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Towards sustainable well-being

Industrial Design Engineering

Research portfolio IDE/TUD 2008-2012

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TU Delft Delft University of Technology

Challenge the future

Towards sustainable well-being

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Contents

Introduction

This brochure documents the content of a new research portfolio for the Faculty of Industrial Design Engineering (IDE) for 2008–2012. Six research programmes outlined in Part II represent this content. The choices made for this portfolio are based on the goals, research objective and strategic positioning of IDE. Part I describes these starting points and concludes with a short description of the research organisation and policy.

Launching this portfolio, slated to begin in 2008, at the start of 2009 may seem a little belated, but 2008 was an important transitional year in which the six programmes were extensively presented, shaped and modified. It took us one year to finalise the old portfolio, process the results of the research assessment report and fully define the six programmes presented in the new portfolio. So, though this portfolio was initiated in 2008, it is only now, at the start of our 40th lustrum, that we are fully equipped to make a fresh start. The main goal of this brochure is to serve as a source of inspiration, for all the researchers within our faculty, for all our research minded students, and for all academic and industrial partners with whom we cooperate, now and in the future. The portfolio described in Part II of this brochure is therefore not a portfolio in the strictest sense of the word. Here we have chosen to present foremostly the underlying starting points, the focus and the vision of the six programmes instead of giving a comprehensive overview of all research projects.

The basis of this portfolio was designed more than a year ago when the '3H-team' (professors Hekkert, Horvath, & Hultink) laid down its main contours. Following this pioneering groundwork, many individuals inside and outside the faculty – we would especially like to thank the Research Advisory Board – have contributed to its vision, content and structure.

The result is an inspiring research agenda for the years to come, an agenda that is both novel and challenging and at the same time builds on the 40 year foundation of human-centred design and research at our faculty.

The Research Council of Industrial Design Engineering

January 2009

Part I

Goals, objective and position of Industrial Design Engineering

It is impossible to define a new research portfolio, including research domains, without first determining the main goals in terms of strategic intent and research objective. The major goals of research at IDE are: (a) to solve scientifically challenging and socially useful knowledge problems, (b) to embed/position the design research activities of the Faculty in line with national and international trends/ objectives, and (c) to harmonise the overwhelming majority of research activities within the faculty. To define these important starting points of our portfolio, a number of considerations and external driving forces were taken into account.

These considerations and driving forces allowed us to formulate and define (1) the development of the discipline of IDE over the next decades, (2) the research objective until 2012, and (3) the role of the designer in the years to come. These three elements of the vision are outlined below, followed by an indication of how these starting points are supported by research organisation and policy.

I.1

Towards a transdisciplinary science of IDE

As a creative profession, industrial design engineering deals with the design of sustainable and durable products for people and society, which typically appear as artefacts or artefact-service combinations. However, industrial design engineering is also an evolving academic discipline, which is developing its own body of knowledge, research and design methods, and practice.

Industrial design engineering was introduced as an academic discipline at TU Delft some 40 years ago and has become one of the most prosperous and prominent faculties in the field. Forty years is a relatively short period from the perspective of an academic discipline, but is long enough to observe a line of evolution. Industrial design engineering is currently evolving from a set of monodisciplinary sciences to a transdisciplinary field of knowledge, where research is conducted between disciplines, across different disciplines and beyond individual disciplines. The general competencies for industrial product development have been based on the knowledge and methods of four fields of study, namely marketing/innovation management, ergonomics, design/aesthetics, and engineering. Each of these fields of study extend to several related disciplines. For example, engineering concerns materials, electronics, information, manufacturing and energy.

Like other disciplines based on a heterogeneous knowledge platform, industrial design engineering will need a long time to come into its own as a transdisciplinary field of knowledge, requiring its own body of knowledge and dedicated research methods. In the first phase of this process, the emergence of interdisciplinary developments will be facilitated. The objective of the second phase is to create a multidisciplinary synergy in terms of research methods and contextualisation of knowledge. This development, triggered by scientific research, is intended to break down the interdisciplinary boundaries of the related sciences in order to weld them into the discipline of industrial design engineering which simultaneously pursues disciplinary inquiry and insight and constructs proper knowledge for knowledge-intensive design praxis. The general objective of this research portfolio is to contribute to this disciplinary development.

I.2

Research objective

Following the mission of the Faculty of IDE, the overall research objective for 2008-2012 has been defined as follows:

> *Fostering sustainable well-being by exploring, generating and transferring knowledge and technologies for industrial design.*

The key element of this goal is 'sustainable well-being'. Well-being refers to an experiential state of people and organisations, which can have many shapes, such as satisfaction, fulfilment, support, inspiration, protection, acknowledgment, comfort, happiness, and involvement. The terms of this well-being is not unconditional; it must be sustainable. Its realisation must consider the interests of 'others', i.e. culture, other people and organisations. This sustainability may take the form of (material) durability, sustained use, or prolonged affective or aesthetic life span; or it will take the form of social or cultural responsibility. Sustainable well-being thus refers to an array of desirable states that are not at the expense of others, but address the importance of the ecological, social, cultural and economic contexts in which we operate. It takes into consideration the resources that are rapidly diminishing, the inequality of wealth and access, and the global competition in which companies must survive.[1]

By fostering this sustainable well-being, we emphasise our desire to encourage and feed it when and where needed, and otherwise cultivate or maintain it. This fostering is done by exploring and transferring knowledge and technologies with research-driven innovation as our key tool. On the one hand, we will develop knowledge in the form of theories, models, principles, and conceptual solutions; on the other hand, we will develop technologies, such as design tools and (measurement) instruments. Finally, our efforts are directed towards the field of industrial design. This is our 'core business' and our main field of competence. We believe that our contribution to sustainable well-being can be channelled through the design and development of competitive products and services in a global market.

1 This notion of 'sustainable well-being' is similar to the concept of sustainability recently propagated by two influential thinkers in the field: John Ehrenfeld and Ezio Manzini. Both argue that a sustainable future is not reached by diminishing unsustainability, but rather requires a radical change in our way of thinking and being-in-the-world. See: Ehrenfeld, J.R. (2008). *Sustainability by Design.* New Haven: Yale University Press. Manzini, E. (2009). New design knowledge. *Design Studies*, 30, 4-12.

I.3

The designer of tomorrow

The designer of tomorrow is an academic designer who is able to integrate scientific knowledge at a strategic level and can cooperate with researchers or scientists from diverse disciplines. Various drivers reveal a need for this type of designer:

- 'Products' nowadays can have many manifestations, from physical to virtual, from identities and policies to services;
- Designers and design approaches are increasingly being recognised in many parts of society as important 'ingredients' for developing innovative outcomes;

- Innovation requires breaking boundaries and making connections between diverse disciplines (paradigm shifts);
- The 'playing field' of the designer is growing; more and more disciplines are involved in the design process and the designer makes his/her way to new and emerging markets;
- According to our research objective, the designer is human-centred, taking the (desired) experiential state of people, subsuming issues of value, usability, meaning, etc. as his/her starting point;
- Research is increasingly becoming an integral part of the design process.

The academic designer is able to integrate principles from diverse fields into innovative ideas or 'manifestation-independent' solutions. Instead of predefining the type of final solution (i.e., a physical product, a website, a campaign, etc.), the academic designer will search for the optimal embodiment of the idea. To achieve this, the designer must reason at multiple levels and collaborate with specialists from various disciplines, including end users. In addition, the academic designer is required to translate these ideas into the best possible manifestation, whether the outcome is a tangible product, a multimedia application, an environment, a brand, a service, or a combination of these. For this, the designer must have an understanding of the realisation and production possibilities and limitations connected to each of these manifestations.

I.4

Research approach

Research in industrial design engineering is conducted to contribute to solving concrete problems encountered by people and society through developing knowledge and technologies for the designer and/or design process. In these terms, it does not make sense to talk about conducting basic scientific (fundamental) research in the context of industrial design. Additionally, taking into consideration the nature of design research, three methodological approaches are considered: (a) research in design context, (b) design inclusive research, and (c) practice-based design research. In a general sense, these approaches are considered instrumental for bridging knowledge between fundamental science and industrial product development (Figure 1).

The three framing research methods will be applied to generate both foundational (disciplinary) knowledge and operative (practical) design knowledge. The approaches support a scientifically rigorous but designerly way of conducting research.

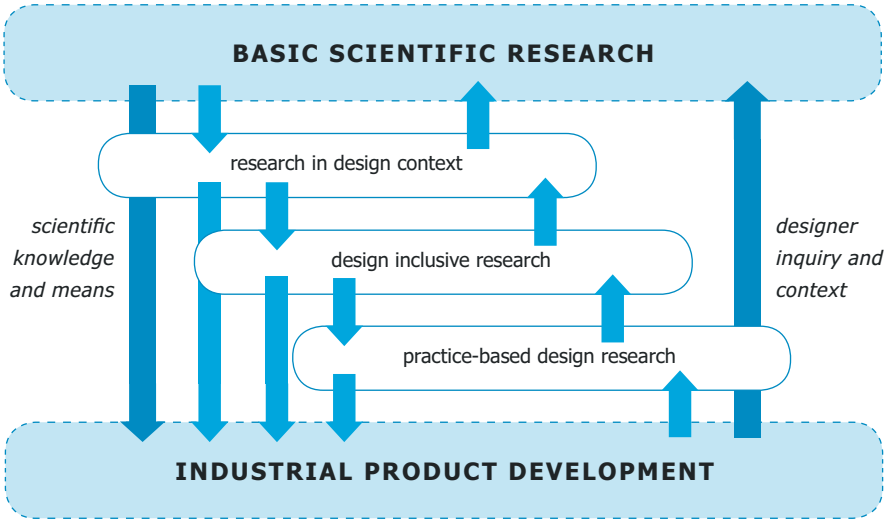


Figure 1
Research methodological approaches in IDE

Research in design context is conducted as analytical disciplinary research aiming for insights and rules. It is based on the knowledge and research methods of design-related disciplines (i.e. engineering, psychology, ecology). Contextualisation of the explored knowledge comes from concern for (1) people (individuals, teams and communities) who are involved in and are influenced by design, (2) artefacts (concepts, designs and products) that form the input and output of design processes, and (3) environment (natural, social, economic, ecological, technological and cultural surroundings).

Design inclusive research, also known as *Research through Design*, is a specific design research method, which involves various manifestations of 'design' as a research means. The goal is to create new opportunities for generating knowledge that cannot be obtained otherwise. 'Design' as a research means may be an evolving artefact, process, phenomenon or knowledge.

Practice-based design research mainly concerns operative research towards general principles and patterns. It reflects the endeavours of designers to extend the knowledge base of design as part of their professional responsibility, and it explores and generalises knowledge based on design activities and products.

I.5

Organisation and policy of research

Part II contains the content and structure of the Research Portfolio of the Faculty of Industrial Design Engineering. Before presenting this structure and the six research programmes we will briefly outline how these programmes will be managed and which policy initiatives will support their success.

To direct and secure the execution of the portfolio, the *IDE Research Council* has been established, consisting of the six programme coordinators. The Research Council (RC) is an advisory body of the faculty MT with the main goal of nourishing and cultivating the academic climate within the faculty and its research orientation, based on the current portfolio. For this, the RC has the following tasks, authorisations and responsibilities:

- set research targets, in terms of output and financing;
- mobilise faculty staff and Master students to participate in various programmes ;
- gear the activities within each programme towards one another;
- contribute to (inter)national initiatives, networks and discussions on design research (i.e., NWO/STW, Design Research Alliance);
- disseminate research results and policy both internally (to staff and students) and externally, a.o. by organising events (i.e., PhD day, seminars, conferences);
- act as a principal discussion partner for the external Research Advisory Board.

Additionally, with respect to their own programme, the six programme coordinators will:

- take responsibility for their programme content, development, and coherence;
- initiate and advise new research projects;
- define and develop relevant research outlets;
- initiate and promote funding of research projects (valorisation);
- take care of required marketing, both internally and externally.

The research policy is directed towards:

> Ensuring that the majority (>90%) of all research activities at the faculty are covered by the Research Portfolio.

> Attracting more and more PhD students and postdoctorates on second and third stream financing. For the latter financing stream (i.e. cooperation with industry), it is deemed necessary to substantially co- or pre-finance projects (up to 50% of the integral costs).

