNO NIDSI project and results in the design of four future scenarios named "Flute Player on the Mountain", "Jazz Improvisation", "Russian State Orchestra" and "Andre Rieu Orchestra". The new future situation (S2) regarding aging in the Netherlands is discussed in section 6.8.3. This process is presented in *Table 8-2*.

Table 8-2: "Autonomous Elderly" – events at societal system level

Chapter	Event	Design step
	S1→ S1*→S2'→TS→S2→ S2*	
6.1.1	Aging in the Netherlands	S1 -- characteristics
6.1.2	"Elderly are sovereign and valued citizens"	S1*-- value judgment
6.2.1	TNO NIDSI, aiming for "breakthrough technology"	S2' -- demands
6.4.1	Four future scenarios	T_{S2} -design
6.8.3	Aging in the Netherlands, situation 2010	S2 -- characteristics
6.8.3	Opinions about the situation surrounding aging in 2010.	S2*-- value judgment

Table 8-3: "Autonomous Elderly" – events at socio-technical system level

Chapter	Event	Design step
	R1→ R1*→R2'→T_R→R2→ R2*→R3'→T_R→R3→R3*	
6.3.1	Situation Apeldoorn, many elderly, many seniors homes	R1 -characteristics
6.3.1	The municipality must anticipate the aging to come	R1*-- value judgment
6.3.1	Municipality Apeldoorn stimulates introduction assisted living zones	R2' -- demands
6.3.2	Vision for assisted living center Hubertus-Drieschoten	T_{R2} -design
6.4.2	Future vision "Living together and carefree"/"Freedom and custom care"	R2 -- characteristics
6.4.3	Actors react to developed future visions	R2*-- value judgment
6.8.1	Demands assisted living center Hubertus-Drieschoten	R3' -demands
6.8.1	Development of Hubertus-Drieschoten	T_{R3} -design
6.8.1	Realization and use of De Groene Hoven	R3 -characteristics
6.8.1	Staff and residents' opinions of De Groene Hoven	R3*-- value judgment

Next we will determine what events occurred on the socio-technical level. The developments surrounding the multifunctional center in Apeldoorn can be considered as changes on the level of the socio-technical system. Here we see that the vision for "assisted living zones" as developed by the municipality of Apeldoorn determines the guidelines (R2') for the assisted living center Hubertus Drieschoten. The development of several end views can be considered as possible designs (T_{R2}) for this new center, resulting in the characteristics (R2) of the two visions "living together and carefree" and "freedom and custom care". The reaction of the various actors on these end views present the value judgment (R2*) regarding these designs. Detailed demands (R3') for the new center are determining the actual development (T_{R3}) of the new center, resulting in the characteristics (R3) of the new assisted living center "De Groene Hoven" which in turn can be subject of a value judgment (R3*) again. This process is presented in *Table 8-3*.

Events at the level of the product-service systems are presented in *Table 8-4*. The "Autonomous Elderly" project description includes a discussion which is focused particularly on the subsector telemonitoring. Various new product-service combinations are designed at this level (T_{Q1}), resulting in the characteristics (Q1) of several new telemonitoring products, among which is the Guide Me system. Companies react this concept with a value judgment (Q1*), resulting in the cooperation with My-Bodyguard. This company determines the demands (Q2') for this new system during the SBIR feasibility study. The detailed design (T_{Q2}) takes place within the context of the SBIR valorization project, resulting in the characteristics (Q2) of the new Guide Me system itself, the study by the Institute for Revalidation questions (iRv) was also placed at this level. It established in how far the use of localization systems can indeed contribute to the independence of elderly.

Table 8-4: "Autonomous Elderly" – events at product-service system level

Chapter	Event	Design step
	Q1→Q1*→Q2'→T_Q→Q2→Q2*	
6.5.1	Splitting the future vision into subsectors	Q1' -- demands
6.5.3	Concept design new telemonitoring products	T_{Q1} -design
6.5.4	Visualization of ideas for new telemonitoring products	Q1-characteristics
6.6.2	Companies react to ideas	Q1*-- value judgment
6.7.2	Feasibility project SBIR Guide Me	Q2' -- demands
6.7.2	Valorization project SBIR Guide Me	T_{Q2} -design
6.7.5	Implementation Guide Me system	Q2 - characteristics
6.8.2	Evaluation localization systems for slightly demented elderly	Q2*-- value judgment

Table 8-5: "Autonomous Elderly" - events at product-technology system level

Chapter	Event	Design step
	P1→ P1*→P2'→T_P→P2→ P2*→P3' → T_P → P3	
6.6.1	Young girl abducted in Ahaus	P1 - characteristics
6.6.1	The region, and manager of My-Bodyguard, are in shock: "this has to change"	P1* - value judgment
6.6.1	"Device must transmit location in emergency"	P2' - demands
6.6.1	Development My-Bodyguard	T_{P2} - design
6.6.3	Guide Me device used by De Woonmensen	P2 - characteristics
6.6.3	Users react to Guide Me device	P2* - value judgment
6.7.2	Demands of customizable casing	P3' - demands
6.7.2	Development innovative synthetic casings	T_{P3} - design
6.7.4	Realization Guide Me sub-technology	P3 - characteristics

Developments on the level of products are specifically focused around the tangible device that is part of the Guide Me system. The value judgment (P1*) of the manager of My-Bodyguard, following the abduction of a young girl in Ahaus, results in the demands (P2’) for the new alarm system. This is subsequently designed (T_{P2}) resulting in the characteristics (P2) of the new Guide Me alarm device. The reaction of the users with regard to this device can be considered as the value judgment (P2*) that leads to new demands (P3’) for the new systems, among others with regard to the casing of the device. The subsequent design (T_{P3}) of this casing leads to the characteristics (P3) of the new Guide Me device. This process is presented in *Table 8-4*.

8.2.3 Evaluation P-01 on the basis of “Youth in Motion” project

Appendix B includes a table listing of all events of the project “Youth in Motion”. Based on this overview, a division can be created of the various design levels that can be used to describe the project. The left column of the table indicates the chapter where the respective component is described, the middle column describes the specific event, and the right column indicates the steps that were completed at each system level, according to the multilevel design model.

When we look at the societal level, here the events that have a more national character are positioned. In the Dutch Standard for Healthy Physical Activity (NNGB) the demands (S2’) for the situation in the area of physical activity are defined. This leads to the design (T_{S2}) of various government policy measures, like the National Action Plan for Sport and Activity, setting the boundaries for concrete projects like TNO Sport, InnoSportEU, InnoSportNL, InnoBrabant, each with their own characteristics (S2), resulting in a value judgment (S2*) regarding the contribution of these projects on the goals that were set with regard to the physical activity of Dutch citizens. This process is presented in *Table 8-6*.

Table 8-6: “Youth in Motion” - events at societal system level

Chapter	Event	Design step
	S2’→T_{S2}→ S2→ S2*	
7.1.1	Dutch Standard for Healthy Physical Activity (NNGB)	S2’ -- demands
7.2.1	Government initiatives, National Action Plan for Sport and Activity	T_{S2} -- design
7.2.2	TNO Sport, InnoSportEU, InnoSportNL, InnoBrabant	S2 -- characteristics
7.10	Societal impact	S2*-- value judgment

Table 8-7: “Youth in Motion” - events at socio-technical system level

Chapter	Event	Design step
	R1→ R1*→R’→T_R→ R2→ R2*	
7.1.2	Study Children in priority neighborhoods	R1 -- characteristics
7.1.2	Children must move more	R1* -- value judgment
7.4.1	Sport and Recreation Memorandum: “people must move more”	R2’ -- demands
7.4.2	Development Sports Promotion Field Lab Eindhoven	T_{R2} -- design
7.4.3	Realization Sports Promotion Field Lab Eindhoven	R2 -- characteristics
7.4.1	“Eindhoven-Noord is the ultimate experimental area for sports innovation”	R2* -- value judgment

At the level of the socio-technical system, the current characteristics (R1) with regard to the situation of children in priority neighborhoods can be considered as the starting point of this study. This situation leads to a value judgment (R1*) described in the sport memorandum of the city of Eindhoven, indicating that it is important for children to be able to move more, which sets the demands (R2') for the design (T_{R2}) of the Sports Promotion Field Lab Eindhoven. The fact that this field lab is now considered to be "the ultimate experimental area for sports innovation" in the Netherlands can be considered as a positive value judgment (R2*) regarding the functioning of this field lab. This process is presented in *Table 8-7*.

At the level of the product-service system, two separate developments can be distinguished. The first one is the Sports, Play and Activity Square in the city of Eindhoven. The characteristics (Q1) with regard to the starting position of this project are determined by an analysis of existing playgrounds. The value judgment (Q1*) with regard to these playgrounds is analyzed by TNO concluding in a program of demands (Q2') for a possible "Playground of the future" (Bakker et al., 2008). This results in a design (T_{Q2}) for a Sport, Sports, Play and Activity Square in Eindhoven-Noord, the characteristics (Q2) of which can be seen at the opening of this new square on October 30, 2008. This process is presented in *Table 8-8*.

The second development at the product-service level has to do with the definition (Q3'), design (T_{Q3}) and functioning (Q3) of the E-Fitzone by Embedded Fitness, targeting the application of innovative activity games. This is presented in *Table 8-9*. Both product-service systems are components of the broader initiative surrounding the Sports Promotion Field Lab, which is placed on the next higher system level. The reason for this is that the field lab is not necessarily one single, inextricable, organizational entity, but a kind of cluster of initiatives, all functioning independently from each other.

Table 8-8: "Youth in Motion" - events product-service system level, Playground of the Future / Sports, Play and Activity Square

Chapter	Event	Design step
	Q1 → Q1* → Q' → T_Q → Q2	
7.6.1	Municipalities establish innovative playgrounds	Q1-- characteristics
7.6.1	Evaluation playgrounds: "Success of a play area depends on support"	Q1* -- value judgment
7.6.2	Program of demands for "Playground of the future"	Q2' -- demands
7.8.1	Development Sport, Sports, Play and Activity Square Eindhoven-Noord	T_{Q2} -- design
7.8.3	Opening Sport, Sports, Play and Activity Square on October 30, 2008	Q2 -- characteristics

Table 8-9: "Youth in Motion" - events at the product-service system level, Embedded Fitness

Chapter	Event	Design step
	Q3' → T_{Q3} → Q3	
7.7.2	Concept design Embedded Fitness	Q3' -- demands
7.7.2	Development of Embedded Fitness and E-Zone	T_{Q3} -- design
7.7.2	The E-Zone is brought into use on January 28, 2008	Q3 – characteristics

At the level of the product-technology system, three developments can be distinguished. The value judgment (P1*) regarding the desirability to apply computer technology in innovative activity games leads to the program of demands (P2') for the Make Me Move play floor. After the design (T_{P2}) of an experimental floor by TU/e students, the characteristics (P2) can be determined, especially with regard to the amount of energy used while playing on the floor. This leads to a positive value judgment (P2*) regarding the qualities of the play floor, and new, more specific demands (P3') for a commercial version of the floor, defined in the feasibility study for the SBIR program. In the valorization phase the detailed floor is designed (T_{P3}) by Colibri Interactive Innovations, leading to the commercial implementation in which the characteristics (P3) of the new Twinkel play tiles can be experienced. This process is presented in *Table 8-10*.

The development of innovative outdoor play environments is presented in *Table 8-11* and *Table 8-12*, in the framework of the student projects Xperience Area and Playground of the Future. Based on a program of demands (P4', P5') the students design (T_{P4}, T_{P5}) several new products, whose characteristics (P4, P5) are judged (P4*, P5*) at the Design for Movement symposium and the Playground of the Future symposium. This process is described in *Table 8-11* and *Table 8-12*. These projects are compatible with the development of the Sports, Play and Activity Square and Embedded Fitness, one system level higher.

Table 8-10: "Youth in Motion" - product-technology system level, Make Me Move tiles

Chapter	Event	Design step
	P1→P1*→P2'→T_P→P2 → P2*→P3'→T_{P3}→P3	
7.3.1	Computer technology, opportunity or threat?	P1 -- characteristics
7.3.2	"Computer technology offers opportunities for innovative activity games"	P1* - value judgment
7.3.3	Program of Demands Make Me Move	P2' -- demands
7.3.5	Design Make Me Move play floor -- Lighting Tiles	T_{P2} -- design
7.3.6	Energy monitoring while playing on the Make Me Move	P2 -- characteristics
7.3.7	Presentation and assessment of the play floor	P2* -- value judgment
7.9.1	SBIR feasibility study Make Me Move play tiles	P3' -- demands
7.9.2	SBIR valorization project by NPSP / Colibri Interactive Innovations	T_{P3} -- design
7.9.2	Promotion Make Me Move play tiles / Twinkel tile	P3 -- characteristics

Table 8-11: "Youth in Motion" - product-technology system level, Xperience Area project

Chapter	Event	Design step
	P4'→T_{P4}→P4→P4*	
7.5.1	Design assignment Xperience Area project	P4' -- demands
7.5.1	Six groups of students commence work	T_{P4} -- design
7.5.2	Students develop new products	P4 -- characteristics
7.5.3	Judging at the Design for Movement symposium	P4* -- value judgment

Table 8-12: "Youth in Motion" - product-technology system level, Playground of the Future project

Chapter	Event	Design step
	P5'→T_{P5}→P5→P5*	
7.6.1	Design assignment "Playground of the future" project	P5' -- demands
7.6.2	Six groups of students commence work	T_{P5} -- design
7.6.2	Students develop new products	P5 -- characteristics
7.6.3	Judging at Playground of the Future symposium	P5* -- value judgment

8.2.4 Conclusion P-01

Based on the previously discussed analysis of the projects "Autonomous Elderly" and "Youth in Motion", it can be established that the various system levels are indeed recognizable in both projects. The exact positioning of events in relation to each other appears to depend on the specific situation. In other words, the levels do not appear to be absolute indications of scale, but rather a means of arranging certain design initiatives in relation to each other. Still, it appears that the design process can indeed be *described* with the help of the various design levels, thereby providing an affirmative answer to question A.

An answer to question B requires one to determine in how far the design process can indeed be *organized* at each of these levels. It became apparent in both projects that this may indeed be the case. It also became apparent that different actors may have a different view of the desired aggregation level of a specific design project. This tension particularly occurred in the "Autonomous Elderly" project. On the one hand, one was striving for "the broad outline", in order to search for synergy between the various subsystems. On the other hand, one was striving for innovative in-depth knowledge, which required working at the technological sublevel. The multilevel design model makes it obvious that it is possible to work simultaneously at the various system levels. This is also related to the speed at which design processes take place at the various system levels. For example, the development of a new product progresses faster than the development of a new assisted living center. In practical terms, if the developers of the Guide Me alarm system would have had to wait until it could be implemented in the new assisted living center De Groene Hoven, then they would still not have been able to sell a single product until the year 2010. On the other hand, the development of the Sports, Play and Activity Square Eindhoven progressed much faster than the development of the Make Me Move play tiles. In other words it's not self-evident that developments at a higher level must always progress slower than the development of a new product. All in all the answer to question B is affirmative, where the expectation is that an even more deliberate differentiation on the basis of various system levels can benefit the design process at each of these levels.

And finally, question C relates to the way the design process takes place at the various system levels. Is it indeed possible to recognize a comparable process at each level? The assumption was that this is the case and that this process can be described in the form:

$$S1 \rightarrow S1^* \rightarrow S2' \rightarrow Ts \rightarrow S2$$
$$R1 \rightarrow R1^* \rightarrow R2' \rightarrow Tr \rightarrow R2$$
$$Q1 \rightarrow Q1^* \rightarrow Q2' \rightarrow Tq \rightarrow Q2$$
$$P1 \rightarrow P1^* \rightarrow P2' \rightarrow Tp \rightarrow P2$$

From the composition of *Table 8-2* up to and including *Table 8-12*, one can deduce that a similar process can indeed be recognized at each of the system levels. When taking a closer look at the proposition and the experiences of the two projects, the proposition may have to be reformulated slightly. Where the proposition states that the steps that are taken during the various processes "are comparable" at each of the various system levels, this statement may be formulated too certain. One cannot say that processes are indeed comparable, but it is indeed possible to "describe" the processes in a similar manner. Based on this comments, we propose to adapt P-01 slightly, to emphasize that the model is useful for describing the processes that occur in a similar manner, but not implying that these processes are indeed comparable in real life.

P-01 (amended): "The design process can be described and organized at various system or aggregation levels. The steps that are taken during this process can be described in a similar manner at each of the various system levels."

8.3 P-02: Systems at various aggregation levels influence each other's functioning

8.3.1 Introduction

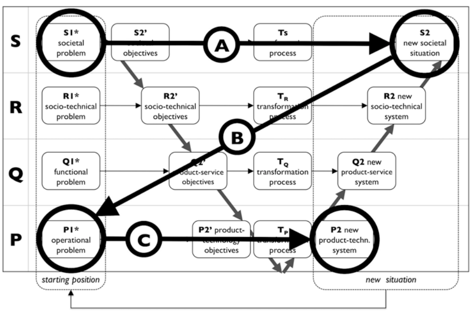
P-02: "Design processes can be described and directed at various system or aggregation levels. Systems at various aggregation levels affect each other's functioning, in both a "top-down" as well as a "bottom-up" direction."

In how far is this proposition substantiated by the results of the two design projects as discussed in chapters 6 and 7? This requires answers to the following questions:

- A) Does the functioning of systems at the various aggregation levels indeed influence each other in a top-down direction?
- B) Does the functioning of systems at the various aggregation levels indeed influence each other in a bottom-up direction?

Two figures related to the mutual influence between the system levels were presented in chapter 5 and again, smaller, in this chapter (Figure 8-1 and Figure 8-2). The first figure visualizes the top-down influence where a functioning of the bigger system (arrow A) influences the functioning of the products that are part of this (arrow B). These may also change on the basis of this influence (arrow C). The second figure indicates the bottom-up process where a new product is developed (arrow D), which function influences the functioning of the bigger system (arrow E), which may change in turn on the basis of this influence (arrow F).

In order to answer questions A and B, a graphical interpretation is created from the events, as presented in *Table 8-2* to *Table 8-12*. To enhance clarity of these tables, certain events were combined into a single block, but the broad outline of the events has not been changed. The reciprocal relationships between the discussed activities are indicated by means of arrows between the events. Having mapped both projects in this manner, let's consider in how far questions A and B can be answered.



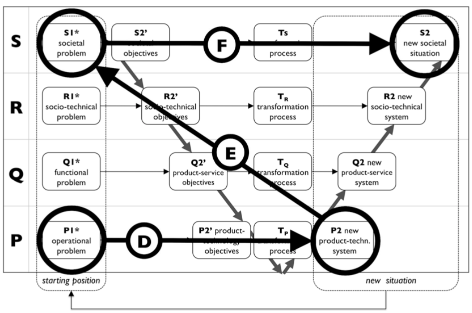


Figure 8-5 (left): P-02 – Functioning of socio-technical or societal system influences functioning of product

Figure 8-6 (right): P-02 – Functioning of product influences functioning of socio-technical or societal system

8.3.2 Evaluation P-02 on the basis of "Autonomous Elderly" project

The mutual influence between developments at the various design levels is shown in *Figure 8-7*. Top-down influence can be recognized in the national demographic developments that lead to the design of new assisted living centers, such as Hubertus Drieschoten in Apeldoorn. Such a living center can be regarded as a small socio-technical system which is made up of various product-service combinations, such as the Guide Me system, in combination with other elements. In its turn, this alarm system leads to the development of various technical components at the product-technology level, like a new casing. The downward pointing arrows indicate this influence from top to bottom.

Besides the top-down influence, it is also possible to recognize a bottom-up influence. This is where technical developments and the design of new products and services lead to changes at overlying levels. For instance, the emergence of GPS technology makes it possible to track objects and individuals, whereby the demand for this type of personal detection systems can get going. Developments in the area of home automation, exert potential influence on the way care institutions function and the way they are designed. Because of the positive expectations of these types of systems, government incorporates these technologies in its policy planning, thereby attempting to stimulate their introduction. Of course this is not only about positive but also about potentially negative effects of technological developments. For example, the question is whether people in care would appreciate the fact they can be tracked anytime of the day by their family, volunteer caregiver or employer. In any case it is obvious that this bi-directional influence of the multilevel model clearly emerges in the “Autonomous Elderly” project.

8.3.3 Evaluation P-02 on the basis of “Youth in Motion” project

The mutual influence between developments at the various design levels in the “Youth in Motion” project is shown by the arrows in Figure 8-8. For instance, the report “Children in priority neighborhoods” describes the effect of the way that city neighborhoods are designed on the activity behavior of children. Based on recommendations from this study, a number of initiatives are started towards the development of concrete new products. For instance, in the Loosco project, where the Make Me Move play tiles are developed, and in the TU/e student design project Xperience Area. The design of Sports Promotion Field Lab Woensel is also partly inspired by the study of the activity behavior of children. Then this field lab in turn contributes to the development of new products and services, such as the E-Fitzone, the Sports, Play and Activity Square and the various TU/e design projects. In other words, the influence of “top to bottom” can indeed be recognized within the “Youth in Motion project.

