DESIGNING FOR THE DEEPEST NEEDS OF BOTH PUBLIC SERVICE CONSUMERS AND PROVIDERS; INNOVATION IN MENTAL HEALTH CRISIS RESPONSE

van der Bijl-Brouwer, Mieke; Watson, Rodger
University of Technology, Sydney, Australia

Abstract
Design is increasingly used as an approach to support innovation outside the traditional design domain, including the public sector. One of the design principles that is used in these so-called design innovation processes is gathering ‘deep’ insights into users or customers needs to support reframing of problems. In an earlier publication we proposed a model of levels of depth of insights into human needs. This model indicates that the deepest level to analyse human needs for design innovation is the thematic level which describes human values and meanings outside the context of the problem. Analysing those themes supports reframing of problems. In this paper we argue that innovation in the public sector can benefit from analysing these deepest needs beyond the needs of just the public service consumer, to include the needs of public service providers. Meeting the needs of service providers might positively influence the quality of the service itself. We illustrate this through a case study which was aimed at developing solutions for the systemic problem of supporting people with severe and persistent mental health problems.

Keywords: Design methods, human-centred design, design innovation, service design, social design

Contact:
Dr. Mieke van der Bijl-Brouwer
University of Technology, Sydney
Faculty of Design, Architecture & Building
Australia
mieke.vanderbijl-brouwer@uts.edu.au

Please cite this paper as:
1 INTRODUCTION

In the past decade design has been increasingly adopted by organisations in both the private and the public sector as a new approach towards innovation (Dorst 2015, Brown 2009, Martin 2009, Verganti 2008). The concept that links design and innovation is called design thinking or design-led, design-driven or design-inspired innovation. In this paper we will use the umbrella term design innovation to refer to approaches that do not just lead to the design of solutions, but also consider the implementation of solutions, which then leads to a new practice. Innovation in the public sector is usually not a physical artefact, but more often a change in the relationships between service providers and their users (Hartley 2005). It considers the design of products, services, processes, positions, strategies, governance and rhetoric (ibid). The application of design to public sector innovation is relatively new compared to its adoption in the private sector. Exemplary are the establishment of government innovation centres such as MindLab in Denmark and ThinkPlace in Australia, and initiatives such as the UK Design Council’s Public Services by Design program. In parallel to these government institutions, academic research centres have been established recently for scholarly research into public sector design and innovation. At the Design Innovation research centre of the University of Technology, Sydney, we study the practice of design innovation in the public sector and explore how design can contribute to improving these practices.

One of the main principles that public innovation practices can borrow from design is the activity of (re-)framing problems (Dorst 2015). Studies into how expert designers think have shown that framing design problems is at the core of their practice (Cross 2007, Schön 1983, Dorst 2011). Another design principle that has been particularly popular in design innovation in the private sector is gathering ‘deep customer insights’ (Bucolo et al. 2012) and ‘putting people first’ (Brown 2009). In our work we have found that this human-centred approach to design innovation can support reframing of problems if people’s needs are analysed at its deepest level. To describe this level we developed a model of levels of depth of insights into human needs for design innovation (van der Bijl-Brouwer and Dorst 2014). The deepest level of this model concerns ‘themes’, the human values and meanings that underlie needs for specific solutions or scenarios.

Innovation in the public sector is often about solving networked problems. This means that multiple stakeholders are involved who each are affected by the problem and/or can contribute to solving the problem. Developing solutions that meet the needs of each of these stakeholders makes sure that solutions allow people to contribute to, as well as benefit from that solution. In this paper we show through a case study how an exploration of the needs of a broad selection of stakeholders on particularly the deepest level of insights into human needs, the thematic level, supported innovation in the public sector.

In the next section we will first present the model of insights into human needs for design innovation, as well as show how an analysis of the themes at the deepest level of this model supports reframing problems and, through that, radical innovation.

2 HUMAN-CENTRED DESIGN INNOVATION

2.1 Levels of depth in insights into human needs

In the design field as well as in the broader design and innovation field there is general consensus that insights into human needs support design and innovation. To develop radically new designs these insights should be deep (Bucolo et al. 2012) and explore the ‘why’ or ‘reason for existence’ of products and services (Hekkert and van Dijk 2011). When studying what scholars and practitioners mean when talking about deep insights into human needs, we found that the definition of ‘deep’ is rather blurry. Based on the question ‘how deep is deep?’ we therefore developed a model of levels of depth of insights into human needs for design innovation (van der Bijl-Brouwer and Dorst, 2014). The model contains a solution, a scenario, a goal, and a thematic level (figure 1). The solution level describes what people need: products and services. In the public sector this level also includes other types of interventions such as policies and protocols. The scenario level describes how people want to interact with these interventions. The deepest levels, the ‘whys’, are the goal and thematic levels. The goal level describes what people want to achieve with a product or service within the context of the problem, while the thematic level describes what people want to achieve outside the context of the problem, their underlying meanings and values. For example, the design of a sports car might be based
on the themes ‘identity’ and ‘independence’. The goals, in the context of a car, could be that someone likes to have a car all to him- or herself and that the car should fit that identity of independence. The scenario that achieves these goals is ‘getting attention while driving’, ‘being visible while driving’ and ‘driving a car by yourself’. The solution is a two-seater (just for yourself) and/ or a convertible car (being visible).

Figure 1. four-layer model of insights into human needs for design innovation (van der Bijl-Brouwer and Dorst, 2014)

Note that the model does not prescribe a step-by-step method. Insights on the top three levels can be gathered through several existing human-centred design techniques. We do propose a specific approach for identifying themes from these insights, and using these themes to reframe the problem, which then supports the generation of proposals for future scenarios and solutions.

2.2 Reframing problems through analysing themes

The idea to distinguish goals and themes is based on the work of Dorst (2015) on the role of themes in the design activity. Based on extensive studies of the practices of expert designers, various scholars have found that what designers are particularly good at is (re-) framing problems, finding new perspectives on a problem and through that developing new solutions (Cross 2007, Schön 1983, Dorst 2011). Dorst and Tomkin (2011) found that the explorations that designers engage in to be able to reframe problems are a subtle process of analysis that is very close to methods used in the creation of phenomenological descriptions of ‘lived experience’. Just like phenomenologists, designers analyse the situation by discerning the ‘themes’ in the life and world of the stakeholders (Dorst and Tomkin 2011). Phenomenological themes may be understood as the structures of experience. So when we analyse a phenomenon, we are trying to identify the themes: the experiential structures that make up that experience (van Manen 1990).

Dorst (2015) furthermore found that as the reframing practice of designers is similar to the practice of phenomenologists, we can borrow methods from phenomenologists to support reframing problems and through that design innovation. To identify and analyse themes we can use the method of hermeneutic phenomenology (van Manen 1990). We have applied hermeneutic phenomenology in design innovation projects in the public sector. The methods we use have evolved based on previous case studies (Dorst 2013), and are inspired by the guidelines for thematic analysis provided by Rijken (2013). First, existing human-centred design research methods are used to gather insights into stakeholder needs at the scenario and goal levels of the 4-layer model. For example, contextual inquiry (Beyer & Holtzblatt, 1998) can be used to gain insights into desired scenarios, and persona techniques (Cooper, 1999) can be used to identify desired goals (see for a comparable example (Tomkin and Watson 2013)). Next, themes are identified by searching for common patterns in those insights across stakeholders. We then proceed to further analyse these themes by investigating their meaning and relationships in workshop sessions. A core element of the method is to explore the themes by sharing personal experiences related to a theme. For example, Rijken (2013) explains how to investigate the theme ‘fear’ through asking workshop participants: have you ever experienced fear? What triggered it? What did it feel like? What were you thinking? What changed it? What did you do? Did others play a role? By having different team members share these experiences in an iterative process a pattern can
emerge that shows the structure of a theme. For example, fear is related in a structured way to insecurity, risks, confidence, uncertainty etc. Other ways to explore themes are consulting scientific literature and philosophy on specific themes; and gathering artworks that express a theme (Rijken, 2013). The universality of the themes makes it possible to analyse them independently of customers or end-users, and independent of the problem context. To move from the themes to reframe the problem, it is useful to look at how the elements of the theme are dealt with in domains outside the problem context (Dorst, 2013). Through using metaphors, a frame can then be created which forms a bridge between problems and solutions.

2.3 Designing for both service consumers and providers
In the above we explained how an analysis of themes at the deepest level of the model of insights into human needs for design innovation supports reframing and design innovation. Themes can be applied across a broad variety of innovation contexts in both the public and private sector (see Dorst, 2015). In this paper we focus on the question of whose needs should be considered in a public sector context. Traditionally design theory and methods have been centred on the end-user of products, so called user-centred design (e.g. (Norman 1998)). The adoption of design innovation in businesses in the private sector has broadened the focus from the user to the customer or consumer, as the person who uses a product or service is often not the same person that purchases the product or service. Likewise, in the public sector the term citizen-centred public service design has recently emerged (Mager et al. 2013). Design innovation in the public sector is mainly aimed at improving the public service. Service design is therefore a concept that is gaining popularity in this sector. Service design is a young field of practice and like traditional product design it is user-centred or customer-centred (e.g. (Stickdorn and Schneider 2010)). In service design we can generally distinguish two types of stakeholders: the service providers and the service consumers. Interactions between service provider and consumer can be either digital or through personal interaction. Although technology is rapidly replacing many personal interfaces, there are many services in the public sector that by their nature require personal interactions. For example in the case study we will present in this paper, we investigated services provided by ambulance, emergency departments and police.

We argue that particularly when services are provided through personal interactions, future interventions should not only meet the needs of the service consumers, but of the service providers as well. The underlying assumption is that if interventions meet the service providers’ needs, the experience of providing the service will be positive which in turn will positively influence the quality of the service itself. A waiter or waitress with a satisfying waitressing experience is more likely to provide restaurant customers with a positive experience than one whose waitressing needs are not met. We furthermore argue that if needs of service providers are analysed at its deepest level, as suggested in the model of levels of depth in insights into human needs (section 2.1), this analysis supports radical innovation through reframing. In the next section we illustrate this argument with a case study.

3 CASE STUDY

3.1 Objectives
The case study concerns the design of interventions that were aimed at supporting people with severe and persistent mental health problems who acutely need help. These people are referred to by the service providers as ‘consumers’. We were invited to support this project by a non-government agency that aims to generate and implement interventions for this problem through particularly looking at the systemic aspects of this problem. The systemic aspects concern the problems that arise from the fact that many service providers are currently involved when people with a severe mental health problem acutely need help when they are very unwell (for example when they are psychotic, severely anxious, and/or suicidal). In these situations the first call can be made by the consumer him/herself, by carers (family or friends), landlord, or non-governmental organisations (NGO). Ambulance might be called to transport someone to the hospital or a mental health unit, the police might be involved when someone is threatening self-harm or harming others, the emergency department (ED) provides help when someone arrives at the hospital, and various service providers can be involved in follow-up care including general practitioners, social workers, mental health professionals, NGO’s etc. The client wanted to engage all these stakeholders in the process of generating interventions, but had no capacity
The objectives of the research project were twofold. Firstly, the project was aimed at generating solutions for the systemic problems of supporting people with severe and persistent mental health problems in emergency situations. Secondly, the project was aimed at exploring methods to gain insights into the deep needs of multiple stakeholders as well as investigating the usefulness of these insights for innovation.

3.2 Research method

The research method for the project consisted of a series of methods to gain insights into the needs of the various stakeholders and/or reframe the problem based on a thematic analysis of those needs. The project can be summarised as follows (see figure 2):

- 10 semi-structured interviews with various stakeholders to gain insights into their needs
- A scoping session to focus the project. At this stage the project was focused on emergency situations
- A stakeholder workshop with 20 different stakeholders aimed at investigating their needs and reframing problems. Tools applied in the workshop included personas, theme identification and analysis, reframing, and future scenario generation
- A frame creation session (see Dorst 2015) with 7 different stakeholders in which the insights from the different sessions were brought together and used to reframe the problem
- In parallel to these sessions we analysed the data from the interviews and sessions, and identified and analysed themes. The themes were fed back into the final frame creation session.

To evaluate the process itself we furthermore interviewed the participants after the last frame creation session.

Respondents and workshop participants included consumer representatives, carers, ambulance paramedics, police officers, emergency department (ED) nurses, social workers, case workers, mental health professionals, NGO’s (e.g. an NGO that provides meals for the homeless), housing provider, indigenous housing support employees, and staff from the agency that organised the project.

4 RESULTS

4.1 Themes

Through the interviews and workshop we identified several themes. In this paper we will explain the themes of drive, growth, contribution, and care.

4.1.1 Drive & Growth

A reoccurring theme found in the interviews and in the stakeholder workshop was the theme of ‘drive’ or ‘motivation’. All interviewees and workshop participants who work in the sector mentioned their motivation to make a difference. For example, an ambulance paramedic mentioned that ‘there’s no better feeling than saving someone’s life’.

Figure 2. visualisation of the research method
On the other hand we found several indications that it is difficult to sustain this motivation for stakeholders supporting people with severe and persistent mental health problems in emergency situations. Police officers for example indicated a sense of futility and frustration around repeat cases. Likewise, ambulance paramedics mentioned similar experiences as there is no quick fix to mental health problems: ‘It’s not like stopping the bleeding or starting the heart’. This frustration seems to be caused by a lack of feedback:

Police officer: ‘If we do not hear from the person again, there is an assumption that one of three things happened to them: 1) they got better, 2) they moved away, 3) they died. We are essentially feeding our efforts into a ‘cone of silence’ that does not speak back.’

The need for feedback to sustain a drive to do the work is indicated in the inner circle figure 3. One of the things that a hermeneutic analysis of this theme shows, is that when you are driven to do something, you feel a sense of achievement when you can see what the results of your efforts are. For example, when cooking for friends it feels good when these friends look like they are enjoying the meal or tell you they appreciate it. This feeling might in turn motivate you to continue organising dinner parties for your friends. Note that this is a simplified analysis of the theme ‘drive’ as there are other elements that contribute to this theme as well.

Feedback is also an essential element of learning or ‘growth’. Apart from learning through training, people learn ‘by doing’ and reflecting on what they do (reflective practice). But you only learn if you know what the effects of your actions are (figure 3). In the cooking example you can only become better at cooking when you can taste the food or when your friends tell you (honestly) what they think of the meal you prepared for them. Feedback on actions is therefore essential. A police officer confirmed this and indicated it would be useful to know what works and what wouldn’t. A part of the systemic problem of supporting people with severe and persistent health problems is therefore this broken cycle of motivation and learning, or drive and growth.