> Inviting staff members to participate in projects crossing the traditional disciplinary boundaries. To that end, interdisciplinary and multidisciplinary initiatives and publications, extending departmental borders, will be rewarded.

> Promoting publications in dedicated design journals. To establish a transdisciplinary body of knowledge in the design field, it is of the utmost importance that articles in key journals for our discipline are cited elsewhere, preferably in other disciplinary journals. For that reason, we need to invest in publication by these key journals instead of those from the traditional disciplines. Such a policy can only be successful through broader international cooperation.

Imperative to the growth of knowledge and the success of our research programmes is cooperation and collaboration. While acknowledging that much of this cooperation is based on personal contacts of individual researchers, part of this can be stimulated through institutional interventions. Some of these methods are listed below, from a micro to a macro level:

- *TU level:* strengthening of our position in the Delft Research Initiatives.
- *3TU level cooperation*: we have started the first discussions with our partner institutes in Eindhoven and Twente for the establishment of a 3TU research school in industrial design.
- *Collaboration with industry*: long-term industrial partners could be connected to our research programmes. Within the thematic areas defined, we could become the preferred partner of a select group of industries. In this, we can act pro-actively.
- *International cooperation*: the international Design Research Alliance is the ideal platform for the further enhancement of the (scientific) quality of design research in an international context.

Part II

Research programmes of the new portfolio

Six comprehensive research programmes have been defined. Three of these programmes , **(1) Strategic Design, (2) User Experiences, and (3) Technology Transformation**, provide foundational multidisciplinary knowledge for the discipline of industrial design. These three programmes are hierarchically connected in that they cover the three defining stages of a design process: the strategic/context level, the human-product interaction level, and the product level, respectively. The programmes are furthermore directly linked to the three departments within IDE, Product and Innovation Management (PIM), Industrial Design (ID) and Design Engineering (DE), respectively.

It is also important for the future of industrial design that operative knowledge is generated. The proposed research portfolio secures this generation of operative knowledge in three applied programmes in which foundational knowledge is applied in solutions for specific application areas. These areas are: **(4) Healthcare, (5) Personal Mobility, and (6) Living/ Working**. Such operative based research and knowledge development in turn generates many issues and questions that require and feed foundational research in the three foundational programmes.

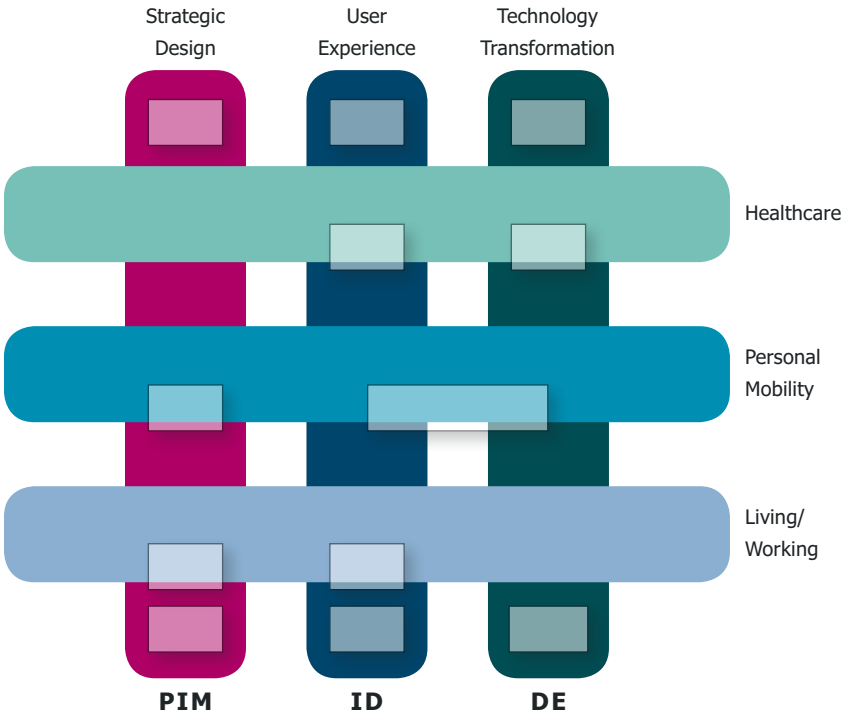


Figure 2
The six research programmes of the new portfolio and their interrelations. The boxes in the columns represent research projects in the foundational programmes; boxes in the rows refer to research projects in the applied programmes (see text below for a full explanation).

It must be emphasised all six programmes share the objective of 'sustainable well-being' as the primary driving force for research topic and question formulation. In each programme, research projects of various types and sizes will be carried out. Whereas projects in the foundational programmes can be, but do not need to be, programme-specific, projects in the applied programmes always carry a strong link to one or more foundational programmes (see Figure 2) to secure their primary knowledge-driven objective (instead of being mere design projects). Next, each of the six programmes is described in more detail.

Research Programme

Strategic Design

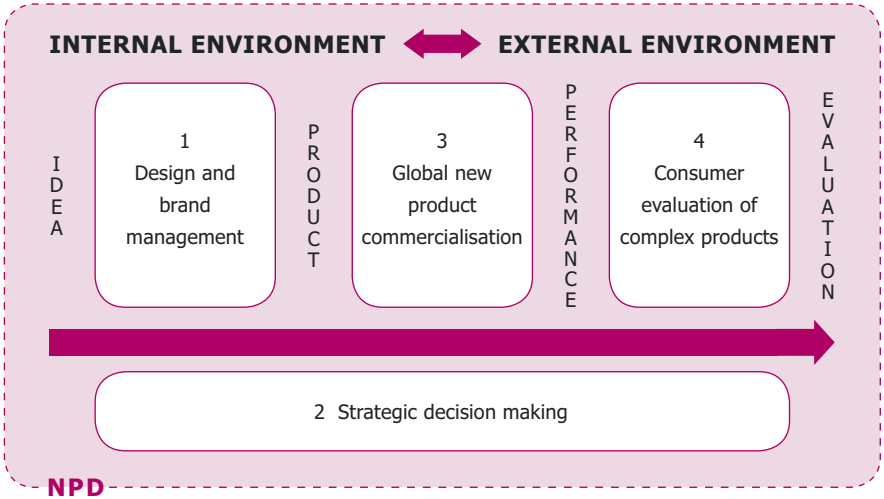
Programme coordinator

Dr. Gerda Gemser

Strategic Design

Industrial design does not take place in a vacuum. Thus, it is imperative for firms and designers to take into account both the external environment (e.g. competition, trends, regulations, ecological concerns) and the internal environment (e.g. corporate strategy, company capabilities, current product/ brand portfolio) when deciding which direction to move in. The ultimate aim of this research programme is the in depth examination of the strategic and commercial context of industrial design to optimise new product development (NPD) processes and outcomes. This 'optimisation' of NPD processes and outcomes implies the design and development of products and services that are competitive, sustainable and durable for people and society. In other words, this research programme pursues knowledge to optimise NPD processes and outcomes in such a fashion that sustainable well-being will be fostered.

The research programme is divided into four themes. Each addresses different but interrelated issues that examine the strategic and commercial context of industrial design. The first three themes are effective design and brand management, strategic decision making in the fuzzy front end, and global new product commercialisation, respectively, and focus on optimising NPD projects. The first theme does so by examining design capabilities and brand strategies, the second by studying decision making processes and knowledge exchange during product development, and the third by focusing on the impact of strategic and tactical commercialisation decisions on new product performance. The fourth and final theme, consumer evaluations of complex products and services, focuses on NPD outcomes, by examining how customers perceive and evaluate complex products or services and how this feeds back into the NPD process.



The research programme generates both disciplinary and operative knowledge that serves two purposes. First, it operates as an independent and self-contained focus field of research. Second, the research results are integrated in the educational curriculum of the Master of Strategic Product Design.

Within this research programme, different methodological approaches are adopted, with an emphasis on collecting empirical data by means of multiple case studies, large-scale surveys and controlled experiments. By using these methods and techniques, knowledge is generated that provides a better understanding of NPD processes and their outcomes. This knowledge, embedded in theories, frameworks, or tools, is disseminated to academic and business circles through numerous publications in scientific and practice-related journals and presentations on conferences, for example.

Funding for the research programme has been obtained from the Dutch Science Foundation (NWO), the Dutch Ministry of Economic Affairs, the Association of Dutch Designers (BNO), the Finnish Ministry of Science and Technology, the Portuguese Science Foundation and industrial companies to name some. Additional funding is being sought from organisations such as the European Commission (FP7 Programme), The Netherlands Foundation for Technical Sciences (STW), Senter Novem, the Dutch Association of Purchasing (NEVI) and the Dutch Ministry of Public Works, Transport and Water Management.

Publications are sought in recognised marketing, design, innovation, and general management journals. Some recent research output was published in journals including: *Design Studies*, *Journal of Product Innovation Management*, *Journal of Marketing Management*, *Journal of Engineering and Technology Management*, *Journal of Design Research*, *CoDesign*, *IEEE Transactions on Engineering Management*, *Advances in Consumer Research*, and *International Journal of Research in Marketing*.

Theme 1

Effective Design and Brand Management

This theme focuses on optimising firms' industrial design and brand strategies to create a sustainable competitive advantage. Research has shown that effective industrial design and brand strategies may contribute significantly to company performance, but that design and brand impact is not unconditional. For example, in industries were industrial design is generally accepted as important, ID may no longer constitute a basis for competitive advantage; instead ID may have become a baseline requirement for participation (e.g., Gemser & Leenders, 2001; Candi & Saemundsson, 2007). More insight is necessary in understanding the relationships between ID, brands, and performance, particularly with regard to the factors that may moderate these relationships.

To establish effective design and brand strategies, this subtheme includes research into the weight placed on creating aesthetic, symbolic, and ergonomic value in firms' innovation activities and on their design and brand management capabilities. Important elements belonging to design and brand management capabilities are, for example, a manager's ability to manage the aesthetic aspects of their product portfolio. A shortcoming of current research is the assumption that designing aesthetic product aspects is an unmanageable process best left to the intuition and creativity of designers. However, leaving the designers and the aesthetic design process without managerial involvement is problematic because decisions on aesthetics are often intertwined with decisions about brands, product line and a product's positioning in relation to its competitors (e.g., Ravasi & Lojacono, 2005). A current PhD project seeks to develop generic approaches to the management of aesthetics to point out the main strategic paths that can be followed by companies, applying both a multiple case study research design and a more large-scale survey design (e.g., Person et al., 2007). An example of a future research project, to be initiated in the first quarter of 2009, is a study on the relationship between ID capabilities and NPD success in which data on about 150 new product development projects in Business-to Business and Business-to-Consumer markets will be collected. Future research is also envisioned to question how NPD strategies that 'embrace' sustainable well-being can contribute to creating competitive advantage, for example by creating or refortifying brand capital and/or the development of products and services that better fit customer demand.

In this theme we cooperate with, for example, Erasmus University (The Netherlands), Bocconi University (Italy), Reykjavik University (Iceland), and Helsinki School of Management (Finland).

Theme 2

Strategic decision making in the Fuzzy Front End

This theme addresses strategic decision-making and organisational aspects of the fuzzy front end, such as which direction and which projects to pursue, and how to manage interfaces within the organisation and with other partners. Research has consistently emphasised the need to consider a multitude of criteria such as strategic relevance, context of product use, sustainability or availability of technologies as early as possible in the NPD process, thereby placing more constraints on how to manage and make decisions in thefuzzy front end (Langerak et al., 2008). The increasing complexity of design problems necessitates collaboration across disciplinary and organisational boundaries. These changes in work practice affect individual design processes as well as organisational processes and call for a modification or even new development of theoretical frameworks (e.g., Lauche, 2007).

The research in this theme addresses this challenge by integrating expertise from design, management, organisational processes and psychology of decision making into a systems approach. Topics addressed include strategic sustainability, distributed collaboration and codesign, transfer and sharing of expertise, the role of information and communication technologies for e-sourcing, team coordination and support of communities of practice. For example, a multiple case study of portfolio decision-making investigates how firms decide which products to develop, terminate and launch from a strategic portfolio perspective (Kester et al., 2008). The determinants of portfolio management effectiveness identified in the cases will be validated in a survey in large firms. Another project addresses the support of designers in terms of Community Based Design Support; the aim is to create an online community platform which enables design practitioners to search, share, evaluate and choose appropriate approaches for successful innovation (e.g., Daalhuizen et al., 2008).