As for the influence of underlying levels on overlying levels, here it's among others about the influence of technological developments in the area of ICT, sensors and LEDs, which exert an influence on the development of new “smart” products. These new products are then implemented in innovative product-service combinations, such as the Sports, Play and Activity Square and the E-Fitzone. After all, these concepts could never have existed if no new activity games had been developed. Ultimately, the question is what effect the development of innovative play equipment and renewing activity games has on the activity behavior of young people. Here the criterion is in how far these new products indeed have a positive effect on the activity behavior of Dutch youth. In any case it is clear that the top-down as well as the bottom-up influence are recognizable in the “Youth in Motion” project.

8.3.4 Conclusion P-02

The experiences in both projects make it clear that both questions A and B, which were posed in the introduction, can be answered in an affirmative way. The functioning of systems at various levels indeed exert influence on each other in a top-down, as well as a bottom-up direction. The next question can be how exactly this reciprocal influence takes place. This can provide insight into the manner in which the transition between the different design levels takes place.

The downward influence especially appears to take place through the objectives and demands of the higher system level, which are converted into objectives at a lower design level (S’ influences R’, R’ influences Q’, Q’ influences P’). In the multilevel design model this corresponds to the arrow on the left which points downward, where a higher objective continuously influences a lower lying objective. For instance, the objective to make neighborhoods activity-friendly is converted into the objective to realize an attractive Sports, Play and Activity Square, where residents can exercise in a safe and pleasant manner. This objective in turn means that there is a need for innovative play equipment within this Sports, Play and Activity Square. This objective can be realized by the development of entirely new play equipment, or by installing play equipment already developed elsewhere. The latter situation (installing existing play equipment in a broader context), actually involves an upward influence. The fact is that a currently functioning product is implemented at a higher system level.

Before this upward influence can occur in a similar manner, the function must first actually be realized at a certain level. For instance, play equipment that is still in development is indeed a wonderful promise for the future, but has very little value for a Sports, Play and Activity Square which is opening its doors next week. Not until the new product is finished can it be utilized at a higher level. The upward motion therefore appears to take place through the actual functioning of relevant systems. Only once a product-technology system at level P is functioning well, it can be implemented at the higher product-service level Q. And this product-service system must first function well before it can be applied and before it can influence the socio-technical level R. In the multilevel design model this corresponds with the upward pointing arrow on the right, where a certain sub-element fulfills a function within an element at a higher system level.

All in all we can conclude that the functioning of systems at the various aggregation levels indeed exert a reciprocal influence, both "from top to bottom" as well as "from bottom to top", which confirms proposition 02.

8.4 P-03: Functioning of product is dependent on the system that it is a part of

8.4.1 Introduction

P-03: "The functioning of a system influences the functioning of the elements that it is composed of. The functioning of a product is therefore dependent on the product-service system, the socio-technical system and the societal system that it is a part of."

In how far can this proposition be substantiated by the results of the two innovation projects as discussed in chapters 6 and 7? This requires answers to the following three questions:

- A) Can each product indeed be viewed as an element of an overlying product-service, socio-technical or societal system?
- B) Does the functioning of this larger system indeed influence the functioning of the respective product in either a positive or negative manner?

The hierarchical structure of systems at the various aggregation levels is shown in Figure 5-8. The schematic indicates that each system is divided into various subsystems, which in turn are divided into sub-subsystems. A comparable schematic will be drawn up for both projects. Following this is an examination to see if products which are well adapted to the larger system that they are a part of, indeed function better than products which are not, and vice versa. P-03 reasons from the position of one product within the entire system. The analysis will therefore also be based on one concrete product in relation to the system that this product is a part of. In the first project it's about the Guide Me localization device, in the second project it's the Make Me Move play floor.

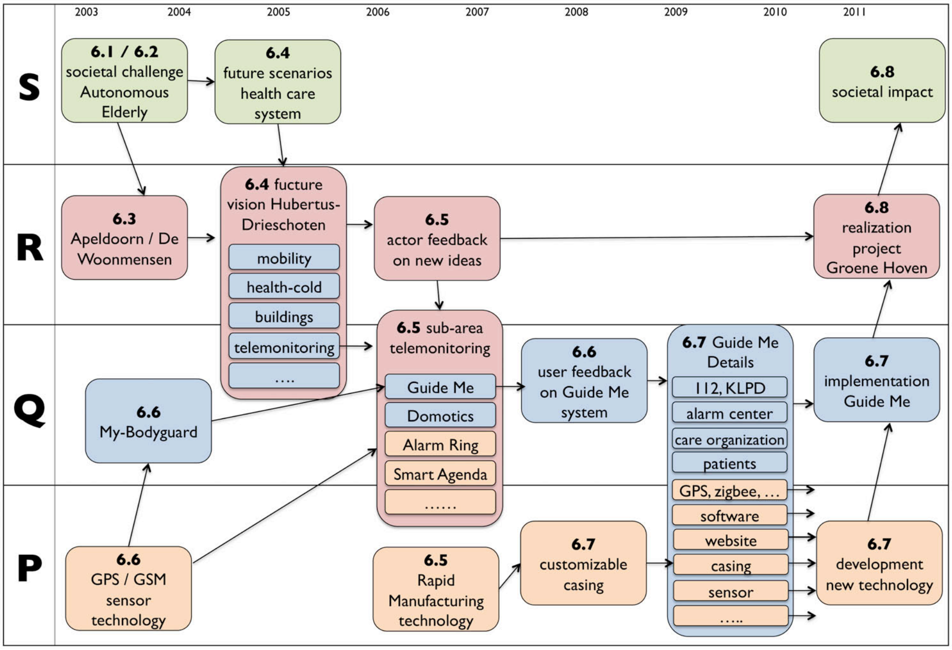


Figure 8-7: Reciprocal influence between system levels – "Autonomous Elderly" project

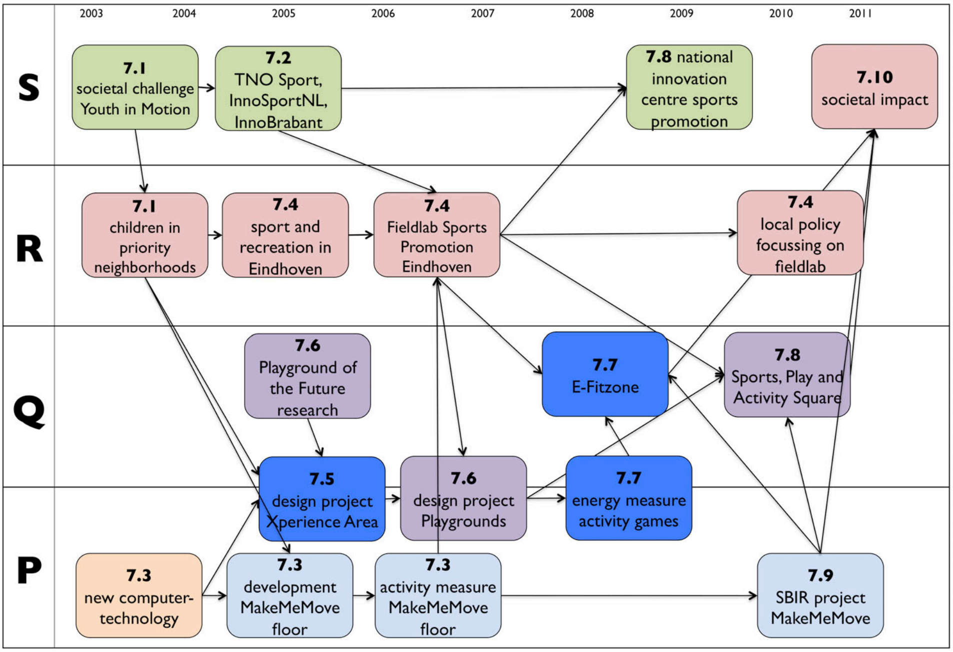


Figure 8-8: Mutual influence between system levels – "Youth in Motion" project

8.4.2 Evaluation P-03 on the basis of "Autonomous Elderly" project

From a traditional industrial design perspective, the physical device is the most recognizable and tangible part of the Guide Me system. This is the component you can hold, that has to be assembled somewhere, that has to be moved from A to B until it arrives at the consumer who starts using it. The device is assembled from electronics, hardware, software and sensors, which are all housed in a synthetic casing with a few knobs. Depending on the situation, the device communicates through GPS, GPRS, ZigBee or some other communication protocol with the outside world, either the 112 switchboard of the Dutch police or a private alarm center. In other words, the physical artifact is only one of the many components of the total alarm system that it is a part of.

The product-service system Guide Me is in turn a small part of the entire care service that is offered to consumers by organizations such as De Woonmensen. Here, even within the subsector of telemonitoring, the alarm system is only one of various related systems like burglar alarms and fall detection. This subsector of telemonitoring is in turn joined by themes such as housing, mobility, health and finances, which all interact. Although users, both elderly as well as caregivers, react very positively to the system, it turns out that actual sales are slow to get going. This appears to be directly related to the national system of subsidies for medical aids, with which we have immediately arrived at the societal system level. After all, care institutions are being financed by government, which has largely assigned payment for medical aids to care insurers. The fact that these insurers are very careful where compensation for new medical aids is concerned, has a lot of influence on the acceptance of the Guide Me system.

At the same time the Guide Me system (under the name My-Bodyguard) is rather successful within a different domain, that of surveillance and security trade. Financing by insurers does not play a role in this domain and the product appears to be a valuable addition to the existing assortment of devices that are carried by security personnel. Although this is also a matter of a renewal and there is indeed resistance against the introduction of the system, this resistance is not so much at the higher system level as it is at the level of the individual user (Joore, 2008, 261). In this case however, resistance from individual users appears to be weaker than the interests of the employer and the trade. Because the new product is quite compatible with the "higher" interests of the employer, the "lower" interests of the employer must conform to this, as it were.

When converting this back to the multilevel design model, the difference between the two situations can be described as follows. The new product-service system Guide Me apparently doesn't fit well within the existing socio-technical system of elderly care, although "on the work floor" reactions are rather positive. However, for the proper functioning of the Guide Me system it is necessary that other system components are adapted, in this case health insurance. As long as these components are not adapted, the new product-service system will not function properly within the broader socio-technical system of care. With regard to the other domain that the Guide Me system is used, considerably less enthusiasm was encountered among the security guards on the work floor, as was demonstrated by a small-scale but targeted opposition during the implementation of the system (Joore, 2008). However, because there appears to be a need at the "higher" system level for the new product-service system, and moreover, relatively few other system aspects need to be adapted, the implementation in the security trade takes place relatively quickly. The security system is ready to embrace, as it were, the new product, as opposed to the care system, where particularly the compensation rules by insurers appear to be an important barrier.

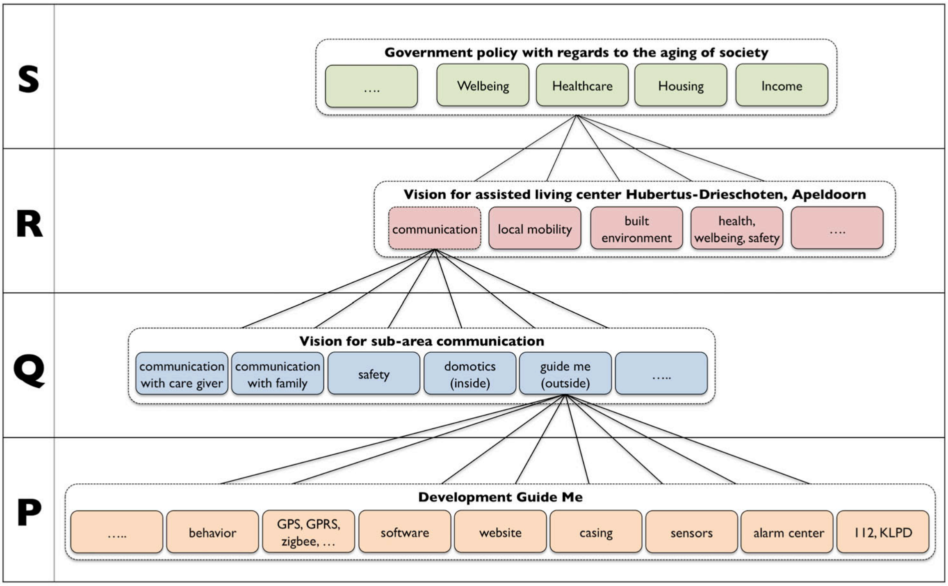


Figure 8-9: Analysis of "Autonomous Elderly" experiment

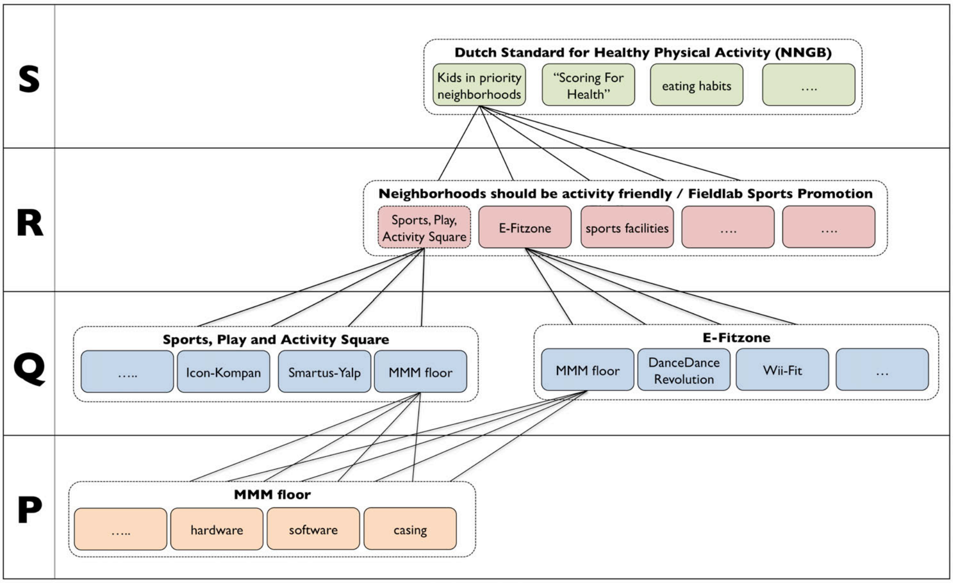


Figure 8-10: Analysis of "Youth in Motion" experiment

8.4.3 Evaluation P-03 on the basis of "Youth in Motion" project

This analysis focuses especially on the interactive play floor which was developed within the "Youth in Motion" experiment, from initial idea to actual, commercial product. It's not a question here of an elaborate product-service systems. The physical artifact is the essence of the system: An interactive play floor which reacts to the environment by turning on or off the lights in various tiles in various colors.

In how far does this individual product have anything to do with other, overlying systems that it may or may not be a part of? This influence appears to be clearly discernible, even in the case of a fairly isolated artifact. First of all, the size of the tile (30 x 30 cm) is based on the most commonly used tile in city neighborhoods and schoolyards. The ambition of the developers is that this will make it easier to fit the play tiles into the envisioned use environment: neighborhoods where children have an ever-decreasing amount of outside play area at their disposal. Other than the size of the tiles, it appears that there are a number of other system aspects connected to the introduction of the play tiles. For example, they need electricity. But since currently hardly any electric outdoor play products exist, there are no rules or standards which indicate how this power supply should be arranged. Where most playgrounds are now maintained by the Parks Department of the local government, all of a sudden it needs to be decided who will be paying the monthly electricity bill. And what needs to happen when there is an electronics failure in the equipment? If one would ask the suppliers of the play equipment this question, it turns out that they are not at all prepared for the maintenance of electrical equipment. The Make Me Move play floor therefore requires the system within which it functions to adapt. That's why the initial installation of the above-mentioned interactive play equipment occurs in special locations, like the Sports, Play and Activity Square in Eindhoven, where the added value of the unique play product apparently offsets the effort it takes to arrange the accompanying services. Such an environment can be recognized as the strategic "niche" environment as discussed in chapter 4, which apparently has room for the development of novelties that situations elsewhere are not yet ready for. For their part, both Embedded Fitness and the Sports, Play and Activity Square are part of the Sports Promotion Field Lab, which in turn fits within the policy plans of the municipality of Eindhoven and the province of Brabant. For example, the introduction of the Sports Promotion Field Lab was partly financed by the InnoBrabant project, but after the initial launch it obtained its own, full-fledged position within the municipality of Eindhoven, as is explicitly mentioned in the sports policy memorandum 2008-2015 *(Gemeente Eindhoven, 2008b, 31)*.

So let's return to the Make Me Move tiles. At the time of writing this thesis (October 2010), these tiles have not been implemented, neither at Embedded Fitness, nor at the Sports, Play and Activity Square, nor elsewhere in the Sport Promotion Field Lab. This in spite of the fact that it has green lights all the way. Meanwhile other producers are definitely making use of the positive secondary conditions that are apparently available at the system level. For instance, the Pebbles play tiles by the company Boer Playground Equipment have already been installed at various outdoor locations since October 2009. Apparently, the fact that the "system is ready for it" does not yet guarantee success and companies that develop products must still get their own affairs in order. After the enthusiastic presentation of the Twinkel tiles at October 27, 2010, we will now have to wait and see if the play tiles will be installed in the Sports Promotion Field Lab or elsewhere in the neighborhood. Then it may become clear in how far the play tiles will indeed fulfill the function as envisioned with their creation in 2005.

8.4.4 Conclusion P-03

The two experiments demonstrate that both products, the Guide Me device and the Make Me Move play floor, can indeed be viewed as an element of an overlying product-service, socio-technical or societal system. This provides an affirmative answer to question A. It also becomes apparent that the functioning of this larger system indeed influences the functioning of the respective product, either positively or negatively. This provides an affirmative answer to question B in the introduction, which leads to the confirmation of proposition 03.

In the case of the Guide Me system this emerges most emphatically, since the product will absolutely not function without the corresponding services and infrastructure. Without these elements the physical artifact would merely be a useless box, at best useful as a paperweight. Moreover it is apparent that developments at the societal system level are essential for the broader implementation of the Guide Me. After all, because insurers provide only limited compensation for the system, its application in care is very slow to get off the ground, in spite of positive reactions by all concerned users. The system does appear to be successful in the domain of surveillance, where the funding model is completely different. Apparently, even with a relatively autonomous product such as the Make Me Move play tiles, system aspects indeed play a role. The simple fact that the product uses electricity, in contrast with existing outdoor play equipment, suddenly demands that suppliers and consumers need to take a different approach to the installation (providing electricity, standards, security), monthly expenses (who pays the power bill) and maintenance (who repairs a dysfunctional tile).

Critics might say that there is a risk that this proposition will be studied as a kind of self-fulfilling prophecy. If the product was not successful, it was "therefore" not well adapted to the respective system. And if it was successful, it was "therefore" well adapted to the environment. However, both experiments provide enough reason to counter this criticism. For instance, the lack of subsidies by care insurers is undoubtedly one of the vital bottlenecks for the introduction of the Guide Me system. In a more abstract sense, the more that other elements of the system (in this case the matter of compensation) must be adapted in order to let the new element (Guide Me) function, the bigger the chance of failure at one of these elements. On the other hand, in the case of the Make Me Move tiles it is becoming clear that even if the whole system is ready to adopt the new product, that this does not guarantee success. In this case, the company that is developing the Make Me Move tiles needed until the end of 2010 to come up with a commercially available product. Fitting into the larger system is apparently an important condition for the success of an innovation, but it is certainly not the only or sanctifying prerequisite for success.

8.5 P-04: New products can help to achieve societal objectives

8.5.1 Introduction

P-04: "Each socio-technical or societal system is made up of subsystems. Change of a subsystem, as takes place in the introduction of a new product, influences the functioning of the entire system. Therefore the development of a new product which is a component of an envisioned future socio-technical or societal system, will hasten its realization."

The discussion of P-02 and P-03 already demonstrated that the various system levels exert a reciprocal influence. P-04 will include a closer examination of the nature of this influence. The difference between P-02, P-03 and P-04 is mainly in the essence of arrow F in figure 8-6. Arrow D in this same figure indicates the change of a certain product. Arrow E indicates that this change influences the societal system that the product is a part of. Thus far there is no difference with P-02 which states that systems at various levels influence each other's functioning. However, P-04 expresses the expectation that it is possible to develop a product in such a way that it can guide a socio-technical or societal change in a controlled, specified direction. After all, by developing one of the elements of an envisioned new bigger system, the realization of that system gets one step closer. Chapter 5 includes a sketch of how such a process could proceed within the multilevel design model, as presented in Figure 8-11. First of all this includes the formulation of the objectives at the level of the socio-technical or societal system (arrow G). These objectives are then converted into sub-objectives at the level of product-technology systems (arrow H). The realization of these products (arrow I) subsequently forms one of the building blocks of the envisioned new socio-technical or societal system (arrow J). In how far has P-04 now been substantiated by the results of the two projects, as described in chapters 6 and 7? This will require answering the following three questions:

- A) Can the socio-technical or societal system indeed be considered as a collection of subsystems and sub-subsystems such as products?
- B) Can the introduction of a new product indeed influence the functioning of a socio-technical or societal system?
- D) Can the development of carefully chosen new products indeed hasten the realization of an envisioned socio-technical or societal system?