Figure 3. analysis of the themes drive and growth

4.1.2 Contribution/ shared response

A number of themes that came up in the interviews and workshops were related to responding together. They included ‘participation’, ‘contribution’, and ‘shared response’. Workshop participants for example mentioned the importance of the right person in the right place being integral to responding effectively.

To be able to contribute (figure 4) you need to identify the area you can influence, the skills you have and the part you play. In order to know what your part is you also need to know the parts of others. A shared response is influenced by trust, expectations, coordination, inclusion and exclusion. Like the individual drive and growth cycle, shared response can also benefit from a feedback cycle which stimulates people’s drive to continue contributing and which allows groups of people to learn about how to collectively respond next time.

In the context of situations in which people with mental health problems acutely need help there are a number of issues that sometimes lead to conflicts. This seems to be related to people not understanding each other’s priorities and resources. For example there can be conflicts between police
and ambulance about whether someone needs to be transported and if so by whom, or between ambulance/policen and ED about the priorities of patients when transported to ED.

4.1.3 Care: (shared) understanding of individual needs

A reoccurring problem was that service providers in emergency situations did not know what the best course of action was for individuals, because they had no insights into the needs of individual consumers. In emergency situations consumers are not able to indicate what they need because of their mental illness.

*Ambulance paramedic: “I wish there was someone more closely involved with Bob’s [consumer] mental health management to consult”*

*ED: “We would like to get advice and information flow from the mental health professionals dealing with patients to the emergency department to guide actions and decisions when dealing with this client.”*

This problem is related to the theme of ‘care’ which is strongly related to (shared) understanding of individual needs. It is generally difficult to care for someone when you do not know what that person needs. An understanding of needs of an individual might be achieved by gathering that knowledge from experts or others who are closely involved with the individual, or by including the person who is cared for in a learning cycle in which care is evaluated and adjusted. Sharing information about someone’s needs is related to issues of trust, relationships and privacy (figure 5).

With regard to the understanding of the needs of people with severe and persistent mental health problems we can again recognise a learning cycle when there is a repetitive cycle of crisis. Ideally a crisis response should then be evaluated together with a consumer to gain a better understanding of the
needs of the individual. If it would be possible to share this information, a next crisis response could then be better informed.

The analysis of the themes showed that a large part of the systemic problems of mental health crisis situations are rooted in incomplete learning cycles on different levels: the ability for individual service providers to learn about mental health response in general, the ability of groups of people to learn about collective response, and the ability of service providers to learn about the needs of individual consumers.

Furthermore, the abovementioned themes are all interrelated. For example, the ability to grow or achieve ‘mastery’ is intrinsically linked to people’s drive (Pink 2009), and being able to contribute collectively as well as to care for an individual both contribute to growth and drive.

4.2 Frames and solutions
At the time of writing this paper we had only explored initial frames and solutions. We present some preliminary results here.

To frame the problem we looked at how the elements of the themes are dealt with in domains outside the problem context. Exploring these metaphors can lead to new frames (Dorst, 2013). A fruitful frame for ‘shared response’ was the local emergency management committee (LEMC). The LEMC is a support mechanism for the combat agency that’s responsible in case of an emergency like flooding or a bush fire. The main characteristic of the LEMC is that a local multi-disciplinary committee comes together a couple of times a year to discuss a plan for potential emergencies. When there is an emergency the plan is executed by the combat agency and after recovery the complete response is evaluated together to be able to respond better next time. What we can learn from this for mental health crisis response is that there could be a multidisciplinary support committee on a local level that develops joint and individual response plans, informs service providers on a tactical level, and evaluates response. This solution particularly supports the themes ‘shared response’ and ‘understanding individual needs’. If evaluations are fed back to service providers who work on a tactical level it could also potentially support ‘growth’. A crucial element of this solution is the locality of the committee which allows people to see the results of their efforts and learn from it as well as get a sense of achievement that sustains a drive for future collective response.

The above solution also mentions an ‘individual response plan’ for consumers. This idea is related to the theme ‘care’ and ‘understanding individual needs’. The plan should mention what an individual consumer needs in case of emergency (an example was mentioned of a consumer who should not be taken inside the emergency room as this person experienced that room as extremely traumatising) and what the wider support network of the consumer is. For a plan like this to work the complete learning cycle of care and understanding should be covered. The consumer should be involved in evaluating a crisis response and in case of emergency the plan should be available to inform the response. Participants mentioned that this could be achieved for example with a laminated card that briefly explains the main issues. Figure 6 illustrates how the developed solutions are related to the underlying scenarios, goals and themes. Note that both the scenarios and solutions need to be developed in more detail.

![Figure 6. insights into human needs for the case ‘supporting people with severe and persistent mental health problems’ on the four levels for the two solutions.](image-url)
4.3 Reflection on the process

In this project we used various methods to gain insights into what the different stakeholders needed. When comparing the results to the levels of insights into human needs presented in section 2.1, we found that in the interviews respondents mostly communicated on a solution or scenario level. For example they indicated the need for ‘suitable services for patients’ and ‘supervision’. In the workshops we had participants think about underlying themes, but it was difficult for them to connect themes to scenarios and solutions within one session. We found it helpful to identify and analyse the themes and present them to the client, rather than facilitate the client and participants through a deeper analysis required to identify and expand on the themes. In the last session these insights could then be used to reframe the problem together with the stakeholders.

Different stakeholders participated throughout the various project stages. The only people who participated in all the sessions were the client and the researchers. When asking participants about the process they mainly appreciated being offered the opportunity to participate in the process and to step back and reflect on their work and the problem. They indicated the process was very engaging. Although this engagement is useful to stimulate future buy-in of new interventions, the engagement itself was not the main goal of the sessions. The problems we encountered with the ability of participants to identify and analyse themes, and reframe problems, might have been caused by the fact that they were only involved in parts of the project. Therefore it would have been difficult for them to connect the dots. Who to involve in workshops is therefore a trade-off between having as many as possible stakeholders engage on the one hand, and having a continuity of thinkers on the other. The latter would allow building capacity to connect insights to themes, and using themes to reframe the problem and generating solutions.

5 DISCUSSION AND CONCLUSIONS

In this paper we presented a case study in which the design process was centred on the needs of both service consumers and service providers in the public sector. We found that investigating the deepest needs of service providers supports a better understanding of the problem and potentially supports developing solutions that better meet these needs. The client particularly appreciated the way the process led to a coherent view of the service system as a whole, by showing the underlying themes. How this will support the further development and implementation of interventions is, at the time of writing, yet to be shown.

The application of design innovation and frame creation in the public sector to develop public services is still very new and more research is necessary to investigate what the benefits and limitations are of solving these kinds of problems through design compared to other innovation methods. However, the focus on needs of service providers seems to be an essential prerequisite for service systems including personal interaction to succeed. Not meeting their needs might unnecessarily frustrate or dissatisfy service providers, which might negatively influence the quality of the service itself. This seems particularly relevant in the context of innovation in the public sector in which people who work as public service providers are very rarely motivated by financial incentives, but are in the job to be able to ‘make a difference’. The work should be a rewarding experience in itself to motivate people to do their work well.

The results of the case study also have implications for service system design in general. Theories and methods of design innovation now mainly consider service providers as resources to implement solutions. Tools such as the business model canvas (Osterwalder and Pigneur 2010) are aimed at mapping providers of these resources to roles in the supply chain of product-service systems. At the centre of the model is the customer who is provided with a ‘value proposition’ in return for revenue, which is then distributed amongst the service providers. Viewing the design of service systems as one in which the needs of all stakeholders need to be met leads to a different model of the exchange of value. Stakeholders in the systems are not viewed as resources, but as people who can each both contribute to as well as benefit from the service, in a process of give and take. For example, ambulance paramedics contribute to looking after someone with a severe mental health problem, and at the same
time could experience this as a rewarding experience through hearing about the results of their efforts, or to be able to learn. We could even think about a new role for end-users of a service in which they not only receive but also contribute. A consumer of mental health services could for example be actively involved in the generation of their care plans. The service system thus becomes both supporting as well as empowering.

REFERENCES


Cooper, Alan. (1999) The inmates are running the asylum: why high-tech products drive us crazy and how to restore the sanity. Indianapolis: Sams.


ACKNOWLEDGEMENTS

This project was funded by the Australian Government Partners in Recovery Program. We would like to express our gratitude to all the participants of the workshops and the respondents in the interviews for their valuable input to this research project. We would like to thank Hunter Partners in Recovery for collaborating on this project, and our colleagues Amira Vijayananayagam, Nicole Chojecka, Lucy Kaldor, Minke Dijkstra, Kees Dorst and Clementine Thurgood for their contribution to the research and feedback on the paper.
Preface by the Programme Chair

We welcome you to the proceeding of the 20th International Conference on Engineering Design 2015 (ICED 15) held at the Bovisa campus of Politecnico di Milano, Milan, Italy. The theme of the Conference is “DESIGN FOR LIFE”, inspired by EXPO 2015 in Milan.

These proceedings of ICED 15 contain 427 double-blind peer-reviewed and accepted papers. The proceedings are published in different forms: a book of abstracts and a soft-copy of all contributions on a USB-based memory device for conference delegates plus printed books (11 volumes), which are available to the public via a print-on-demand service. All these different forms of proceedings are numbered against both Design Society and ISSN/ISBN referencing to allow wider access, better referencing and improved citation in the near and distant future. Additionally, all papers contain a citation proposal for a reproducible citation. The 11 volumes of the books are structured according to the conference topics and the sequence of the sessions. All papers in the proceedings have successfully fulfilled the criteria for acceptance in ICED 15.

Continuing on from the changes introduced for ICED 13, the papers in the proceedings were produced by combining an automatically generated cover page, based on the contribution details in the Conference Management System (ConfTool), with the paper as submitted by the authors, starting with the introduction section. This procedure supports consistent data for the papers, the conference programme, the Book of Abstracts, etc.

ICED 15 and its proceedings are the result of the dedicated efforts of many people:

- the authors who submitted excellent papers (both in content and form),
- the reviewers who provided timely comments and positive feedback that helped to optimise the quality of papers,
- the chairs, assistant chairs and members of the Programme and Organising Committee and the Design Society Administration who had to deal with details galore in getting the conference and the proceedings planned, structured, organised and ready to go (it was also fun, though!).

Thank you all very much!

On behalf of the Programme Committee we hope that you enjoy the programme and participate fully in what is arguably the Premier engineering design research conference in the world. We also hope that you find time to discover Milan and EXPO 2015, that you meet old friends and make some new ones, and that – besides work – you also have as much fun as we had when preparing the conference!

Christian Weber
Programme Chair

Stephan Husung
Assistant Programme Chair
Preface by ICED15 Conference Chair

Having reached its 20th edition, ICED15 confirms to be a well-established conference in the scientific design community and we are very pleased and honoured to host this edition, which has received a very significant attention from researchers and practitioners throughout the world.

ICED15 is being organized at the same time and in the same location as the Universal EXPO. The EXPO has also inspired the theme of our conference - Design for Life - which has been further formulated as Design for a Healthy, a Sustainable and a Contented Life. While the submissions were arriving and the conference program was taking shape, we were very pleased to observe that this conference theme has indeed been picked up by many authors and has permeated their contributions. As an outcome of this emerging synergy between ICED and EXPO, we expect participants to return to their countries not only with the usual benefits that come from the ICED experience, but also with a stronger capability and determination to make positive and effective contributions to humankind through design research, education and practice.

If one looks at the program of previous ICED conferences, it is quite apparent that the field of design is continuously evolving, and that the Design Society community that is at the heart of ICED is also at the forefront of this continual evolution and adaptation to emerging opportunities and challenges. Specifically, ICED15 welcomes a growing number of contributions in fields pertaining to the human and social aspects of design, looking at humans both as actors and as recipients of the design activity. We all know that these advancements do not only take place in the formal presentation sessions, but also through other gatherings, including business meetings, information events, workshops and — of course — social events. The conference program has therefore been designed with the objective of providing ICED participants with a variety of opportunities for meeting and exchanging views.

All this will occur within the setting of a country such as Italy that — since ancient times, going through the Renaissance and until today — has been uniquely able to blend its technical know-how with an amazing quality of life. We therefore hope that you will make a memorable experience of ICED 15, the EXPO and of the ideal of Designing for Life.

Gaetano Cascini
Conference Chair

Marco Cantamessa
Conference Chair
Preface by the Design Society President

ICED 15, the 20th edition of the International Conference on Engineering Design (ICED) is coming back to Italy, the country where the idea of a design conference first took shape. The first ICED took place in Rome in March 1981. The aims were, as its initiator Vladimir Hubka wrote in December 1980, set towards: “…determining the latest state of knowledge in areas of scientific design methods, and of gathering information about current results and future trends in research, to achieve a free co-ordination of scarce research resources.”

This year, we are not in Rome, but in Milan - and for a good reason. The city of Milan itself is a synonym for quality of design as a way of thinking and living, in activity or in outcome. The conference themes indicate the broadness of thinking about design in and around the host city and connect the conference with the Universal EXPO that is also taking place at the same time. ICED 15 participants will have chance to experience the dynamics of a city that reflects all of the dichotomies that define design old and new, the art and technology, the research and practice, the chaotic and systematic. In the past thirty-five years the conference has become the event where all the richness of design research from all the continents is presented and all aspects of design explored ICED 15 sessions are the results of continuous improvements in every aspect of conference organisation. The format of the conference is based on the previous events with a programme made up of plenary sessions, podium presentations, discussion sessions with a focused debate and workshops led by the Design Society’s Special Interest Groups. In addition, the Young Members’ Event and PhD Forum extend the networking opportunities of ICED 15 for younger or first-time participants. The ICED 15 programme will provide an exciting opportunity for researchers and practitioners to learn about the latest developments in design research and practice.

The programme of ICED 15 is the result of a joint effort from great teams that have been working together since the last ICED conference in Seoul. The Society extends its gratitude to all the authors who have submitted their papers and all the reviewers who have helped to select papers ensuring an outstanding conference experience for all participants. A special thank you goes to all the authors and Session Chairs who will make this experience possible.