The research is conducted on individual, team and organisational levels in qualitative field studies as well as in laboratory studies with the aim to better understand the challenges that managers, designers and NPD teams face. These serve to develop frameworks and tools to support strategic decision-making at the fuzzy front end.

Making the right decisions…

In this theme, some collaborators are the University of Notre Dame (US), the University of Cambridge (UK), Technion – Israel Institute of Technology, University of Salt Lake City, University of Darmstadt (Germany), the University of Porto, and the University of Sydney.

Theme 3

Global New Product Commercialisation

In the last two decades much new knowledge has been generated on the impact of strategic and tactical commercialisation decisions on new product performance (e.g., Hultink et al., 1997), with market entry timing decisions receiving most of the research attention. While the consequences of these important commercialisation decisions have become much clearer, not much research has been done on the antecedents of these decisions. The few studies that are available focus on the impact of the corporate mind set, a market orientation and company resources on the effectiveness of commercialisation decisions (e.g., Langerak et al., 2004; Talke & Hultink, 2009).

One of the aims of the researchers in this theme is to supplement this knowledge by researching both the antecedents and consequences of commercialisation decisions in a globalising and interconnected world. For example, one PhD project that started in October 2008 analyses the antecedents of proficient market entry timing. In this PhD study, an industry study of the global market for mobile phones is combined with a large-scale questionnaire study design to reveal the antecedents and importance of proficient market entry timing for new product performance. Furthermore, researchers participating in this theme aim to broaden the classical focus of research on new product commercialisation. Instead of studying solely commercialisation activities directed at overcoming customer adoption barriers, we will also examine activities that address diffusion barriers caused by other stakeholders such as suppliers, competitors or the company's own sales force (e.g., Hultink & Atuahene-Gima, 2000). The relevance of such a broader commercialisation perspective was recently empirically tested in a business-to-business setting (Talke & Hultink, 2009). The study found proof that, to optimise new product performance, commercialisation tactics should indeed aim at lowering barriers related to customers, suppliers, and stakeholders of the further firm environment (Talke & Hultink, 2009). Future research will investigate the nature of commercialisation activities aimed at one specific stakeholder group in further detail, and will test the findings in a business-to-consumer setting. An example of such a project is the investigation of customer discussion groups on the web and internet product reviews on the effectiveness of new product commercialisation decisions.

In this theme, cooperations exist between, for example, TU Eindhoven (The Netherlands), the Erasmus University (The Netherlands), University of Utah (USA), Northeastern University (USA), Koç University, (Turkey) and Technical University of Denmark.

Theme 4

Customer evaluations of complex products and services

Collaborations have been established with researchers from, for example, City University of London, City University of New York-Baruch, the Swedish School of Economics and Business Administration, Helsinki School of Economics (Finland), the Norwegian School of Economics and Business Administration, Rensselaer Polytechnic Institute (USA), the Boston University (USA) and University of British Colombia (Canada).

Customer research for product and service development is problematic when new products or services are very complex and/or new (Hoeffler, 2003). These type of products or services may be hard to categorize for consumers (i.e. with hybrid products), and the underlying reasons influencing choice can be hard to imagine or verbalise as is often the case for high-tech products or products in which aesthetics and branding play an important role.

The researchers investigating this theme aim to better understand customer evaluations of these new and complex products and services. This research can assist designers and developers in improving their designs, not only with regard to services and service touch points. To this end, for example, one research examined how the many touch points that make up a service can be grouped into separable (and therefore manageable) design tasks (Secomandi et al., 2008). Another important goal is to better understand customers' attachment to products -whether these be very complex or not - to help designers and developers in realising an eco-design strategy. If customers feel attached to a product, they will try to postpone its replacement, resulting in product longevity. Stimulating product attachment may thus contribute to sustainable consumption (Mugge et al., 2005).

An example of current research into customer evaluations of complex products is a study into concept tests in narrative format and their effectiveness in helping potential customers imagine technologically advanced products (Van den Hende et al., 2008).

A new PhD project, initiated in 2008, examines customers' automatic (pre-conscious) responses to aesthetic design, a product aspect for which underlying reasons are hard to verbalise. Recently completed research on product attachment, aimed at explaining the emotional bond a person experiences with a product, suggested different strategies to strengthen customers' emotional bonding with products based on empirical data analysis (see e.g., Mugge et al., forthcoming).

Both current and new research projects in this sub-theme are predominantly based on experimental or survey design research, reflecting the quantitative orientation for most of the participating researchers.

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Research Programme

User Experience

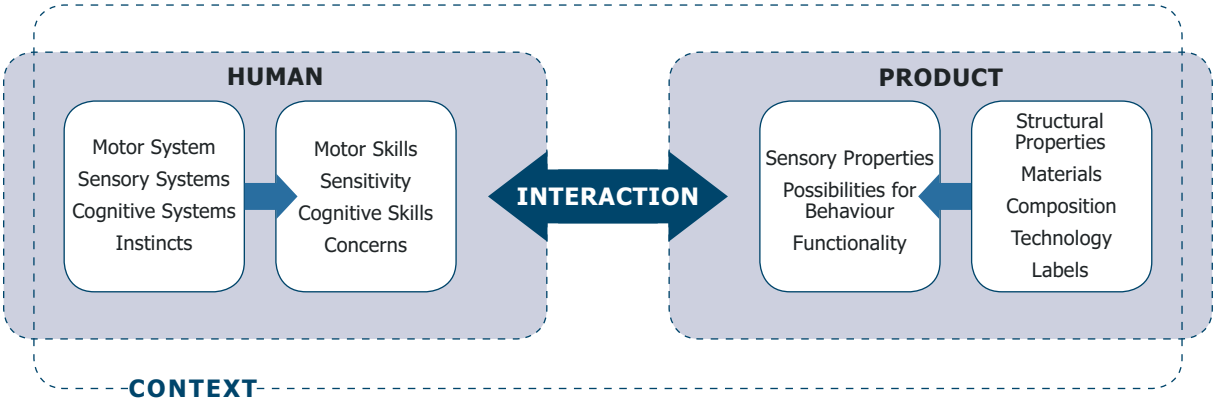
Programme coordinator

Prof.dr. Paul Hekkert

User Experience (UX)

Products are designed to contribute to our well-being: to make us happy, feel connected or safe, to enable us to belong, to preserve our health, to challenge us, to develop ourselves, or in general, to reach or maintain a high quality of living. Research has shown that the effect of our everyday emotional experiences, many of them involving products, outweighs the effects of seemingly important factors like age, education, beauty, health and material wealth in determining our well-being (Diener et al., 1999). We therefore need to understand how desired experiential states, such as involvement, security, health or happiness, result from our interactions with products, be they physical, immaterial or virtual. To pose the question in design terms: how can we design the user or product experience in such a way that people will flourish through a sense of being rather than purely having (Ehrenfeld, 2008)?

In order for products to have such powerful effects, we must interact with them, physically or mentally, in a goal-directed or casual manner (Desmet & Hekkert, 2007). Human-product interactions are shaped by the human (user, consumer), with varied senses, capacities, personality characteristics, and concerns, and also by properties of the product, embodying material properties, formal properties, and technology, as well as immaterial properties such as, functionality (see Model). Through interaction, we give value and meaning to the product, render it usable, and experience an aesthetic or emotional experience. Furthermore, these aspects of human-product interaction are continuously shaped and altered by the physical, social and cultural situation in which the interaction takes place. Finally, new technologies (i.e. new materials, connectivity, digitalisation, sensors and intelligent context modelling) demand and facilitate new modes of interaction, shifting the boundaries of what products are (physical/virtual), what they offer (functionality) and how they do it (usability/experience).



Model of human-product interaction (adapted from Hekkert & Schifferstein, 2008).

Programme aim

The overall and long-term aim of this research programme is to *understand* how people experience products (i.e. systems, services, etc.), to be able to *measure* such experiences, and to support designers in *designing for* them. Understanding and designing for the dynamics of this complex system of personal, product and context characteristics underlying our ultimate well-being requires a multidisciplinary approach in which social scientists, human factors specialists and designers work closely together.

In order to meet the overall aim, the research programme runs four major themes that are closely connected, each approaching the main theme of user experience from a different angle. The first theme, *sensory & cognitive fluency*, takes its starting point in the human sensory systems and cognitive make-up. It aims to investigate how these systems work (together) in human-product interaction and how these system's capabilities and limitations can be expanded or overcome in the design of new technological systems. In the second theme, we unravel experience into its main components, *aesthetics, meaning & emotion*, study each in isolation and examine how these components integrate dynamically. The third theme, *culture, situation, & sociability*, looks at the context of human-product interaction, how people in their everyday social and cultural settings experience products, and how we can begin to recognise changes and adapt to the user context of interaction from individual and social perspectives. Finally, the fourth theme, *usage, comfort & safety*, approaches UX from an embodied, usability point of view and closely examines various key experiences forming a gratifying human-product interaction, such as safety, comfort and love to use. While following different trajectories and (possibly) implementing different scientific paradigms, each theme is essentially directed towards understanding, measuring and designing for user experience.

The UX programme is strongly linked to the Master of Design for Interaction. Students from this Master Programme will be heavily involved in this research programme and its results will be disseminated through the educational programme.

The research in this theme is (will be) partly financed by Ministry of Economic Affairs, NWO and STW, the European Union, and NSF.
Furthermore, proposals for funding have been or will be submitted to NWO (e.g. VENI, open call), the European Research Council, FP7 (e.g. FET-OPEN), and IOP/IPCR.

Publications under this programme have been published/will typically appear in design journals, such as *International Journal of Design, The Design Journal, Design Studies, CoDesign,* and *Design Issues*, as well as in more applied journals in psychology and computer science, such as *Acta Psychologica, Applied Ergonomics, Applied Optics, Cognition and Emotion, Computational Vision and Image Understanding, Creativity and Cognition, Empirical Studies of the Arts, Ergonomics, Gesture, J. of Experimental Psychology: Applied, J. of the Optical Society of America, J. of Vision, Perception, Perception & Psychophysics, Personal and Ubiquitous Computing, The International Journal of Computer Vision,* and *Human Computer Interaction*.

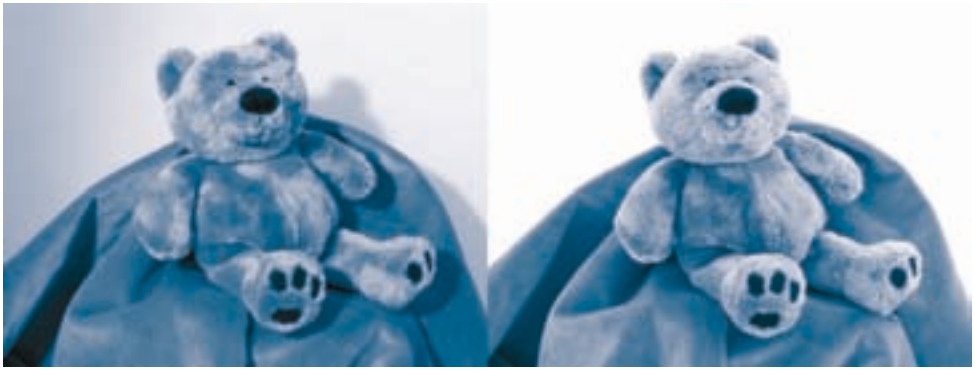
Publications are also aimed at practicing academic designers, especially in user-centred and computer-human interaction areas (*CHI, D&E, DPPI*, and related conferences).

Theme 1

Sensory & cognitive fluency

A growing variety of consumer and professional products are being equipped with mechatronics, sensors, actuators, data storage capacity, information processing technology, communication technology and information rendering technology. Advances in network and wireless communication technology will allow us to connect such products to create smart (real and virtual) environments that can sense and interpret user behaviour, i.e. intentions and/or emotions, in a natural setting and react and anticipate accordingly (de Ridder, 2008). This upcoming technology yields a unique opportunity to enhance human capabilities by creating smart products and environments based on thorough insights into human-information interaction in natural settings. In this context, it is important to realise that the experience of products and services is perceived through the senses and interpreted by our cognitive system and that it becomes essential to understand how these senses and cognitive systems operate if one wants to simplify or enhance our daily human-product interaction.