Questions A and B have already been dealt with in the discussion of P-02 and P-03, so that in the evaluation of P-04 the main focus is on question C. In order to discuss this question, the author has focused his attention in both experiments on the development of at least one new product which is a part of an envisioned future societal system. This is where the process of arrow H in Figure 8-11 has been followed as much as possible during the practical experiments. The question is whether the realization of these new products has indeed brought the envisioned new socio-technical or societal system closer.

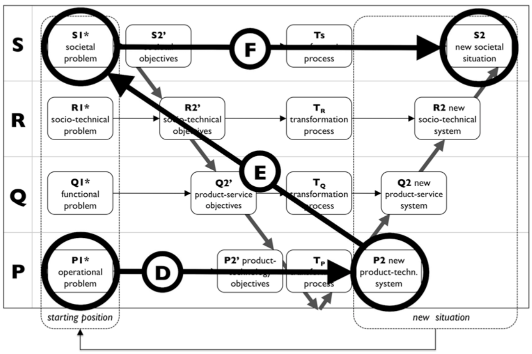


Figure 8-11: P-04 - New products influence development of socio-technical or societal system

8.5.2 Evaluation P-04 on the basis of "Autonomous Elderly" project

In order to evaluate P-04, the target objectives and sub-objectives will be studied at the various design levels, based on *Table 8-2* to *Table 8-5* and *Figure 8-7* in this chapter. At the societal system level, one of the focus points is article II-24 of the charter of the Constitution of the European Union, which mentions the rights of the elderly:

> *"The European Union recognizes and honors the rights of the elderly to lead a dignified and independent life and to participate in society and culture" (EU, 2000)*

Dutch government recognizes the importance of the above-mentioned values and translates this into seven operational objectives: Remain healthy and fit, Participate in rights and duties, Sufficient income, Suitable dwellings, Health insurance, Dying in dignity and Freedom of movement. The latter means, for example, "that 'elderly' can also move freely and safely in a physical sense in the environment that they are a part of" (Ministerie van VWS, 2005, 42). These objectives are in keeping with the objectives of the "Autonomous Elderly" project, which is focused on the following innovation question:

> *"How can seniors in 2015 remain independent longer, with a higher quality of life, at acceptable costs" (TNO, 2005)*

For this purpose a sketch is presented of an integral vision of the yet-to-built complex Hubertus Drieschoten. One of the many components of this vision is the portable alarm button (TNO, 2005, 15) which is developed further by the company My-Bodyguard BV. During this process the company defines seven likely innovation tracks : Link with health alarm, intelligent on and off switching, inside/outside residence detection, addition of alarm function, interaction with caregiver or companion, miniaturization and attractive casing (Siemerink, 2006b). This constitutes a summary of the process that includes a stepwise "descent" from the European rights of the elderly to live a dignified and independent life, to the development of an attractive casing for a personal detection device that is marketed by a small company. A visual representation of this process is presented in Figure 8-12.

Steps G, H and I of Figure 8-11 are now behind us. But what about arrow J? In how far does the developed product actually have an effect on the socio-technical or societal system that it is a part of? Based on sales figures in the care sector, one could conclude that the Guide Me system is not making much progress in care, especially when it is compared with other markets where it is active, such as in surveillance. And even less can be said about the impact of this alarm system in the new assisted living center by De Woonmensen, since the actual construction of the new complex, after several years of preparation, did not start until late 2009. The assumption in P-04 is that the development of a new product which is a part of an envisioned future system will hasten its realization. However, the initial impression appears to be that the development of a new product can best be compared with the proverbial "drop in a bucket", as it has hardly any effect.

And yet, the multilevel design model can indeed provide some clarification here. Although the effect of the specific Guide Me system from one specific company may be difficult to identify, the fact is that this is a matter of the development of a certain *type* of product in a new *class* of systems, of which Guide Me is just one of the many variants. For instance, a study conducted in 2005 by the Institute for Revalidation Questions (iRv) examined how individuals with dementia and their volunteer caregivers experience this type of technical support. The results of this study are rather positive (Rasquin et al., 2006, 32). Although the specific Guide Me system by one specific company may not offer the ultimate solution for aging in the Netherlands, the development of the system and comparable systems is potentially useful in allowing people to live independently longer. As a matter of fact, as discussed in chapter 6, De Woonmensen introduces an alarm system that is very similar to the one by My-Bodyguard BV, under the name Mobielparaat. Apparently it is not about the specific system by a specific manufacturer, but about a certain type or class of product, regardless of the brand or supplier. In other words, it's about a specific functionality that is realized and it is less important how that happens. A comparable reasoning can be used for the new assisted living center Hubertus Drieschoten. Although the center is only recently finished at the time of writing, it is only one of many comparable assisted living centers that are currently being built in the Netherlands. Therefore it is not about the added value of one specific assisted living center, but about the added value of this type of care center, whether this is realized in Apeldoorn or elsewhere.

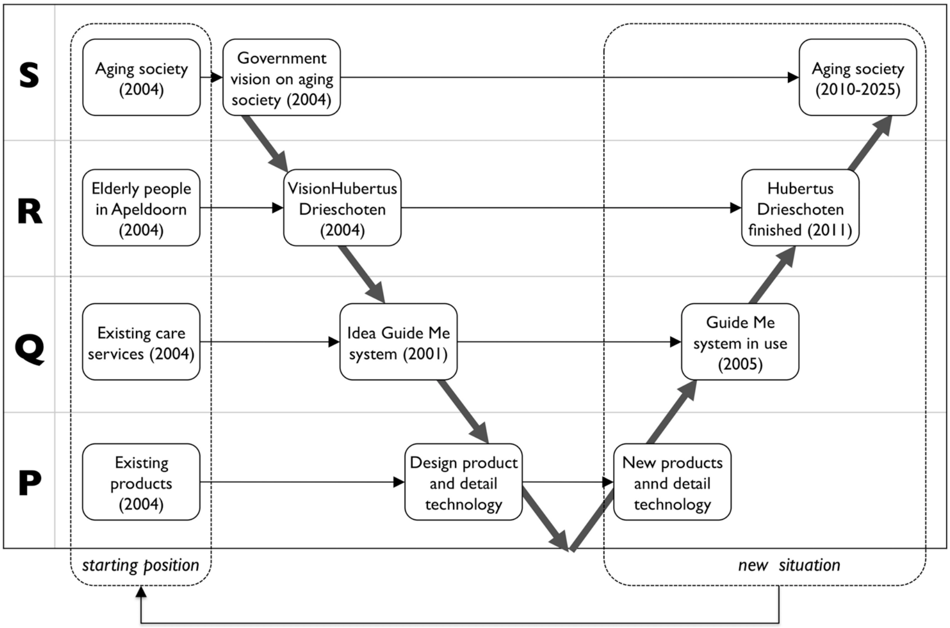


Figure 8-12: Evaluation P-04 in relation to "Autonomous Elderly" experiment

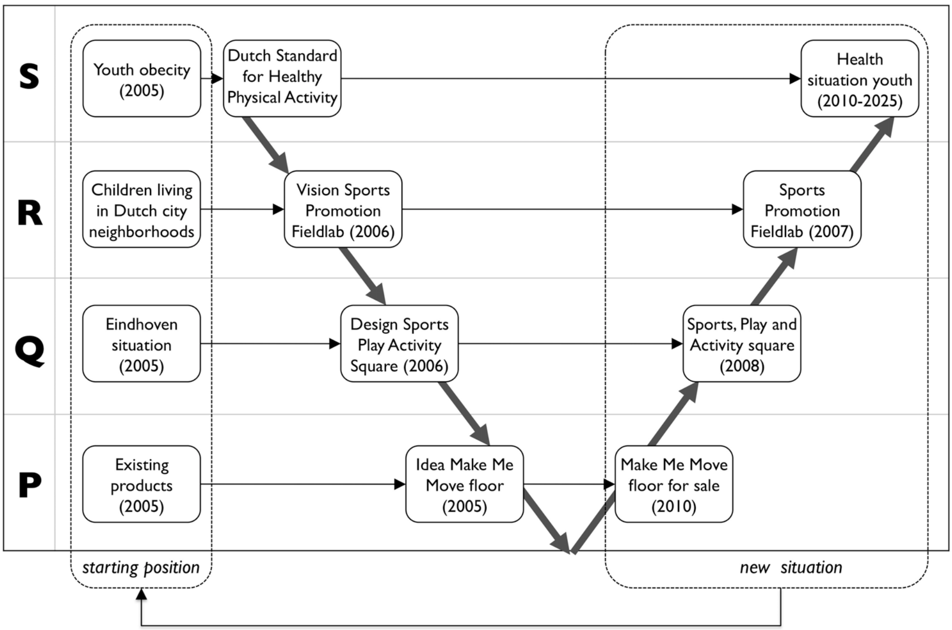


Figure 8-13: Evaluation P-04 in relation to "Youth in Motion" experiment

8.5.3 Evaluation P-04 on the basis of "Youth in Motion" project

Also for the "Youth in Motion" project the target objectives and sub-objectives will first be studied at the various design levels, starting with the highest societal level. This will be based on *Table 8-6* to *Table 8-12* and Figure 8-8 in this chapter. The inspiration of this project is in the Dutch Standard for Healthy Physical Activity (NNGB), formulated in 1998, which states that youth up to the age of 18 must be involved in at least one hour of fairly intensive activity per day (Kemper et al., 2000). The report "Children in priority neighborhoods" mentions a decrease in physical activity by young people. The impression is that this is partly caused by a growing passive use of leisure, such as watching television or playing on computers. But the layout of the city neighborhood also appears to be a cause for less and less outside playtime. The objective of the project "Youth in Motion" is to be able to answer the question:

> *"How can Dutch city neighborhoods be improved to stimulate physical activity by children aged 3-7 in the elementary school system? (de Vries et al., 2005)*

That's why TNO and TU/e, with support from the Loosco fund, are designing a stimulating environment that motivates children to start moving spontaneously. The design includes, among others:

> *"…modern play equipment that is adapted to the interests of the current generation of children who grew up with multimedia (computers, television, DVD, mobile telephone)" (Jongert, 2005a).*

The project results in a prototype of the interactive Make Me Move play floor, based on lighted sidewalk tiles, where jumping kids can play games and move at the same time. Thus a relatively pragmatic translation has been made from a societal challenge (the objective to get youth to move more) to a physical product that makes a contribution to this problem (the interactive play floor) which is developed to a production-ready system by the companies NPSP BV and Colibri Interactive Innovations BV between 2007 and 2010. A visual representation of this process is presented in *Figure 8-13*.

Steps G, H and I of Figure 8-11 are now behind us. But what about arrow J? Has the development of the Make Me Move play floor managed to get young people to move more? The answer to this question will have to wait, because development of the floor was finished only recently. Although a study with the various prototypes provides positive results regarding energy consumption of children playing on the floor, the floor will only have a societal effect when it is implemented on a large scale in practice, and that is not yet the case at the time of writing.

And yet, it's certainly possible to draw a first conclusion, based on the conducted experiment, from proposition 04. After all, the project included a study and implementation of comparable, interactive activity games in practice. A fair amount of interactive activity games, available at the market, were installed and tested in the E-Fitzone of Embedded Fitness, such as the DanceDanceRevolution, Gamebike, Sensamove, Makoto, Wii, Laser Squash, Sportwall and Lightspace. As for outdoor play products, the "Icon" play equipment of company Kompan and the "Sona" and "Smartus" systems of company Yalp are installed in the Sports, Play and Activity Square in Eindhoven. Although the Make Me Move floor itself is not yet widely implemented, comparable products are most certainly widely in use. And these products may indeed have a positive effect on the activity behavior and energy consumption of young people (van den Boogaard et al., 2007). Furthermore, the development of this type of product has led to new previously mentioned E-Fitzone. After all, this new concept could not have been developed if the interactive activity games that are implemented here would not have existed. The elements of the system (the interactive activity games) had to be present first, before the larger system (the E-Fitzone) could be realized.

Also in this case, P-04 must therefore be amended to the extent that it isn't about the development of one specific product from one specific supplier, but about a specific *type* of product with a specific *type* of functionality. In this case it's the combination of gaming and moving.

8.5.4 Conclusion P-04

Based on the experiences from the projects "Autonomous Elderly" and "Youth in Motion", it can be stated that proposition 04 in its original form must be rejected, but can be confirmed in an amended form. The reference point behind P-04 is that socio-technical and societal systems are made up of subsystems. Once these subsystems are realized, the realization of the envisioned socio-technical or societal system will come closer. Regarding the manner in which this is accomplished, the reasoning is as follows: A system objective can be applied to sub-objectives and sub-sub-objectives at a lower aggregation level. The realization of all these sub-objectives jointly leads to reaching the overlying objective. The development of a new product which is a part of an envisioned future socio-technical or societal system will hasten its realization.

Next are some remarks, based on the conducted experiments. First, it appears that derived objectives are often mutually interchangeable. For instance, seniors can also live independently longer without applying any technology, and young people can move perfectly well without interactive activity games. If the choice is made for a technological solution anyway, then it also becomes apparent that for the fulfilling of certain functions it is not so much about one specific product that must fulfill this function, but about a certain *type* of product that fulfills a certain *type* of functionality. The various interactive activity games are quite interchangeable amongst themselves, and from a societal level it doesn't matter whether young people move on the DanceDanceRevolution mat or on the Make Me Move play tiles, as long as they move. Only in the specific case that a specific functionality cannot be fulfilled in any other way, and the development of a new product or technology really is the only way to fulfill this function in the future, the original form of the proposition would be valid. That's why P-04 is amended to place more emphasis on the type of functionality that is realized rather than the specific product that is developed, and to emphasis that we can only say something about the <u>potential</u> impact of new products.

With regard to the actual impact that can be achieved on the socio-technical or societal level, we can only say things with a lot of restraint. Based on the outcomes of the research, it is not possible to draw any conclusion with regard to the societal impact. In both cases, a direct impact of the new products could not be distinguished within the project, although a potential impact, certainly at the socio-technical level, seems plausible. Therefore proposition 04 is amended and the expected impact on the societal impact is replaced by a potential impact on the socio-technical system. All in all the amended P-04 is:

P-04 (amended): Each societal system is made up of subsystems. Change of a subsystem, as takes place in the introduction of a new type of product, influences the functioning of the entire system. Therefore the development of a new type of product which is a component of an envisioned future socio-technical system, can potentially hasten its realization, particularly when these products fill a unique and necessary function that cannot be fulfilled in any other way.

8.6 P-05: Contribution from the designer varies by system level

8.6.1 Introduction

P-05: "Design processes take place at various system or aggregation levels. The nature of the system to be developed is different at each of these levels. A logical connection exists between the respective aggregation level, the system to be developed and the contribution from the designer during this process."

To find out if this proposition can be substantiated by the results of the two projects as discussed in chapters 6 and 7, we need to answer the following two questions:

- A) Does the nature of the system to be developed indeed vary between system levels?
- B) Is there indeed a logical connection between the various system levels, the nature of the system to be developed and the designer's contribution during this process?

To find an answer to question A, let's consider the developments at the various system levels, with a particular focus on the form and nature of the "design" at each of these levels. This includes a closer examination of the results of the synthesis phase, to determine whether this result varies between the different aggregation levels. Question B is then whether a logical connection indeed exists between the various system levels, the nature of the developed system and the contribution by the designer during this process. For this purpose, the actor(s) who create(s) this design will be designated as the designer. This means that this actor doesn't necessarily carry the title "designer" on his business card. Certainly at the higher aggregation levels one of the questions is whether the synthesis or design process indeed takes place by "official" designers. But that has to be shown in the evaluation of the projects.

8.6.2 Evaluation P-05 on the basis of the "Autonomous Elderly" project

An examination of the selection of design steps at the various aggregation levels is presented in *Table 8-2* to *Table 8-5*. In these tables, step Tx always indicates the design or synthesis phase. In order to answer question A, we'll examine what the "design" looks like at the various system levels. In case of the project "Autonomous Elderly" this is about the following components:

- Product-technology level P: Development of the Guide Me device, including the synthetic casing, electronic components such as motion sensors, GPS and GSM elements and batteries
- Product-service level Q: Design of the different telemonitoring systems among which the design of the Guide Me system, including website where one can track the location of a user, the subscription from the GSM provider or the subscription from the alarm center that processes emergency calls. At this level, the "design" is particularly related to the way the organizational model, presented in the form of different scenarios which describe how the system functions.
- Socio-technical level R: Design of the assisted living center Hubertus-Drieschoten / De Groene Hoven. Here the design is about the form of urban development and architectural planning. In order to draft a vision from the perspective of the end user, the vision booklet "Inspiration for Housing, Care and Well-Being of Elderly" was developed. This vision booklet includes a sketch of various products, services and situations that collectively clarify what the new assisted living center could look like in the future.
- Societal level S: A discernible "design" is not really an issue at the societal level. Perhaps one could consider the policy plans and initiatives from government as the result of a design or synthesis process. The scenarios for the future of care ("Flute Player on the Mountain", "Jazz Improvisation", "Russian State Orchestra", "Andre Rieu Orchestra") could also be considered as a form of design, created as a result of a synthesis process where various contradictory

demands and interests are combined into a single entity, albeit with four possible variants.

As for question B, the role of the designer, in the case of the product-technology level it is a matter of "normal" product development, where the activities of the designer are aimed at design, sketching, detailing, combining technical components in light of the way that the product will be produced. The electronics for the Guide Me system were developed by Brunelco BV and the design of the casing is from Smool Design (although alternately the product has retained the casing that was self-developed by the manufacturer). In all of these cases, My-Bodyguard is the client and decision-maker for the selection of the design that was ultimately implemented.

At the product-service level, the role of the designer is more that of the inventor of certain organizational scenarios, in which the physical artifact fulfills a limited sub-function. Although several ideas were initiated by TNO at the beginning of the project, the innovation process really gets going once the idea has been taken over by a commercial actor. After My-Bodyguard takes hold of the initiative, it is then the coordinating party, also as far as consultations with other actors that are concerned, for instance the emergency call centers, the national police regarding the use of the 112 alarm protocol and the various patient organizations such as the Aphasia Association.

At the socio-technical level, the initiative is by De Woonmensen. My-Bodyguard and all other concerned actors are now no longer leading but following; De Woonmensen decides about the choice of specific products and services and is in that sense leading in the design process. However, this organization is not autonomous either, and in turn has to deal with a multitude of involved actors such as the municipality of Apeldoorn, Social Services, children's day care, welfare, the future residents, etcetera. In addition, De Woonmensen doesn't actually design all the elements that are part of their new assisted living center. They merely apply solutions that other actors (like My-Bodyguard) have designed.

There doesn't seem to be an explicit role for the "designer" at the societal level. The most distinct role is perhaps that of the visualizer of certain likely future options or innovation directions, in addition to the role as one of the many "co-thinkers" who can provide input during the thought process. On the other hand a "designing" role can perhaps be identified when looking to policy makers who "design" how the increased aging situation in the Netherlands can be handled in the future. In this case we are looking mostly to design as presented by Herbert Simon, cited in chapter 1, where he says that everybody designs who devises courses of action aimed at changing existing situations into preferred situations, including the one that devices a new social welfare for a state (Simon, 1969, 111).

8.6.3 Evaluation P-05 on the basis of "Youth in Motion" project

The design steps at the various aggregation levels can be identified in *Table 8-6* to *Table 8-12*. In these tables, step Tx always indicates the design or synthesis phase. In case of the project "Youth in Motion" this is about the following components:

- Product-technology level P: The design at the product-technology level is aimed at the development of the physical artifact, like the activity games in the TU/e student projects and the Make Me Move play tiles. This is about direct interaction with the user and the way he handles the product, recorded with the help of storyboards and tested with the help of simulation methods, such as the "wizard of Oz" approach (Stuyfzand et al., 2005, 16). Here it is also about the development of a variety of sub-technologies, such as the electronic components, sensors, LED lighting, computer hardware, software and the casing of the tiles.

- Product-service level Q: Here it is about the design of the Sport, Sports, Play and Activity Square, and the design of the E-Fitzone. In both situations, the design is about combining existing products in an umbrella product-service system. Or, reasoning in reverse, it is about the development of the total concept that can subsequently be "split" into sub-elements that can then be purchased "off the shelf", for instance from companies such as Kompan, Yalp and Nijha. Also at the E-Fitzone, a combination is created based on existing products such as the Wii, DanceDanceRevolution, Laser squash and Lightspace, which collectively form a new product-service system in the shape of the E-Fitzone. For that matter, the Make Me Move play tiles are not implemented in the E-Fitzone because they are not yet available at that moment. However, comparable interactive play tiles called Lightspace from the USA are used.

- Socio-technical level R: Here the design is about the development of the Sports Promotion Field Lab. This field lab is physically discernible, up to a point, since it coincides to a great extent with Sports Complex Eindhoven-Noord. However, for the latter it is about a sports environment, managed by government and aimed at carrying out existing sports activities. For the field lab the objective is more about starting new initiatives, as a breeding place for new developments.