Many things have changed through the last 19 conferences. The conference started in Rome by WDK (Workshop – Design – Konstruktion), has, since 2001, been organised by the Design Society. Design as a field has expanded tremendously and the conference programme has become more interactive and complex, opening new opportunities and challenges. Organising a conference with such a history takes an enormous amount of work and attention to detail. I would like to express sincere thanks of the Society to Gaetano Cascini and Marco Cantamessa and all colleagues from Politecnico di Milano and Politecnico di Torino who have made this conference happen. Special thanks also to Programme Chair Christian Weber and Assistant Programme Chair Stephan Husung and all the members of Programme Committee for ensuring that this conference presents a tremendous quality of content. Finally, thank you to all of the participants whose attendance and input are a constant sign that this conference and design as a field are going in the right direction.

Dorian Marjanovic
Design Society President
ICED15 Programme Committee

Christian Weber - TU Ilmenau, Germany
Stephan Husung - TU Ilmenau, Germany
Monica Bordegoni - Politecnico di Milano, Italy
Marco Cantamessa - Politecnico di Torino, Italy
Gaetano Cascini - Politecnico di Milano, Italy
Dorian Marjanovic - University of Zagreb, Croatia
Srinivasan Venkataraman - TU Munich, Germany

ICED15 Organising Committee

Gaetano Cascini - Politecnico Di Milano
Marco Cantamessa - Politecnico di Torino, Italy
Serena Graziosi - Politecnico Di Milano, Italy
Francesca Montagna - Politecnico Di Torino, Italy
Federico Rotini - Università degli studi di Firenze, Italy
ICED15 Scientific Committee

Agogino, Alice Merner - University of California at Berkeley
Agogue, Marine - HEC Montréal
Ahmed-Kristensen, Saeema - DTU
Albers, Albert - Karlsruhe Institute of Technology (KIT)
Allen, Janet Katherine - University of Oklahoma
Allison, James T. - University of Illinois at Urbana-Champaign
Almefelt, Lars - Chalmers University of Technology
Anderl, Reiner - TU Darmstadt
Andersson, Kjell - KTH Royal Institute of Technology
Andrade, Ronaldo - Universidade Federal do Rio de Janeiro
Annamalai Vasantha, Gokula Vijaykumar - University of Strathclyde
Aoussat, Améziane - ENSAM
Arai, Eiji - Osaka University
Arciszewski, Tomasz - George Mason
Aurisicchio, Marco - Imperial College London
Austin-Breneman, Jesse - Massachusetts Institute of Technology
Badke-Schaub, Petra - TU Delft
Balan, Gurumoorthy - Indian Institute of Science
Becattini, Niccolo - Politecnico di Milano
Becetic, Sanja - University of Zagreb
Ben-Ahmed, Walid - RENAULT
Bender, Beate - Ruhr-Universität Bochum
Beneke, Frank - FH Schmalkalden
Bertoni, Marco - Blekinge Institute of Technology
Bhamra, Tracy - Loughborough University
Binz, Hansgeorg - University of Stuttgart
Birkhofer, Herbert - TU Darmstadt
Bjärnemo, Robert - Lund University
Björk, Evastina, Lilian - Göteborg University
Blanco, Eric - Univ. Grenoble Alpes, G-SCOP, F-38000 Grenoble, France CNRS, G-SCOP, F-38000 Grenoble, France
Blessing, Lucienne - University of Luxembourg
Boa, Duncan R - University of Bristol
Bohemia, Erik - Loughborough University
Bojicetic, Nenad - Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb
Boks, Casper - Norwegian University of Science and Technology
Booker, Julian David - University of Bristol
Bordegoni, Monica - Politecnico di Milano
Borg, Jonathan C. - University of Malta
Borgianni, Yuri - Free University of Bolzano-Bozen
Boujut, Jean-François - Grenoble Institute of Technology
Bouwhuis, Dominic G - TU Eindhoven
Broberg, Ole - TU Denmark
Brown, David C. - Worcester Polytechnic Institute
Burvill, Colin Reginald - University of Melbourne
Bylund, Nicklas - Sandvik Coromant
Cagan, Jonathan - Carnegie Mellon University
Caillaud, Emmanuel - Université de Strasbourg
Campean, Felician - University of Bradford
Cantamessa, Marco - Politecnico di Torino
Casakin, Herman - Ariel University
Cascini, Gaetano - Politecnico di Milano
Cash, Philip - TU Denmark
Cavallucci, Denis - INSA Strasbourg
Chakrabarti, Amarendra - Indian Institute of Science
Chen, Wei - Northwestern University
Chen, Chun-Hsien - Nanyang Technological University
Childs, Peter R.N. - Imperial College London
ICED15 Scientific Committee cont.

Chiu, Ming-Chuan - National Tsing Hua University
Choi, Young Mi - Georgia Institute of Technology
Chu, Chih-Hsing - National Tsing Hua University
Clarkson, Peter John - University of Cambridge
Coatanéa, Eric - Aalto University
Collado-Ruiz, Daniel - Dynavio Cooperative
Cormican, Kathryn - National University of Ireland
Coutellier, Daniel - University of Valenciennes
Crawford, Richard - University of Texas at Austin
Crilly, Nathan - University of Cambridge
Cugini, Umberto - Politecnico di Milano
Culley, Steve - University of Bath
De Guio, Roland - INSA de Strasbourg
Deans, Joe - University of Auckland
Dekoninck, Elies Ann - University of Bath
Dhokia, Vimal - University of Bath
Dong, Andy - The University of Sydney
Donndelinger, Joseph A. - General Motors LLC
Dorst, Kees - University of Technology, Sydney
Duffy, Alex - University of Strathclyde
Duflou, Joost - KU Leuven
Eckert, Claudia - Open University
Egan, Paul Francis - ETH Zurich
Eifler, Tobias - Technical University of Denmark
Eigner, Martin - TU Kaiserslautern
Ekman, Kalevi - Aalto University
Ellman, Asko Uolevi - Tampere University of Technology
Emrah Bayrak, Alparslan - University of Michigan
Eppinger, Steven - Massachusetts Institute of Technology
Erbe, Torsten - Jenoptik OS GmbH
Ericson, Åsa - Luleå University of Technology
Eris, Ozgur - MITRE Corporation
Fadel, Georges M. - Clemson University
Fan, Ip-Shing - Cranfield University
Fantoni, Gualtiero - University of Pisa
Fargnoli, Mario - Ministry of Agriculture
Ferrise, Francesco - Politecnico di Milano
Filippi, Stefano - University of Udine
Finger, Susan - Carnegie Mellon University
Fischer, Xavier - ESTIA
Frankenberger, Eckart - Airbus
Fu, Katherine Kai-Se - Georgia Institute of Technology
Fujita, Kikuo - Osaka University
Fukuda, Shuichi - Keio University
Gardoni, Mickael - ÉTS / INSA de Strasbourg
Georgiev, Georgi V. - Kobe University
Gerhard, Detlef - Vienna University of Technology
Gericke, Kilian - University of Luxembourg
Gero, John - UNCC & GMU
Goel, Ashok - Georgia Institute of Technology
Goh, Yee Mey - Loughborough University
Göhlisch, Dietmar - TU Berlin
Goker, Mehmet H. - Salesforce.com
Goldschmidt, Gabriela - Technion - Israel Institute of Technology
Gooch, Shayne - University of Canterbury
Gopsill, James Anthony - University of Bristol
Governi, Lapo - University of Florence
Grässler, Iris - Heinz Nixdorf Institute, University of Paderborn
Graziosi, Serena - Politecnico di Milano
Grimheden, Martin - KTH Royal Institute of Technology
Grobman, Yasha Jacob - Technion, Israel Institute of Technology
Gupta, Ravi Kumar - Ecole Centrale de Nantes
Gzara, Lilia - Grenoble Institute of Technology
Hales, Crispin - Hales & Gooch Ltd.
Hallstedt, Sophie - Blekinge Tekniska Högskola
Hansen, Claus Thorp - TU Denmark
Hasse, Alexander - FAU University of Erlangen-Nuremberg
Hatchuel, Armand - Mines ParisTech
Hicks, Ben - University of Bath
Höhne, Günter - Technische Universität Ilmenau
Holliger, Christoph - University of Applied Sciences Northwestern Switzerland
Holmild, Stefan - Linköping University
Hong, Yoo Suk - Seoul National University
Horvath, Imre - Delft University of Technology
Hosnedl, Stanislav - University of West Bohemia
Howard, Thomas J. - Technical University of Denmark
Husung, Stephan - Technische Universität Ilmenau
Ijomah, Winifred - University of Strathclyde
Ilies, Horea - University of Connecticut
Ion, William - University of Strathclyde
Isaksson, Karl Ola - GKN Aerospace Engine Systems
Jackson, Mats - Malardalen University
Jagtap, Santosh - Lund University
Ji, Haifeng - Massachusetts Institute of Technology
Johansson, Glenn - Jönköping University
Johnson, Aylmer - University of Cambridge
Jones, Simon Lloyd - University of Bath
Jowers, Iestyn - The Open University
Jun, Thomas - Loughborough University
Kannengiesser, Udo - Metasonic GmbH
Karlsson, Lennart - Alik Communications AB
Kazakci, Akin Osman - Mines ParisTech
Keates, Simeon - University of Greenwich
Keldmann, Troels - Keldmann Healthcare A/S
Kim, Yong Se - Sungkyunkwan University
Kim, Kee-Ok - Sungkyunkwan University
Kim, Harrison - University of Illinois at Urbana-Champaign
Kiriyama, Takashi - Tokyo University of the Arts
Kishita, Yusuke - Osaka University
Kitamura, Yoshinobu - Osaka University
Kleinsmann, Maaike - TU Delft
Kloberdanz, Hermann - TU Darmstadt
Koh, Edwin - National University of Singapore
Kokkolaras, Michael - McGill University
Komoto, Hitoshi - National Institute of Advanced Industrial Science and Technology
Kota, Srinivas - Birla Institute of Technology and Science
Kovacevic, Ahmed - City University London
Krause, Dieter - Hamburg University of Technology
Kreimeyer, Matthias - MAN Truck & Bus AG
Kremer, Gul - Penn State University
Kroll, Ehud - Technion
Krömker, Heidi - Technische Universität Ilmenau
Krus, Petter - Linköping University
Kuosmanen, Petri - Aalto University
Le Masson, Pascal - Mines ParisTech
Leary, Martin John - RMIT University
Lee, Sang Won - Sungkyunkwan University
Legardeur, Jeremy - ESTIA
Lenau, Torben Anker - TU Denmark
Liem, André - Norwegian University of Science and Technology
Lindahl, Mattias - Linköping University
Lindemann, Udo - TU Munich
Linsey, Julie - Georgia Institute of Technology
Liu, Ying - Cardiff University
Lloveras, Joaquim - TU Catalonia (Universitat Politècnica de Catalunya)
Long, David Scott - University of Dayton
Lulham, Rohan - University of Technology Sydney
Mabogunje, Ade - Stanford University
Maier, Anja Martina - Technical University of Denmark (DTU)
Malak, Richard - Texas A&M
Malmqvist, Johan Lars - Chalmers University of Technology
ICED15 Scientific Committee cont.

Manfredi, Enrico - University of Pisa
Marjanovic, Dorian - University of Zagreb
Marle, Franck - Ecole Centrale Paris
Matta, Nada - Universite of Technology of Troyes
Matthews, Jason Anthony - University of the West of Englandf
Matthiesen, Sven - Karlsruhe Institute of Technology
Maurer, Christiane - The Hague University
Maurer, Maik - TU Munich
McAlpine, Hamish Charles - University of Bristol
McDonnell, Janet Theresa - Central Saint Martins
McKay, Alison - University of Leeds
McMahon, Christopher Alan - University of Bristol
Meboldt, Mirko - ETH Zurich
Mekhilef, Mounib - University of Orleans
Merlo, Christophe - ESTIA
Millet, Dominique - SEATECH Toulon
Mocko, Gregory Michael - Clemson University
Moehringer, Stefan - Simon Moehringer Anlagenbau GmbH
Mohan, Rajesh Elara - Singapore University of Technology and Design
Montagna, Francesca - Politecnico di Torino
Moreno Grandas, Diana Paola - University of Luxembourg
Mortensen, Niels Henrik - TU Denmark
Mörtl, Markus - Technische Universität München, Germany
Mougnot, Céline - Tokyo Institute of Technology
Moulec, Marie-Lise Therese Lydia - University of Cambridge
Moultrie, James - University of Cambridge
Mulet, Elena - University of Jaume
Mullineux, Glen - University of Bath
Murakami, Tamotsu - University of Tokyo
Nagai, Yukari - Japan Advanced Institute of Science and Technology
Newnes, Linda - University of Bath
Ng, Ricky, Yuk-kwan - Vocational Training Council, Hong Kong
Nicquevert, Bertrand - CERN
Nielsen, Ole Fii - Worm Development
Nomaguchi, Yutaka - Osaka University
Norell Bergendahl, Margareta E B - KTH Royal Institute of Technology
Oehmen, Josef - Technical University of Denmark
Öhrwall Rönnbäck, Anna B - Luleå University of Technology
Olsson, Annika - Lund University
Onkar, Prasad - Indian Institute of Technology Hyderabad
Otto, Kevin - Singapore University of Design and Technology
Ottosson, Stig - Gjøvik University College
Querani, Mohamed Zied - ABB / University of Cambridge
Paetzold, Kristin - University Bundeswehr Munich
Palm, William John - Roger Williams University
Papalambros, Panos Y. - University of Michigan
Parkinson, Matt - Pennsylvania State University
Pavkovic, Neven - University of Zagreb
Peters, Diane - Kettering University
Petersen, Soren Ingomar - ingomar&ingomar - consulting
Petiot, Jean-François - Ecole Centrale de Nantes
Pigosso, Daniela - Technical University of Denmark
Prakash, Raghu Vasu - Indian Institute of Technology Madras
Qureshi, Ahmed Jawad - Newcastle University
Radkowski, Rafael - Iowa State University
Raine, John Kenneth - Auckland University of Technology
Ray, Pascal - Ecole Nationale Supérieure des Mines de Saint-Etienne
Reich, Yoram - Tel Aviv University
Reid, Tahira - Purdue University
Remmen, Arne - Aalborg University
Ren, Yi - Arizona State University
Riel, Andreas Erik - Grenoble Institute of Technology
Riitahuhta, Asko Olavi - Tampere University of Technology
Rinderle, James - University of Massachusetts
Ringen, Geir - Sintef Raufoss Manufacturing
Ritzén, Sofia - KTH Royal Institute of Technology
Rizzi, Caterina - University of Bergamo
Robotham, Antony John - Auckland University of Technology
Rohmer, Serge - University of Technology of Troyes
Rosen, David - Georgia Institute of Technology
Rotini, Federico - Università degli Studi di Firenze
Roucoules, Lionel - ENSAM
Rovida, Edoardo - Politecnico di Milano
Russo, Davide - University of Bergamo
Sakao, Tomohiko - Linköping University
Salehi, Vahid - University of Applied Sciences Munich
Salustri, Filippo Arnaldo - Ryerson University
Sarkar, Prabir - Indian Institute of Technology Ropar
Sarkar, Somwrita - University of Sydney
Sato, Keiichi - Illinois Institute of Technology
Schabacker, Michael - Otto-von-Guericke University Magdeburg
Schaefer, Dirk - Georgia Institute of Technology
Schaub, Harald - IABGmbH
Seepersad, Carolyn Conner - University of Texas at Austin
Seering, Warren - Massachusetts Institute of Technology
Sen, Dibakar - Indian Institute of Science, Bangalore
Setchi, Rossi - Cardiff University
Shah, Jami - Arizona State University
Shea, Kristina - ETH Zurich
Sheldrick, Leila - Loughborough University
Shi, Lei - University of Bath
Shimomura, Yoshiki - Tokyo Metropolitan University
Siadat, Ali - ENSAM
Sigurjónsson, Jóhannes B. - Norwegian University of Science and Technology
Simpson, Timothy W. - Penn State University
Singh, Vishal - Aalto University
Škec, Stanko - University of Zagreb
Snider, Chris - University of Bristol
Söderberg, Rikard - Chalmers University of Technology
Sonalkar, Neeraj - Stanford University
Spitas, Christos - TU Delft
Stal-Le Cardinal, Julie - Ecole Centrale Paris
Stankovic, Tino - ETH Zurich
Stappers, Pieter Jan - Delft University of Technology
Stark, Rainer G. - Berlin Institute of Technology
Stetter, Ralf - University of Applied Sciences Ravensburg-Weingarten
Stevanovic, Milan - Markot.tel
Stören, Sigurd - Norwegian University of Science and Technology
Storga, Mario - University of Zagreb/Faculty of Mechanical Engineering and Naval Architecture
Subrahmanian, Eswaran - Carnegie Mellon University
Suh, Eun Suk - Seoul National University
Summers, Joshua David - Clemson University
Sundin, Erik - Linköping University
Tahera, Khadija - University of Huddersfield
ICED15 Scientific Committee cont.