The research within the theme *Sensory & Cognitive Fluency* aims to contribute to the above-mentioned trend by investigating how the sensory and cognitive systems work (together) in human-product interaction and how their capabilities and limitations can be expanded or overcome in the design of new technological systems. The research concerns topics like *natural perception*, *multisensory integration, sensory dominance* and *multimodal interaction.* For example, a project on natural perception has investigated how context (i.e. illumination) influences the visual appearance of objects (Pont & te Pas, 2006). Another project concerns the identification of specific categories of product sounds (Ozcan & Van Egmond, 2007). Of course, products are perceived through all the senses, raising questions about the way the senses work together, i.e. haptics and vision. It is therefore interesting to note that, in our interaction with a product, some senses are more dominant than others; however, the kind of dominance experienced depends on the product itself as well as on how long the product is in our possession (Schifferstein, 2006).



An example of an illumination-material ambiguity: the bear at the left looks like it is made of a more shiny material than the bear at the right, which has a more dull appearance. A change in illumination causes this effect.

Although much is known about how our sensory and cognitive systems work, there are still many challenges in understanding how these systems work in our daily interaction with products and environments. In future research, we will increase our knowledge on perception and the natural world (visual, audition, touch), how the situatedness of a product affects perceptual dominance, how similar parameters in different perceptual modalities (i.e. roughness and sharpness in vision and audition) can be used to enhance each other in multimodal interactive environments, and how products and humans can communicate in smart environments more effectively. This knowledge will be transferred to the design community via new methods and tools. For example, the project 'new media tools to support design conceptualisation' explores the possibility of highly interactive and sensory rich qualities of new media in supporting designers in the early phases of design. One example, is Skin (Saakes, 2009) where the visual surface qualities of a 3D model can be evaluated and rapidly modified as surface texture patterns are projected upon a physical model.

For the research in this theme we collaborate with the New Delft Experience Lab at faculty of EEMCS (Delft University of Technology), faculty of Architecture (Delft University of technology), Radboud University Nijmegen, Utrecht University, Heriot-Watt University (UK), Plymouth University (UK), Max Planck Institute Tuebingen, New York University (USA), Johns Hopkins University (USA), MIT (USA), Northwestern University (USA), Philips (Lighting, Research, Design), European Space Agency, Procter & Gamble, Rijkswaterstaat, Unilever.

Theme 2

Faces of user experience: Aesthetics, meaning & emotion

Recently, user or product experience has been defined as "the awareness of the psychological effects elicited by the interaction with a product, including the degree to which all our senses are stimulated, the meanings and values we attach to the product, and the feelings and emotions that are elicited" (Hekkert & Schifferstein, 2008). Characteristic of this definition is that it divides an experience into its three main components, i.e. the *aesthetic experience* we obtain from sensory gratification (or displeasure), the *experience of meaning* that results from attributing values and meaning to the surrounding world, and the *emotional experience*, resulting from an evaluation of the personal significance of the product. Over the past years, we have extensively studied each of these components in isolation and in the recent volume by Schifferstein and Hekkert (2008) much of this research is laid down. Moreover, the knowledge acquired thus far has been very helpful in supporting designers to make the transition from a desired interaction/ experience to products exhibiting these desired characteristics and features. However, in this transition, we also encountered the limitation of this work.

Firstly, in real design, as well as in our daily experience, the three components are difficult to separate. How these components affect each other is still largely unknown. Current and future studies will therefore look

into the ways these three components work together to jointly shape our user experience and how this experience can be defined and measured as a whole. This need for integration is not restricted to the experience itself; at the human and product level, an integrative approach encompassing the various properties involved is required to understand people's experiences. In a recent project, we studied how various product characteristics, such as materials, shape and function and various individual characteristics, like expertise and cultural background, jointly affect the meaning people attribute to product materials (Karana et al., 2009). Secondly, in most studies we looked at people's experiences at a single moment in time. Most interactions with products dynamically change and develop over time. In more and more projects we take this dynamics of the experience into account by, for example, developing an instrument to measure changes in people's emotional responses while interacting with a product (Laurans et al., 2009).

For the research in this theme we cooperate with Erasmus University and Vrije Universiteit (Netherlands), University of Vienna (Austria), University of Toronto (Canada), and the Centre for Affective Sciences of the University of Geneva (Switserland), as well as with a number of industrial partners, such as KLM, Chanel, Renault, and Microsoft.

Despite this shift in attention to integration and dynamics, it still remains necessary to study these separate experiences in isolation, to understand their underlying structure and processes, and to see what role the various senses, our cognitive system, and our body play in this. For this, systematic variation of real products on relevant stimulus dimensions is and will remain a key research method. The most realistic integration and a full sense of dynamics can, however, only be obtained when we 'prototype experiences', for example in research on interactive user experiences and affective tangible interaction. A successful execution of this programme will support our students and the industry at large to design authentic experiences contributing to sustainable well-being.

Example of systematic stimulus construction from a study by Ludden et al. (2009).

Theme 3

Contexts around us(e): Culture, situation, & sociability

The design of a product, and of a user-product interaction, depends on many factors that lie external from the product and user themselves and comprise the context of product use. Designers need to understand these contexts, especially when designing products to fit lives of people different from themselves. Besides situational and locational differences, social dimensions can be extremely important. Such contexts can be discerned on small or large scales, from specific target groups (i.e. autistic children) to cultural historical factors, and (international) cultural differences. Moreover, as products become equipped with sensors, actuators, connectivity, and intelligence, the products themselves may be made to exhibit sensitivity to these contexts, social and otherwise. Again, designers are in need of understanding how to design for these interactions between product, user, and context (Stappers, 2005).

In designing for specific contexts, designers will often work with domain experts, including both disciplinary experts (i.e. cultural specialists) and users (i.e. end-user participatory design), to explore what they seek to understand about the context.

The aim of this theme is to understand which contextual factors, models, methods, and techniques from relevant disciplines (i.e. sociology, ethnography) can be integrated or adapted for design. Because we expect a large variety of factors, the aim is not at first to build a single overarching theory, but rather to develop methods, apply these in case studies, and attempt to generalise insights from these. The emphasis on methods and cases in this theme is in line with a strong connection to actual design projects in both education and industrial practice.

Carolien Postma analysing data from a contextmapping field study on people's social interactions.

In the past five years, a connection has been made in the area of contextmapping, i.e., techniques for learning about parts of users' lives by involving them as experts of their experience (Sleeswijk Visser et al., 2005; Sanders & Stappers, 2008). In collaboration with, i.e., Liz Sanders of MakeTools Inc., generative techniques for user

involvement have been developed, formalised, and applied in a series of larger and smaller industrial case studies, first in establishing the techniques and communicating the results, then in focusing on social interactions within difficult-to-reach target groups and scaling the methods to make them affordable for Small and Medium Enterprises.

An important element in the theme is to develop techniques to support the relation between user and designer, i.e. through participative design games (de Jong & De Bruijne, 2008) and experiential prototyping techniques (Boess, 2008).

Another project that has recently started is 'implicative design'. In this project, a methodology is developed that allows designers to intentionally incorporate the implicit effects products have on people's social behaviour in the design process.

Cultural differences are seen as important factors to consider in designing for far cultures, such as Bottom of the Pyramid (BOP) projects. Many BOP projects show that designers have problems in dealing with intercultural differences, and need guidance in accounting for these. Such cultural aspects of interface design encompass, i.e., how to communicate health information in a persuasive manner to illiterate, rural villagers.

For the research in this theme we collaborate with Philips Research, Sara Lee, Vodafone, Achmea Insurance, the Netherlands Police, Ohio State University (USA), and NTUST Taipei (Taiwan).

Theme 4

Usage, Comfort and safety

Usage, comfort and safety are becoming unique selling points for today's products. They can help create positive user experiences and prevent damage to the human body. Yet much is still unknown about how to optimise these aspects in products. Moreover, product users are often unaware of how their interaction with products contributes to their user experiences. The research in this theme therefore observes and models actual user activities, physical and other conditions that influence comfort, and the risks involved in product use. Methodologies and recommendations for design are developed on the basis of the research. Research strategies are qualitative, quantitative, and/or prototype-based. Usage, comfort and safety influence each other and are therefore considered in relation to each other.

Designers are often surprised when their newly designed products are used differently than expected. We develop tools and insights to address this situatedness of product *usage* and to provide inspiration in designing; some examples of these are observational methods for specialists and/or designers to study people's activities and product usage, or concepts to anticipate on functional meanings that users will attribute to product characteristics (De Jong et al., 2007; Boess & Kanis, 2007). We also investigate how the usage of products influences specific user experiences, such as, love for products, in order to provide design recommendations.

The users' experience of *comfort* depends on the first visual impression, the experienced and actual bodily fit, and the dynamics of use and posture (Vink, 2005).

From actual product usage to modelling and back: an iterative process of observing and testing the usage of products in context, capturing human dimensions and establishing guidelines for i.e. goggle design. Adapted from the research by Roger Ball.

A model of the comfort experience is proposed for systematic research and for communication into design processes. Designers can profit from knowing when people experience something as more comfortable than they expected (Kuijt-Evers et al., 2007), or from knowing how physical discomfort can lead to back and neck pain. Research into comfort acknowledges that humans move and use products within spaces such as rooms or cars.

Western societies are increasingly concerned with *safety* at the macro- and micro-level, including product safety. However, no product can be 100% safe. Our research into product safety assesses people's usage situation and behaviour. It also assesses and models the necessary trade-offs to be made between risk prevention and risk perception. For example, a helmet increases safety, but also introduces hazards when it restricts the wearer's view. Additionally, with better body protection, snowboarders take more risks. The research challenges related to safety will be mapped out and main questions will be identified.

Research in this theme investigates the aspects of usage, safety and comfort through various research foci. Research with an Inclusive Design focus seeks to reduce the risk of falls and increase comfort (Buzink et al., 2006), for example in public amenities such as toilets. Dynamic Anthropometry focuses on establishing comfort and safety guidelines for products through advanced 2D and 3D measuring and modelling of human dimensions around the globe. Design for Usability focuses on the transfer of knowledge on usage, safety and comfort into the design of electronic consumer products.

For the research in this theme we cooperate with Twente University, University of Technology Eindhoven, University of Munich (Germany), and Hong Kong Polytechnic University (China), and commercial partners such as Philips, Océ, Thales, Indes, Dutch Rail, BMW and TNO.

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Research Programme

Technology Transformation

Programme coordinator

Dr. Joris Vergeest

Technology Transformation

Engineering design is the process of synthesising a product or system, where both fundamental and engineering sciences are applied. It is the task of the design engineer to manage the decision making processes successfully, while accounting for requirements and limitations presented by customers, users, production and material resources, legislation, etc. The actual technical functioning of the design is the design engineer's responsibility as well.
In the curriculum of the faculty of IDE, the role of engineering design has been further expanded by deeply integrating the technological features of products with human aspects, marketing, management and culture.
The linkage between technology, user and business is nowadays a major scientific focus and regarded as a key factor in attaining global sustainable well-being (Kandachar, 2008; STOA, 2006). The Technology Transformation programme is directed to this field of research.

In recent years, the interaction between emerging technologies on the one hand and end-user and markets on the other hand has been researched and developed successfully at IDE due to its unique scientific scope, position and resources. For example, a multidisciplinary method has been developed to predict customer acceptance of alternative energy forms and new materials in future products. More generally, the adaptation and application of new engineering solutions in design concepts, and the possible influence of these implementations on man and society remains one of the major themes of research of the faculty. The Technology Transfer programme aims at extending the scope of product design into the domain of emerging technologies. New opportunities will be gained when engineering design is linked with technological research in ICT, materials, bio- and nanostructures, energy forms, and optics to name some. To advance the engineering design process, improved tools are needed to anticipate and to simulate the relationships between technology, product concepts, product usage, market acceptation and sustainability. Each of these relationships demands its specific forecasting technique or prototyping method. To handle the increasing complexity of products, a systems design approach should be developed to support the engineering design process. The methodology will encompass the factors of society, culture, user, product attributes, resources and technologies.