- Societal level S: Here, policy plans and initiatives from government, for example in the form of the National Action Plan for Sport and Activity, the Dutch Standard for Healthy Physical Activity could perhaps be considered as the result of design effort. Although it is indeed a matter of a synthesis process, where often contradictory demands and wishes from various parties have to be balanced against each other, this would be a matter of design in a rather abstract sense of the word.

As for question B, the role of the designer, at the product-technology level this is mainly about the development of the physical artifact and the way in which consumers, in this case youth, handle the product. During the project, this role has been shifting between various actors. The initial idea appears to have come from the project manager of TNO Quality of Life, who in turn appears to have been inspired by one of the ideas from an earlier design project, the Interactive Kite Experience (Ahn et al., 2004). The actual design of the first model of the floor is developed by a group of students. When the project is taken up by the company NPSP BV, from that moment on this organization is responsible for the further development of the system. This includes forming a consortium around the idea, where three parties jointly found a new company under the name Colibri Interactive Innovations BV. During the course of the project, the relationship between designer and client remains a point of attention, because none of the parties involved seem to be really in charge of the design project. Perhaps that is one of the reasons that the actual development of the play floor takes up a rather long development time.

In the case of the Sports, Play and Activity Square, the leading party at the product-service level is the municipality of Eindhoven. They are in control of the development process, even though they cooperate actively with a lot of actors to get things done. But when, for example, multiple attempts to convince Innosport to become a partner in the development of the project seem to fail, then this does not mean the project won't continue. On the contrary, the project goes full steam ahead in order to realize the new park within a year and to be able to open it in late 2008. Also at E-Fitzone, one single leading party can be identified in the form of the managing director of the new business. Her ideas gain some momentum from the Sports Promotion Field Lab Eindhoven, but even without this involvement the project would probably have gotten off the ground (although that is hard to determine after the fact, of course). In any case, the vision of the director and the vision of the municipality are a good match and they succeed in establishing a viable new concept in the form of the E-Fitzone.

At the socio-technical level, intensive cooperation by various actors takes place during the development of the Sports Promotion Field Lab. In this case it is much less a matter of one leading party, but it is about a cluster of involved parties. Here it is about a collaboration in which a steering committee is formed that includes the municipality of Eindhoven as well as TNO and the Stichting Sports and Technology. This steering committee then organizes meetings where discussions take place with companies from the playground equipment sector, with knowledge institutions such as TU/e and with sports related societal organizations such as NOC*NSC, Innosport and the Netherlands Institute for Sport and Physical Activity (NISB). Innovative products or services from the parties involved are then presented at these meetings, for example, on March 21, 2006 (TNO, 2006b), on June 18, 2007(TNO, 2007) and at the annual Sports and Technology Conferences.

An explicit role for "the designer" does not appear to be directly discernible at the societal level, unless the development of policy is viewed as a design process. On the other hand, the initiation of concrete initiatives is directly influenced by this policy issues, and concrete innovations also have their "bottom-up" influence on these policy plans. However, this has already been dealt with in discussions about P-02 and P-04, among others.

8.6.4 Conclusion P-05

Based on these results, in how can P-05 be confirmed or not? Question A examines whether the nature of the system to be developed does indeed differ between system levels. Based on both experiments, it can indeed be determined that this appears to be the case. The lower the system level, the more concrete, tangible and detailed the design will be. The higher the aggregation level, the more organizational and abstract the nature of the design. Although there most certainly is a discernible, physical aspect in the case of the Hubertus-Drieschoten project, this is particularly related to the urban development and architectural design of the new assisted living complex. In order to indicate "the way of life" in the new residential complex, an attempt is made to give an impression of the "experience" of a future resident with the help of the story which describes one day in the life of such an individual. With the Sports Promotion Field Lab it's not even a matter of a story about a future user, but about a plan of action which explains the societal objectives of the field lab and how they will be realized. Finally, at the societal system level the question is whether it's possible to speak of a "design". At this level it is particularly about broad policy plans, which sketch secondary conditions and underlying objectives for new developments at the socio-technical level. This definitely does not mean that this highest level is not relevant, on the contrary. All concrete initiatives at the socio-technical, product-service and product-technology levels have something to do with this level, because the "playing field" and the "rules of the game" are defined here, within which one can move. The conclusion is that the nature of the system to be developed varies between aggregation levels, although on the societal level we cannot really speak about a discernable "design" at all.

Question B involves an examination to see if there is indeed a logical connection between the various system levels, the nature of the system to be developed and the contribution of the designer during this process. On the basis of both experiments, it seems appropriate to observe a considerable degree of restraint at this point. Although on the basis of logical reasoning something can certainly be said about the possible contribution of the designer at the various system levels, this does not mean that these thoughts have actually been demonstrated during the experiments. The fact is that there is a recurring question: What actually is a designer? Also in this project there are various parties who do not formally function as designer, but who indeed fulfill this role. For example, the entrepreneurs at My-Bodyguard, the initiators of the E-Fitzone and the inventors of the Sports, Play and Activity Square. However, to conclude on this basis that apparently nothing can be said about the role of the designer is somewhat too simplistic. After all, it seems plausible that, also at the higher aggregation levels, there could indeed be room for a more design-oriented approach. This would allow the development process to proceed in a more systematic and focused manner, instead of the sometimes somewhat intuitive approach that occasionally emerges in the current projects. Moreover, it has become clear that particularly at the socio-technical level so many parties are involved in the development process that it is of the utmost importance to create order in the many opinions, wishes and interests of the various actors. About the development of Hubertus-Drieschoten, as well as the development of the Sports Promotion Field Lab, one can state that a road for driving was built "while driving", as it were. A more structured approach of this synthesis process certainly appears to be desirable, even though at this moment it is not yet clear what exactly it should look like.

Concluding, it seems possible to substantiate a logical connection between the various system levels and the *potential* contribution from the designer. And even when one would conclude that designers have no business at some levels (as seems to be the case at the societal level), even then the proposition can be confirmed because at least now it is clear where the boundaries of the design influence are. The proposition is amended so that it becomes clear that nothing definite can be said, on the basis of the practical experiments, about the role of the designer at the various system levels, but that it certainly seems possible to say something about the *potential* contribution from the designer at each level. Therefore the amended proposition states:

P-05 (amended): "Design processes take place at various system or aggregation levels. The nature of the system to be developed is different at each of these levels. A logical connection exists between the respective aggregation level, the system to be developed and the potential contribution from the designer during this process."

8.7 Summary

In chapter 8, the five propositions as they are discussed in chapter 5, are evaluated on the basis of the results from the two practical experiments as presented in chapters 6 and 7. In order to test P-01, the following questions need to be considered:

- A) In how far can the design process indeed be described with the help of the four system levels?
- B) In how far can the design process indeed be organized at each of these levels?
- C) In how far are the steps that are taken at each of these levels indeed comparable?

With regard to question A, it can be established that the various system levels are indeed recognizable in both projects, indicating that the design process can indeed be *described* with the help of the various design levels. An answer to question B requires one to determine in how far the design process can indeed be *organized* at the different levels. It became apparent in both projects that this may indeed be the case, although certainly at the higher system levels it is arguable if one can really speak of a "design" (an issue that is further being discussed in chapter 9, in light of the "manipulability of society"). In any case, the expectation is that a more deliberate differentiation on the basis of various system levels can benefit the design or change process at each of these levels. With regard to question C, the question is asked if it is possible to recognize a comparable process at each level. Where the original proposition states that the steps that are taken during the various processes "are comparable" at each system level, this statement may be formulated too certain. However, it appears that it is indeed possible to "describe" these processes in a similar manner. Based on this comments, P-01 is amended:

P-01 (amended): "The design process can be described and organized at various system or aggregation levels. The steps that are taken during this process can be described in a similar manner at each of the various system levels."

In order to test P-02, the following questions need to be considered:

- A) Does the functioning of systems at the various aggregation levels indeed influence each other in a top-down direction?
- B) Does the functioning of systems at the various aggregation levels indeed influence each other in a bottom-up direction?

Downward influence (question A) especially appears to take place through the objectives and demands of the higher system level, which are converted into objectives at a lower design level. For instance, the objective to make neighborhoods activity-friendly is converted into the objective to realize an attractive Sports, Play and Activity Square. This objective in turn means that there is a need for innovative play equipment. With regard to question B, it appears that a certain system functionality must first be realized, before being able to exert any upward influence. For instance, play equipment that is still in development may be a wonderful promise for the future, but has little value for a Sports, Play and Activity Square which is opening its doors next week. Not until the new system is actually finished can it be applied (and thus influence) a higher level. This conclusion does not affect the description of P-02, which can be confirmed in its original form.

P-02: "Design processes can be described and directed at various system or aggregation levels. Systems at various aggregation levels affect each other's functioning, in both a "top-down" as well as a "bottom-up" direction."

In order to test P-03, the following questions need to be considered:

- A) Can each product indeed be viewed as an element of an overlying product-service, socio-technical or societal system?
- B) Does the functioning of this larger system indeed influence the functioning of the respective product in either a positive or negative manner?

The two experiments demonstrate that both products, the Guide Me device and the Make Me Move play floor, can indeed be viewed as an element of an overlying product-service, socio-technical or societal system. This provides an affirmative answer to question A. It also becomes apparent that the functioning of this larger system indeed influences the functioning of the respective product, either positively or negatively (for instance, even a simple subject as the supply of energy for the Make Me Move play floor turns out to be a rather complex system related issue, involving infrastructural change, the organization of a new maintenance structure and the decision who pays for the monthly electricity bills). This provides an affirmative answer to question B in the introduction, which leads to the confirmation of proposition 03.

P-03: "The functioning of a system influences the functioning of the elements that it is composed of. The functioning of a product is therefore dependent on the product-service system, the socio-technical system and the societal system that it is a part of."

In order to test P-04, the following questions need to be considered:

- A) Can the socio-technical or societal system indeed be considered as a collection of subsystems and sub-subsystems such as products?
- B) Can the introduction of a new product indeed influence the functioning of a socio-technical or societal system?
- C) Can the development of carefully chosen new products indeed hasten the realization of an envisioned socio-technical or societal system?

The reference point behind this proposition is that all systems are made up of subsystems. Once these subsystems are realized, the realization of the bigger system will also come closer. This implies that the development of a new product which is a part of an envisioned future socio-technical or societal system will hasten its realization. However, from the projects it appears that for the fulfilling of certain functions it is not so much about one specific product that must fulfill this function, but about a certain *type* of product that fulfills a certain *type* of functionality. For instance, from a top down perspective the various activity games are quite interchangeable, as from a societal level it doesn't matter whether young people move on the DanceDanceRevolution mat or on the Make Me Move play tiles, as long as they move. With regard to the actual impact that can be achieved on the socio-technical or societal level, we can only make guarded comments. In both cases, a direct societal impact of the new products could not be distinguished, although a potential impact, certainly at the socio-technical level, seems plausible. Therefore proposition 04 is amended as follows:

P-04 (amended): Each societal system is made up of subsystems. Change of a subsystem, as takes place in the introduction of a new type of product, influences the functioning of the entire system. Therefore the development of a new type of product which is a component of an envisioned future socio-technical system, can potentially hasten its realization, particularly when these products fill a unique and necessary function that cannot be fulfilled in any other way.

In order to test P-05, the following questions need to be considered:

- A) Does the nature of the system to be developed indeed vary between system levels?
- B) Is there indeed a logical connection between the various system levels, the nature of the system to be developed and the designer's contribution during this process?

Based on both experiments, it can indeed be determined that the nature of the system to be developed does differ between system levels. The lower the system level, the more concrete, tangible and detailed the design will be. The higher the aggregation level, the more intangible and abstract the nature of the design. With regard to the question if a logical connection exists between the various system levels, the nature of the system to be developed and the contribution of the designer during this process, it seems appropriate to observe a considerable degree of restraint. Although on the basis of logical reasoning we can speculate about the possible contribution of the designer at the various system levels, this does not mean that these thoughts have actually been demonstrated in this research. Therefore the proposition is adapted to emphasize that at this point it is only possible to say something about the *potential* contribution from the designer at each level:

P-05 (amended): "Design processes take place at various system or aggregation levels. The nature of the system to be developed is different at each of these levels. A logical connection exists between the respective aggregation level, the system to be developed and the potential contribution from the designer during this process."

This analysis concludes phase 3 of the study in which the tentative theory (the multilevel design model) has been evaluated. In this step, the focus was expressly on the question to what extent the results of the two practical experiments confirm or refute the proposed multilevel design model and the corresponding propositions. A broader reflection on the subject of the study and the research question is presented in chapter 9.

9 Chapter 9: Conclusions and Recommendations

9.1 Introduction

In chapter 1, an analysis of the fields of expertise of industrial design engineering, sustainable product development, systems engineering and sustainable system innovation was presented, resulting in the following research question:

Research question: "How can the design process and the role of designers be described (and potentially be structured) in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner?"

Chapter 2 includes a discussion of the research approach which is used to find the answer to this question, including the development of a conceptual model. On the basis of the research question and related subquestions, four research issues were defined (product and society, problems and objectives, design process, designer and actors). In chapter 3 and 4, the first phase of the research was conducted, the discussion of "problem situation 1". Based on the conclusion that none of the existing design and innovation models provide the insight as mentioned in the research question, in chapter 5 a new multilevel design model was presented, including the corresponding propositions. This new model can be regarded as a "tentative theory" which is subsequently tested in a process of "error elimination" with the help of two practical experiments, entitled "Autonomous Elderly" (discussed in chapter 6) and "Youth in Motion" (discussed in chapter 7). Subsequently, in chapter 8 we discussed in how far the 5 propositions from chapter 5 are confirmed or refuted by the experiences in the two experiments. This step completes the testing of the new design model.

Next is the closing chapter of this thesis, which includes a reflection on the new "problem situation 2" we have arrived at after conducting this research. First the four research issues will be studied separately, after which it is determined in how far the new multilevel design model can indeed provide the insight as described in the research question. Included in this chapter is a last reflection in how far the now completed study has actually made a contribution to the field of expertise of industrial design engineering. Finally there will be a discussion of the possible consequences of this study for various actors and recommendations will be made for potential supplementary studies.

9.2 Product and society

9.2.1 Response to subquestion 1: product and society

Research subquestion 1 reads: *"What is the relationship between (new) products and the socio-technical or societal system that they are a part of, and how can this relationship be described in a systematic manner?* The assumption of this study is that the new multilevel design model can provide insight into the design process in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner. The essence of the model is the assumption that this relationship can be represented by distinguishing different system or aggregation levels. Distinguishing the different system levels came up for discussion with P-01, P-02, P-03 en P-04 *("The design process can be described and organized at various system or aggregation levels...")*.

In the "Autonomous Elderly" project it turned out that the way that personnel was operating needed to be adapted, before the new product-service system Guide Me could function properly in the socio-technical system of the respective assisted living home. As long as this was not the case, a necessary link in the new system remains missing and the system as a whole cannot function. In the project "Youth in Motion" it was a matter of an inverted situation, where from a socio-technical perspective there certainly appeared to be room for new activity games which are suitable for use in an outdoor environment. Here the socio-technical system was "ready", but the manufacturers of the Make Me Move tiles where not. At the same time, other products are filling the available void. Some of them fulfill a comparable function, but look completely different, such as the Wii-Fit by Nintendo. Other products actually look a lot like the Make Me Move play tiles, such as the Pebbles play tiles by the company Boer Playground Equipment, although they serve a slightly other function (the Pebbles play tiles don't stimulate movement, but focus on educational games aimed at literacy and numeracy).

Assuming that the results of the practical experiments are also applicable to other situations, the results of the study can be summarized as follows: It is plausible that the relationship between new products and socio-technical and societal situation can be represented by the use of different system or aggregation levels. Product-technology systems, product-service systems, socio-technical systems and societal systems can be positioned hierarchically in relation to each other. Here the concept "hierarchical" does not indicate a relationship of "superior-subordinate", but a logical arrangement of systems and subsystems in relation to each other. Each system (or product, for that matter) can be regarded as an element of a larger system which functions at a higher aggregation level. Inversely, each of these larger systems can be regarded as a collection of subsystems, made up of smaller elements such as products. Functioning of a product is influenced by other elements of the larger (product-service, socio-technical or societal) system that it is part of, for example when a certain element satisfies a prerequisite which enables the product to function. Inversely, the functioning of the product influences the larger (product-service, socio-technical or societal) system that it is part of. With regard to the aspect "product and society", the conclusion of this research can be summarized as follows:

The relationship between new products and the socio-technical or societal system that they are a part of can be described by the application of different system or aggregation levels, whereby product-technology systems, product-service systems, socio-technical systems and societal systems can be placed in a hierarchical arrangement in relation to each other.

9.2.2 Reflection product and society

What do these conclusions contribute to the field of expertise of industrial design and sustainable product development? Is this about a new discovery or is it something that has been known for a long time? Or is it perhaps about insights that were already known in another discipline, but had not been previously applied in this way?

The insight that new products are part of a larger system was already obvious at the start of this investigation. And yet, this insight is only applied to a limited extent within the field of expertise of industrial design and sustainable product development. As discussed in chapter 4, the environment of the product is still frequently viewed as a constant factor. Although it is indeed considered to be important to take this context into account, it is itself not part of the design process. Bill Buxton, on the occasion of his honorary doctorate at the Technical University Eindhoven, also concludes that industrial designers are still primarily focused on the "physical artifact". This Canadian, employed as a designer and researcher with Microsoft Research, reflects on the way new products are still being assessed:

> *"If we would discuss books the way we currently assess an e-reader, we would be discussing the convenient format, the fine cover, the pleasant table of contents and choice of a legible font. Oh yes, and the story is pretty good too. As a reviewer of serious literature you would be ridiculed if you don't place books in a social, cultural and historic perspective" (Van Ammelrooy, 2010)*

And yet, several design and innovation models were discussed in chapter 4 that most certainly include the system aspect, represented in tables 5-1, 5-2 and 5-3 of chapter 5. Consider the distinction between the immediate context, the ecological context and the systemic context of intelligent products (Andrews), or the distinction between systems, subsystems, elements, components and parts as employed in systems engineering (INCOSE, 2000). Researchers in the field of expertise of sustainable system innovations will indicate that they have been using a multilevel approach for years. Consider the emphasis on developments which take place in niches and the dynamic multilevel model (Geels, 2001), where it becomes clear that "novelties" gain their place in a "bottom-up" fight in the socio-technical regime and the overlying "landscape".

The multilevel design model in this study indeed builds on all these models (as is explained in chapter 5), but it most certainly adds something new to this. In relation to the field of expertise of industrial design and systems engineering it is a matter of the "higher", socio-technical and societal levels that do not occur in, for example, the division between the "overall problem" and respective "sub-problems" (Cross and Roozenburg, 1993), the division between the "physical product" and the "comprehensive product" (Buijs and Valkenburg, 2005), or the levels of the V-model from systems engineering (KBST, 2004) (Peterfeso, 2005). In relation to the field of expertise of sustainable system innovations, a "lower" level has been added, and the more prescriptive "design" aspect was included in the model. This complements the more descriptive and analyzing approach that experts in the area of sustainable system innovations usually take. All in all it can be said that the multilevel design model adds a new element to existing insights because it introduces a multilevel perspective to sustainable innovation, combined with a distinct design perspective.

It should be emphasized that this systematic design approach, certainly at the higher system levels, cannot be applied nearly as strictly as is the case in systems engineering, for example. For instance, the "100% rule" -- which was explained in chapter 4 and which indicates that the sum of all functions at the sublevel must be equal to that at the overlying level (Haugan, 2001, 17) -- is much less applicable at the higher system levels. Cross and Roozenburg already indicate that many engineering methods assume that systems can be divided neatly into pieces, while in the case of design it is usually a matter of so-called "wicked" or "ill-defined" problems (Cross and Roozenburg, 1993). If this is already the case for developments at the product level, at the higher aggregation levels of socio-technical or societal changes it is even more so. After all, developments at these levels are much less well-defined than the development of a physical building or artifact. Having said that, the multilevel design model can certainly be helpful to describe the relationship between new products and the socio-technical or societal system that they are a part of in a systematic manner.

While the hierarchical approach appears to be rather new for the field of industrial design engineering and sustainable product development, one might pose the question if this hierarchical approach is also useful for explicitly "networked" products (Andrews, 2003) (Feijs and Kyffin, 2005). After all, in this domain it appears to be less about a "top down" development of new concepts, but more about a kind of self-developing ecological network structure. The question regarding the possible benefits of the multilevel approach for these kinds of innovations could be the subject of further research. A possible connection between the two approaches could assume that the "immediate context" is compatible with the product-technology level P. The "ecological context" is compatible with product-service level Q and the "systemic context" with socio-technical level R. At the societal level S several systems converge that are not functionally related but that do influence each other. *Figure 9-1* shows an initial onset of what such a division could look like.