Tan, James Ah-Kat - Ngee Ann Polytechnic
Taura, Toshiharu - Kobe University
Terpenney, Janis P. - Iowa State University
Thoben, Klaus-Dieter - University Bremen
Tiwari, Ashutosh - Cranfield University
Todeti, Somasekhar Rao - National Institute of Technology- Goa, India
Tollenaere, Michel - Grenoble Institute of Technology
Tomiyama, Tetsuo - Cranfield University
Törlö, Peter - Luleå University of Technology
Trimingham, Rhoda - Loughborough uni
Troussier, Nadege - University of Technology of Troyes
Udiljak, Toma - University of Zagreb/FMENA
Uflacker, Matthias - Hasso Plattner Institute
Umeda, Yasushi - the University of Tokyo
Vajna, Sandor J. - Otto-von-Guericke University Magdeburg
Valderrama Pineda, Andres Felipe - Aalborg University
Valkenburg, Rianne C. - The Hague University of Applied Sciences
van der Bijl-Brouwer, Mieke - University of Technology, Sydney
Van der Loos, Mike - University of British Columbia
Vaneker, Tom Henricus Jozef - University of Twente
Venkataraman, Srinivasan - Technische Universität München
Vidovics, Balazs - Budapest University of Technology and Economics
Vietor, Thomas - Braunschweig University of Technology
Vukasinovic, Nikola - Faculty of Mechanical Engineering, University of Ljubljana
Vukic, Fedja - Graduate School of Design, Faculty of Architecture, University of Zagreb
Walter, Michael - Friedrich-Alexander-Universität Erlangen-Nürnberg
Wang, Charlie C.L. - Chinese University of Hong Kong
Wang, Yue - Hang Seng Management College
Wartzack, Sandro - Friedrich-Alexander-Universität Erlangen-Nürnberg
Watanabe, Kentaro - National Institute of Advanced Industrial Science and Technology
Watty, Robert - University of Applied Sciences Ulm
Weber, Christian - Technische Universität Ilmenau
Weil, Benoit - Mines ParisTech-PSL Research University
Weiss, Menachem Peter - Technion - Israel Institute of Technology
Whitfield, Ian - University of Strathclyde
Whitney, Daniel E - Massachusetts Institute of Technology
Winkelmann, Paul Martin - University of British Columbia
Wodehouse, Andrew James - University of Strathclyde
Wood, Kristin - Singapore University of Design and Technology
Yan, Xiu-Tian - University of Strathclyde
Yanagisawa, Hideyoshi - University of Tokyo
Yang, Maria - Massachusetts Institute of Technology
Yannou, Bernard - Ecole Centrale Paris
Yilmaz, Seda - Iowa State University
Zainal Abidin, Shahriman - Universiti Teknologi MARA
Zavbi, Roman - University of Ljubljana
Zeng, Yong - Concordia University
Zolghadri, Marc - Supmeca
Table of Contents

Preface by ICED15 Programme Chair
Preface by ICED15 Conference Chair
Preface by the Design Society President
ICED15 Programme Committee
ICED15 Organising Committee
ICED15 Scientific Committee

VOLUME 1: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN FOR LIFE

DESIGN FOR A SUSTAINABLE LIFE

Design Strategies for Circular Economy
Devadula, Suman; Chakrabarti, Amaresh ..................................................1-1

Implementing Ecodesign Principles in Product Design: the Role of Usability
Sousa, Ana M.; Sampaio, Alvaro M.; Simoes, Paulo; Oliveira, Raquel ..................1-11

Model Based Decision Support for Value and Sustainability in Product Development
Isaksson, Ola; Bertoni, Marco; Hallstedt, Sophie; Lavesson, Niklas .......................1-21

Improving the Management of Environmental Requirements in Clients/Suppliers Co-Design Process
Michelin, Fabien; Reyes, Tatiana; Vallet, Flore; Eynard, Benoit; Duong, Viet-Long ....1-31

The Business Model, A Tool for Transition to Sustainable innovation
Bisiaux, Justine; Gidel, Thierry; Huet, Frédéric; Millet, Dominique .......................1-43

Quantification of Indoor Environmental Quality in Sustainable Building Designs using Structural Equation Modeling
Piacenza, Joseph R; Fields, John J; Hoyle, Christopher; Tumer, Irem Y ..................1-53

Archaeonics – How to use Archaeological Solutions for Modern Product Development
Guertler, Matthias R.; Schaefer, Simon; Lipps, Johannes; Stahl, Stephan;
Lindemann, Udo ....................................................................................1-65

Comparison and Classification of Eco Improvement Methods
Russo, Davide; Serafini, Marco; Rizzi, Caterina; Duci, Stefano .........................1-77

Ecodesign Maturity Model as a Framework to Support the Transition towards ISO 14.001:2015 Certification
Pigosso, Daniela C. A.; McAloone, Tim C. ........................................................1-87

Introduction of the Ideality Tool for Sustainable Design
Helfman Cohen, Yael; Reich, Yoram ..................................................................1-97

Development of a System for Production Energy Prognosis
Stetter, Ralf; Witzczak, Piotr; Witzczak, Marcin; Kauf, Florian; Staiger, Benjamin;
Spindler, Claudius .....................................................................................1-107

Environmental Evaluation of Ideas in Early Phases: A Challenging Issue for Design Teams
Leroy, Yann; Tyl, Benjamin; Vallet, Flore; Cluzel, François ..............................1-117

ICED15 xi
Identifying Needs for New Ecodesign Tools with the DSM Value Bucket tool
- An Example in the Construction industry
Lamé, Guillaume; Leroy, Yann; Lasvaux, Sébastien .............................................................. 1-127

Supporting Environmentally-Benign Design - Elucidating Environmental Impact Propagation in Conceptual Design Phase By Sapphire Model of Causality
Acharya, Shakuntala; Chakrabarti, Amarendra ................................................................. 1-139

Collaborative Process Between Functional Analysis et Life Cycle Assessment: Integrating Environmental Considerations into Early Stages of Design Process
Rodriguez Moreno, Paulina; Rohner, Serge; Ma, Hwong-Wen ........................................ 1-151

Task-Based LCA for Environmental Impact Assessment of Multiple Heterogenous Systems
Quan, Ning; Kim, Harrison; Knight, Erica; Nelson, Jeffrey; Finamore, Peter ............. 1-161

Heuristic Guidelines in Ecodesign
Sarnes, Julian; Kloberdanz, Hermann ............................................................... 1-171

Investigating the Sustainability of Product Supply Chains
Germani, Michele; Mandolini, Marco; Marconi, Marco; Marilungo, Eugenia; Papetti, Alessandra ........................................................ 1-181

Degrees of Customization and Sales Support Systems - Enablers to Sustainability in Mass Customization
Gembarski, Paul Christoph; Lachmayer, Roland ..................................................... 1-191

Interaction Design for Sustainable Mobility System
Gaiardo, Andrea; Di Salvo, Andrea ............................................................... 1-199

Meeting Sustainability Challenges: Soft Systems Thinking as an Enabler for Change
Ericson, Åsa; Holmqvist, Johan ............................................................... 1-209

Bringing a Fuller Socio-Technical Perspective to Design Decisions
Kokotovich, Vasilije ............................................................... 1-217

Firing up Sustainable Behaviour
Daae, Johannes; Boks, Casper; Goile, Franziska; Seljeskog, Morten ........................................ 1-227

Design for Sustainability – Trade-off Dilemmas from the Consumer Perspective
Shiu, Eric .............................................................. 1-239

Systematic Framework for the Development of Fuons
Ostad-Ahmad-Ghorabi, Hesamedin; Collado-Ruiz, Daniel ..................................... 1-249

Application of Subtract and Operate Method for Developing Function Energy Structures of Products and Systems - A Rule-Guided Approach
Markos, Panagiotis; Dentsoras, Argyris ......................................................... 1-259

Stakeholder Centred Approach to Sustainable Design: A Case Study of Co-Designing Community Enterprises for Local Food Production And Consumption
Pahk, Yoonhee; Baek, Joonsang .............................................................. 1-269

Substituting Conventional Materials and Manufacturing for Sustainable, Near Net Shape Grown Components
Löwer, Manuel; Beger, Anna-Lena; Feldhusen, Jörg; Wormit, Alexandra; Prell, Jürgen; Usadel, Björn; Seiler, Thomas-Benjamin; Kämpfer, Christoph; Hollert, Henner; Moser, Franziska; Trautz, Martin ........................................ 1-279
Similarities and Differences Between Environmental Soundness and Resource Efficiency and their Consequences for Design Support
Link, Sandra; Kloberdanz, Hermann; Denz, Naemi .......................................................... 1-289

Integrated Design of Dynamic Sustainable Energy Systems
Allison, James T.; Herber, Daniel R.; Deshmukh, Anand P .................................................. 1-299

Exploring Sustainability Impact on Interior Design Solutions
Rashdan, Wael .......................................................................................................................... 1-309

Study on a Determination of Design Policies for Solar-Boats with Different Design Philosophies
Oizumi, Kazuya; Aoyama, Kazuhiro ....................................................................................... 1-319

DESIGN FOR A HEALTHY LIFE

Remember to Remember: A Feasibility Study Adapting Wearable Technology to the Needs of People Aged 65 and Older with Mild Cognitive Impairment (MCI) and Alzheimer’s Dementia
Maier, Anja M; Özkil, Ali Gürcan; Bang, Maria M; Forchhammer, Birgitte H ..................... 1-331

Prototyping and Testing Basic Designs of Centrifugal Microluidic Platforms for Biomedical Diagnostics
Fox, Stephan Cecil; Lohmeyer, Quentin; Meboldt, Mirko .................................................... 1-341

A New Design System of Below-Limb Prostheses - the Role of a Visual Prosthetic Designer
Sansoni, Stefania; Wodehouse, Andrew; Buis, Arjan ............................................................. 1-351

A Knowledge-Based Design Process for Custom Made Insoles
Marinelli, Paola; Mandolini, Marco; Germani, Michele ....................................................... 1-371

Improving Wellbeing for Victims of Crime
Kaldor, Lucy Joanna; Watson, Rodger ..................................................................................... 1-381

Can the Sports Design Process Help the inclusive Design Community?
Wilson, Nicky; Thomson, Avril; Riches, Philip ....................................................................... 1-391

Applying Design Ethnography to Product Evaluation: A Case Example of a Medical Device in a Low-Resource Setting
Mohedas, Ibrahim; Sabet Sarvestani, Amir; Daly, Shanna R.; Sienko, Kathleen H. ........... 1-401

Applying Fishbein’s Multi-Attribute Attitude Model to the Tata Swach Water Purifier
Ricks, Sean T; Winter V, Amos G ........................................................................................... 1-411

Design for Physical Activity: Design Aspects of Wearable Activity Trackers
Kuru, Armağan; Erbuğ, Çağdem ............................................................................................. 1-421

The Effects of Training Background and Design tools on Multi-Level Biosystems Design
Egan, Paul; Ho, Tiffany; Schunn, Christian; Cagan, Jonathan; LeDuc, Philip ....................... 1-433
Designing for the Deepest Needs of Both Public Service Consumers and Providers; Innovation in Mental Health Crisis Response
Van der Bijl-Brouwer, Mieke; Watson, Rodger ..................................................1-443

Design and Validation of Diagnosis Tool of Inclusion of Children with Disabilities in Playgrounds
Mejía Piedrahita, Tatiana .......................................................................................1-453

The HESD-Model: Merging Multiple Perspectives and Creating Flexible Use Scenarios for Service Design in Healthcare
Sarri, Tommaso; Kleinsmann, Maaike; Melles, Marijke ........................................1-465

A Multi-Level Activity Analysis for Home Healthcare ICT Tool Redesign
Borgiel, Katarzyna; Christophe, Merlo; Minel, Stéphanie .....................................1-475

A Comprehensive Process of Care Coordination: A Skin Cancer Application
Boudjemil, Sonia; Duong, Tu-Anh; Jankovic, Marija; Le Cardinal, Julie ...............1-485