Technology transformation can occur at different levels:

1 on the most common level this means the import and implementation of engineering solutions from industrial R&D in actual (product) designs;

2 through understanding recent and emerging technologies to invent, investigate and create potential applications to design;

3 through co-researching and co-engineering with partners from technological disciplines to establish a communication channel between engineering design and technology development;

4 by considering didactically, how to incorporate technology transfer efficiently into design processes.

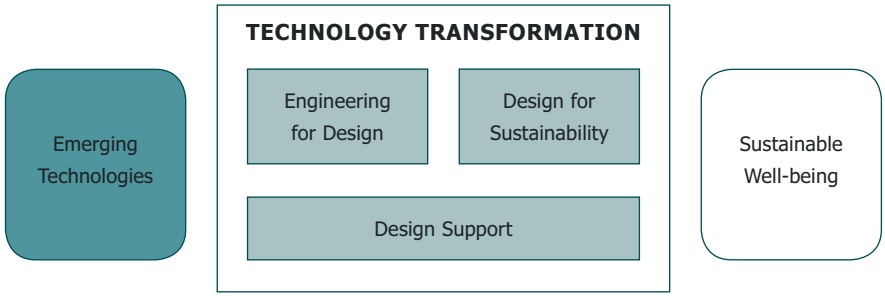
The research programme comprises three themes:
Design for Sustainability interprets the needs and trends of national and global society concerning sustainable well-being and develops new methods to translate policies and legislation into industrial life cycle requirements for new concepts of products and product-service systems.

The ***Engineering for Design*** theme investigates two interrelated topics, a) the incorporation of emerging technologies into product engineering and b) how to increase the efficiency of the process of complex system engineering itself. The research is strongly geared towards product design and aims to support innovation processes dealt with by Design for Sustainability.

Design Support focuses on the development of improved methods and efficient implementation of advanced tools. New methods and technologies, including ubiquitous computing, rapid manufacturing and augmented prototyping are developed, adapted, evaluated and implemented in engineering design processes.

The integral approach that the Technology Transformation programme takes towards the development of engineering design is, first of all, reflected by the multitude of disciplines involved in the research, including basic engineering, materials, manufacturing, environment, and computer science. Additionally, the types of research conducted differ over projects and vary from theoretical to empirical; models are tested through qualitative methods, by numerical simulation and/or by physical experiments. In general, any method or theory is (in part) evaluated through actual designs and prototypes.

Structure of the Technology Transformation programme



With respect to acquisition, the 3TU Cartesius Institute's programme will play a vital role in the coming years. In addition, UNIDO, EU and other international programmes are becoming more and more interested in becoming research partners. Scientific networks will be extended to BoP (Base of the Pyramid) interested companies, BoP venture funds, hospitals, and medical faculties, on top of the existing network. Furthermore, cooperation with a number of other Delft faculties will be continued and strengthened (EWI), guaranteeing necessary input from both adjacent design disciplines and novel technologies relevant for future products' superior functionalities. Within TU Delft there is an opportunity to cooperate with the Section of Wireless and Mobile Communications at EWI. As international cooperation partners, we are considering: Berkeley Institute of Design, University of Berkeley, The Wearable Computing Lab at ETH Zürich and the Pervasive Interaction Technology Lab at the University of Copenhagen. Strategic industrial collaboration partners can be Nokia Research Center, Intel research, Microsoft Research and TNO Connectivity/Information and Communication Technology. NWO, STW and IOP continue to be a source of research funding.

Some relevant journals for publication from the programme include *Journal of Engineering Design, Computer-Aided Design, Journal of Design Research, Design Studies, Pattern Recognition, The Visual Computer, Journal of Personal Ubiquitous Computing, Journal of Cleaner Production, Research in Engineering Design, Journal of Power Sources, Journal of Materials Science, Business Strategy and the Environment, Science Technology*.

Theme 1

Design for Sustainability

The mission of this theme is inspired by the globally accepted need for sustainable development, which implies that mass consumption goods and their functional contexts should be characterised by continuously improving environmental, economic and socio-cultural values. Therefore, the exploration, description, understanding and prediction of problems and opportunities for innovating products and product systems with superior quality with respect to sustainability values are central to the theme (Diehl & Brezet, 2004). The research activities comprise the systematic development, testing and international development of methods and tools for the design of artefacts with superior life cycle efficiency and effectiveness. Since sustainability is of increasing concern in all of the three applied programmes , the Design for Sustainability theme is strongly integrated with those programmes.

Building on the outcomes of earlier phases, research is also undertaken on the effective diffusion of knowledge in developing countries. The design of products and services fitting the BoP approach for emerging markets in India, China, Africa and South America has been adopted as a new focus in the programme. The business network involved includes Shell and Unilever as potential new partners, as well as SMEs and new student ventures.

Another part of the research focus conducted in collaboration with the Design Support theme, is on modelling and on actual application in pilot projects within the context of new product-service systems which are attractive to society (consumers, producers and other stakeholders). Soft mobility, smart energy and sustainable living, including "smart healthcare" are the fields of application here.

Electronic and automotive products and their respective industrial chains are an important object of study. This part of the research will be conducted in collaboration with the Personal Mobility programme, with extra attention paid to product-related energy problems. Furthermore, to take into account the functional aspect of products in their future user and systems context, the research deals with developing methodologies to design new, radical, sustainable product systems and industrial processes with superior environmental life cycle performance, and the study of technology collaborative agreements and their potential for sustainable product conceptualisation, product development, engineering and mass production (Brezet et al., 2002). Consequently, due to its radical nature, research and design cooperation is not only developed with large existing companies but with advanced SMEs and new ventures as well.

Concept of a fuel cell people mover
(Graduation project, Hanna Hellman)

The research is especially important for the entrepreneurial/service context and regional creativity for the eventual success of sustainable product innovations. In addition, future scenarios are developed and potential technology collaborative agreements and entrepreneurship is stimulated for sustainable product business development.

The theme presents the challenge of knowledge generation that can support the innovation and design engineering of complex products and product service-systems with superior sustainability characteristics, in close connection with the dynamics of systems of living, travelling, working and optimisation of networking and entrepreneurship as success factors for implementation. The proposed design solutions should be globally significant i.e. fit the 'bottom-of-the-pyramid' challenge as much as possible.

An example project focuses on fuel cell technology as an upcoming clean energy replacement for batteries and combustion engines in several applications. This project demonstrates how an Industrial Design Engineer can work in collaboration with a Research and Development institute (Energy research Centre the Netherlands) and an electric vehicle engineering company (*Spijkstaal*) in the development of a niche market application for the current pre-commercialisation phase of the technology. The power train, the fuel cell system and the module have been designed in this project. The project demonstrates that a fuel cell system can enable the broad implementation of clean public transport. Additionally it can be expected that Industrial Design Engineers will play a role in the integration of fuel cell systems into products.

Theme 2

Engineering for Design

Research in the Engineering for Design theme aims at identifying possibilities for non-conventional energy sources, generating knowledge on the transformation of emerging technologies into products as well as increasing the efficiency of this process. Both environmental awareness and increased mobile use of products can be seen as driving forces in this development.

In many areas, large innovative steps (i.e. the higher steps on the BSC-ladder) can only be achieved by combining new technologies and new product concepts (Jansen & Stevels, 2006). Examples can be seen in the development from CRT to LCD and from light bulb to LED. Recent developments also demonstrate the need to move away from single source energy systems and into the direction of hybrid energy systems, even for smaller consumer products (Flipsen, 2005).

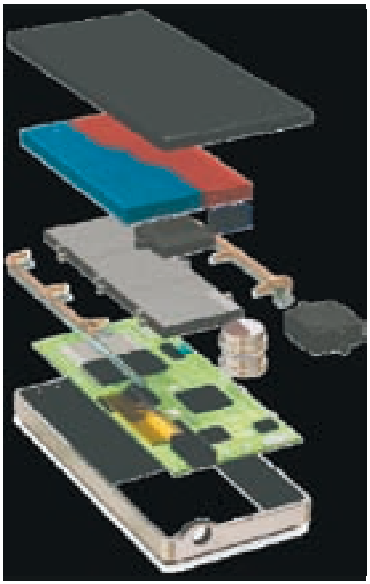
Whenever emerging energy technologies present themselves, it is always a question of how they can be integrated into energy systems at a product level, and how they can be integrated with existing energy systems into combined or hybrid systems. The scientific challenges and main research questions therefore are:

- How will the use of non-conventional energy systems influence the future of product design and the design process? Where can the main application areas be found?
- How can the implementation of new technologies into consumer products be sped up?
- How can we identify the right push-pull mechanism in the transformation of new technology into the product creation process?

These questions can be addressed through a wide range of theoretical, empirical and experimental research. Cooperation exists both internally within the TU Delft and with external parties. Graduate students are strongly encouraged to get involved both in internal as well as company based research efforts.

An example project aims at finding guidelines for the design of impact-resistant products. Although sophisticated tools to simulate mechanical behaviour of products exist, they are typically of little use in the concept phase of design, where the physical impact of the product, as well as the behaviour of the user (or abuser) of the product are of concern. The research methodology here is to approach the problem from two angles, via the product attributes and via the user; for each angle, models are built on which experiments can be conducted.

Proposed product structure of an MP# player powered by a direct methanol fuel cell

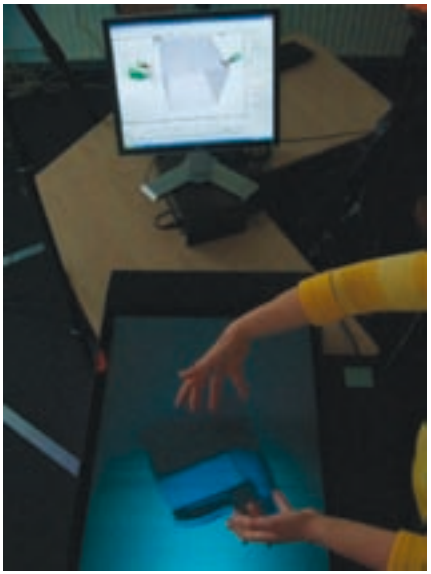


Theme 3

Design Support

Information and computer technology support has played an important role in the success of product development processes in the last decades. As these technologies evolve, new opportunities emerge for supporting concept generation, product and process modelling, virtual behavioural simulation, communication and collaboration, and data and document management in product design processes. As a trend, early analogue and digital technologies are gradually evolving into web-hosted, mobile and ubiquitous technologies.

This theme aims at the exploration, adaption and application of existing and emerging ICT to support design processes of products and product-service systems. The research is motivated by the emergence of a wide spectrum of devices and products based on ubiquitous ICT (wireless, mobile) technologies and the expectation that they posses a large potential to open up new dimensions of design support, which can then be extended from being available exclusively at the desktop to include access from other locations. These locations can be for example, where stakeholders meet or where prototypes are evaluated. Issues regarding effective prototyping (Verlinden & Horváth, 2008) and intelligent shape processing (Song et al., 2008) remain essential. The research connects to the theme of Engineering for Design, where personalised energy supply for (mobile) products is one of the research issues. There will be collaboration with the Design for Sustainability theme to conceptualise, prototype and put into industrial application novel tools (systems), which support the search for design solutions to complex social sustainability problems. Of special interest here is also design education to provide knowledge for students about the available technologies and their potential application to consumer products, and to develop a prototype of ubiquitous design learning environment which offers students flexibility, personalisation and contextualisation.



Experimental setup to combine volumetric display and physical interaction.

Ubiquitous technologies will play a significant role in achieving the objectives of sustainable well-being and the research theme will provide a subset of means and solutions needed to realise consumer products and services in ecologically

and socially responsible ways. The relevance of this research initiative from the perspective of the Faculty's Research Portfolio is obvious. This research initiative features multidisciplinary approaches, extends to education and valorisation, and can pave the way to external grants; its importance can not be underlined enough.

As an example, one project focuses on the development of a synthetic environment for multi-stakeholder product review and cooperation. It is an IOP-funded Ph.D. project in collaboration with the University of Twente. The research deals with the decision and negotiation processes in early phases of the design of a product or system. In such phases, communication is traditionally based on the meetings of expert teams and stakeholder representatives (such as end-user, manufacturer, maintenance, or designer). By offering a model, or synthetic environment, having the right manifestation (i.e. physical, virtual, or drawing), communication can be made more efficient at a relatively low cost. Together with industrial partners, a balance between cost and benefit for communication is investigated.