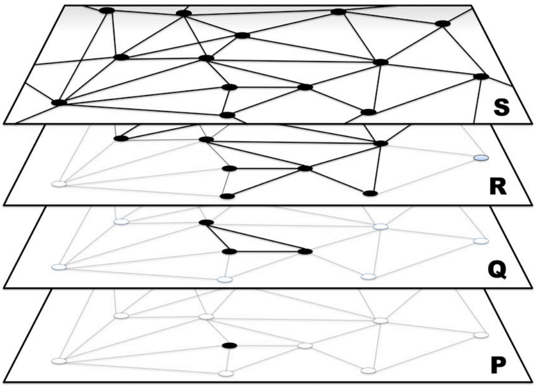


Figure 9-1: Multilevel visualization for networked systems

This question in how far a strict hierarchical arrangement at the higher system levels can be extended is in keeping with the contrast between "pyramid organizations" versus "pancake organizations". In this contrast, the pyramid structure represents the hierarchical culture where "top-down" decisions are made high up in an organization which are subsequently executed lower down in the organization. In that case the pancake represents the new way of working, in the form of a non-hierarchical, flat culture where employees make decisions themselves. While the pyramid world is neat and orderly, the pancake world is much less predictable: "If the Pyramid era was about accountability, management, planning and controlling, then the Pancake is about responsibility, questioning, learning and creating" (Green, 2009). It is indeed important to realize that it is impossible, certainly at the level of the socio-technical and societal system, to pursue real change in a "top-down" fashion. In that sense the multilevel approach is merely a tool to help describe and structure the sometime chaotic reality, and is not intended to create the expectation that from now on we have a crystal-clear view to steer us in the direction of societal development.

9.3 Problems and objectives

9.3.1 Response to subquestion 2: problems and objectives

Research subquestion 2 reads: *"What is the relationship between the problems and objectives that are being met by means of the functioning of a product, compared to the societal problems and objectives which are being met by means of the functioning of a socio-technical system, and how can this relationship be described in a systematic manner?"* The assumption of this study is that the new multilevel design model can provide insight into the relationship between problems that can be solved by means of new products, and problems that have to do with the way that society is functioning as a whole. This issue is related to P-03 ("The functioning of a system influences the functioning of the elements that it is composed of. The functioning of a product is therefore dependent on the product-service system, the socio-technical system and the societal system that it is a part of") and P-04 ("...Change of a subsystem, as takes place in the introduction of a new product, influences the functioning of the entire system. Therefore the development of a new product which is a component of an envisioned future socio-technical or societal system, will hasten its realization").

The Autonomous Elderly project included a description of the relationship between the objectives of the European Union to allow elderly to lead a valued and independent life, the objectives of the Dutch government to allow elderly to live independently longer, the functional objectives of a personal localization system which allows individuals with light dementia to live at home longer, and the detailed technical objectives for a specific casing, battery and sensor system of the Guide Me device. The Youth in Motion project includes a discussion of the relationship between the government objectives to promote healthy physical activity for Dutch citizens, the objectives of a regional Sports Promotion Field Lab, the functional objectives for the E-Fitzone and the Sports, Play and Activity Square, and the operational objectives for modern playground equipment, like the Make Me Move tiles. When assessing these products, not only the "fun factor" of the product was considered, but also a focused examination of the energy consumption while a certain game is played was taken into account. Based on that analysis, TNO judged the Xerbike and Lasersquash to be considerably "healthier" than the Nintendo Wii (van den Boogaard et al., 2007, 2). On the other hand, Nintendo Wii sales are many times more than the first two systems together. The next question is if it is better that millions of people are "moderately" active with a Wii, or that a few hundred people are "super" active with the Xerbike. And that judgment in turn depends on the system level from which it is judged. In order to demonstrate this, the following formula could be used: $n*h=H$, where n represents "the number of people that use the product", h represents the "health value per product" and H represents the "contribution to public health". From an individual perspective (what device should I use for healthy movement), the Xerbike scores higher (because $n = 1$ and h = "high" for the Xerbike, and h = "reasonable" for the Wii), but from the perspective of national public health the Wii may probably have a bigger impact (where n = millions of users for the Wii and n = a few hundred users for the Xerbike).

If we assume that the results of the practical experiments are also applicable to other situations, then results of the study can be summarized as follows: In the study it was demonstrated that it is plausible that working on functional problems and objectives at the product level can potentially make a discernible contribution to the solution of complex socio-technical and societal questions. The influence of the new product is especially relevant when it fulfills a unique and necessary function that cannot be fulfilled in any other way. The more unique and the more relevant this functionality, the greater the potential impact of the new product. The less unique or relevant, the smaller the contribution. Furthermore this is not about the product itself, but about the introduction of a certain type or class of products, irrespective of the brand, the supplier or the design.

The value judgment of a certain product is dependent on the system level from which the functioning is assessed. The system boundaries that are employed determine the assessment of a certain development. A product can function perfectly in a technical sense and the user may be quite satisfied, while it can have quite negative effects when viewed from the societal perspective. Inversely, a product that is moderately functional (so far) at a technical level, can on the other hand realize an important objective from a societal viewpoint.

Based on this study, no verdict can be given about the ideal relationship between functioning at the product-technological level compared to functioning at the other system levels. However, it is plausible that the assessment from the highest aggregation level under consideration determines the final value judgment regarding a certain development. If there is no agreement at this level about the objectives to be achieved, it isn't possible to clarify what contribution new products can make to this new situation. Only as soon as the involved actors agree about the objectives to be achieved at societal, socio-technical or product-service level, it can be determined what contribution new products can make to these objectives. This potential contribution is greatest when it is a matter of a necessary function, which is difficult to fulfill in any other manner. If, with the help of a new product, it suddenly becomes possible to fulfill this function after all, then the impact of this new product will be that much greater. In the case of new products that deliver practically the same result as existing solutions, this influence will be limited. From the product development perspective it is important to realize that the way a certain function is fulfilled, judged from a "top-down" perspective, is not relevant. All is well as long as the respective function is fulfilled in one way or another, and it does matter whether this occurs with the help of a certain physical artifact, through a certain organizational solution, or in any other way. With regard to the aspect "problems and objectives", the conclusion of this research can be summarized as follows:

Working on functional problems and objectives at the product-technology level can potentially make a discernible contribution to the solution of complex questions at the socio-technical of societal level. The new products must then make a contribution to the realization of an envisioned future situation that is agreed upon by the actors involved. The potential influence of new products is especially relevant when they fulfill a unique and necessary function that cannot be fulfilled in any other way.

9.3.2 Reflection problems and objectives

What do these conclusions contribute to the field of expertise of industrial design and sustainable product development? The fact that people maintain different value judgments of the same subject is not new. Also in chapter 3, the difference between what people say and their actual behavior was already discussed. For example the contradiction between the consumer who at one moment fills in a questionnaire about free-range meat, and the next moment is filling his basket at the "Bargain Butcher" (van Dinther, 2003), which is sometimes described as the contradiction between man as a citizen and man as a consumer (Dagevos and Sterrenberg, 2003). And the contrast between the ideal view of the Innovation Platform, where everyone lives long and is always healthy (Innovatieplatform, 2005), as opposed to the "right" to danger, pain and suffering that was demanded by "the Savage" in Aldous Huxley's Brave New World. Furthermore, chapter 4 also includes a discussion of the difference between the "real problem" and the problems designers are usually focused on (Papanek, 1985), the difference between first order learning and higher order or "double loop" learning (Argyris and Schön, 1978) and the four different "levels of discourse" from where organizations consider problems (Vergragt and Brown, 2004). All of these models indicate that the objectives and value judgments differ between system levels, even when the exact same situation is viewed by the exact same person or organization. The similarities with these models is partly due to the fact that the multilevel design model expressly builds on these

insights, as described in chapter 5.
And yet, connecting the various system levels to the respective learning levels is a new aspect that has come up for discussion in this study. The learning levels of Argyris and Schön have no connection, so far, to the system level where a certain change is attempted. And yet, it seems logical to make this connection, where "higher order" learning is especially related to changes at socio-technical and societal system level, and "first order" learning relates especially to changes at the product-technology and product-service level. The four "levels of discourse" also connect well to the four system levels, where the "problem solving level" is compatible with the product-technology level, the "problem definition for particular technology-society coupling" with the product-service level, the "dominant interpretive frame" with the socio-technical level and the "preferences relative to social order" with the societal level. And yet, this connection cannot be made 1 to 1, as it is also possible to view a pure product innovation from a "higher order" learning approach. A bicycle tire that was designed in a new way and that will never again spring a leak can indeed be based on a higher order learning effect, while it is still about an innovation at the product-technology level.

In a similar way, the means-end chain can be compared to the multilevel design model. Chapter 4 includes a discussion of this means-end chain which allows stepwise reasoning from form, characteristics, function and needs, towards underlying values. The design of a product follows this process in reverse. Placing this schematic on the multilevel design model creates Figure 9-2. At the bottom level is the form of the product; one level higher its characteristics; above that the function it fulfills, followed by the needs it fulfills and finally, the values on which all of this is based. It may seem that the means-end chain and the multilevel model can in this way be made to agree. But it's not quite that simple, because a product-service system also has a form, just like a socio-technical system and a societal system. Also such systems have "forms" that have certain characteristics, have a certain function, fulfill certain needs and subsequently influence the values that are maintained. Apparently the means-end schematic cannot be "pasted" one to one on top of the multilevel model.

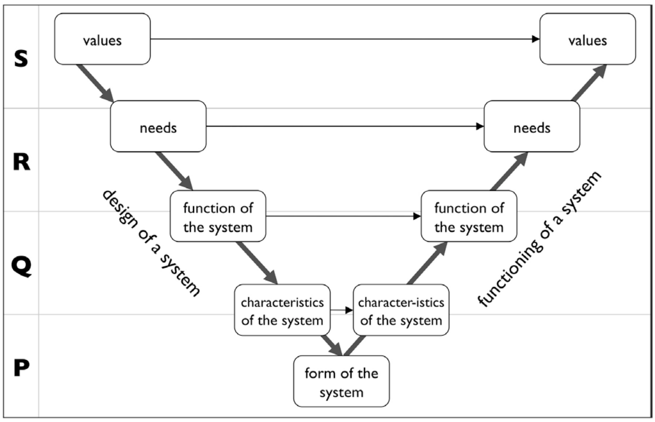


Figure 9-2: Means-end chain, projected on the multilevel design model

It remains clear however that the values and the worldview that one maintains significantly influences the value judgment regarding a certain situation. After all, the boundary of the means-end reasoning is reached when a certain objective can no longer be considered as a means, but is valuable in itself. That's 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, 1991, 123). The significance of the underlying values that are maintained during the design process is discussed by several researchers. For instance, John Ehrenfeld, in "Sustainability by Design", emphasizes the significance of the worldview that people employ. He states that the majority of experts who are focused on sustainable innovation are in fact occupied with reducing "unsustainability". In other words, a kind of negative ambition, which is building, consciously or unconsciously, on the ruling paradigms related to behavior, culture and the values they are based on. Ehrenfeld suggests that products subtly make the user aware of the broader context in which he is located, a term he coins "presencing". Such a "presence moment" subtly forces the user to decide whether to continue on his current track or to take a different approach (Ehrenfeld, 2008, 153). In order to accomplish this, products must contain "scripts" to at least make the user think about his or her own actions, albeit in a not too forceful manner: "The designer must walk a fine line in creating the proper language in the scripts. Producing presencing requires a delicate touch. One wants to create obstinacy or obtrusiveness, but not too much. It will be important to balance the inscripted ethics lesson with the added annoyance" (Ehrenfeld, 2008, 168-169). One might call it a kind of ethics lesson during the use of products.

This concept of "scripts" is described by Madeleine Akrich (1992) and Bruno Latour (1992). They state that, like a theater play or a movie, technologies possess a "script" in the sense that they can prescribe the actions of the actors involved. Technologies can influence a certain kinds of behavior: a speed bump can invite drivers to drive slowly, a car can demand from a driver that he or she wear the safety belt by refusing to start if the belt is not used, a plastic coffee cup has the script "throw me away after use", whereas a porcelain cup "asks" to be cleaned and used again. According to Akrich and Latour, these scripts are the result of "inscriptions" by designers who anticipate how users will interact with the product they are designing. This approach gives a specific responsibility of the designer, who can be seen as the "inscriber" of these scripts. This "scripts" approach brings us back to the issue mentioned in the "delimitations" section of chapter 1. Here we discussed the contrasting view of most philosophers and engineers towards technological developments. Also it was explained that in this study we will initially employ an instrumentalist perspective on the relationship between man and technology. At this point we can look back and determine if this "engineer's perspective" indeed can meet the requirements of this research. We have seen that, on the product-technology level, a rather straight-forward means-end approach appears to be a feasible way of working. On the higher aggregation levels however, the relationship between objectives and means cannot be structured in such a systematic manner. And even on the product level, there turned out to be unexpected side effects. Although this was not the main subject of this study, with the Guide Me tracking system the "big brother" aspect came to the front several times, an issue related to the concept of "geoslavery" (Dobson and Fisher, 2003) and separately discussed in "Social aspects of location-monitoring systems: the case of Guide Me and of My-SOS" (Joore, 2008). Here we touch the subject of the sometimes unexpected way that new products affect human behavior.

To define the complex relationship between people and objects, philosopher Peter-Paul Verbeek uses the concept of the "mediating role of technology". Based on Don Ihde's analysis of the relationships between humans and technological artifacts (Ihde, 1990) he explains that people and technology are more or less equals, where technology mediates in the way people are present in the environment and the way they experience it. From this perspective, the product "eye glasses" are not only a means to improve vision, but also mediate the way people observe their environment. As technologies are inherently moral entities, this implies that "designers are doing 'ethics with other means:' they materialize morality". Usually, this "doing ethics" happens in an implicit way, where designers develop a new product with specific functionalities in mind, without explicitly aiming to influence the actions and behavior of users. Verbeek proposes to apply this knowledge in a more conscious, normative manner to influence human actions in a certain direction. Therefore designers should not only focus on the functionality of technologies but also on their mediating roles. The fact that technologies always mediate human actions charges designers with the responsibility to anticipate these mediating roles. This anticipation is a complex task, however, since the mediating role of technologies is not entirely predictable. To tackle this risk, he proposes to carry out a "mediating analysis", together with all stakeholders that are involved with the new design, "and decide in a democratically organized debate how to feed back the outcomes of this analysis into the design process" (Verbeek, 2006).

Although the mediating concept may offer to be very relevant to reach certain societal or ethical objectives (e.g. Ross, 2008), the approach doesn't necessarily change the outcomes of this research. The point remains that, also from the mediating perspective, the problems and objectives to be reached still vary, according to the aggregation level that the issue is approached. This can be seen in the example of the speed bump that forces drivers to drive slowly. From the perspective of the individual driver, this may be a nuisance, but from the perspective of the local neighborhood, it is a blessing. Introducing a democratic "mediating analysis" process (somewhat comparable with the "transition arena" (Rotmans, 2003) discussed in chapter 4) doesn't solve this question. At the end, the design process is not about a democratic "majority rule" process, but about making difficult choices that balance the often conflicting interests of all actors involved. And here we can agree with that it is important to "profoundly rethink the moral responsibility of designers" (Verbeek, 2006). Which brings us back to the question, what is the way that the designer perceives the world. For this eventually determines the development direction -- and judgment -- of new products and their place in society. It might therefore be appropriate to replace the old design guideline "Form Follows Function" with the guideline: "Form Follows Value", or even better: "Form Follows Worldview". And if we carefully consider the original quotation from architect Louis Sullivan, then these deeper, underlying ideas are already recognizable in this as the "metaphysical", as "the things superhuman", as the "head", the "heart" and the "soul" that he discusses:

> *"It is the pervading law of all things organic and inorganic, of all things physical and metaphysical, of all things human and all things superhuman, of all true manifestations of the head, of the heart, of the soul, that the life is recognizable in its expression, that form ever follows function. This is the law." (Sullivan, 1896)*

9.4 Design process

9.4.1 Response to subquestion 3: design process

Research subquestion 3 reads: *"What are the similarities and differences between the product design process and the way that socio-technical and societal change processes take place, and how can these processes be interlinked in a systematic manner?"* The assumption in this study is that the new multilevel design model can provide insight into the development of the design process of products as well as into the development of societal change processes. The design process was discussed in particular with P-01 ("...the steps that are taken during this process are comparable at each of the various system levels.") and P-02 ("...systems at various aggregation levels affect each other's functioning, in both a "top-down" as well as a "bottom-up" direction.")

In both design projects, the steps taken during the design process where mapped. Here it was made plausible that the design process at each of the various system levels can be described in a largely comparable manner, where the phases "experience, reflection, analysis, synthesis" are completed consecutively. It should be emphasized that this structuring doesn't mean that the process actually can be executed in such a systematic manner. At this phase, it is merely a matter of describing the various processes in a comparable manner.

As for the "top-down" influence between the developments at the various system levels, this influence appears to be created particularly by the rules and secondary conditions that the larger (product-service, socio-technical, societal) system places on the smaller subsystems that it is made up of, such as products. At the higher level the demands are determined, as it were, that must be satisfied by elements at a lower level. Where existing products are concerned, this means that their functioning is already subject to the demands that are placed within the broader system context. After all, they must satisfy existing legislation, match certain cultural customs, satisfy all sorts of norms and be compatible with specific technical protocols. If products do not satisfy these demands, then in many cases they simply have no right to exist. Evidently, a product that does not conform to legislation will give big problems when being introduced on the market. But even if it is legally allowed, a product must fit into the "larger system". For instance, there is nothing illegal about a device with a "different" type of electrical plug-in, but in practice people will prefer a device that does make use of the available electrical outlets.

As for the "bottom-up" influence, it is plausible that functioning of the "larger" system is directly dependent on the functioning of the elements of the system (after all, it is made up of these elements). The influence on the larger system appears to flow through the actual characteristics of these elements, which can be used at a higher level. Only when a component actually exists and functions can it be implemented in order to fulfill a certain function in the larger system. And yet, influence can sometimes be exerted by products that are not yet actually realized, by communicating their potential (but not yet actually realized) characteristics. Even if they don't yet actually exist, expectations of these characteristics may often have a "bottom-up" effect *("that new product will make it possible to..., with the help of this yet to be developed technology we will be able to effectively...")*. But ultimately these expectations will have to be realized at some time. Incidentally, this immediately clarifies how raising high expectations regarding the future characteristics of certain new products can be an effective way to gain organizational, political and thereby financial support for a certain development. With regard to the aspect "design process", the conclusion of this research can be summarized as follows:

The product design process, the product-service development process, the development of socio-technical systems and the way that societal change process take place can be described in a similar manner, where the phases "experience, reflection, analysis, synthesis" are completed consecutively. These steps can be distinguished at various system or aggregation levels, where developments are mutually dependent and influence each other in a "top-down" as well as in a "bottom-up" direction. The initial impression is that influence in a "top-down" direction may occur through the demands that the larger system makes of the smaller elements of the system, and influence in a "bottom-up" direction may occur through the actual (or potential) characteristics of these elements which can be implemented at a higher level.

9.4.2 Reflection design process

What do these conclusions contribute to the field of expertise of industrial design and sustainable product development? Three issues are discussed here. First, the bottom up influence of "expectations" will be discussed briefly, referring to the concept of the "motors of change" (Hekkert et al., 2007). Second, the possibility of a "cyclic multilevel design model" is being discussed. Third we will look at the issue regarding the "manipulability of society".

The first issue discussed deals with the bottom up influence of expectations regarding new technology. The observation in the previous section that "bottom-up" influence takes place on the basis of the (potential) characteristics of a certain renewal, matches the observation by Hekkert that "expectations are an important, though elusive, phenomenon" in the guidance of the search that determines what technology to invest in. Government funding (at the higher system levels) is often initiated by positive research results, or the expectations vis-à-vis these results (at the lower system levels). The "Science and Technology Push Motor" they describe, "involves a sequence consisting of positive expectations and/or research outcomes leading to the setting up of government-supported R&D programs" (Suurs and Hekkert, 2010). Often actors (whether R&D focused or policy minded) are initially driven by little more than a hunch. Vague ideas are often tried out in experiments, after which their success (and failure) can be communicated to other actors, thereby reducing the (perceived) degree of uncertainty. This in turn triggers expectations, which are communicated throughout the system. Occasionally, under the influence of "success stories", expectations on a specific topic converge and generate a momentum for change in a specific direction (Hekkert et al., 2007). Combining the multilevel design approach and the "motors of change" approach could raise the question if these motors could exist in different "sizes", depending on the system level from which a certain issue is approached. Where the examples as given by (Suurs and Hekkert, 2010) mainly involve financial support from a government sources, one could imagine that similar "motors" exist on a smaller scale, for instance within the boundaries of single organizations. If this would be the case, the positive expectations regarding the future characteristics of a certain new product would create the financial support within the organization itself, to carry out further research regarding a specific new technology or product. This possibility could be a potential topic for follow-up research.