The Competitive Advantage of Using 3D-Printing in Low-Resource Healthcare Settings
Rismani, Shalaleh; Van der Loos, H.F.Machiel .......................................................1-495

Designing Child-Sized Hospital Architecture: Beyond Preferences for Colours and Themes
Verschoren, Laure; Annemans, Margo; Van Steenwinkel, Iris; Heylighen, Ann ....1-505

DESIGN FOR A CONTENTED LIFE

A Framework for Understanding, Communicating and Evaluating User Experience Potentials
Kremer, Simon; Lindemann, Udo .............................................................................1-515

Why Product Design Support for Improved Worker Contentedness?
Farrugia, Lawrence; Borg, Jonathan .....................................................................1-525

Design for Infants is not Design for Children: On the Quest of Tools to Model a Method to Design for Infants
Monsalve, Juliana; Maya, Jorge .............................................................................1-537

Personal Values as a Catalyst for Meaningful Innovations: Supporting Young Designers in Collaborative Practice
Onselen, Lenny Van; Valkenburg, Rianne .........................................................1-547

Reconceptualizing Design Thinking and Equipping Designers for the Next Wave of Digital Innovation
Kleinsmann, Maaike; Snelders, Dirk .....................................................................1-557

Designing with Crime Prevention – Creating Community Wellbeing through Design
Watson, Rodger; Kaldor, Lucy .............................................................................1-565

Development of a National Survey on Aging and the Domestic Bathroom: the Livable Bathrooms Survey
Mintzes, Alicia; Bridge, Catherine; Demirbilek, Oya ...........................................1-575

Design for Contented Life: A Proposed Framework
Ashour, Ayman Fathy .........................................................................................1-585
VOLUME 2: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN THEORY AND RESEARCH METHODOLOGY, DESIGN PROCESSES

DESIGN THEORY AND METHODOLOGY

Case Study: Individualization of a Fully Automated Coffee Machine
Kosiol, Maike; Böhmer, Annette Isabel; Lindemann, Udo ......................................................... 2-1

Design of Medical Devices for Pressure Ulcer Prevention
Velasquez, Alejandro; Almonacid, Ana Maria; Jaramillo, Lisa Maria; Aramburo, Mauricio; Velasquez, David; Iza, Camilo; Zapata, Luis Miguel ................................................................. 2-13

Bioinspired Design: A Case Study of Reconfigurable Crawling-Rolling Robot
Kapilavai, Aditya; Mohan, Rajesh Elara; Tan, Ning ................................................................. 2-23

Computational Design-to-Fabrication Using Spatial Grammars: Automatically Generating Printable Car Wheel Design Variants
Chen, Tian; Shea, Kristina ................................................................. 2-35

Virtual Validation of Functional Automotive Door Assembly Properties by Means of Superposed CAT and FEM Analysis
Ehlert, Matthias; Heling, Björn; Wartzack, Sandro ................................................................. 2-45

Generic Technique and the Dynamics of Technologies: Using Matroid and Design Theory to Design Techniques with Systemic Impact
Le Masson, Pascal; Hatchuel, Armand; Kokshagina, Olga; Weil, Benoit ......................................... 2-55

Definition of the Form-Based Design Approach and Description of it Using the FBS Framework
Filippi, Stefano; Barattin, Daniela ................................................................. 2-65

Effectiveness of the Systematic Engineering Design Methodology
Motte, Damien ................................................................. 2-77

Product Line Design, Evolution and Pricing
Wu, Shuli; Chen, Songlin ................................................................. 2-87

An Approach for Industrial Application of Axiomatic Design
Weber, Jakob; Kößler, Johannes; Paetzold, Kristin ................................................................. 2-97

Dittenberger, Sandra; Koscher, Andrea ................................................................. 2-107

A Search and Optimization Perspective on Conceptual Design
Kroll, Ehud; Weisbrod, Gil ................................................................. 2-117

Attributes in Integrated Design Engineering - A New Way to Describe both Performance Capability and Behaviour of a Product
Vajna, Sandor J. ................................................................. 2-127

Designing PSI: An Introduction to the PSI Framework
Reich, Yoram; Subrahmanian, Eswaran ................................................................. 2-137

Improving Design Methodology: Systematic Evaluation of Principle Synthesis
Katzwinkel, Tim; Heller, Jan Erik; Schmid, Alexander; Schmidt, Walter; Löwer, Manuel; Feldhusen, Jörg ................................................................. 2-147
Towards Genetic Modeling of Machines for Engineering Design Synthesis
Shah, Jami .................................................................................................................................2-155

Challenges in Developing an Ontology for Problem Formulation In Design
Dinar, Mahmoud; Park, Yong-Seok; Shah, Jami J ........................................................................2-165

Biocards and Level of Abstraction
Lenau, Torben Anker; Keshwani, Sonal; Chakrabarti, Amaresh; Ahmed-Kristensen, Saeema ........................................................................................................................................................................2-177

Using Biology as a Model for Sustainability: Insights for Ecodesign and Bioinspired Design Practitioners
O'Rourke, Julia; Seepersad, Carolyn Conner ................................................................................2-187

Influence of Information and Knowledge from Biology on the Variety of Technical Solution Ideas
Hashemi Farzaneh, Helena; Helms, Katharina; Lindemann, Udo .................................................................................................................................2-197

Biologically Inspired Fault Adaptive Strategies for Engineered Systems
Jensen, David Charles; Huisman, Nicholas .....................................................................................2-207

Visual Representations as a Bridge for Engineers and Biologists in Bio-Inspired Design Collaborations
Hashemi Farzaneh, Helena; Helms, Katharina; Lindemann, Udo ......................................................2-215

Modeling Biological Systems to Facilitate their Selection During a Bio-Inspired Design Process
Fayemi, Pierre-Emmanuel Ifeolohoum; Maranzana, Nicolas; Aoussat, Ameziane; Chekchak, Tarik; Bersano, Giacomo ........................................................................................................................................................................2-225

System for Deriving Diverse Solutions via a Modification Method for Emergent Design
Sato, Koichiro; Matsuoka, Yoshiyuki ...............................................................................................2-235

Design Repository & Analogy Computation via Unit-Language Analysis (Dracula) Matching Algorithm Development
Briana, Lucero; Julie, Linsey; Turner, Cameron ...............................................................................2-245

Computational Support of Design Concept Generation through Interaction of Sketching, Ontology-Based Classification and Finding Voids
Nomaguchi, Yutaka; Nakagiri, Taku; Fujita, Kikuo ........................................................................2-257

Ontology in Design Engineering: Status and Challenges
Lim, Soon Chong Johnson; Liu, Ying; Chen, Yong ........................................................................2-267

Designing with Priorities and Thresholds for Health Care Heterogeneity: the Approach of Constructing Parametric Ontology
Eivazzadeh, Shahryar; Anderberg, Peter; Berglund, Johan; Larsson, Tobias .................................2-277

Design Talking: An Ontology of Design Methods to Support a Common Language of Design
Roschuni, Celeste; Kramer, Julia; Zhang, Qian; Zaksorn, Lauren; Agogino, Alice .........................2-285
DESIGN RESEARCH METHODOLOGY

Measuring Prototypes - A Standardized Quantitative Description of Prototypes and their Outcome for Data Collection and Analysis
Jensen, Matilde Bisballe; Balters, Stephanie; Steinert, Martin ................................. 2-295

Modelling in Business Model Design: Reflections on Three Experimental Cases In Healthy Living
Simonse, Lianne W.L.; Badke-Schaub, Petra ................................................................. 2-309

Distributed Experiments in Design Sciences, a Next Step in Design Observation Studies?
Kriesi, Carlo; Steinert, Martin; Aalto-Setälä, Laura; Anvik, Anders; Balters, Stephanie; Baracchi, Alessia; Bisballe Jensen, Matilde; Bjørkli, Leif Erik; Buzzaccaro, Nicolo; Cortesi, Dario; D’Onghia, Francesco; Dosi, Clio; Franchini, Giulia; Fuchs, Matt; Gerstenberg, Achim; Hansen, Erik; Hiekkanen, Karii Matias; Hyde, David; Ituarte, Iñigo; Kalasniemi, Jani; Kurikka, Joona; Lanza, Irene; Laurila, Anssi; Lee, Tik Ho; Lønvik, Siri; Mansikka-Aho, Anniina; Nordberg, Markus; Oinonen, Päivi; Pedrelli, Luca; Pekuri, Anna; Rane, Enna; Reime, Thov; Repokari, Lauri; Rønningen, Martin; Rowlands, Stephanie; Sjöman, Heikki; Slättseven, Kristoffer; Strachan, Andy; Strømstad, Kirsti; Suren, Stian; Tapio, Peter; Utriainen, Tuuli; Vignoli, Matteo; Vijaykumar, Saurabh; Welo, Torgeir; Wuwik, Andreas .............................................................. 2-319

Teaching Nurses CAD: Identifying Design Software Learning Differences in a Non-Traditional User Demographic
Stephenson, Katherine Jo; Pickham, David; Aquino Shluzas, Lauren ................................ 2-329

Differences in Analysis and Interpretation of Technical Systems by Expert and Novice Engineering Designers
Ruckpaul, Anne; Nelius, Thomas; Matthiesen, Sven .................................................... 2-339

Mobile Eye Tracking in Usability Testing: Designers Analysing the User-Product Interaction
Mussgnug, Moritz; Waldern, Michael Frederick; Meboldt, Mirko .................................. 2-349

How we Understand Engineering Drawings: An Eye Tracking Study
Investigating Skimming and Scrutinizing Sequences
Lohmeyer, Quentin; Meboldt, Mirko ................................................................................... 2-359

Reviewing Peer Review, an Eye Tracking Experiment of Review Behaviour
Boa, Duncan R; Hicks, Ben ............................................................................................... 2-369

DESIGN PROCESSES

Enhanced Analytical Model for Planning the Verification, Validation & Testing Process
Yakov, Shabi; Reich, Yoram ............................................................................................... 2-379

ICED15 xvii
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Product and Process Models: Towards an Integrated Framework and Review</td>
<td>Eckert, Claudia; Albers, Albert; Bursac, Nikola; Chen, Hilario Xin; Clarkson, P. John; Gericke, Kilian; Gladysz, Bartosz; Maier, Jakob F.; Rachenkova, Galina; Shapiro, Daniel; Wynn, David</td>
<td>2-389</td>
</tr>
<tr>
<td>FBS Models: An Attempt at Reconciliation Towards a Common Representation</td>
<td>Spreafico, Christian; Fantoni, Gualtiero; Russo, Davide</td>
<td>2-399</td>
</tr>
<tr>
<td>Modelling Practices Over Time: A Comparison of Two Surveys Taken 20 Years Apart</td>
<td>Moullec, Marie-Lise; Maier, Jakob; Cassidy, Stephen; Sommer, Anita F.; Clarkson, P. John</td>
<td>2-409</td>
</tr>
<tr>
<td>Value Modelling in Aerospace Sub-System Design: Linking Quantitative and Qualitative Assessment</td>
<td>Bertoni, Alessandro; Amnell, Henrik; Isaksson, Ola</td>
<td>2-421</td>
</tr>
<tr>
<td>Process Types and Value Configuration in Modelling Practice – An Empirical Study of Modelling in Design and Service</td>
<td>Sommer, Anita Friis; Maier, Jakob; Mak, Jonathan; Moullec, Marie-Lise; Cassidy, Stephen; Clarkson, P. John</td>
<td>2-431</td>
</tr>
<tr>
<td>Towards the Next Generation of Design Process Models: A Gap Analysis of Existing Models</td>
<td>Costa, Daniel Guzzo; Macul, Victor Cussiol; Costa, Janaina Mascarenhas Hornos; Exner, Konrad; Pförtner, Anne; Stark, Rainer; Rozenfeld, Henrique</td>
<td>2-441</td>
</tr>
<tr>
<td>An Investigation of Design Process Changes</td>
<td>Shapiro, Daniel; Sommer, Anita Friis; Clarkson, Peter John</td>
<td>2-451</td>
</tr>
<tr>
<td>Structure-Based System Dynamics Analysis - A Case Study of Benchmarking Process Optimization</td>
<td>Kasperek, Daniel; Berger, Sandra; Maisenbacher, Sebastian; Lindemann, Udo; Maurer, Maik</td>
<td>2-461</td>
</tr>
<tr>
<td>The Long Road to Improvement in Modelling and Managing Engineering Design Processes</td>
<td>Gericke, Kilian; Eckert, Claudia</td>
<td>2-471</td>
</tr>
</tbody>
</table>
DESIGN ORGANISATION AND MANAGEMENT

The Evolution of Terminology within a Large Distributed Engineering Project
Gopsill, James Anthony; Jones, Simon; Snider, Chris; Shi, Lei; Hicks, Ben James .................3-1

Different Levels of Product Model Granularity in Design Process Simulation
Maier, Jakob F.; Eckert, Claudia M.; Clarkson, P. John ...................................................3-11

Modularization Management and Network Configuration
Hansen, Poul Kyvsgaard; Nielsen, Louise Møller .................................................................3-21

Influence of Design-For-X Guidelines on the Matching Between
the Product Architecture and Supply Network
Behncke, Florian G. H.; Thimet, Paula; Barton, Benjamin; Lindemann, Udo .......................3-31

A Study to Identify Engineering Design Resources in Complex
Product Development Projects
Xin Chen, Hilario Lorenzo; Clarkson, Peter John; Sommer, Anita Friis ......................3-43

Matching Product Architecture and Supply Network - Systematic Review
and Future Research
Behncke, Florian G. H.; Kayser, Liza; Lindemann, Udo .......................................................3-53

Understanding Engineering Projects: An Integrated Vehicle Health
Management Approach to Engineering Project Monitoring
Snider, Chris; Gopsill, James A.; Jones, Simon; Shi, Lei; Hicks, Ben ..........................3-65

Implementation of R&D Management Models in Global Organisations
Johansson, Glenn; Säfsten, Kristina; Adolfsson, Ann-Cathrine ........................................3-75

An Agent-Based Approach to Support Planning for Change During Early Design
Fernandes, João; Henriques, Elsa; Silva, Arlindo; Pimentel, César ...............................3-83

Considering Risk Attitude in a Value of Information Problem
Hsiao, Chuck; Malak, Richard ......................................................................................3-93