Other running and planned projects include research into European Automotive Digital Innovation Studio (EADIS – currently the EU Leonardo project), and conceptualisation of a car driver assistance system based on risk assessment which includes active warning and instantaneous vehicle intervention (running Ph.D. project).

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Research Programme

Healthcare

Programme coordinator

Dr.ir. Richard Goossens

Healthcare

Healthcare is one of the most dynamic and rapidly expanding areas in both western society and developing countries. As a result of increasing demand for technological innovations, the demand for highly skilled engineers in this field will rise in the near future. For Industrial Design Engineering (IDE) this means that engineers capable of translating the practical needs of the healthcare sector into products specially designed for medical applications in low-tech, as well as high-tech applications will have to be trained. In this way, they can contribute to the diagnosis, treatment, and prevention of diseases and disorders.

The aim of the Healthcare programme is to generate design requirements and methods for the design of products that focus on the medical professional, the medical environment and the patient. The focus is on human-product interaction during product use.

The research has 3 themes, namely:

1 The Specialist, where the focus is on error-free task fulfilment in complex multi-user situations.

2 The Environment, where the emphasis is on influencing the external factors of the interaction.

3 The Patient, where the emphasis is on patient musculoskeletal complaints and treatment.

Furthermore, the Healthcare research programme trains dedicated and skilled engineers whom are capable of marrying the skills of design and healthcare in order to design products which meet the needs of specialists, physicians and therapists in all disciplines as well as patients and their families. These engineers will provide products and services for the future on behalf of the medical field, on the basis of research regarding the interaction between humans, products and their environment.

The Healthcare programme translates knowledge and skills into design guidelines for medical product concepts in medical systems. The aim is to improve the effectiveness, usability, safety and economical feasibility of products and systems. The expertise in research and development is built on the integrated approach of Industrial Design Engineering. This approach focuses on the following joint aspects simultaneously: engineering, usability and interface design, aesthetics, marketing and management. 'Research through design' will be the leading research method.

With the amount of current expertise, it is possible to conduct all research projects within the Healthcare programme together with other faculties at Delft University within the Delft Health Initiative and Medical Delta and with external medical partners from (academic) hospitals and the medical industry.

Scientific relevance

For the field of human-product interaction it means a scientific breakthrough if procedural safety will be integrated in new technology (e-safety) and devices. The theoretical foundations for human-product interaction are physical and informational ergonomics, modality theory, activity theory, perception theory, and cognitive science. The research group consists of design engineers, mechanical engineers, electrical engineers and computer scientists that work closely together with surgeons. Theories from these research fields are found mainly in cooperation with the foundational programmes User Experiences and Technology Transformation. Knowledge generated in these programmes are implemented in demonstrators that show the result of interaction between users, digital devices and interactive products, and they lay a human behavioural foundation for how these devices and products should be designed to allow people to interact naturally, collaborate with each other, work in an unbroken activity flow, and to be satisfied as users.

Intelligence in medical technology - Reducing chances of medical failure

Operation and intensive care environments are already becoming more and more technology driven. As a result, interaction with medical equipment has to become more transparent. Above all, different medical equipment have to be designed with the functionality and feedback systems of other medical systems in mind, thus reducing chances on medical failure. The exchange of information between different devices and people to improve safety can only be established by introducing new design methods.

Funding for this programme will be provided through KP7 Health, STW, and NWO. Local funds such as, the Scientific funding Catharina Hospital, the European Association of Endoscopic Surgery and various companies will also be approached.

Research results are already published in peer reviewed journals with ergonomic and medical focus. Journals in which results are regularly published are: *Ergonomics*, *Applied Ergonomics, Journal of Biomechanics, International Journal of Industrial Ergonomics, Physiological Measurement, World Journal of Surgery, Surgical Endoscopy, Clinical Physiology, Journal of Laparoendoscopic & Advanced Surgical Techniques, Minimally Invasive Therapy and Allied Technologies*. We will continue to publish in these journals.

Theme 1

The Specialist

The research in this theme is focused on human-product interaction, where the patient is treated by a professional healthcare worker in the operation room or in intensive care.

The operation room is very well suited for product research since it contains both high tech and low tech products that are used in an well defined environment (the operation room), in a well defined way (the operation protocol), by a team of professionals (the surgical team) with various responsibilities.

The intensive care unit also offers a good platform for product interface evaluation and new concept testing, with its wide variety of patient health status monitoring devices.

Reducing chances on medical failure

Operation and intensive care environments are already becoming more and more technology driven. As a result, interaction with medical equipment has to become more transparent. Above all, different medical equipment have to be designed with the functionality and feedback systems of other medical systems in mind, thus reducing chances on medical failure. The exchange of information between different devices and people to improve safety can only be established by introducing new design methods.

Surgeon's Cockpit

It is estimated that in Dutch hospitals between 1.500 to 6.000 people die each year because of incidents (medical errors) that could have been prevented. The goal is to reduce this number by 75% within a period of 15 years, and will save € 1-3 billion in expenses.

Currently, the skills of surgeons are still evaluated in simulation tests (Buzink et al., 2008). In order to establish safe operation environment and patient handling, a platform is needed in which tests of new technologies can be performed with controlled environmental variables. This means that a simulated operation room is needed that can be supplied with specially designed equipment, surgical robots, product interfaces and evaluation software. This test platform is realised in the Surgeon's Cockpit, a dedicated interface for this purpose.

The Surgeon's Cockpit will offer a completely new interface for surgeon and surgical team that surpasses current, commercially available innovations developed by single companies. Current protocols are not always followed (Wauben et al., 2008), but the Surgeon's Cockpit establishes the integration of procedural-technical and process information, in which products become an 'active' partner in a dialogue with the user, bringing in far more perspective in the development of intelligent tools.

This research project, in which several PhD projects are defined, will develop insight into human-product interaction, haptic feedback (Westebring et al., 2008), intelligent interfaces, proficiencies, manipulation of soft tissue, integration of information in products and team behaviour.

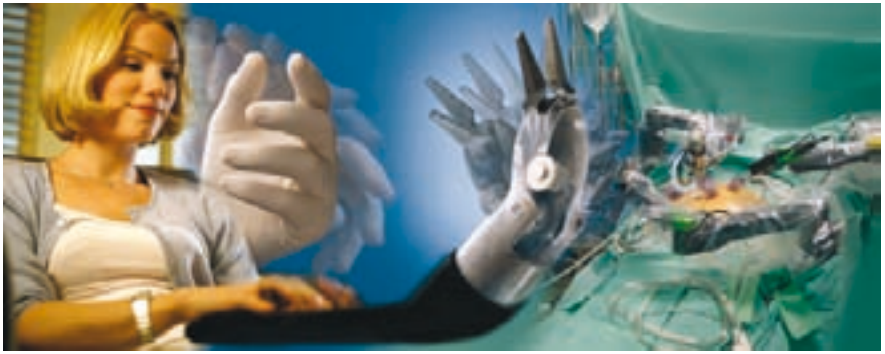
The Surgeon's Cockpit is established in close cooperation with medical professionals and it facilitates checklist based surgery so that surgical equipment has interfaces that are combined with multi-sensor systems; these systems have integrated intelligence, so that instruments are able to learn and adapt to different users of the surgical team. All system and patient data is integrated and stored in an intelligent database, which is consulted by both team members and instruments during surgery.

The Intensive Care Unit

The presence of digital technologies in medical practice provides an overwhelming amount of information. Deciding which information to present and what functions to offer is a major challenge faced by product developers today.

Medical practitioners can play an important role in this phase of the design process by providing insights into their actual working methods and the information they use. This research, based within the context of intensive care nursing, aims to define design directions and product functions for nursing informatics applications in close collaboration with the nursing staff. A general design approach is developed which structures as well as generates knowledge for next generation intensive care systems.

The essence of the design approach is a model of the nursing process that starts from the idea that a nurse fulfils three different roles. A distinction is made between the nurse's role of practitioner (using information immediately to base actions upon) and the nurse's role of scholar (using information later on to learn from). The third role is defined as the human role; coping with stress and dealing with emotions, using information later on for reflection. The model is used to structure interviews between product developers and intensive care nurses in which nurses are asked to recount an imposing event they experienced. Some of the resulting design ideas are implemented in experiential prototypes. Examples include



embedded help in an infusion pump, a software module to log the nurse's intuitive assessment of a patient, and a graphic representation of the nurse's working environment. The design approach is now part of the teaching programme of the IDE Medisign master.

Design goal

A main design goal for both projects is to develop intuitive, robust and inexpensive devices for end-users. The development of infrastructure and user interfaces will be coordinated with the development of sensors that deliver status information about medical devices. Testing and evaluation will be performed in real clinical settings, thereby offering system evaluation and analysis of impact based on use.

For this theme it is necessary to cooperate in teams with specialists from (academic) hospitals and companies. These hospitals are located in close vicinity to Delft as well as throughout Europe. The hospitals that share a long lasting cooperation with the programme at the TU Delft are the Erasmus Medical Center and the Catharina Hospital. Additional, cooperations exist with the University of Groningen, the University of Dundee, Philips Medical Systems and Karl Storz GmbH.

In the European project, ARISER, cooperation is established with the Graz University of Technology, University of Leuven, Ljubljana Medical Center, Siemens Molecular Imaging, Systems in Motion, and IFC-CNR. A follow up project with the involvement of a some of these partners is in preparation.

Theme 2

The Environment

The partner for the telemedicine research is the Cartesius Institute (a 3TU initiative). For the BoP related research it is the University of China.

This theme focuses on how to influence the patient's well-being through external factors in the environment, and not through explicit medical treatment. Current projects are concerned with improving the current hospital environment, namely the waiting room. Another project studies the new environment created by telemedicine, when healthcare is provided at a distance. Yet another topic concerns the case where healthcare is provided in a different cultural setting, namely rural areas in China; this theme is studied in cooperation with BOP Health.

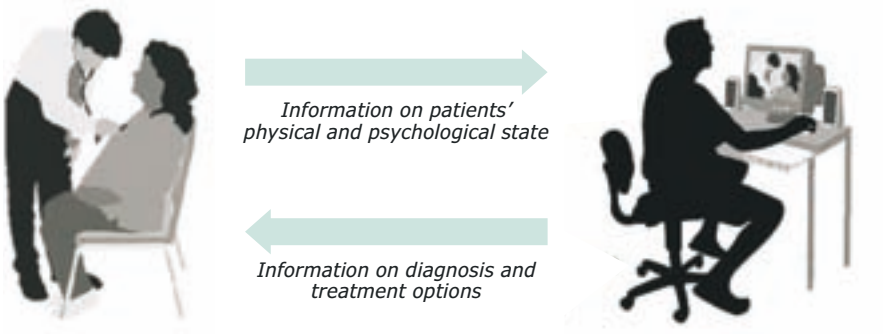
The goal of these research programmes is to provide designers with tools to study and influence the user's state of mind (or mood, stress and comfort) in different situations.

Telemedicine

Telemedicine changes the way healthcare delivery takes place in a fundamental way

Telemedicine is an example ICT application in healthcare, and refers to the use of medical information exchanged from one site to another, via electronic communication to improve patients' health status. The diffusion of telemedicine into current healthcare delivery remains low despite expectations of a positive impact on the accessibility, quality, and costs of care.

Telemedicine has the potential to offer a solution to challenges facing healthcare services worldwide, such as rising costs due to a rapidly growing demand for care and increasing demands from patients concerning the quality of care. Acceptance by medical professionals is vital to the implementation of new technologies in the medical practice and of telemedicine in particular. Even with more favourable boundary conditions that influence user acceptance, such as higher technological standards and reimbursement agreements, these are factors that cannot be directly influenced by an industrial design engineer (Esser & Goossens, 2009). Therefore, the problem definition is operationalised as the manner in which a design can maximise the acceptance of telemedicine services.



The overall goal of the research project is thus, the development of a manual for designers of telemedicine services. This goal will be met, and the research questions will be answered by following a participative, research-through-design approach.