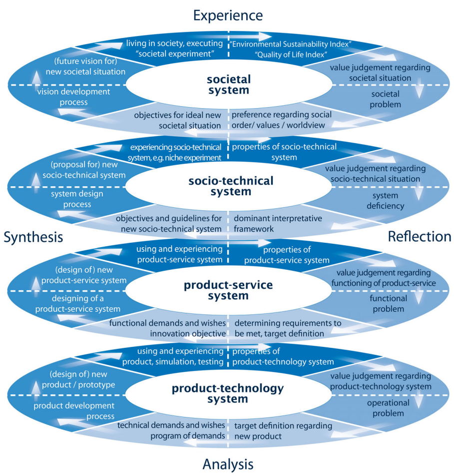


Figure 9-3 (left): Cyclic multilevel design model - perspective (see appendix C)
Figure 9-4 (right): Cyclic multilevel design model - flat (see appendix C)

The second issue discussed is about the possibility of a cyclic version of the multilevel design model. It is obvious that dividing the design process into "steps" is more than familiar terrain for anyone who has anything at all to do with the field of expertise of design. However, projecting this systematic process on the higher aggregation levels is much less common. In the evaluation of both practical experiments it was possible to recognize, also at the higher system levels, a cyclic design or change process. Based on these experiences the question is whether it is possible to allow this cyclic process to emerge more clearly in the multilevel design model. Based on the results of the study it seems quite possible to develop the cycles further at each of the four system levels and to develop a specific design cycle at each of those levels. The design process can then be described at each level, starting with the experience in the current situation. At the product-technology level it is about the experience with a certain product, at the societal level it is the experience with "living in society". Preferably this can be given an objective value, for instance with the help of the "Environmental Sustainability Index" (Yale-CIESIN, 2005) or the "Quality of Life Index" (Economist, 2005). Next is a reflection that results in a value judgment, in the form of a functional problem, a system imperfection or a societal question. Then follows the analysis phase where the objectives for the envisioned new situation are determined. At the product-technology level these can be determined with the help of a program of demands; at the socio-technical or societal level this is about the preferences for social order. Last of all is the synthesis phase, where the more abstract ideals are converted into a concrete "design", for instance in the form of a vision that describes what the ideal future situation can look like. If we then place the processes at each of the four system levels one below the other, as in the multilevel design model, it will look as in *Figure 9-3*. In the framework of the earlier discussion about "pyramids" or "pancakes", the exact same model can be presented as in *Figure 9-4*, where the smallest cycle indicates the development of the product-technology system and the systems increase in size, step-by-step, until we arrive in the outermost cycle at the societal system level. It will be obvious that the contents of *Figure 9-3* and *Figure 9-4* are identical, except for their representation. Investigating and substantiating the exact structure of the cycles is expressly not the intent. The explanation of *Figure 9-3* and *Figure 9-4* should be seen as the onset for possible follow-up studies, rather than as the direct result of this study. In support of this process, appendix C includes a proposal on how to complete the design cycles at each of the four system levels.

The third issue discussed has to do with the "manipulability of society". After all, the question remains whether it is at all possible and desirable to "design" society in the same way as a technical system can be designed. Opinions differ, depending on political beliefs that one maintains, about the question in how this process can indeed be guided "top-down" into a certain direction. The confirmed socialist or communist will sooner believe in the possibilities of a top-down approach, where certain political configurations could in fact be viewed as one large societal experiment. One example of such an experiment is the introduction of the "one-child" policy in China. A development to which the Delft University of Technology professor Geert Jan Olsder contributed a great deal, without being aware of it. In 1975 he studies the theoretical possibilities of using Mathematical System Theory as a way to solve the optimization problem for population, by finding the best fertility trajectory (number of children per woman in each period). A Chinese visitor, named Song Jang, turns out to be very interested in the subject. Only thirty years later Olsder finds out that this visitor has become a high ranking Chinese official that was so much inspired by his ideas that he has brought this mathematical theory into practice (Greenhalgh, 2008, 162). Authorities claim that this policy has prevented more than 250 million births from its implementation to 2000 (BBC News, 2000), but the policy is controversial because it may have caused an increase in forced abortions, female infanticide, and underreporting of female births. Being asked the question if he ever feels guilty being one of the founding fathers of China's "one-child policy", Olsder answers: "It was a big coincidence that Song and I met. Otherwise, the one-child policy would probably have been developed anyway, but things would certainly have gone a bit different. I ask myself sometimes: Should I feel guilty about this? But things go as they go" (Muller, 2008).

His visitor Song Jang could be considered as a "Utopian engineer" that uses the engineering approach to solve social problems. Karl Popper describes this "Utopian engineering" as a way to rationally reconstruct society as a whole by introducing far-reaching changes whose practical consequences are hard to calculate. In view of this criticism, the Utopian engineer is likely to answer that it is necessary to execute these large scale social experiments, so we will know more about these matters. When considering how to deal with unexpected side effects, the Utopian engineer will have to be deaf to many complaints: "In fact, it will be part of its business to suppress unreasonable objections. (He will say, with Lenin, "You can't make an egg without braking eggs") But with it, he must invariably suppress reasonable criticism also" (Popper, 1945, 169). He suggests an alternative approach and introduces the concept of the "piecemeal engineer". This professional certainly has ideals as well, but chooses to try these out in small steps, so that possible undesirable side effects can be discovered and avoided at each step: "The piecemeal engineering knows, like Socrates, how little he knows. He knows that we can learn only from our mistakes. Accordingly, he will make his way, step by step, carefully comparing the results achieved, and always on the lookout for the unavoidable unwanted consequences of any reform;

and he will avoid undertaking reforms of a complexity and scope which make it impossible for him to disentangle causes and effects, and to know what he is really doing." (Popper, 1957, 61)

The conclusion is that the influence of man as "designer" is limited, or should be, certainly at the level of societal developments. On the other hand it has also become clear that his influence reaches further than the development of a few individual products or artifacts. Although we cannot, and should not want to guide society "top-down" into a preferred direction, it is most certainly possible and necessary to work on a collective view of a desired future. And once agreement about this is reached, it then becomes important that this desired future is realized step by step. Each new product that can make a small but tangible contribution in this is yet one more step ahead.

9.5 Designer and actors

9.5.1 Response to subquestion 4: designer and actors

Research subquestion 4 reads: *"How can the (potential) role of the designer with regard to the product design process, as well as with regard to the way that socio-technical and societal change processes take place, be described in a systematic manner?"* The assumption of this study is that the new multilevel design model can provide insight into the role of the designer, both in relationship to individual companies and in relationship to various societal actors. The role of the designer and other actors came up for discussion with P-05 in particular : *("…The nature of the system to be developed is different at each of these levels. A logical connection exists between the respective aggregation level, the system to be developed and the contribution from the designer during this process.")*

The role of the designer is closely related to the "properties" of the design at the various system levels. At the level of the product-technology system and the product-service system, the nature of the system to be developed can be defined in a fairly straight-forward manner. Here the role of the designer is especially aimed at the actual development of one new product-technology system or one new product-service system, for instance by means of a drawing, a computer model or a scenario. At these levels, the most effective operating procedure appears to be when design activities are commissioned by one problem owner or client. In this situation, the designer is commissioned by this client, who ultimately decides about the course of action to be taken.

At the socio-technical level, the nature of the design becomes more abstract and less tangible. Here it is about a combination of various products, services, organizational, infrastructural or policy elements. Many different actors are involved at this level, each with their own wishes and interests. During the synthesis process it is therefore necessary that contradictory demands are considered and combined into one integrated design. At this level, it is hard to predict which elements a certain new socio-technical system will consist of (with a car one knows fairly well which components are necessary, but with a "transportation system" this is already becoming a lot less obvious). Therefore it is not known in advance which organizations can realize the respective system, whereby the involvement of actors can change during the design process. The effect of this is that the relationship client-designer appears to be a lot less obvious at the higher aggregation levels. For instance in the case of the development of the assisted living complex Hubertus-Drieschoten, it is not a matter of one single problem owner or decision-maker. Although De Woonmensen carries final responsibility for the development of the new housing complex, they are not themselves responsible for many of the other developments. Consider the function of mobility in the neighborhood and the home care and medical care services. These are all aspects where De Woonmensen can at best act as facilitator, but not as principal decision-maker. Also in the Youth in the Motion project and the development of the Sports Promotion Field Lab, it is much more a matter of a network of actors who jointly determine the direction of the development process.

At the societal system level the synthesis process is aimed more at broad policy plans, where the secondary conditions and underlying objectives for new developments are sketched. In that case the form of the design is more like developing a common thought framework, a shared vision or a common vocabulary. One might even ask here whether it is still a matter of a "design" at all. This definitely does not mean that this highest 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. However, it doesn't seem very obvious what role the designer should have at this level. With regard to the role of "designer and actors", the conclusion of this research can be summarized as follows:

A logical connection exists between the respective design level, the nature of the system under development and the potential contribution from the designer during this process. At the lower system levels, this contribution appears to be especially aimed at the development of one product-technology system or one product-service system, where design activities are commissioned by one client. At the socio-technical level it is more about combining the usually contradictory demands, wishes and interests of many actors involved, into an integrated design of a new socio-technical system. Development of a discernible "design" is not really an issue at the societal level. At this level it is more a matter of developing a common thought framework, a shared vision or an identical vocabulary. It might perhaps be possible for the designer to contribute to the clarification of this vision, but this issue has not been further developed in this study.

9.5.2 Reflection designer and actors

What do these conclusions contribute to the field of expertise of industrial design and sustainable product development? Certainly the insights at the lower system levels are compatible with the existing insights concerning the product design process. The designer is usually commissioned by one company and works on the development of one product-technology system or one product-service system.

The conclusion that parties must collaborate beyond the boundaries of their own field of expertise has been common knowledge since the economist Schumpeter (1934) emphasized the development of "Neue Kombinationen". For instance, in chapter 3 Richard Florida was cited, stating the emergence of the "Creative Economy" makes it necessary that the spheres of innovation (technological creativity), business (economic creativity) and culture (artistic and cultural creativity) increasingly draw closer together, thereby creating promising new combinations (Florida, 2002, 201). And in chapter 1 we mentioned Stefano Marzano, who emphasizes that new disciplines must work together to "redefine their assumptions about our most fundamental needs". This requires a commitment on behalf of all actors "to continue to question what kind of world we want to live in and how we want to live and communicate within it, and then to address those questions as a group" (Aarts and Marzano, 2003, 11). As discussed in the previous section, also here the aspect of worldview plays an important role: "Cooperation is easy to speak about, but more difficult to put into practice. The more distant the partners are with regard to their world-views, or physical context, the more challenging cooperation becomes" (Kandachar and Halme, 2008a). In any case, we arrive at a situation where not one client is discernible who is responsible to achieve a certain "corporate result". Although government can sometimes act as client in order to initiate a certain research process, it is not the party that ultimately decides whether or not to realize the new societal system. After all, quite a few parties are necessary for this, necessitating a kind of "collective client association". One could ask how such a collective client association could potentially be materialized, and what would be the relationship of the designer with such a new constellation.

Based on this perspective, the role of the designer could be broadened to more of a coordinating role between or above the parties. Besides the image of the designer as visionary, the designer can also fulfill a mediating role in this process. As a visionary mediator, the designer can reconcile the interests of the various parties, including his own. This role is in keeping with the skills of the designer, who always has to mediate between mostly conflicting objectives (Roozenburg and Eekels, 1991, 58). Here we can remember the exhortation of Papanek once more, stating that "in a dramatically changing world that is (tremblingly) afraid of change and that educates its young into ever-narrowing areas of specialization, the integrated, comprehensive, anticipatory designer is a dedicated synthesist" (Papanek, 1985, p332). John Tackara also indicates that the designer is given a new role when he states that "old style top-down, outside-in design simply won't work". The days of the individual designer who develops a product on his own are gone, because the complex systems we deal with nowadays are in fact shaped by all parties involved in these systems. Cooperation is a must, and the designer has to assume a new position in this: "Designers are having to evolve from being the individual authors of objects, or buildings, to being the facilitators of change among large groups of people" (Thackara, 2006, 7).

So on the one hand the role of the designer becomes broader, but at the same time his position appears to be threatened because an increasing number of "new" designers appear on the horizon. Ezio Manzini therefore indicates that "designers should accept the fact that they can no longer aspire to a monopoly on design, since we are living in an era in which everybody designs. They should accept that today design is not only executed in design studios, but everywhere" (Meroni, 2007, 13). Where Papanek was wondering 35 years ago whether designers wouldn't be better off to stop with the work, it might turn out that specialized designers will no longer be required at all. After all, everyone has now become a designer. And yet, especially within these developments there appears to be a need for the specific expertise of the designer. Although no longer as the creator of individual products, commissioned by one company, but as the architect of overlying solutions and systems that are capable of reconciling different interests. Manzini also comes to this conclusion, when he explains that designers can continue playing their specific role. "It is precisely because contemporary society is the way that it is that the role of 'design professionals' acquires even greater importance. Designers can come to the fore in the great 'diffuse' design arena, becoming 'solution providers', contributing their specificities, such as their capacity to produce visions of what is possible (i.e. the ability to imagine something that does not exist but could potentially exist) and set in motion strategies to help them materialize (i.e. concrete steps to transform potential visions into real solutions)" (Meroni, 2007, 13). In other words, there is work to be done for designers. First of all as creators of appealing future visions which clarify the possibilities (e.g. Silvester et al., 2010) and subsequently as initiators in order to contribute to the actual realization of these visions

This matches a reflection of Tim Brown, CEO of design agency IDEO, who describes in "Change by Design" (Brown, 2009) how his design agency is increasingly being asked to help solve complex problems, instead of designing tangible products. So are the designers that tackle these problems the same as the ones who take on the design of new products? Must each designer drastically broaden his skills, so that from now on, in addition to developing new products and services, they are also capable of developing broad societal future visions? Here one sometimes hears the discussion about the designer having to become a "Renaissance person" (Guest, 1991) or a "generalizing specialist", who is not only proficient in his specific field of expertise, but who also has a broad orientation on the world. Tim Brown, indicates that his agency is indeed looking for such individuals who possess "vertical", specialist knowledge as well as "horizontal", generalist characteristics. He calls them "T-shaped people" (Brown, 2005) who have a principal skill that describes the vertical leg of the T – they're mechanical engineers or industrial designers. At the same time these individuals are so empathic that they can branch out into other skills, such as anthropology, and do them as well. Actually, Brown also takes the next step when he emphasizes that IDEO's "design thinking" approach can, especially for "non-designers", make a valuable contribution to the solving of complex societal problems. Where traditionally, designers have integrated what is desirable from a human point of view with what is technologically feasible and economically viable, designers have been able to create the products we enjoy today. "Design thinking takes the next step, which is to put these tools in the hands of people who may have never thought of themselves as designers and apply them to a vastly greater range of problems" (Brown, 2009, 4).

With this suggestion that a design thinking approach is useful, not only for professional designers but also for other experts, we have returned to the starting point of this study, where reference was made the observation by Herbert Simon that everyone who wishes to change an existing situation into a new, desirable situation, is in fact a designer. From this it could be concluded that the results of this study are not only relevant for professional designers, but for all professionals who are faced with complex questions that demand a solution (and for the time being there are enough of those).

9.6 Conclusion

9.6.1 Response to the research question

The preceding sections include a discussion of the four research issues that have been discussed in this study. Finally we need to determine whether the new multilevel design model can indeed describe, and potentially help structuring, the design process and the role of designers in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner. The answers to the four research subquestions indicates that the new multilevel design model can provide insight in the relation between product and society (the "what"), the problems and objectives (the "why"), the design process (the "how") and the role of the designer and other actors (the "who") of the design process. The answer to the research question can therefore be summarized as follows:

Implementation of a multilevel design model can help to describe, and potentially structure, the design process and the role of designers, in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner. The distinction between the various system or aggregation levels can clarify (1) the relation between product and society (2) the relation of problems and objectives at different system levels (3) the way that the design process takes place and (4) the role of the designer in relation to the other involved actors.

Re 1) The relationship between new products and the socio-technical or societal system that they are a part of can be described by the application of different system or aggregation levels, whereby product-technology systems, product-service systems, socio-technical systems and societal systems can be placed in a hierarchical arrangement in relation to each other.

Re 2) Working on functional problems and objectives at the product-technology level can potentially make a discernible contribution to the solution of complex questions at the socio-technical of societal level. The new products must then make a contribution to the realization of an envisioned future situation that is agreed upon by the actors involved. The potential influence of new products is especially relevant when they fulfill a unique and necessary function that cannot be fulfilled in any other way.

Re 3) The product design process, the product-service development process, the development of socio-technical systems and the way that societal change process take place can be described in a similar manner, where the phases "experience, reflection, analysis, synthesis" are completed consecutively. These steps can be distinguished at various system or aggregation levels, where developments are mutually dependent and influence each other in a "top-down" as well as in a "bottom-up" direction. The initial impression is that influence in a "top-down" direction may occur through the demands that the larger system makes of the smaller elements of the system, and influence in a "bottom-up" direction may occur through the actual (or potential) characteristics of these elements which can be implemented at a higher level.

Re 4) A logical connection exists between the respective design level, the nature of the system under development and the potential contribution from the designer during this process. At the lower system levels, this contribution appears to be especially aimed at the development of one product-technology system or one product-service system, where design activities are commissioned by one client. At the socio-technical level it is more about combining the usually contradictory demands, wishes and interests of many actors involved, into an integrated design of a new socio-technical system. Development of a discernible "design" is not really an issue at the societal level. At this level it is more a matter of developing a common thought framework, a shared vision or an identical vocabulary. It might perhaps be possible for the designer to contribute to the clarification of this vision, but this issue has not been further developed in this study.

9.6.2 Contribution to body of knowledge

With regard to the contribution to the body of knowledge of this study, eight issues are discussed. First, the contribution is indicated, as seen from the perspective of each of the four fields of expertise that form the basis of this research (industrial design engineering, sustainable product development, systems engineering, sustainable system innovation). The combined outcome of these results determine if a certain issue is not new at all, if some new insight has been gained, or that the issue offers indeed a significant contribution to the body of knowledge in the field of industrial design. In Table 9-1, the discussion of the previous sections is summarized, summarizing the extent to which a contribution to knowledge has been made as a whole.

Although important for this research, describing the relationship between new products and a socio-technical or societal situation by means of different system levels (discussed in section 1.2.2), and analyzing the way that the mutual influence between different system levels takes place (discussed in section 1.4.1) both offer no significant contribution to the body of knowledge.

Including the socio-technical and societal level as distinct system levels within this multilevel approach (discussed in section 1.2.2), following a systematic, step wise approach to structure the design process (discussed in section 1.4.2), linking the value judgment regarding a certain (sub)system to the aggregation level from which this assessment is being made (discussed in section 1.3.1) and connecting the role of the designer to the respective system level on which a specific development takes place (discussed in section 1.5.1) are four issues that are somewhat new for some of the four fields of expertise, but have been common knowledge is others fields of expertise discussed.

Combining the multilevel approach with a systematic, design oriented approach, especially when related to the socio-technical and societal levels, is indeed a new contribution to the body of knowledge (this is discussed in section 9.2.2 and 1.4.2). Although the multilevel approach in itself is not new (it is common knowledge in the field of expertise of sustainable system innovation), and even the combining of these levels with a systematic design approach is not new (this is common knowledge in the field of expertise of systems engineering), combining both approaches, especially when interlinking them to the higher aggregation levels, has not been done before.

Table 9-1: Contribution of this research to body of knowledge

Field of expertise Knowledge issue	Industrial design engineering	Sustainable product development	Systems engineering	Sustainable system innovation	Contribution to body of knowledge
Describing the relationship between new products and a socio-technical or societal situation by means of different system levels (see section 9.2.2)	+/-	+/-	--	--	--
Including the socio-technical and societal level as distinct system levels within the multilevel approach (see section 9.2.2)	+/-	--	++	--	+/-
Following a systematic, step wise approach to structure the design process (see section 9.4.2)	--	--	--	+-	--
Combining the multilevel approach with a systematic design oriented approach (see section 9.2.2 and 9.4.2)	++	++	--	++	++
Linking the value judgment regarding a certain (sub-) system to the aggregation level from which this assessment is being made (see section 9.3.1)	++	++	+/-	+/-	+/-
Analyzing the way that mutual influence between different system levels takes place (see section 9.4.1)	++	+/-	--	--	--
Describing the way that change processes take place at the socio-technical and societal levels, in a systematic, design oriented manner (see section 9.4.2)	++	++	++	++	++
Connecting the role of the designer to the respective system level on which a specific development takes place (see section 9.5.1)	+/-	+/-	++	++	+/-

-- no new knowledge has been gained
+/- some new insight has been gained
++ significant contribution to body of knowledge

9.7 Limitations

Combining a multilevel design perspective, including product-technology, product-service, socio-technical and societal developments, with a concrete and hands-on product development approach, can be considered as unique contribution to the field of expertise of industrial design engineering. However, when interpreting the results of this research, certain limitations with regard to the generalizability of the outcome of this study should be kept in mind.

In section 2.7, the delimitations of this research have been discussed, emphasizing the conscious choice of maintaining a relatively "instrumental" attitude towards the way that new technology and new products function in society. This issue has been further discussed in section 9.4.2 (where the "manipulability of society" was discussed) and in section 9.3.2 (in which the "mediating role of technology" was discussed). This section presents other limitations that became apparent during the progress of the research. These should be kept in mind when interpreting the results of the study.