Crisis Situations in Engineering Product Development - A Method to Identify Crisis
Muenzberg, Christopher; Venkataraman, Srinivasan; Hertrich, Nicolas;
Fruehling, Carl; Lindemann, Udo ........................................................................3-103

Safety of Individual Products – Perspectives in the Context of
Current Practices and Challenges
Roth, Michael; Gehricher, Steffi; Lindemann, Udo .........................................................3-113

Utilizing Failure Information for Mission Analysis for Complex Systems
DeStefano, Charlie; Jensen, David .................................................................................3-123

Framing in Design: A Formal Analysis and Failure Modes
Vermaas, Pieter; Dorst, Kees; Thurgood, Clementine ................................................3-133

Design Driven Startups
Petersen, Søren Ingomar ......................................................................................3-143
Characteristics and Enablers of Transparency in Product Development
Risk Management
Shaffer, Ryan M.; Olechowski, Alison L.; Seering, Warren P.; Ben-Daya, Mohammad .......................................................... 3-153

Actor-Based Signposting: A Modeling Tool to Improve the Socio-Technical Design Processes
Hassannezhad, Mohammad; Cantamessa, Marco; Montagna, Francesca ......................... 3-165

The Impact of Technology Uncertainty on Early Supplier Integration in Product Development
Geissmann, Lukas; Rebentisch, Eric Scott ...................................................... 3-175

Impact of Architecture Types and Degree of Modularity on Change Propagation Indices
Colombo, Edoardo Filippo; Cascini, Gaetano; De Weck, Olivier L. .................................. 3-187

Dependency Identification for Engineering Change Management (ECM): An Example of Computer-Aided Design (CAD)-Based Approach
Masmoudi, Mahmoud; Leclaire, Patrice; Zolghadri, Marc; Haddar, Mohamed .................... 3-199

An Intelligent Design Environment for Changeability Management
- Application To Manufacturing Systems
Benkamoun, Nadjee; Kouiss, Khalid; Huyet, Anne-Lise ................................................. 3-205

Changes on Changes: Towards an Agent-Based Approach for Managing Complexity in Decentralized Product Development
Kehl, Stefan; Stiefel, Patrick; Müller, Jörg P. ............................................................... 3-215

How to Integrate Information about Past Engineering Changes in New Change Processes?
Wickel, Martina Carolina; Lindemann, Udo ............................................................... 3-229

Envisioning Products to Support the Agile Management of Innovative Design
Carvalho, Fabio Henrique Trovon De; Costa, Janaina Hornos Mascarenhas Da; Amaral, Daniel Capaldo .......................................................... 3-239

Exploring Tensions Between Creativity and Control in Product Development Projects
Bojesson, Catarina; Backstrom, Tomas; Bjurstrom, Erik ............................................. 3-249

Constant Dripping Wears Away the Stone: Linking Design Thinking and Effectual Action in Designing New Ventures
Niedworok, Anja; Schloegl, Stephan; Mirski, Peter J.; Greger, Rudolf; Ambrosch, Marcus .......................................................... 3-259

Constructing a Multi-Dimensional Model to Understand Team Design through Language
Xu, Jiang; Guo, Feng; Gan, Xiang; Wang, Xiuyue ...................................................... 3-269

The Use and Value of Different Co-Creation and Tools in the Design Process.
Ali, Abu; Liem, Andre .......................................................... 3-279
Physical Interaction Mappings: Utilizing Cognitive Load Theory in order to Enhance Physical Product Interaction
Young, Bryan Gough; Wodehouse, Andrew; Sheridan, Marion 3-289

An Exploratory Study of the Specifications Process in a Customer-Supplier Collaborative New Product Development
Yager, Matthieu; Le Dain, Marie-Anne; Merminod, Valéry 3-299

Correlations Between Successful Consumer Goods in the Market and Creativity in Form And Function Attributes
Sehn, Cristina Morandi; Bernardes, Mauricio Moreira E Silva; Jacques, Jocelise Jacques De 3-309

Meetings in The Product Development Process: Applying Design Methods to Improve Team Interaction and Meeting Outcomes
Bavendiek, Ann-Kathrin; Thiele, Lisa; Meyer, Patrick; Vietor, Thomas; Kauffeld, Simone; Fingscheidt, Tim 3-319

Modelling of Immersive Systems for Collaborative Design
Rohmer, Serge 3-329

Online Ways of Sharedness: A Syntactic Analysis of Design Collaboration in OpenIDEO
Bianchi, Joost; Knopper, Yuri; Eris, Ozgur; Badke-Schaub, Petra; Roussos, Lampros 3-339

Can Algorithms Calculate The “Real” Sharedness in Design Teams?
Yamada, Kaori; Badke-Schaub, Petra; Eris, Ozgur 3-349

How an Open Source Design Community Works: The Case of Open Source Ecology
Macul, Víctor; Rozenfeld, Henrique 3-359

A Framework of Working across Disciplines in Early Design and R&D of Large Complex Engineered Systems
McGowan, Anna-Maria Rivas; Papalambros, Panos; Baker, Wayne 3-367

Identifying and Visualising KPIs for Collaborative Engineering Projects: A Knowledge Based Approach
Shi, Lei; Newnes, Linda; Culley, Steve; Gopsill, James; Jones, Simon; Snider, Chris 3-377

The Sensory Delivery Rooms of The Future: Translating Knowledge across Boundaries in a Public-Private Innovation Partnership
Pedersen, Signe 3-387

Meaning Making in the Intersection between Sketches and 3D Mock-Up
Ali, Abu; Liem, Andre 3-397

Argumentation Analysis in an Upstream Phase of an Innovation Project
Abou Eddahab, Fatima-Zahra; Prudhomme, Guy; Masclet, Cedric; Lund, Kris; Boujut, Jean-François 3-407

Rethinking Operating Models for Intangible Services: From a Mechanistic Structure to a Sustainable Model
Minzoni, Angela; Mounoud, Eleonore 3-417

ICED15 xxi
Pragmatic Team Compositions in Scrum-Based Development Projects
Ovesen, Nis .................................................................3-427

A Longitudinal Study of Globally Distributed Design Teams:
The Impacts on Product Development.
Taylor, Thomas Paul; Ahmed-Kristensen, Saeema ........................................3-437

Boundary Objects in Open Source Design: Experiences from OSE Community
Affonso, Claudia Andressa Cruz; Amaral, Daniel Capaldo ..........................3-447

Work Sampling Approach for Measuring Intellectual Capital Elements
in Product Development Context
Škec, Stanko; Štorga, Mario; Tečec Ribarić, Zlatka; Marjanović, Dorian ........3-457
VOLUME 4: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN FOR X, DESIGN TO X

Approach to Consider Rapid Manufacturing in the Early Phases of Product Development
Weiss, Florian; Binz, Hansgeorg; Roth, Daniel ................................................................. 4-1

Result Visualization and Documentation of Tolerance Simulations of Mechanisms
Walter, Michael Simon Josef; Pribek, Michael; Spruegel, Tobias Constantin; Wartzack, Sandro ................................................................. 4-11

The Design and Manufacture of Individualised Perfect-Fit Packaging Solutions
Dhokia, Vimal; Newman, Stephen Thomas ........................................................................ 4-21

Assembly Sequence Planning with the Principles of Design for Assembly
Sąsiadek, Michał .................................................................................................................. 4-31

Handling Product Variety in a Mixed-Product Assembly Line: A Case Study
Asadi, Narges; Jackson, Mats; Fundin, Anders ................................................................. 4-41

Design for Recovery - Applying Multivariate Statistics to Define Groupings of French WEEE Pre-Treatment Operators
Alonso Movilla, Natalia; Zwolinski, Peggy ........................................................................ 4-51

Design for Retrofitting
Coenen, Jenny; Ruiz, Valentina; Fernandez Hernando, Jose Manuel; Frouws, Koos ................................................................. 4-61

The Realization of an Engineering Assistance System for the Development of Noise-Reduced Rotating Machines
Küstner, Christof; Wartzack, Sandro .................................................................................. 4-71

Development of Portability Design Heuristics
Hwang, Dongwook; Park, Woojin ......................................................................................... 4-81

Dealing with Non-Trade-Offs for Frugal Design
Lecomte, Chloë; Blanco, Eric ............................................................................................... 4-91

Exploring Benefits of Using Augmented Reality for Usability Testing
Choi, Young Mi; Mittal, Sanchit .......................................................................................... 4-101

Development of an Interface Analysis Template for System Design Analysis
Uddin, Amad; Campean, Felician; Khan, Mohammed Khurshid ........................................ 4-111

The Application of Crowdsourcing for 3D Interior Layout Design
Wu, Hao; Corney, Jonathan; Grant, Michael ...................................................................... 4-123

Assessing Time-Varying Advantages of Remanufacturing: A Model for Products with Physical and Technological Obsolescence
Kwak, Minjung; Kim, Harrison ........................................................................................... 4-135
Product Development in Low-Volume Manufacturing Industries: Characteristics and Influencing Factors
Javadi, Siavash; Bruch, Jessica; Bellgran, Monica .......................................................... 4-145

Methodical Support for Concurrent Engineering across Product and Production (System) Development
Stoffels, Pascal; Vielhaber, Michael .......................................................... 4-155

Modeling Factory Systems Using Graphs - Ontology-Based Design of a Domain Specific Modeling Approach
Plehn, Christian; Stein, Florian; Reinhart, Gunther .......................................................... 4-163

Tasks and Challenges in Prototype Development with Novel Technology – An Empirical Study
Ravn, Poul Martin; Guðlaugsson, Tómas Vignir; Mortensen, Niels Henrik .......................................................... 4-173

Design-For-Manufacture of Sheet-Bulk Metal Formed Parts
Breitsprecher, Thilo; Sauer, Christopher; Sperber, Christian; Wartzack, Sandro .......................................................... 4-183

Digital Aesthetic of New Products Obtained by Selective Laser Melting Process
Galimberti, Giorgia; Guagliano, Mario; Previtali, Barbara; Rampino, Lucia .......................................................... 4-193

Additive Manufacturing Design Feature Selection for Variable Product Platforms
Yao, Xiling; Moon, Seung Ki; Bi, Guijun .......................................................... 4-205

Approach for a Comparatively Evaluation of the Sustainability for Additive Manufactured Aluminum Components
Lachmayer, Roland; Gottwald, Philipp; Lippert, Rene Bastian .......................................................... 4-215

Indicators and Design Strategies for Direct Part Production by Additive Manufacturing
Leutenecker, Bastian; Klahn, Christoph; Meboldt, Mirko .......................................................... 4-225

Design Method and Taxonomy of Optimized Regular Cellular Structures for Additive Manufacturing Technologies
Savio, Gianpaolo; Gaggi, Flavio; Meneghello, Roberto; Concheri, Gianmaria .......................................................... 4-235

Design for Mass Customization Using Additive Manufacture: Case-Study of a Balloon-Powered Car
Chen, Tian; Fritz, Stöckli; Shea, Kristina .......................................................... 4-245

A Call for FDM Design Rules to Include Road Deposition
Fornasini, Giacomo; Schmidt, Linda C. .......................................................... 4-255

Redefining Product Family Design for Additive Manufacturing
Lei, Ningrong; Moon, Seung Ki; Rosen, David W. .......................................................... 4-267

Combining Additive Manufacturing with CFRP Composites: Design Potentials
Türk, Daniel-Alexander; Züger, Andreas; Klahn, Christoph; Meboldt, Mirko .......................................................... 4-279

Crowdsourced Design Principles for Leveraging the Capabilities of Additive Manufacturing
Perez, K Blake; Anderson, David S; Holta-Otto, Katja; Wood, Kristin L .......................................................... 4-291
Exploring the Significance of In-Process Knowledge to Composites Design and Production
Jones, Helene Victoria; Chatzimichali, Anna; Potter, Kevin; Ward, Carwyn 4-301

Natural Fibre-Reinforced, Injection Moulded Polymers for Lightweight Constructions – Simulation of Sustainable Materials for the Automotive Industry –
Albrecht, Katharina; Osswald, Tim; Wartzack, Sandro; Müssig, Jörg 4-313

Energy Efficiency Oriented Development of Production Systems
Stoffels, Pascal; Vielhaber, Michael 4-323

Evaluation of a Strategic Method to Improve Prototype Performance with Reduced Cost and Fabrication Time
Camburn, Bradley Adam; Jensen, Daniel; Crawford, Richard;
Otto, Kevin; Wood, Kristin 4-333

A Generic Approach to Sensitivity Analysis in Geometric Variations Management
Schleich, Benjamin; Wartzack, Sandro 4-343
Kang, Namwoo; Emmanoulopoulos, Manos; Ren, Yi; Feinberg, Fred M.; Papalambros, Panos Y. ................................................................. 5-1

A Comparison of Conjoint Analysis and Interactive Genetic Algorithms for the Study of Product Semantics
Petiot, Jean-François; Francisco, Cervantes Chavez; Ludivine, Boivin ..................................................... 5-11

Stakeholders’ Diverging Perceptions of Product Requirements: Implications in the Design Practice
Borgianni, Yuri; Rotini, Federico .................................................. 5-21

The Malicious Labyrinth of Requirements - Three Types of Requirements for a Systematic Determination of Product Properties
Mattmann, Ilyas; Gramlich, Sebastian; Kloberdanz, Hermann .................................................. 5-31

Requirements Checklists: Benchmarking the Comprehensiveness of the Design Specification
Becattini, Niccolo; Cascini, Gaetano; Rotini, Federico .................................................. 5-41

Considering User’s Impact in Validation Activities – An Approach for the Determination of Requirements
Pinner, Tobias; Jost, Franz; Schmid, Daniel; Albers, Albert .................................................. 5-51

Understand the Design Requirement in Companies
Li, Xuemeng; Ahmed-Kristensen, Saeema .................................................. 5-63

A Product Planning of E-Sports Headphone by Blending Replication ZMET with QFD
Wang, Hung-Hsiang .................................................. 5-75

Quality Function Deployment Using Multispace Design Model and its Application
Kato, Takeo; Horiuchi, Shigehiro; Miwa, Toshiharu; Matsuoka, Yoshiyuki .................................................. 5-83

Moreno Grandas, Diana Paola; Blessing, Luciènne; Yang, Maria; Wood, Kristin .................................................. 5-93

A Qualitative Investigation of Ideation Practices in Engineering and Product Design
Currano, Rebecca; Henriksson, Emily .................................................. 5-105