Theme 3

The Patient

This theme aims to optimise professional products and product usage by reducing strain on the human body. The emphasis is on patient musculoskeletal complaints and treatment (i.e. RSI). Dedicated mathematical modelling of the human biomechanical system, combined with experimental verification based on data from various user groups and varying working conditions comprise the methodology developed and applied in this research. Once scientifically validated, the acquired knowledge can be transformed into engineering recommendations, which themselves can be evaluated as well.

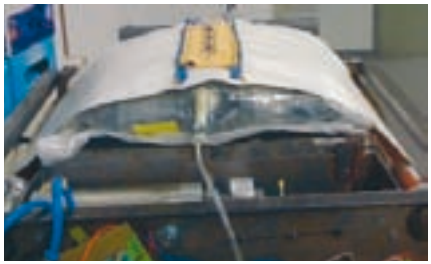
The research questions of this theme include:

- How to develop an applicable dynamic biomechanical model (i.e. of the abdomen for the study of incisional hernia)?
- How to apply the results of biomechanical modelling in design processes?

The main outcome is concerned with the implementation of human biomechanical models to gain insight in the musculoskeletal system (i.e. Pel et al., 2008). This insight will provide tools that can be used in the design process (i.e. for special body supports, Goossens, 2007) in order to be part of an Ergonomics Information System.

Example project: Abdomen

Together with the *REPAIR*-group (Rotterdam Erasmus Project on Abdominal Innovative surgical Research), a model was made of the abdomen and the *linea alba* tissue (van Ramshorst et al., 2008). The research of the REPAIR group ranges from basic material science to clinical trials on nerves to identify aspects of inguinal hernia repair.



Model of a human abdomen on which sutures can be tested.

The main partner for this theme is Erasmus University of Rotterdam, by means of a previous professorship of prof. Chris Snijders in Medical Technology, and a new professorship, Physical Ergonomics, that studies the field of physical ergonomics in the context of medical design at both universities (Delft and Rotterdam) slated to start in 2009.

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Research Programme

Personal Mobility

Programme coordinator

Dr.ir. Sacha Silvester

Personal Mobility

People desire mobility, for its own sake – just the pleasure of moving - and because it enables them to overcome the distance that separates their homes from the places where they work, shop, seek medical attention, spend their holidays, go to school, do business, or visit friends and relatives. Businesses also require mobility because it helps them overcome distances — the distances that separate them from their sources of raw materials, from their markets, and from their employees. However, mobility is the cause of a variety of negative impacts — congestion, pollution, greenhouse gas emissions, disruption of neighbourhoods, noise and accidents, to name a few. Another concern is that the world's current mobility systems rely almost exclusively on a single limited source of non-renewable energy — petroleum.

The recent crisis in the worldwide automotive industry illustrates the necessity to adjust our stance towards mobility. Mobility needs to become more efficient, more equitable and less disruptive – both socially and environmentally. How can we design our mobility systems in such a way that it contributes to our sustainable well-being?

Mobility in these terms can be defined (WBCSD, 2001) as "the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future."

The challenges we are confronted with, in the area of personal mobility, require a multidisciplinary approach to realise radical innovations. Knowledge from the foundational programmes of the IDE research portfolio – user experience, strategic design and technology transformation - can have an important contribution, when fine tuned, integrated and validated, to these needed radical innovations. The aim of this research programme is to contribute to the knowledge development of radical innovations or transitions[1] in the field of mobility. This multidisciplinary approach, combining user, business, organisational and technological knowledge, is a crucial difference that distinguishes our mobility programme from other research programmes.

In parallel with the other application areas, another aim of this programme to demonstrate and increase the added value of design within a scientific context. This can be accomplished through demonstrating breakthrough artefacts and artefact/service systems, and by establishing designs that will function as platforms for integrating and validating existing knowledge and generating new knowledge. The epistemological aim of this programme is to contribute to the development of the scientific knowledge through 'design inclusive research'. Besides the contribution of knowledge towards alleviating the huge challenges society face, the research in the mobility domain is

1 Transitions are major; long-term (50 years or more) processes of change in for example energy supply, communication, and mobility. Transitions imply more than just technological change, but also change in (consumer) habits, knowledge, institutional organisation, policies, cultural aspects, law and other aspects of society. Thus, transitions are labeled as the co-evolution of technology and society. (ECN, http://www.ecn.nl/en/ps/research-programme/transition-management/)

also intended to serve as a means to generate new foundational, scientific knowledge.

The research results will be integrated in the educational curriculum of the Master Specialisation, Automotive Design.

The transition from petroleum, diesel and LPG – as the most important energy carriers of our present road transport – towards a completely electric powered fleet is one of the most promising options for a sustainable mobility system. A large-scale introduction of electric powered vehicles can result in a 'Well-to-Wheel'-efficiency improvement of 50%, when compared to present-day practices (Van Mierlo et al., 2004). A second advantage of this transition is the avoidance of local emissions namely, CO2, NOx, fine dust and noise. Thirdly, the batteries of the electric vehicles can serve as extra storage capacity in the electric grid (Tomic & Kempton, 2007). This expansion in storage capacity will increase the contribution of renewable energy sources, such as wind and sun, towards our electricity supply.

Several failed attempts have been made in the past to introduce electric mobility to the general populace. These cases have taught us that radical innovation processes are at stake, which are very difficult to manage. To be successful, synergetic research and innovation processes have to take place; these will form the backbone of this programme. The following themes are defined:

Theme 1

Vehicle product & service design

In our daily life we are acquainted with well-functioning electric vehicles like trains and subway cars. In the near future, the concept of the present scooter, motorcycle, car and van will drastically change. The substitution of the internal combustion engine by electric motors and batteries or fuel cells is a first step. Additionally, different requirements must be adopted for future mobility concepts due to the changing interaction between user and vehicle as well as between vehicle and infrastructure. Some questions our research addresses are:

- How will the design of future vehicles and associated services change due to the transition towards electricity?
- What will be the influence of specific socio-cultural contexts on design solutions?
- Will these transition processes stimulate multimodal travelling?
- Will these new mobility constructs be accepted by users?

Recent developments in the automotive industry not only show that existing concepts of vehicles are no longer suitable anymore, but also that research and innovation networks are changing. Old players are having a hard time surviving as new players entering the mobility arena. New forms of cooperation are evolving. Interesting new methods of knowledge and innovation development, like 'open innovation' and 'open source,' are being introduced in this domain.

An example of research within this theme is the research on acceptance of new mobility concepts which includes studies on the way sustainability is perceived, and its social impact, formulated in the c'mm'n research programme (Egmond et al., 2009).

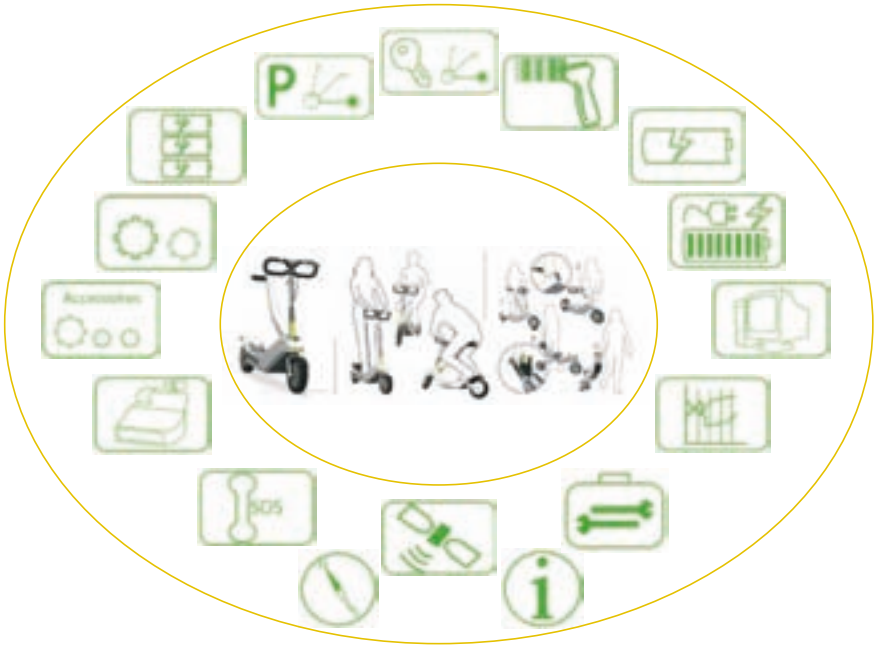
One of the important foundations for the c'mm'n platform is open source concept development. Though this concept should increase the involvement of actual users, trust becomes a major issue. The issue of how people can trust one another and types of trusted information becomes an issue in an open source network. There has been some investigation into how users will deal with sharing, in relation to software development or digital content. Hardware was not investigated in this study. Because future innovations are often hard to investigate, some research into understanding acceptance of future mobility concepts will be investigated in a simulated environment. One of the most important success and acceptance factors for new cars is the appearance factor. New technologies need to be developed (new types of drive trains, etc.) in order to transition towards new forms of energy; this will have a direct impact on the car's technological layout (package), and its derived form (exterior and interior). Furthermore, the car should also 'look' sustainable. In

c'mm'n an open source future electric mobility vision

addition to the appearance of the car, the interaction with the car as a sustainable environment is of importance. This can be accomplished through sensory information other than sight (e.g. hearing) This brings up questions on how a car can sense the needs of the driver and its environment, which information should be communicated (through which sense) and how travel behaviour (driving) can be manipulated in order to become more sustainable. All these aforementioned aspects raise ethical issues concerning the societal impact contributed by these new ways of enhancing sustainable behaviour. In conclusion, this sub-programme aims to deal with aspects of human behaviour that require change or adaptation, because new forms of mobility and upcoming new technology will require this.

This sub-programme involves cooperation with IDE Strategic Design, IDE User Experience, IDE Technology Transformation, Faculty of Policy, Management & Technology, and Cartesius Institute.

Link, personal mobility solution and its services



Theme 2

Electric and ICT-infrastructure

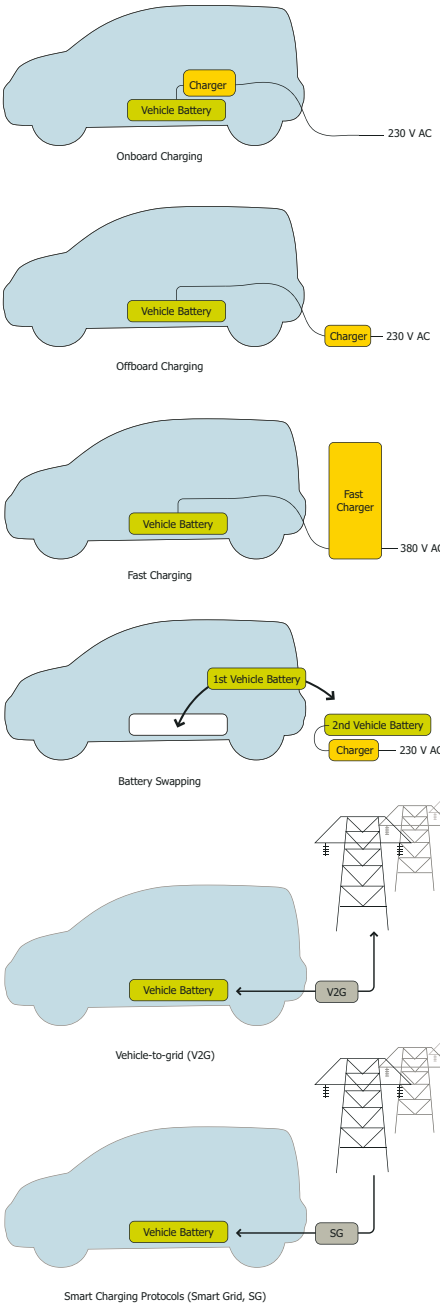
Cooperation with IDE Strategic Design, IDE User Experience, IDE Technology Transformation, Faculty of Architecture, Faculty of Electrical Engineering, Cartesius Institute.

Maximum efficiency gain of the energy system will depend on the semi-permanent linkage of the vehicles to the energy grid. This is almost a '*contradictio in terminis*'. We want to be autonomous as much as possible when moving around, but the linkage of vehicles to the grid when not in-use would be preferable. Considering this, design of these linkages will have to be developed for the different situations which occur in everyday life (e.g. for at home, at work, during shopping, during holidays). Additionally, the question of whether fast or slow charging facilities are preferable will have to be decided.