The results of this research are based on two projects, which of course is a limited number as a base for final conclusions. More research would be needed to further test the multilevel design model, by analyzing historic cases, as well as testing the model in hands-on design projects. On the other hand it should be noted that both projects have been tracked during several years, which can be regarded as a relatively long time, especially considering the fact that these are not historic case analysis, but design projects in which the researcher was actively aiming at influencing the course of affairs in real life.

Another limitation is the fact that both projects have been analyzed from the perspective of one designer-researcher, working from one organization: the Netherlands Organisation for Applied Scientific Research (TNO). The fact that this organization can be considered as quiet unique (TNO is an independent contract research organization, although it is established by a special Dutch "TNO law") should be kept in mind when interpreting the results of this study. On the other hand, the way of working within this organization is very similar to the way of working in other knowledge organizations like universities, certain parts of government and internal research and development departments of commercial companies. In addition, many other actors have been involved in the two projects, ranging from government and knowledge organizations to companies.

The third limitation that can be noticed is somewhat linked to the previous one. The fact is that both projects have occurred in the Dutch situation, with a relatively close link between government and business, among others by means of numerous subsidies available for companies. Several initiatives that have been described in chapter 6 and 7 would not have been possible without these subsidies from either local, regional or national government. That means that the outcome of this research should be regarded as specifically valid for the Dutch situation.

Although these limitations should certainly be acknowledged when assessing the outcomes of this research, the contribution to the body of knowledge as presented in the previous section still maintains its relevance, also in the light of these limitations. At the same time, more research is advised in order to further substantiate the outcomes of this study. For this purpose, several potential follow-up research subjects are presented in the next section.

9.8 Potential follow-up research

Even after the completion of this study, a fair number of questions remain unanswered. As onset for potential supplementary studies, 9 possible follow-up questions were mapped. Roughly speaking, the first two questions deal especially with the "product and society" aspect, questions 3 deals with the issue of "problems and objectives", questions 4 through 6 deal with the "design process" and questions 7 through 9 with the roles of "designer and actors". The various aspects of this study can in this way also be dealt with in potential supplementary studies.

9.8.1 Further testing of the multilevel design model

In this study, the results of two practical experiments were converted to more general insights with regard to the multilevel design process, as discussed in section 9.6. The question is in how far this extrapolation on the basis of two projects indeed appears to be correct. In order to investigate this, more research would be necessary in order to test the developed model. This could take place by quantifying, on the basis of a larger number of historic cases, the degree in which these cases "fit" into the multilevel design model. This can also take place by initiating a representative number of follow-up projects, where the design process develops specifically on the basis of the multilevel perspective. This could clarify if the focused application of the model can in fact support the design process in practice.

9.8.2 Applicability of the model for non-physical products

In section 9.2.2, and *Figure 9-1*, we discussed if the multilevel approach is also applicable to the development of other then physical products. In this study, physical products were approached as the lowest aggregation level. The addition of information and communication technology could still be seen in these products as a "supplement" to the physical artifact. The question is in how far the results of this study are also applicable to solutions that are almost completely digital in nature. Although also in that case there is usually a physical "carrier" of the system, the emphasis in many developments is increasingly on the digital interaction with the user. Supplementary study could look into the question whether the multilevel approach also works when there is hardly a question of a physical artifact as a component of the system, and the system should be considered more like an ecological network structure.

9.8.3 The influence of worldview on the design process

A possible supplementary study concerning the aspect "problems and objectives" as discussed in section 9.3.2 could be focused on the way in which the worldview of the involved actors influences the design process. Certainly during developments at the higher system levels, where different actors must collaborate in more or less equivalent ways, the expectation is that making the underlying assumptions and ideas explicit is essential for successful cooperation between client and designer as well as for the internal cooperation within design teams. A related issue may be regarding the difference in outcome between design projects where the exact same problem definition is developed, while different worldviews are employed as reference point in the design process. For that matter, it seems appropriate that in the area of design different classifications should be used than for instance current political or religious worldviews.

9.8.4 Development of the cyclic multilevel model

In section 9.4.2, *Figure 9-3* and *Figure 9-4* and in appendix C, an initial onset is made towards more explicitly combining the multilevel approach examined in this study with a cyclic approach of the design process. Supplementary research must demonstrate whether it is indeed possible to explicitly identify the different steps in the design process, particularly at the higher aggregation levels, and to distinguish them from each other. For each step in the process the additional question is what exactly are the similarities and differences for each aggregation level. At each step the study can also examine which approach and design tools are the most suitable for implementation in each specific phase.

9.8.5 Designing at one system level at a time

Other follow-up research may focus on the design process at different aggregation levels, where the question is what the results will be when the design process is consciously implemented at only one specific innovation level at a time. This may involve approaching the same problem definition from three or four aggregation levels, after which the results of each of these projects are compared with each other. Here the expectation is that design projects that are implemented at the level of the socio-technical or societal system, will contain more radical renewals than projects that are implemented at the product-technology or product-service level. The next question is whether guidelines can be identified regarding which type of design projects should be implemented at which level, and what the secondary conditions are in order to move to the next higher or lower level.

9.8.6 Reciprocal influence between system levels

In section 9.4.1 the reciprocal influence between various design levels is discussed, where it is also indicated that this aspect needs further attention. From a "top down" perspective, one issue could be how the demands and wishes at a higher system level can be communicated effectively to the actors at a lower system level, so that these will indeed develop the necessary subsystems. A "bottom-up" issue relates to the question how the (potential) characteristics of new products can be translated to objectives that are aimed for at a higher system level. The term "technology push", which carries a somewhat negative connotation, could perhaps be modified to terminology with a more positive connotation, for example, indicating a "technology opportunity" approach.

9.8.7 Available design tools at each system level

In section 9.5.1 it was discussed that the nature and properties of a "design" varies according to the various system levels. A relevant follow-up question concerns the available design tools at each system level. At the level of the physical product a large number of design tools are available (varying from a technical drawing, a CAD model, a physical model or prototype), where it's also well-known which tool can best be utilized in which phase of the design process. However, hardly any information is available for this at the higher system levels. Further study would be necessary to examine which tools, means and other sub-processes can make a contribution to the design process at the higher system levels of the multilevel design model.

9.8.8 Competencies of the designer at each system level

In section 9.5.2, the competencies of the "new" T-shaped designer were discussed. The question could be asked whether working at the various system levels is merely a matter of utilizing the right tools, or if is it a matter of fundamentally different knowledge and skills. In this case it then goes without saying that different kinds of people would be interested or suited for this. A variant of this issue would be about the possible composition of T-shaped design teams, including "non-designers". Here the team could act publicly as one entity, but divide the various kinds of activities internally, depending on of the phase in which a design process takes place.

9.8.9 Collective client association

As discussed in section 9.5.2, not one client is discernible who can act as decision-maker, particularly at the higher aggregation levels, while it is also obvious that this role is essential for each design process. The question could be discussed whether it is possible to develop a kind of "collective client association", where, for example, this group can act publicly as one collective client, while the freedom exists "in the background" to manage the composition of the group with flexibility. This could allow the design process to progress in a more systematic manner and to create a more explicit distinction between the role of "client" and "designer", without being dependent on one commissioning party.

9.9 Consequences of the study

9.9.1 Consequences for designers

The results of this study suggest that it may potentially be useful for designers to consider the system level at which a certain design process takes place. In general, the higher the design level that the designer is involved in, the more substantial the potential available degrees of freedom. Presumably the potential impact of a certain design will also be greater in that case, although the thresholds for actual implementation will in many situations also be higher. Particularly at the higher system levels, this means that one often must have patience to actually see a new concept realized in practice. Designers who are looking for "quick wins" in order to fill up their portfolio would therefore be better off to focus on the development of concrete artifacts, since their development time span is usually considerably shorter. However, they must accept that the available freedom for change and impact at society at these lower system levels is also more limited.

For designers who work at the product-service and socio-technical levels, it could potentially be relevant to realize that they do not have to design all of the elements of a new system themselves. In view of the nature of most designers, who are after all always looking for renewal, there is a possibility that might be tempted, for example in the case of a new product-service combination, to redesign the new service as well as the artifact that is part of this service. This study indicates that this in most cases this should be avoided, unless the new product fulfills a unique function that cannot be fulfilled in any other way. In all other cases, the outcome of this study suggest that it may be advisable that existing products be used as much as possible. That will allow the focusing of all design efforts on the development of the way the "whole" is put together, instead of on the development of one of its components.

9.9.2 Consequences for entrepreneurs

The results of this study suggest that it may potentially be relevant for entrepreneurs to realize that the products and services they deliver are part of a larger system. Therefore it may be advisable that development of new products and services are expressly based on this system context. Balancing between those elements of the system that are developed within the organization, versus elements that are instead taken over from others, would in this case become increasingly important. This coincides with the impression that rapidly increasing development costs make it impossible for companies to carry out all research and development activities within the boundaries of one single organization. Therefore the system approach could probably fit well with the "open innovation" approach (Chesbrough, 2003) and it may potentially be of use for companies to help them determine the best innovation level for them to get involved in.

This shouldn't suggest that there would be one "correct" level for companies to select, but it is plausible that companies could potentially benefit from an awareness of the consequences of working at a specific system level. At the lowest levels the organization will most probably have to adapt as much as possible to the prevailing paradigms, protocols and infrastructure that currently exist. At the higher levels there is probably more playroom to implement other system elements, where one must however be aware whether the organization is indeed capable of initiating change at this level. If, for instance, it is necessary to introduce new legislation before a certain idea can become commercially successful, then it appears fairly certain that the introduction of that system will not be anytime soon. This is not a problem for multinationals, which can operate in the long-term, but it would appear to be a problem for most small to medium enterprises. On the other hand, large organizations have their own internal rules and regulations that cannot easily be bent, while smaller organizations can adapt faster to a changing environment.

9.9.3 Consequences for government

Results of this study suggest that government might do well to make more conscious use of the expertise of designers, especially with regard to their ability to synthesize new solutions, based on mostly contradictory demands and wishes from various actors. For this purpose one could employ existing designers, where these will then be retrained into professional "vision developers". Another option is primarily about adopting a new way of working in the form of "design thinking" (Brown, 2009), to be executed by other professionals.

A second point of potential interest for government relates to the difference in development speed at the various system levels. This lesson should be taken into account in two directions. First of all it appears that the promises made regarding the performance of new products often take several years to be realized. The formulation of policy which is based on the potential characteristics of new products that have not in actual fact been realized is naturally accompanied by the necessary risks. On the other hand, government often exercises a lot of patience when thinking about the future at relatively high abstraction levels, which are often focused on developments that are planned for more than 10 years into the future, while most companies are focused on results that can be achieved within the term of no more than two years. It is therefore important that mutual expectations of the implementation horizon for a certain development are clearly defined.

This brings us to the third point of interest to government, namely the necessity to translate long-term government plans at the higher system levels, into appealing short-term objectives at the lower aggregation levels. It appears to be true that, when developing a future vision it is indeed important to involve as many parties as possible in the process. However, for the realization of this vision it would be necessary that the elements of this vision are presented in such a way that companies can be stimulated to make a concrete contribution to this.

9.9.4 Consequences for societal organizations

Societal organizations, such as care institutions and NGOs, can benefit from the results of this study by filling the "gap" between developments at the product-technology and product-service on the one hand (where companies often take the lead), and developments on the socio-technical and societal level on the other hand (where government often takes the lead). Such organizations may have a certain interest in specific developments on each of these levels, but depend on others for its realization. This is the case in the area of government policy and legislation, as well as for the development of certain new products. Societal organizations may potentially be able to create an attractive test environment in order to "boost" such developments, for example in collaboration with knowledge institutions and education. Such a "field lab" environment can make it attractive for companies to introduce their new products or services in just that location, because here it is possible to create the focus for new developments. Government can subsequently be stimulated to authorize specific policy or certain exceptions for current legislation, exactly for such a test environment. Although for societal organizations this would indeed entail a certain effort to support all of these new developments, but at the same time it means that they are "front and center" where the new developments are concerned.

9.9.5 Consequences for education

The results of this study indicate that it could be advisable for education in the field of expertise of industrial design to pay specific attention to the system context in which product development takes place. Designing at the various system levels could become an explicit part of the education curriculum, such that each student will at least have the basic tools for designing at each level. One might even seriously wonder if in the foreseeable future the development of physical artifacts will become past tense, since these can be developed elsewhere else just as well and for a fraction of the price. In order to continue to be at the fore-front of the international "design playing field", it may be necessary, especially for future designers, to considerably broaden the focus of the field of expertise.

The results of this study may also be relevant for educational programs that are not explicitly focused on the actual industrial design process. Particularly studies that are aimed at professional practice may take to heart the statement by Herbert Simon that design is the core of all professional training, as it is the principal mark that distinguishes the professions from the sciences. That implies that schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design (Simon, 1969, 111). This is not about the design of "things", but about a form of "design thinking" in order to tackle complex problems in a systematic manner. Future professionals would therefore be recommended to explicitly make the design process their own, as a basic tool for exercising their trade in practice.

9.10 Summary

In chapter 9, the broader implications of the research are investigated. For that purpose, the four research issues (product and society, problems and objectives, design process, designer and actors) that have been determined on the basis of the research subquestions are being discussed. Together these four issues relate to the "what", the "why", the "how" and the "who" of the subject under investigation. Based on this analysis, the answer to the research question can be summarized as follows:

Implementation of a multilevel design model can help to describe, and potentially structure, the design process and the role of designers, in such a way that the mutual relationship between new products and the socio-technical or societal context in which these products function is taken into account in a systematic manner. The distinction between the various system or aggregation levels can clarify (1) the relation between product and society (2) the relation of problems and objectives at different system levels (3) the way that the design process takes place and (4) the role of the designer in relation to the other involved actors.

Re 1) The relationship between new products and the socio-technical or societal system that they are a part of can be described by the application of different system or aggregation levels, whereby product-technology systems, product-service systems, socio-technical systems and societal systems can be placed in a hierarchical arrangement in relation to each other.

Re 2) Working on functional problems and objectives at the product-technology level can potentially make a discernible contribution to the solution of complex questions at the socio-technical of societal level. The new products must then make a contribution to the realization of an envisioned future situation that is agreed upon by the actors involved. The potential influence of new products is especially relevant when they fulfill a unique and necessary function that cannot be fulfilled in any other way.

Re 3) The product design process, the product-service development process, the development of socio-technical systems and the way that societal change process take place can be described in a similar manner, where the phases "experience, reflection, analysis, synthesis" are completed consecutively. These steps can be distinguished at various system or aggregation levels, where developments are mutually dependent and influence each other in a "top-down" as well as in a "bottom-up" direction. The initial impression is that influence in a "top-down" direction may occur through the demands that the larger system makes of the smaller elements of the system, and influence in a "bottom-up" direction may occur through the actual (or potential) characteristics of these elements which can be implemented at a higher level.

Re 4) A logical connection exists between the respective design level, the nature of the system under development and the potential contribution from the designer during this process. At the lower system levels, this contribution appears to be especially aimed at the development of one product-technology system or one product-service system, where design activities are commissioned by one client. At the socio-technical level it is more about combining the usually contradictory demands, wishes and interests of many actors involved, into an integrated design of a new socio-technical system. Development of a discernible "design" is not really an issue at the societal level. At this level it is more a matter of developing a common thought framework, a shared vision or an identical vocabulary. It might perhaps be possible for the designer to contribute to the clarification of this vision, but this issue has not been further developed in this study.

Regarding the originality of the outcome of this study, eight potentially new issues are examined. For each of these, their "newness level" is being discussed from the perspective of the four fields of expertise that form the basis of this research (industrial design engineering, sustainable product development, systems engineering and sustainable system innovation). The combined outcome of these results determine if a certain issue is not new at all, if some new insight has been gained, or if the issue indeed offers a significant contribution to the body of knowledge in the field of industrial design.

Although important for this research, describing the relationship between new products and a socio-technical or societal situation by means of different system levels, and analyzing the way that the mutual influence between different system levels takes place, both offer no significant contribution to the body of knowledge.

Including the socio-technical and societal level as distinct system levels within this multilevel approach, following a systematic step wise approach to structure the design process, linking the value judgment regarding a certain (sub-)system to the aggregation level from which this assessment is being made and connecting the role of the designer to the respective system level on which a specific development takes place are four issues that are somewhat new for some of the four fields of expertise, but have been common knowledge is others fields of expertise discussed.

Combining the multilevel approach with a systematic, design-oriented approach, especially when related to the socio-technical and societal levels, is indeed a new contribution to the body of knowledge. Although the multilevel approach in itself is not new (it is common knowledge in the field of expertise of sustainable system innovation), and even the combining of these system levels with a systematic design approach is not new (this is common knowledge in the field of expertise of systems engineering), combining both approaches, especially when interlinking them to the higher aggregation levels, has not been done before.

The study gives rise to several new research questions. A first attempt was made to define these issues in the form of 9 potential follow-up questions. These follow-up questions are related to (1) further testing of the multilevel design model, (2) the applicability of the model for non-physical products, (3) the influence of worldview on the course of the design process, (4) the development of a potential cyclic multilevel design model, (5) the effects of designing on one system level at the time, (6) the reciprocal influence between the various system levels, (7) the available design tools at each system level, (8) the competencies of the designer at each system level and (9) the possibility of creating a potential multi-actor client association. Finally there is a description of the consequences that the results of the study can have for various kinds of experts. Here it becomes clear that the results of this study are not only useful for designers, but may also benefit entrepreneurs, government, societal organizations and education.

10 Epilogue

The title of this research is ‘New to Improve”, referring to the slogan that many new products are being promoted with. In chapter 1 it was discussed that nowadays designers are not only to deliver these “new and improved” products, but also products that may be “new to improve” the society in which they function. After finishing this research, we should now be able to answer the question if is indeed possible to create new products that support the creation of a more sustainable society. The answer to this question is certainly positive, albeit with many footnotes that should be taken into consideration. While developing a new product can be a huge challenge in itself, it doesn’t come near the challenge that we face when trying to influence the structure of a socio-technical or societal system. Which brings us back to the question what such an improved society should look like. And this again is based on the way we look at the world, which is emphasized in a lecture by the Dutch minister Piet Hein Donner at the opening of the academic year of the Faculty of Theology in Kampen, in which he establishes the relationship between future societal developments and the many seemingly insignificant decisions that it is based on. Which should be an encouragement for designers, as their unique skills and knowledge, especially in the area of synthesizing new and promising future solutions, can certainly be of great value in this process. Together with other experts, designers can contribute their unique skills to help create many “new and improved” products, that together may contribute to a “new and improved” society.

> *“Inquiring after the future is therefore also: asking about what is happening now and how we are handling it now. That does not make the future manipulable. History is the unintentional result of many decisions that are made with different objectives and is seldom the result of targeted decisions. If that is true, then the concepts, norms, values and views that it is based on, partly determine the direction taken by societal development. Then the course of events is partly determined by effort, ethics and idealism; or faith, hope and love. That course is not bent by a single purpose and one phenomenal move, but by a large number of small nudges” (Donner, 2007).*

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Samenvatting (Nederlands)

New to Improve – Hoe nieuwe producten en maatschappelijke veranderingsprocessen elkaar wederzijds beinvloeden.
Proefschrift van Peter Joore, 30 November 2010

Het vakgebied van het industrieel ontwerpen verandert. Waar het werk van de ontwerper enkele jaren geleden nagenoeg helemaal gericht was op het ontwikkelen van tastbare producten, is de ontwerper tegenwoordig meer en meer bezig met het ontwikkelen van ideeën, plannen, strategieën, diensten en het genereren van "oplossingen", in plaats van met het ontwerpen van fysieke artefacten. Daarnaast is een toenemende aandacht voor de verantwoordelijkheid van alle partijen die bij het innovatieproces zijn betrokken, om een bijdrage te leveren aan het realiseren van wereldwijde duurzaamheidsdoelstellingen. Dat houdt in dat nieuwe product niet alleen "nieuw en verbeterd" moeten zijn, maar ook "nieuw om te verbeteren", gericht op het realiseren van een positieve bijdrage aan de maatschappij waar binnen nieuwe producten onderdeel van uitmaken (vandaar de titel van dit onderzoek).

Het vertalen van deze ambitieuze visie naar de praktijk blijkt echter niet vanzelfsprekend te zijn. Bij het analyseren van vier onderling gerelateerde vakgebieden (industrieel ontwerpen, duurzame productontwikkeling, systeemkunde, duurzame systeeminnovatie) blijkt namelijk dat bestaande ontwerp- en innovatiemodellen ofwel te veel gericht zijn op de ontwikkeling van individuele producten of systemen, waardoor er te weinig rekening wordt gehouden met socio-technische of maatschappelijke aspecten. Andere modellen hanteren weer zo'n hoog abstractieniveau dat ze ongeschikt zijn om te gebruiken bij de ontwikkeling van concrete nieuwe producten. Deze vaststelling heeft geleid tot de volgende onderzoeksvraag:

"Hoe kan het ontwerpproces en de rol van de ontwerper op zo'n manier worden beschreven (en zo mogelijk worden gestructureerd) dat er op systematische wijze rekening wordt gehouden met de onderlinge relatie tussen nieuwe producten en de socio-technische of maatschappelijke context waarbinnen deze producten functioneren?"