Synthesis of Conceptual Designs for Sensors Using SAPPhIRE-lite
Sarkar, Biplab; Chakrabarti, Amaresh; Ananthasuresh, G.K .................................................. 5-115

When Costs from Being a Constraint Become a Driver for Concept Generation
Altavilla, Stefania; Montagna, Francesca .................................................. 5-125
Form Follows Data: A Method to Support Concept Generation
Coupling Experience Design with Motion Capture.
Camere, Serena; Caruso, Giandomenico; Bordegoni, Monica;
Di Bartolo, Carmelo; Mauri, Duccio; Pisino, Enrico .......................... 5-135

Integrated Function Modelling: Comparing the IFM Framework with SysML
Eisenbart, Boris; Mandel, Constantin; Gericke, Kilian; Blessing, Lucienne .......................... 5-145

Capture of Actual Development Processes of Hybrid Intelligent
Design Elements in Order to Define a Target Development Process
Crostack, Alexander; Binz, Hansgeorg; Roth, Daniel .......................... 5-157

Improving Generative Grammar Development and Application
through Network Analysis Techniques
Königseder, Corinna; Stanković, Tino; Shea, Kristina .......................... 5-167

Management and Visualization of Relationships Between Engineering Objects
Pavkovic, Neven; Martinec, Tomislav; Rohde, Daniel; Sikic, Bruno .......................... 5-177

Evaluating the Need for Traceability in Product Development:
A Preliminary Study
Koehler, Nico; Naumann, Thomas; Vajna, Sandor .......................... 5-187

Building Brands Through Design: A Systematic Bibliographical Review
Michelini, Gustavo; Amaral, Daniel Capaldo .......................... 5-197

On the Development of Visualisation Concepts as Tools in Product Design
Gebhardt, Nicolas; Krause, Dieter .......................... 5-205

Evaluation of Clay Modelling and Surfacing Cycles From Designers Perspective
Chandra, Sushil .......................... 5-215

Determining the Similarity of Products Using Pairwise Comparisons
and Eye Tracking
Boa, Duncan R; Ranscombe, Charlie; Hicks, Ben .......................... 5-225

The Value of Prototypes in the Early Design and Development Process
Isa, Siti Salwa; Liem, Andre; Steinert, Martin .......................... 5-235

An Automated Function Decomposition Method Based on a
Formal Representation of Solid Material’s Shape
Yuan, Lin; Zhang, Zhinan; Liu, Yusheng .......................... 5-243

A Bayesian Network Approach to Improve Change Propagation Analysis
Lee, Jihwan; Hong, Yoo S. .......................... 5-253

Digital Intermediary Objects: The (Currently) Unique Advantage
of Computer-Supported Design Tools
Guerra, Andrea Luigi; Gidel, Thierry; Vezzetti, Enrico .......................... 5-265

An Approach to the Property-Based Planning of Simulations
Reitmeier, Jochen; Chahin, Abdol; Paetzold, Kristin .......................... 5-275

Applying Matrix-Based Methods for Improving User Experience
of a Driver Advisory System
Michailidou, Ioanna; Diergarten, Lorenz; Lindemann, Udo .......................... 5-287

Eco-Evaluation of Technical Systems in the Conceptual Phase
Midžić, Ida; Štorga, Mario; Marjanović, Dorian .......................... 5-299
Designing of Hybrid Joints at the Early Embodiment Design Stage
Kellermeyer, Markus; Klein, Daniel; Wartzack, Sandro ........................................5-309

Extension of the Lightweight Design Thinking Tools for the Application
on More Complex Problems
Posner, Benedikt; Binz, Hansgeorg; Roth, Daniel ........................................5-319

A Methodical Approach to Model and Map Interconnected Decision Making
Situations and their Consequences
Luft, Thomas; Schneider, Samuel; Wartzack, Sandro ........................................5-329

Using Balance Variables to Describe System Interfaces
and Assess In-Progress Designs
Salustri, Filippo Arnaldo; Rogers, Damian ..................................................5-341

Real-Time Product Recovery Decision Making Algorithm
for Sustainability
Kanchanasri, Passaporn; Moon, Seung Ki; Ng, Gary Ka Lai ..........................5-351
A Visual Interface Diagram for Mapping Functions in Integrated Products
Ingerslev, Mattias; Jespersen, Mikkel Oliver; Göhler, Simon Moritz; Howard, Thomas J. .......................................................... 6-1

How to Define a Sustainability Design Space
Hallstedt, Sophie .......................................................... 6-11

Highlighting the Importance of Testing in the Product Development Process
Tahera, Khadija; Eckert, Claudia; Earl, Chris .......................................................... 6-21

Rerouting Failure Flows Using Logic Blocks in Functional Models
for Improved System Robustness: Failure Flow Decision Functions
Short, Adam R.; Van Bossuyt, Douglas Lee ........................................................................ 6-31

Integrated Approach for Efficient Tolerance Optimization
on Sheet Metal Parts
Litwa, Frank; Gottwald, Martin; Vielhaber, Michael .......................................................... 6-41

An Approach to Analysing Interface Uncertainty Using the Contact and Channel Model
Freund, Tillmann; Kloberdanz, Hermann; Lotz, Julian; Würtenberger, Jan .......................................................... 6-53

A Robust Design Applicability Model
Ebro, Martin; Krogstie, Lars; Howard, Thomas J. .......................................................... 6-63

Measuring Functional Robustness With Network Topological Robustness Metrics
Haley, Brandon; Dong, Andy; Tumer, Irem .......................................................... 6-75

Design Roadmapping: Challenges and Opportunities
Kim, Euiyoung; Yao, Shun; Agogino, Alice Merner .......................................................... 6-85

Avoiding Resonant Frequencies in a Pipeline Application by Utilising the Concept Design Analysis Method
Khamuknin, Alexander; Bertoni, Marco; Eres, Murat Hakki .......................................................... 6-95

Introduction of a Computational Approach for the Design of Composite Structures at the Early Embodiment Design Stage
Klein, Daniel; Malezki, Waldemar; Wartzack, Sandro .......................................................... 6-105

Assessing the Differences Between Numerical Methods, CAD Evaluations and Real Experiments for the Assessment of Reach Envelopes of the Human Body
Delangle, Mathieu; Petiot, Jean-François; Poirson, Emilie .......................................................... 6-115

Efficient Design Evaluation Through the Combination of Numerical and Physical Computations
Foehr, André G. C.; Stücheli, Marius; Meboldt, Mirko .......................................................... 6-125

Simultaneous Optimisation: Strategies for Using Parallelization Efficiently
Wünsch, Andreas; Jordan, André; Vajna, Sándor .......................................................... 6-133
Stack-Up Analysis of Statistical Tolerance Indices for Linear Function Model Using Monte Carlo Simulation
Otsuka, Akimasa; Nagata, Fusaomi ..............................6-143

Taking Into Account the Change of Geometry in System Simulation Processes
Mauser, Kristian; Breitsprecher, Thilo; Hasse, Alexander; Wartzack, Sandro .................6-153

Functional Assembly Using Synaptic Networks: Theory and a Demonstration Case Study
Mavrikas, Georgios; Spitas, Vasilios; Spitas, Christos ...........................................6-163

Integrating the Ability for Topology Optimization in a Commercial CAD-System
Schmelcher, Johannes; Stetter, Ralf; Till, Markus ...............................................6-173

Concept and Application of Automatic Part-Recognition with Artificial Neural Networks for FE Simulations
Spruegel, Tobias C.; Wartzack, Sandro .................................................................6-183

Simulation Ready CAD-Models as a Means for Knowledge Transfer Between Technology Development and Product Development
Johansson, Joel; André, Samuel; Elgh, Fredrik .......................................................6-195

Definition of the Collaborative Simulation System (CM&SS) from a Systemic Perspective in Vehicle Industry Context
Roa Castro, Laura; Stal-Le Cardinal, Julie .................................................................6-205

Graphical Support Adapted to Designers for the Selection of an Optimal Solution in Design By Shopping
Abi Akle, Audrey; Minel, Stéphanie; Yannou, Bernard ...............................................6-215

Heterogeneous Simulated Annealing Teams: An Optimizing Search Algorithm Inspired by Engineering Design Teams
McComb, Christopher; Cagan, Jonathan; Kotovsky, Kenneth ...................................6-225

Feature Based Interpretation and Reconstruction of Structural Topology Optimization Results
Stangl, Thomas; Wartzack, Sandro .................................................................6-235

From Simulation to Invention, Beyond the Pareto-Frontier
Dubois, Sebastien; Lin, Lei; De Guio, Roland; Rasovska, Ivana ..................................6-245

Design for Scalability and Strength Optimisation for Components Created Through FDM Process
Qureshi, A.J.; Mahmood, Shahrain; Wong, W.L.E.; Talamona, Didier ..........................6-255

Fairness and Manipulation: An Empirical Study of Arrow’s Impossibility Theorem
McComb, Christopher; Goucher-Lambert, Kosa; Cagan, Jonathan .............................6-267

Proposal of a Framework for Characterizing Virtual Collectives in the Engineering Design Field
El Badawi El Najjar, Rachad; Blanco, Eric; Pourroy, Franck; Prudhomme, Guy; Maussang-Detaille, Nicolas .................................6-277
Bridging the ‘Valley of Death’ in Product Development:
A Case Study of the Drill Cover Project
Gheorghe, Florin; Hodgson, Antony J.; Van Der Loos, H.F. Machiel .........................6-287

Interactive Immersive Engineering System for Distant Collaboration
Fechter, Marius; Damgrave, Roy Gerhardus Johannes; Wartzack, Sandro ..................6-297

Subject Lines as Sensors: Co-Word Analysis of Email to Support
the Management of Collaborative Engineering Work
Jones, Simon L.; Payne, Stephen J.; Hicks, Ben J.; Gopsill, James A.;
Snider, Chris; Shi, Lei .................................................................6-307
PRODUCT MODULARISATION AND ARCHITECTURE

Assessing Modularisation Transition with Metrics
Heilemann, Markus; Steve, Culley; Meike, Schlueter; Vera, Lindemer ....................................................... 7-1

Cost Prognosis of Modular Product Structure Concepts
Ripperda, Sebastian; Krause, Dieter .......................................................... 7-13

Zapico, Miguel; Eckert, Claudia; Jowers, Iestyn; Earl, Christopher .......................................................... 7-23

Structuring Perceived Quality Attributes for Use in the Design Process
Stylidis, Konstantinos; Landahl, Jonas; Wickman, Casper; Johannesson, Hans; Söderberg, Rikard .......................................................... 7-33

Towards a Decision Support Framework for System Architecture Design
Ben Hamida, Sonia; Jankovic, Marija; Callot, Martine; Monceaux, Anne; Eckert, Claudia .......................................................... 7-43

Framework for Diagnosing Standardization Potential in Current Product Range
Chandra, Sushil .......................................................................................... 7-53

Conceiving Modular Solutions in Early Conceptual Design Activities
Fiorineschi, Lorenzo; Rotini, Federico; Rissone, Paolo .......................................................... 7-63

Platform Concept Development within the Integrated PKT-Approach
Kruse, Moritz; Ripperda, Sebastian; Krause, Dieter .......................................................... 7-73

A Revision of Product Architecture Design for Multi-Modal Products
Liu, Cong; Hildre, Hans Petter; Zhang, Houxiang; Rølvåg, Terje .......................................................... 7-83

The Impact of Criteria in System Architecture Selection: Observation from Industrial Experiment
Moullec, Marie-Lise; Jankovic, Marija; Eckert, Claudia .......................................................... 7-93

Portfolio Management for Electric Drives in Powertools at Hilti: Challenges and Solution Approaches
Ponn, Josef .......................................................................................... 7-105

An Engineering Design Approach to Lithium-Ion Cells - Modular Kit Configuration for an Innovative Technology Application
Tschech, Matthias; Vietor, Thomas ........................................................................ 7-115

Developing an Objective Formulation for Motorcycle Architecture
Chandra, Sushil ...................................................................................... 7-125

Brownfield Process for the Rationalisation of Existing Product Variety Towards a Modular Product Family
Pakkanen, Jarkko; Juuti, Tero; Lehtonen, Timo .......................................................... 7-135
Index-Based Metrics for the Evaluation of Effects of Custom Parts on the Standardization of Mechanical Systems
Sinigalias, Pavlos Christoforos; Dentsoras, Argyris .................................................. 7-145

Design for Embodiment through Smart Archives
Rosa, Francesco; Viganò, Roberto; Rovida, Edoardo .................................................. 7-155

Exploratory Research about the Customization or Personalization of Assistive Products for Walking
Gois, Marcel; Thomann, Guillaume; Autreau, Jeremiah ............................................. 7-165

Product Architecture Design Methodology for Developing Standardized Modules
Thumm, Benjamin Roland; Göhlich, Dietmar ............................................................... 7-175

Sustainability of Modular Product Families
Bahns, Tammo; Beckmann, Gregor; Gebhardt, Nicolas; Krause, Dieter ....................... 7-185

Higher Order Interactions: Product and Configuration Study on DSM Saturation
Phelan, Keith; Summers, Joshua David; Pearce, Brian; Kurz, Mary E. ......................... 7-195

Harnessing Social Media and Cloud-Computing Technologies for Co-Design in Open Collaborative Innovation: The Case of 24 Hours of Innovation
Jimenez-Narvaez, Luz-Maria; Dalkir, Kimiz; Gelinas, Valerie; Gardoni, Mickael ........... 7-207

SYSTEMS ENGINEERING

An Algorithm for Behaviour Prediction of Complex Technical Systems
Osman, Krešimir; Štorga, Mario; Marjanović, Dorian .................................................. 7-217

Cost-Benefit Analysis in Model-Based Systems Engineering: State of the Art and Future Potentials
Eigner, Martin; Huwig, Christian; Dickopf, Thomas .................................................. 7-227

Improving Order Fulfillment Processes with MBSE
Westermann, Thorsten; Anacker, Harald; Dumitrescu, Roman .................................. 7-237

Industrial Application of a Mechatronic Framework
Torry-Smith, Jonas Mørkeberg; Mortensen, Niels Henrik; Ploug, Ole; Achiche, Sofiane ... 7-247

PRODUCT-SERVICE SYSTEMS

A Tool for Facilitating Semantic Reframing of Service Design Insight Discovery
Yuan, Soe-Tsy Daphne; Hsieh, Pei-Kang .................................................. 7-259

A Model to Describe Use Phase of Socio-Technical Sphere of Product-Service Systems
Hollauer, Christoph; Venkataraman, Srinivasan; Omer, Mayada .................................. 7-271