The present energy infrastructure is not yet suited to host huge amounts of electrical vehicles. There is a shortage of existing connection points, as well as additional capacity shortage in local grids, due to uncoordinated charging strategies in the case of large scale introduction of electrical vehicles.

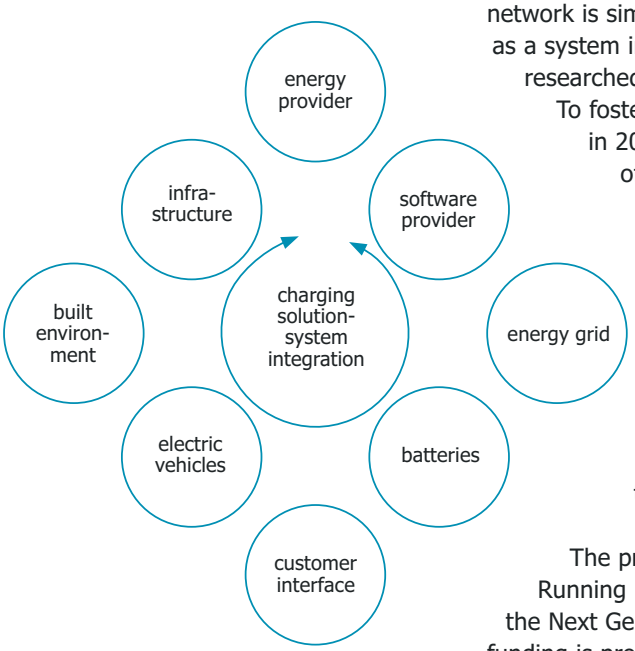
At the same time, an ICT-infrastructure that is closely linked to the electricity grid is needed, for example, to guide drivers to the closest fast-charging facilities and to take care of payments. In addition, an ICT-infrastructure is crucial in facilitating the delivery of electricity back into the grid. Finally, user acceptance of this future infrastructure is essential.

An example of research within this theme is the DIEMIGO-project, funded by the BSIK-programme, TRANSUMO, in which the impact of transition towards electric mobility on the built environment is investigated. For concrete contexts in the Netherlands, research will be conducted into the different options for integrating an electric infrastructure. This will result in the design of an urban plan in which the IDE-research will focus on the interfaces between vehicles, power grid, and the built environment.



Theme 3

System integration



This sub-theme involves cooperation with IDE Strategic Design, Faculty of Policy, Management & Technology and the Faculty of Electrical Engineering.

The results of the aforementioned parts of this project must form a coherent system. Together with the various stakeholders, visions will be developed about electric mobility in relation to sustainable urban infrastructure. Different research methods will be used, like 'backcasting', 'visioning' and '(design-oriented) scenarios'. The system vision will be developed, alongside the exploration of processes towards realising possible futures.

One ongoing project within this theme is financed by the BSIK-programme, Next Generation Infrastructures. The formation of a research and innovation network is simultaneously being developed and studied. The role IDE can play as a system integrator within this research and innovation network will be researched.

To foster this programme, an innovation network is being established in 2008 called D-INCERT (Dutch Innovation Centre for Electrification of Road Transportation). Dutch INCERT provides an open network for established and new (Dutch) initiatives supporting the introduction of electric road transport, and will serve as an information exchange point for policy makers, entrepreneurs, scientists and a broader public. In consultation with experts from various organisations, initiatives will be taken to stimulate research and development addressing critical issues and to prevent effort scattering. The centre will provide independent expert support to local and national electric transport initiatives (www.d-incert.nl)

The programme will be funded primarily from external sources. Running projects are financed for example by the BSIK-programmes , the Next Generation Infrastructures and Transumo. Additional (matching) funding is provided by other public and private organisations.

Other potential financial partners for this programme are the Dutch Ministry of Transportation, the Dutch Ministry of Economic Affairs, local governments (Rotterdam Climate Initiative, Friesland/Leeuwarden), NWO, STW, and European Community FP7.

The programme is embedded within Delft Energy Initiative and Delft Infrastructure Initiative of the new research portfolio of the TU Delft.

Research output is planned to be published in *International Journal of Design, Design Studies, Journal of Design Research, Design Issues* and the domain specific journals like *Transportation Research.*

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Research Programme

Living/ Work

Programme coordinator

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Living/ Work

The growing awareness of the need to create sustainable environments and products which can foster improved quality of life reflects a global shift from consuming to caring societies. Sustainable living and work focuses on maintaining and enhancing the quality of living over time, as related to environmental (planet) variables, socio-economic (profit) factors, and individual (people) life styles. By including the latter two factors under social sustainability, two clusters emerge, namely, social and environmental sustainability.

Despite all the talk about sustainability, very few examples that actually help reduce energy consumption can be found in today's households. Rather, more and more, stand-alone products are being consumed and plugged in. Many such products are not even smart enough to switch themselves off when not in use or able to communicate to users their actual energy consumption. While there is a wealth of sensor and actuator technology, very few examples can be found of applications to improve the social quality of living and work. Instead, there are many examples of care organisations that are struggling with reduced budgets for monitoring elderly living at home, and of companies that are being confronted by the costs of high levels of burnout, relating to environmental stress.

Similar to recent developments in automotive design, sustainable product and service design can offer new commercial opportunities for companies struggling to find the cutting edge in the market. In the late 1980s, quality was a key concept for companies competing with low cost imitations, today sustainability offers a similar cost-benefit potential when projected across the phases of product production, use and recycling. Product definitions need to re-thought as we seek more durable and responsible designs that shift our values from "having to being" (Ehrenfeld, 2008).

Research has begun at IDE on examining the differences between incremental versus radical sustainable product development. Many incremental improvements in products have led to a rebound effect. For example, people may choose to leave their lights on all night outside since they have energy efficient light bulbs, or take longer showers with water saving shower heads. An integral approach to sustainable living and work research is needed whereby the environment, product role and human behaviour are taken into account.

Towards focusing the faculty design research in the area of social and environmental sustainability three themes have been identified, namely:

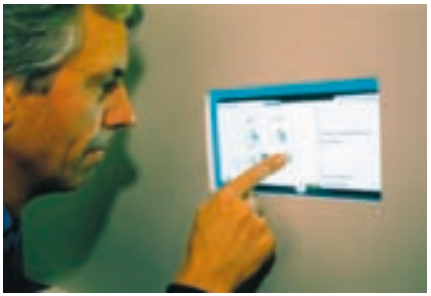
Theme 1

Shaping sustainable behaviour

This research theme, focuses on how the user can be influenced to use products or services which provide a fulfilling user experience while reducing usage of natural resources and environmental impact. Issues such as product usability, physical design of products and interfaces, and social-psychological techniques to change attitudes and behaviours are included here. For example, recent work in India focused on developing a public health information booth to bridge the information divide between health workers and rural villagers. Users interacted with the booth using a tangible interface where media was presented across a range of familiar formats such as puppet shows, street theatre, guru talks, and village chief presentations (Parmar et al., 2009).

The Aware Thermostat developed at IDE provides suggestions on energy savings based on room occupancy rates and observed time to heat a space (below).

Rural users in India using a tangible interface to access health information (right).



Theme 2

Sustained Quality of Living

Sustained Quality of Living focuses on the role of products and environments in structurally maintaining or improving well being, over an extended period of time, in work and living environments. The life cycle of products and services can be extended by recognising and adapting to changing user needs. Similarly, the user environment can be adapted to accommodate and support users at home and at work. For example, the question of how social connectivity can be fostered among the elderly living alone is being examined in the IOP-MMI research project, Independent@Home, as one of several future smart home application scenarios (Vastenburg et al., 2009). The EU/Cartesius project, Energy Valley, examines how semi-remote areas can be socio-economically revitalised and connected via water tourism. Research on restorative environments is currently an area of collaboration between the faculty of Architecture and Industrial Design Engineering, which focuses on hospital patient waiting rooms in terms of lighting and physical artefacts such as seating.

Flowie stimulates elderly people to exercise more by providing immediate feedback on actual activity levels in respect to preset activity goals. This is one of the application scenarios for the MMI-IOP project, Independent@Home.

Theme 3

Lifestyle Research

Lifestyle Research is aimed at building our understanding of current living and work practices in relation to sustainability, via field or simulated context studies. Insight into social and cultural factors and values in relation to sustainable behaviour can guide and inspire design innovation (Weever et al., 2008). Methods and techniques are needed for conducting representative contextual enquiries in the users living and working setting, without being obtrusive or leading to biased results. For example, practice based research may provide a way to elicit user current and future behaviour and explore new product ideas that support future behaviour (Kuijer and De Jong, 2009). To further foster user-designer communication, design concepts that can facilitate a shared design space will be developed in collaboration with design tools and techniques stemming from the User Experience programme. For example, a shared space may include a surface on which digital or physical media information can be displayed. Such a space can also be used to present initial concepts, models, prototypes or drawings to users for exchange of information.

Design methodologies will be developed in close collaboration with the User Experience programme, such as tools to measure the social well-being and connectedness among elderly living independently at home, and participatory design techniques, based on user practice and reporting, to understand current product use. Research explorations relating to the application of new sustainable technologies will be conducted in close collaboration with the research staff involved in the Technology Transformation Programme. Additionally, strategic product driven sustainability questions will be examined in the living and work context in collaboration with the Strategic Design Programme. The EU project, EcoMind, is expected to play a role here, as it focuses on creating new and sustainable product ideas for companies.

Sample Projects

The EU projects, LivingLab and LivingGreen, are geared towards the development and application of novel user centred design and emerging design concepts that can foster sustainable living. Close collaboration with academic partners, industry and end-user organisations are key to both projects.

LivingLab is an EU sponsored design study for a research infrastructure which can facilitate research on human interaction with, and stimulate the adoption of, sustainable, smart and healthy innovations around the home while considering cultural-specific practices. The project began in January 2008 and will run for two years. It involves a mix of industry and academic partners in Spain, Germany, Switzerland, Belgium and the Netherlands, and will lead to pilot studies demonstrating the LivingLab benefits and a detailed plan for building the infrastructure. Feasibility design studies include homes across Europe where actual users will live and involve, for example, portable suitcase like test kits for in-field user participatory studies (Bakker et al., 2008).

LivingGreen is an EU-InterReg sponsored project which recently began in November 2008. The project focuses on sustainable technology innovation in terms of identifying the gaps between knowledge and practice in the living/ regional building renovation and home living context. This will lead to the evaluation of developed products and services to formulate guidelines on effective methods to promote and implement sustainable renovation practice. Five Sustainability centres are slated to be opened in Ludwigsburg, London, Antwerp, Lille and Delft (De Witte Roos). Each of these centres will participate in the organisation of research-centred LivingGreen Labs. Research themes are energy, water, materials, climate robustness and architectural value. The faculty of Architecture at TUD is focusing on the latter theme.

Key sample journals include *Design Studies, Personal Ubiquitous Computing, Applied Ergonomics. The International Journal of Environmental, Cultural, Economic and Social Sustainability.*

Examples of current partners in research projects include: BASF, P&G, ETH, Wuppertal Institute, Acciona, CeDInt Politecnica, - Le CIR – evaluation, monitoring, Espace Environnement & Ecoconstruction, TU Twente, Roessingh Research and Development, Isolectra, & CHETNA.

Programme Funding

The matrix below depicts externally funded sources for projects in the Living and Work Programme. The relation of each project to the three programme themes (Shaping, Sustaining, and Life Style) and adjacent programmes are marked by 'x'. Future projects will build on the existing research portfolio and partner network, supported mainly by EU and national funding.

Project/Remarks	Sponsor	Shaping	Sustained	Lifestyle	Strategic	Experience	Technology	Mobility	Health
Crade2Crade, sustainable Island living	EU/Cartesius		x	x	x	x	x	x	
Energy Valley, water tourism	EU/Cartesius			x		x	x	x	
EcoMind, new company product ideas	EU			x	x	x	x		
Independent@Home, elderly well-being	IOP-MMI	x		x		x			x
Hospital Environments, stress reducing spaces	IDE+A, BK			x		x			x
Smart Environments, office stress monitoring & reduction	EZ-BSIK	x		x		x			
LivingLab, Infrastructure Design Study	EU					x	x		
LivingGreen, Technology and concept innovation	EU				x	x	x		

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