Op basis van de analyse van bestaande ontwerp- en innovatiemodellen zijn de randvoorwaarden voor een ontwerpmodel vastgesteld dat aan deze doelstelling kan voldoen. (1) Dit model zou inzicht moeten bieden in de relatie die bestaat tussen de ontwikkeling van individuele producten, ten opzichte van de ontwikkelingen die plaatsvinden op socio-technisch en maatschappelijk niveau (de "wat" vraag). (2) Het zou inzicht moeten bieden in de manier waarop problemen en doelstellingen die worden gerealiseerd door middel van het functioneren van een product, zich verhouden tot de maatschappelijke problemen en doelstellingen die worden gerealiseerd door middel van het functioneren van een socio-technisch systeem (de "waarom" vraag). (3) Het zou inzicht moeten bieden in de manier waarop het productontwikkelingsproces plaatsvindt, ten opzichte van de manier waarop socio-technische en maatschappelijke veranderingsprocessen plaatsvinden (de "hoe" vraag). (4) Tenslotte zou het inzicht moeten bieden in de potentiële rol van de ontwerper in relatie tot individuele bedrijven en andere actoren (de "wie" vraag). Samen geven deze vier aspecten inzicht in het wat, waarom, hoe en wie van het onderzoeksonderwerp.

Hoewel bestaande modellen niet het gewenste inzicht lijken te bieden, geven ze wel aanleiding voor de veronderstelling dat het onderscheiden van verschillende systeem- of aggregatieniveaus dit inzicht wel zou kunnen opleveren. Daarom is een nieuw multilevel ontwerpmodel ontwikkeld, dat is gebaseerd op vier aggregatieniveaus, dat van het product-technologie systeem, het product-dienst systeem, het socio-technische systeem en het maatschappelijke systeem. Het nieuwe multilevel ontwerpmodel is vervolgens getoetst door middel van een actieonderzoek strategie, uitgevoerd door middel van twee meerjarige ontwerpprojecten. Het eerste project is getiteld "Autonome Ouderen" en richt zich op het maatschappelijke vraagstuk van de vergrijzing. In dit project wordt de ontwikkeling van een nieuw woon-zorgcentrum in Apeldoorn gekoppeld aan de ontwikkeling van de Guide Me, een lokalisatiesysteem dat ouderen met een lichte vorm van Alzheimer kan helpen om langer zelfstandig te blijven wonen. Het tweede project heet "Bewegende Jongeren" en richt zich op het maatschappelijke vraagstuk dat betrekking heeft op het feit dat veel jongeren te dik zijn, als gevolg van een gebrek aan beweging. In dit project wordt de ontwikkeling van een Fieldlab Sportstimulering in Eindhoven gekoppeld aan de ontwikkeling van de interactieve Make Me Move speeltegels, die zo zijn ontworpen dat ze jongeren stimuleren om meer te bewegen.

De conclusie van het onderzoek is dat het nieuwe multilevel ontwerpmodel inderdaad kan helpen om het ontwerpproces en de rol van de ontwerper zodanig te beschrijven, en op termijn te structureren, dat er op systematische wijze rekening kan worden gehouden met de relatie van nieuwe producten en het socio-technische en maatschappelijke systeem waar deze producten onderdeel van uitmaken. Daarbij moet echter wel worden opgemerkt dat het in gang zetten van veranderingen op socio-technisch en maatschappelijk niveau veel complexer is dan het ontwikkelen van een enkel product (hetgeen al geen eenvoudige taak is, zoals de meeste industrieel ontwerpers zullen beamen).

Appendix A: Structure of "Autonomous Elderly" project

The structure of the events as discussed in chapter 6 is presented in table A-1. The left column presents the chapter and section numbers where the events are being described. The middle column presents a short description of the event and the left column indicates what "design step" this event is about. The symbols used are the same as those used in the multilevel design model, as explained in table A-2.

Table A-1: Events in "Autonomous Elderly" project (part 1 of 2)

Chapter	Event	Design step
6.1	The societal challenge – "Autonomous Elderly"	
6.1.1	Aging in the Netherlands	S1 -- characteristics
6.1.2	"Elderly are sovereign and valued citizens"	S1* -- value judgment
6.2	Organizational context - New Initiative Sustainable System Innovation	
6.2.1	TNO NIDSI, aiming for "breakthrough technology"	S2' -- demands
6.3	Cooperation with De Woonmensen, Apeldoorn	
6.3.1	Situation Apeldoorn, many elderly, many seniors homes	R1 -- characteristics
6.3.1	The municipality must anticipate the aging to come	R1* -- value judgment
6.3.1	Municipality Apeldoorn stimulates introduction assisted living zones	R2' -- demands
6.3.2	Vision for assisted living center Hubertus-Drieschoten	T_{R2} -- design
6.4	Future scenarios and future visions	
6.4.1	Four future scenarios	T_{S2} -- design
6.4.2	Future vision Living together carefree/Freedom custom care	R2 -- characteristics
6.4.3	Actors react to developed future visions	R2* - - value judgment
6.5	Subsector telemonitoring	
6.5.1	Splitting the future vision into subsectors	Q1' -- demands
6.5.3	Concept design new telemonitoring products	T_{Q1} -- design
6.5.4	Visualization of ideas for new telemonitoring products	Q1-- characteristics

Table A-1: Events in "Autonomous Elderly" project (part 2 of 2)

6.6	Guide Me and My-Bodyguard	
6.6.2	Companies react to ideas How to continue	Q1* -- value judgment
6.6.1	Young girl abducted in Ahaus	P1 -- characteristics
6.6.1	The region, and Rob Kuipers, are in shock: "this has to change"	P1* -- value judgment
6.6.1	"Device must transmit location in emergency"	P2' -- demands
6.6.1	Development My-Bodyguard	T_{P2} -- design
6.6.3	Guide Me system used by De Woonmensen	P2 -- characteristics
6.6.3	Users react to Guide Me system	P2* -- value judgment
6.7	Detail development Guide Me	
6.7.2	Demands of customizable casing	P3' -- demands
6.7.2	Development innovative synthetic casings	T_{P3} -- design
6.7.2	Feasibility project SBIR Guide Me	Q2' -- demands
6.7.2	Valorization project SBIR Guide Me	T_{Q2} -- design
6.7.4	Realization Guide Me sub-technology	P3 -- characteristics
6.7.5	Implementation Guide Me system	Q2 -- characteristics
6.8	De Groene Hoven	
6.8.1	Demands assisted living center Hubertus-Drieschoten	R3' -- demands
6.8.1	Development of Hubertus-Drieschoten	T_{R3} -- design
6.8.1	Realization and use of De Groene Hoven	R3 -- characteristics
6.8.1	Staff and residents' opinions of De Groene Hoven	R3* -- value judgment
6.8.2	Evaluation localization systems for slightly demented elderly	Q2* -- value judgment
6.8.3	Aging in the Netherlands, situation 2010	S2 -- characteristics
6.8.3	Opinions about the situation surrounding aging in 2010.	S2* -- value judgment

Table A-2: Legend for the multilevel design mod

Symbol	Meaning
P1,Q1, R1, S1	Characteristics of the system in initial situation
P1*, Q1*, R1*, S1*:	Value judgment relating to this situation, problem definition
P2', Q2', R2', S2'	Objectives, criteria for new (sub-)system
Tp, Tq, Tr, Ts	Synthesis process, resulting in design of new (sub-) system
P2, Q2, R2, S2	Characteristics of new the new (sub-)system
P2*, Q2*, R2*, S2*:	Value judgment relating to the new (sub-)system

Appendix B: Structure of "Youth in Motion" project

The structure of the events as discussed in chapter 6 is presented in table B-1. The left column presents the chapter and section numbers where the events are being described. The middle column presents a short description of the event and the left column indicates what "innovation step" this event is about. The symbols used are the same as those used in the multilevel design model, as explained in table B-2.

table B-1: Events in "Youth in Motion" project (part 1 of 2)

Chapter	Event	Design step
7.1	Societal challenge – Youth in Motion	
7.1.1	Dutch Standard for Healthy Physical Activity	S2' -- demands
7.1.2	Study Children in priority neighborhoods	R1 -- characteristics
7.1.2	Children must move more	R1*-- value judgment
7.2	Organizational context	
7.2.1	Government initiatives, National Action Plan Sport and Activity	T_{S2} -- design
7.2.2	TNO Sport, InnoSportEU, InnoSportNL, InnoBrabant	S2 -- characteristics
7.3	Make Me Move	
7.3.1	Computer technology, opportunity or threat?	P1 -- characteristics
7.3.2	"ICT offers opportunities for innovative activity games"	P1* -- value judgment
7.3.3	Program of Demands Make Me Move	P2' -- demands
7.3.5	Design Make Me Move play floor -- Lighting Tiles	T_{P2} -- design
7.3.6	Energy monitoring while playing on Make Me Move	P2 -- characteristics
7.3.7	Presentation and assessment of the play floor	P2* -- value judgment
7.4	Sports Promotion Field Lab	
7.4.1	Sport and Recreation Memorandum: "people must move more"	R2' -- demands
7.4.2	Development Sports Promotion Field Lab Eindhoven	T_{R2} -- design
7.4.3	Realization Sports Promotion Field Lab Eindhoven	R2 -- characteristics
7.4.1	"Eindhoven-Noord is ultimate sports innovation area"	R2* -- value judgment
7.5	Xperience Area and Design for Movement	
7.5.1	Design assignment Xperience Area project	P4' -- demands
7.5.1	Six groups of students commence work	T_{P4} -- design
7.5.2	Students develop new products	P4 -- characteristics
7.5.3	Judging at the Design for Movement symposium	P4* -- value judgment

table B-1: Events in "Youth in Motion" project (part 2 of 2)

7.6	Playground of the Future	
7.6.1	Municipalities establish innovative playgrounds	Q1 -- characteristics
7.6.1	Evaluation playgrounds: "Success play area depends on support"	Q1* --value judgment
7.6.2	Program of demands for "Playground of the future"	Q2' -- demands
7.6.1	Design assignment "Playground of the future" project	P5' -- demands
7.6.2	Six groups of students commence work	T_{P5} -- design
7.6.2	Students develop new products	P5 -- characteristics
7.6.3	Judging at Playground of the Future symposium	P5* -- value judgment
7.7	Embedded Fitness	
7.7.2	Concept design Embedded Fitness	Q3' -- demands
7.7.2	Development of Embedded Fitness and E-Fitzone	T_{Q3} -- design
7.7.2	The E-Fitzone is brought into use on January 28, 2008	Q3 -- characteristics
7.8	Sports, Play and Activity Square	
7.8.1	Development Sport, Sports, Play and Activity Square Eindhoven-Noord	T_{Q2} -- design
7.8.3	Opening Sport, Sports, Play and Activity Square on October 30, 2008	Q2 -- characteristics
7.9	Small Business Innovation Research	
7.9.1	SBIR feasibility study Make Me Move play tiles	P3' -- demands
7.9.2	SBIR valorization project by NPSP / Colibri Interactive Innovations	T_{P3} -- design
7.9.2	Promotion Make Me Move / Twinkle tile	P3 -- characteristics
7.10	Societal Impact	
7.10	Societal impact	S2* -- value judgment

Table B-2: Legend for the multilevel design model

Symbol	Meaning
P1,Q1, R1, S1	Characteristics of the system in initial situation
P1*, Q1*, R1*, S1*:	Value judgment relating to this situation, problem definition
P2', Q2', R2', S2'	Objectives, criteria for new (sub-)system
Tp, Tq, Tr, Ts	Synthesis process, resulting in design of new (sub-)system
P2, Q2, R2, S2	Characteristics of new the new (sub-)system
P2*, Q2*, R2*, S2*:	Value judgment relating to the new (sub-)system
P3', Q3', R3', S3'	Objectives, criteria for new (sub-)system

Appendix C: A Cyclic Multilevel Design Model

As discussed in the section "potential follow up research" (chapter 9), a possible cyclic visualization of the multilevel design model could be a subject for further study. As a preliminary suggestion for such a version of the model, a tentative completion of the various steps of the design process has been made, for each of the four aggregation levels. The way that the model is presented varies between figure D-1, figure D-2 and table D-1. However, the content of these are exactly the same.

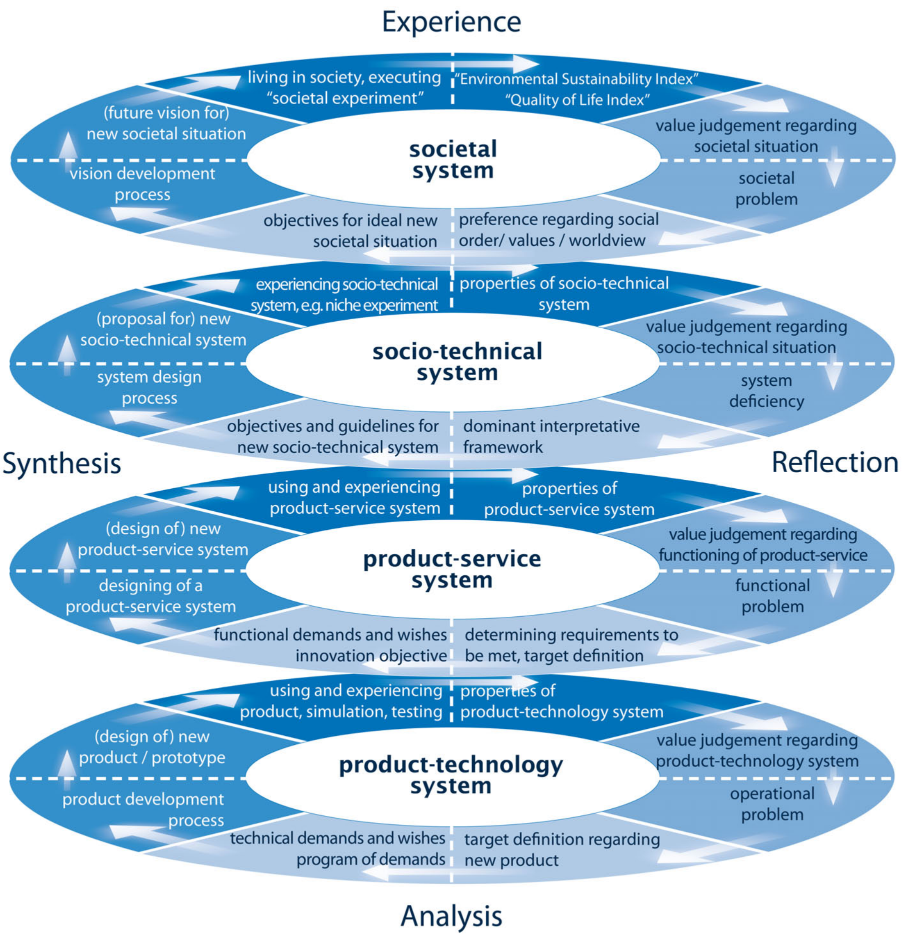

Figure C-1: Cyclic presentation of potential Multilevel Design Model

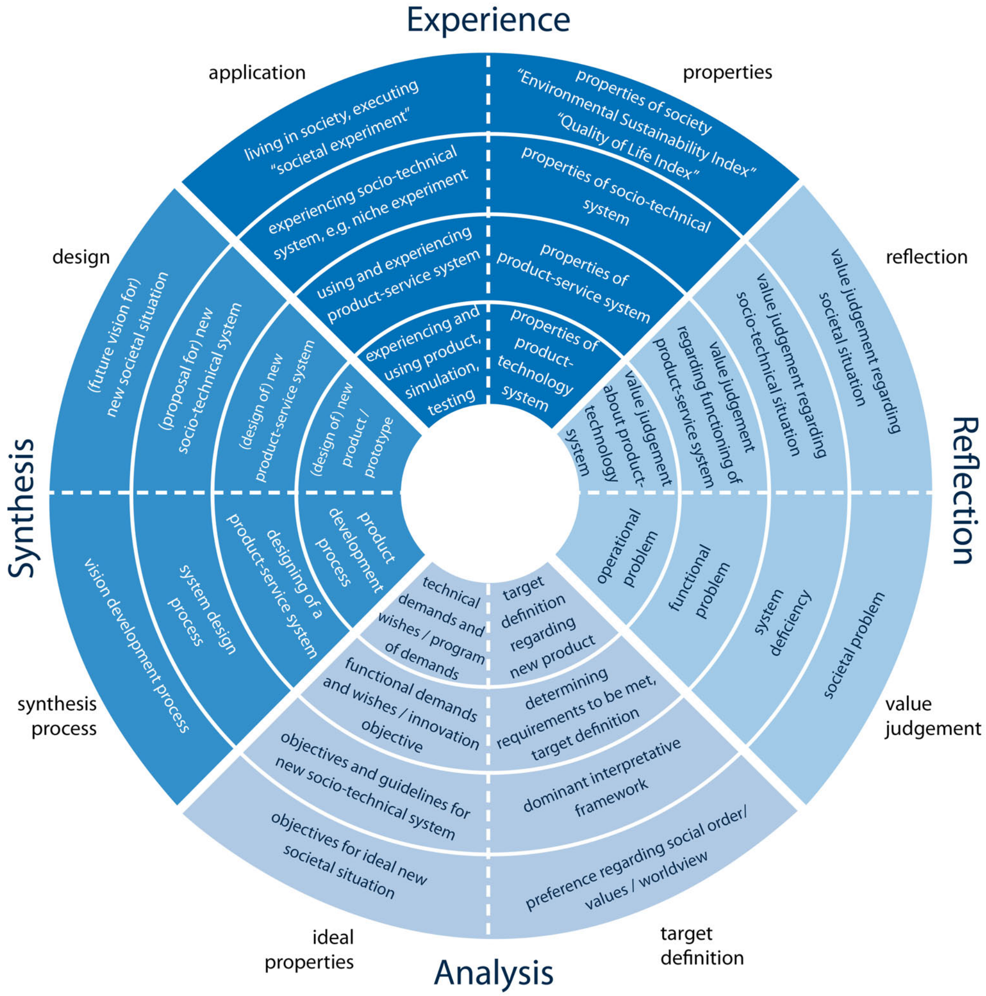

Figure C-2: Flat and cyclic presentation of potential Multilevel Design Model

Table C-1 – The various steps of a potential cyclic Multilevel Design Model

	Experience		Reflection		Analysis		Synthesis	
Societal system	living in society, executing societal experi-ment	properties of society, "Environ-mental Sustaina-bility Index" "Quality of Life Index"	value judgment regarding societal situation	societal problem	preference regarding social order/ values / worldview	objectives for ideal new societal situation	vision develop-ment process	(future vision for) new societal situation
Socio-technical system	experien-cing socio-technical system, e.g. niche experiment	properties of socio-technical system	value judgment regarding socio-technical situation	system deficiency	dominant interpre-tative framework	objectives and guidelines for new socio-technical system	system design process	(proposal for) new socio-technical system
Product-service system	using and experien-cing product-service system	properties of product-service system	value judgment regarding functioning of product-service system	functional problem	determinin g require-ments to be met, target definition	functional demands and wishes / innovation objective	designing of a product-service system	(design of) new product-service system
Product-technology system	using and experien-cing product, simulation, testing	properties of product-technology system	value judgment regarding functioning of product-technology system	operational problem	target definition regarding new product	technical demands and wishes / program of demands	product develop-ment process	(design of) new product / prototype

Curriculum Vitae

Peter Joore (1967) graduated as an Industrial Design Engineer at the Delft University of Technology in 1991. His career started in the area of commercial product design, among others working on the redesign of the Fokker 50 aircraft interior, the development of signage for Hong Kong's MTR metro and the design of the check-in desks for Moscow's Domodedovo Airport. From 1999 until 2008 he worked as a senior researcher and business consultant at the Netherlands Organization for Applied Scientific Research TNO. Here he initiated and coordinated various national and international multidisciplinary innovation projects, applying state of the art technology in the development of radically new products, services and systems. In parallel to his work at TNO he worked on his PhD research with the Design for Sustainability research group at Delft University of Technology. He also worked for several years as a part-time lecturer at the faculty of Industrial Design of the Technical University Eindhoven, a course of study that is focused on the development of intelligent products and systems. Since 2008 Peter works as a professor ("lector") at the NHL University of Applied Science in Leeuwarden, the Netherlands. Here his research is focused on the question how the Open Innovation paradigm can be translated into transsectoral innovation projects in which actors from education, research, business and societal organizations cooperate to realize breakthrough technological and organizational innovations, benefiting business as well as society.

Delft University of Technology

Design for Sustainability program

The focus of design is changing rapidly, as new products are increasingly connected to each other and to the rest of the world. This means that the focus of the designer is less and less on the creation of tangible artifacts, and increasingly on the development of complex interconnected systems. These systems should preferably not only be 'new and improved', but also be "new to improve" society. To support this ambitious vision, a new multilevel design model is discussed that may provide insight in the mutual relationship between new products and the socio-technical and societal contexts in which these products function. This model is tested in two experiments: "Autonomous Elderly", which links the development of an assisted living center to the Guide Me, a personal tracking system, and "Youth in Motion", which links the development of a Sports Promotion Field Lab to the development of the Make Me Move, an interactive play floor.

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