Potential of Nature-Inspired Approach for Organisation Design in Product-Service System
Kim, Sojung; Baek, Joon Sang .................................................. 7-281
Product-Service System (PSS) Design Process Methodologies:
A Systematic Literature Review
Mendes, Glauco H. S.; Oliveira, Maicon Gouvea; Rozenfeld, Henrique;
Marques, Caio Augusto Nunes; Costa, Janaina Mascarenhas Hornos ............7-291
Facilitating Industrial Adoption of Design Methods for
Product-Service Systems
Matschewsky, Johannes; Lindahl, Mattias; Sakao, Tomohiko .....................7-301
An Exploratory Study to Evaluate the Practical Application
of PSS Methods and Tools Based on Text Mining
Marques, Caio Augusto Nunes; Matsuno, Ivone Penque;
Sinoara, Roberta Akemi; Rezende, Solange Oliveira; Rozenfeld, Henrique ..........7-311
Product-Service Systems Representation and Repository for
a Design Support Tool
Kim, Yong Se; Kim, Sohui; Roh, Eunrae .............................................7-321
INNOVATION AND CREATIVITY

INNOVATION

Risk and Innovation Balance in Crowdfunding New Products
Song, Chaoyang; Luo, Jianxi; Hölttä-Otto, Katja; Seering, Warren; Otto, Kevin .................................. 8-1

Open Design Platforms for Open Source Product Development:
Current State and Requirements
Bonvoisin, Jérémy; Boujut, Jean-François ................................................................. 8-11

How to Search for Open Innovation Partners?
Guertler, Matthias R.; Von Saucken, Constantin;
Schneider, Maria; Lindemann, Udo ................................................................. 8-21

Open Innovation Ecosystem: Towards Collaborative Innovation
Böhmer, Annette Isabel; Lindemann, Udo ................................................................. 8-31

Using Crowds in Engineering Design – Towards a Holistic Framework
Panchal, Jitesh H ............................................................................. 8-41

Supporting Need Seeker Innovation: The Radical Innovation Design Methodology
Yannou, Bernard ............................................................................. 8-51

Design Innovation for Societal and Business Change
Thurgood, Clementine; Dorst, Kees; Bucolo, Sam;
Van Der Bijl-Brouwer, Mieke; Vermaas, Pieter ........................................ 8-61

Socio-Technical Design for Resilience: A Case Study of Designing Collaborative Services for Community Resilience
Baek, Joon Sang ............................................................................. 8-71

The Role of Ambiguity and Discrepancy in Early Phases of Innovation
Laursen, Linda Nhu; Tollestrup, Christian ........................................ 8-81

Innovative and Sustainable Design: Perceptions of Experts
Telenko, Cassandra; Wood, Kristin ................................................................. 8-91

Design Methodology Applied for Product Innovation in a Multi-Disciplinary Project – A Case Study
Almefelt, Lars; Claesson, Anders ................................................................. 8-101

A New Knowledge Sourcing Framework to Support KBE Development
Quintana-Amate, Santiago; Bermell-Garcia, Pablo;
Balcazar, Luis; Tiwari, Ashutosh ................................................................. 8-111

An Idea Generation Method for the Late Phases of Engineering Design
Meyer, Andreas Wilhelm; Wünsch, Andreas; Vajna, Sándor; König, Oliver ........................................ 8-121

The Characteristics of Excellent Designers – Findings from an Interview Study with Swedish Innovators
Axelsson, Louise; Blome, Simon; Nourbarpour, Dennis; Nänzen, Johan;
Yvonne, Platon; Malmqvist, Johan Lars ................................................................. 8-131

ICED15 xxxv
Idea Development and its Constituting Elements
– An Empirical Investigation
Karlsson, Anna ................................................................. 8-141

Design Driven Innovation – Minimum Viable Products for Local Entrepreneurship In Nepal
Keitsch, Martina Maria ....................................................... 8-151

A Water Saving Solution with a TRIZ Based Method
Russo, Davide; Spreafico, Christian; Mores, Nicola ........................... 8-163

Production Innovation in Manufacturing Firms:
The Case of Swedish SMEs
Viveros-Eulogio, Brenda; Öhrwall Rönnbäck, Anna; Ramirez-Portilla, Andres ........ 8-173

Investigation and Support of Evolutionary Design
Stetter, Ralf; Möhringer, Stefan; Günther, Joachim; Pulm, Udo ...................... 8-183

A Model of Idea Evaluation and Selection for Product Innovation
Stevanovic, Milan; Marjanovic, Dorian; Storga, Mario .................. 8-193

A Method Model for Distinguishing and Selecting Open Innovation Methods
Von Saucken, Constantin; Gürtler, Matthias; Schneider, Maria; Lindemann, Udo ........ 8-203

The Implementation of Innovation Metrics: A Case Study
Benaim, Andre; Elfsberg, Jenny; Larsson, Tobias C.; Larsson, Andreas ............. 8-213

Innovation Ambidexterity in Medium Size Enterprises
Lavayssière, Pierre; Blanco, Eric; Le Dain, Marie-Anne; Chévrier, Pierre ............... 8-225

Enabling Front End of Innovation in a Mature Development Company
Broennum, Louise; Clausen, Christian ........................................ 8-235

Inverse Technology C-K in Environment C-K to Overcome Design Fixation
Jean, Fabien; Le Masson, Pascal; Weil, Benoît ..................................... 8-245

Maslow Meets the Stonecutter
Winkelman, Paul Martin ............................................................ 8-255

Design Acumen
Petersen, Søren Ingomar ....................................................... 8-265

Formulations of Paradigms of Technical Inheritance
Mozgova, Iryna; Lachmayer, Roland; Gottwald, Philipp ...................... 8-271

The Impact of Design Methods on The Creativity of 1st-Year Engineering Student Projects: The Case Of Computer Programming
Beghelli, Alejandra; Prieto, Pablo ............................................. 8-279

Fusion of Old and New, Creativity In Educational and Historical Way: Board Game with Servicescape Concept in Taipei Tech University Town.
Wang, Sheng-Ming; Huang, Chieh Ju ......................................... 8-289

Reggio Emilia Engineering Education
Vignoli, Matteo; D’Onghia, Francesco ......................................... 8-297
CREATIVITY

Supporting Idea Generation through Functional Decomposition: An Alternative Framing for Design Heuristics
Gray, Colin M.; Yilmaz, Seda; Daly, Shanna; Seifert, Colleen M.; Gonzalez, Richard ..........8-309

A Cross-Functional Approach for the Fuzzy Front End: Highlights from a Conceptual Project
Figueiredo, João Filipe; Correia, Nuno C.; Ruivo, Inês Secca; Alves, Jorge Lino .............8-319

Strategies to Employ Social Networks in Early Design Phases (Idea Generation)
Escandon-Quintanilla, Ma-Lorena; Jimenez-Narvaez, Luz-Maria; Gardoni, Mickael ..........8-329

Modulation of Ambiguity, A Cognitive Function of Representations During Idea Generation
Kasatkina, Olga; De Vries, Erica; Masclet, Cédric; Boujut, Jean-François ...............8-339

Using Idea Materialization to Enhance Design Creativity
Georgiev, Georgi V.; Taura, Toshiharu .................................................................8-349

Creativity Tool Selection for Design Engineers in Idea Generation.
Yan, Yanliuxing; Childs, Peter R N .................................................................8-359

Inspirational Design Briefing Performance
Petersen, Søren Ingomar; Joo, Jaewoo; Takahashi, Shelley .....................................8-371

Evaluation Method which Promote Creativity: Case Study about Ergonomic Design in Pointing Devices
Namayandegi, Mohammad Hossein .................................................................8-379
VOLUME 9: Proceedings of the 20th International Conference on Engineering Design (ICED15)

USER-CENTRED DESIGN

DESIGN OF SOCIO-TECHNICAL SYSTEMS

 USER-CENTRED DESIGN

Empathic-Design Assisted by the Kano Method – A Human-Centered Design Method for Medical Devices Considering Patients
Ahrens, Martin; Hehenberger, Peter .......................................................... 9-1

Navigation System Based on Humane Engineering for Wheelchair Users
Nagai, Yukari; Kihara, Hironori ................................................................. 9-11

A Capability Approach Based Stakeholder Analysis for the Base of the Pyramid: A Case Study Of The Firewood Based Cook-Stoves
Khadilkar, Pramod Ratnakar; Mani, Monto .................................................. 9-23

User Involvement in Product Design Practices: A Case Study on Technologies for Older Adults
Lee, Chaiwoo; Coughlin, Joseph F. ............................................................. 9-33

Inclusive Design; From Physical to Psychosocial - A Literature Analysis Toward a Definition of Psychosocial Dimensions in Design
Lim, Yonghun; Dr. Nickpour, Farnaz ............................................................ 9-45

Description of a Competence Oriented Approach for Designing Technical Assistance Systems
Walter, Johanna; Paetzold, Kristin; Nitsch, Verena .................................. 9-57

Design Towards Better Life Experience: Closing the Gap between Pharmaceutical Packaging Design and Elderly People
Carli Lorenzini, Giana; Olsson, Annika ......................................................... 9-65

Design for Assistive Technology Applications: Usefulness of Re-Use?
Walsh, Edwin Peter; Daems, Walter; Steckel, Jan; Peremans, Herbert; Baelus, Christiaan ................................................................. 9-77

Dynamic Products: An Instrument for Saving Resources. Improve User’s Awareness through Designing Product Experiences.
Bergamaschi, Sara ................................................................................. 9-87

A Study on Consumer Trend and Service Innovation in Korean Market
Ahn, Kyungmi; Kim, Kee-Ok; Sung, Hyunjin .............................................. 9-97

Behaviour-Attentive Prototyping of a Design and Simulation System for IC Chambers
Hou, Yuemin; Horvath, Imre; Rusak, Zoltan; Ji, Linhong; Sun, Yunchun; Lin, Jia ....................................................................................... 9-109

Identifying the Factors to Influence Product Attachment through Product Fandom Phenomenon
Bae, Jieun; Kim, Chajoong ......................................................................... 9-119
Experimental Setup for Visual and Tactile Evaluation of Materials and Products through Napping® Procedure
Faucheu, Jenny; Caroli, Antonio; Del Curto, Barbara; Delafosse, David ...........................................9-129

Product Design of Novel Technology-Based Products
- The Importance of Users
Sampaio, Álvaro M.; Pontes, António J. .................................................................9-139

How Does Expectation Change Perception? : A Simulation Model of Expectation Effect
Yanagisawa, Hideyoshi; Mikami, Natsu .................................................................9-149

Towards Improvement of Interaction Aesthetics of Mobile Music Listening Journeys
Sen, Güzin; Sener, Bahar .......................................................................................9-159

Collective Brand Imagery Weave: Connecting Brand Values to Product Characteristics using Physical Complex Installation
Mulder-Nijkamp, Maaike; Chueng-Nainby, Priscilla .................................................9-169

Aiding Designers to Make Practitioner-Like Interpretations of Life Cycle Assessment Results
Uchil, Praveen; Chakrabarti, Amresh; Fantke, Peter ..................................................9-179

A Model of Lost Habits: Towards a Strategy to Improve the Acceptance of Product Service Systems
Schotman, Hendrikus; Ludden, Geke D.S. .................................................................9-189

Integration of User Knowledge across the Lifecycle of Integrated Product-Service Systems – An Empirical Analysis of the Relevance for PSS Development and Management
Schmidt, Danilo Marcello; Preißner, Stephanie; Hermosillo Martínez, José Alonso; Quiter, Michael; Mörtl, Markus; Raasch, Christina .........................................................9-199

An Investigation of Diet Apps for Enhancing People’s Health and Wellbeing.
Tuna, Nur Nagihan; Şener, Bahar ............................................................................9-209

The Shape of Light: An Interactive Approach to Smart Materials
Piselli, Agnesi; Garbagnoli, Paola; Cavarretta, Giorgia; Del Curto, Barbara .................9-219

HCI/HMI Pleasure: Push Your Buttons
Wendrich, Robert E. ...............................................................................................9-229

Principles for Designing for Perception
Perez Mata, Marta; Ahmed-Kristensen, Saema .......................................................9-239

The “Ideal” User Innovation Toolkit - Benchmarking and Concept Development
Roth, Michael; Harmeling, Jonas; Michailidou, Ioanna; Lindemann, Udo .................9-249

Ielegems, Elke; Herssens, Jasmien; Vanrie, Jan .......................................................9-259

Integration of End-User Needs into Building Design Projects:
Use of Boundary Objects to Overcome Participatory Design Challenges
Latortue, Xavier; Minel, Stéphanie; Pompidou, Stéphane; Perry, Nicolas ..................9-269
Photography - A New Tool in Needfinding
Wulvik, Andreas; Balters, Stephanie; Steinert, Martin ..........................................................9-279

Integration of Universal Design Principles into Early Phases
of Product Design - A Case Study
Kett, Susan Gretchen; Wartzack, Sandro .................................................................9-289

The Role of the Inner Child in Process of Decision Making
for Product Selection
Sepahpour, Ghazaleh .................................................................9-301

Analysis of the Perception of Future Designers about Usage
Scenario Integration in Product Design (SIPD)
Royo, Marta; Mulet, Elena; Galán, Julia; Felip, Francisco; García-García, Carlos .............9-311

Designed for, with, and by Kids. Integrating Children’s Approach
into Design Teaching and Research Visualisation
Luccarelli, Martin; Di Iorio, Mariagiovanna .........................................................9-321

DESIGN OF SOCIO-TECHNICAL SYSTEMS

Designing for Children’s Play Ground, a Social Skills Improvement Approach
Sepahpour, Ghazaleh; Shahabi Haghighi, Hamid Reza; Choopankareh, Vahid ............9-331

Designing with Daylight; The Relationship between Daylight and Health
Hauge, Bettina .................................................................9-341

The Design and Dimensions of Social Innovation: The Brazilian Case
of the “Ecological Network”
Xavier, Amanda Fernandes; Naveiro, Ricardo Manfredi; Auassat, Améziane;
Mello, Carlos Henrique Pereira .................................................................9-353

Effective Simplification for Logo Design
Chen, Chung-Yun; Cheung, Vien; Li, Dian; Cassidy, Thomas ......................................9-365
DESIGN INFORMATION AND KNOWLEDGE MANAGEMENT

Digital Support of Wiring Harness Development
(Based on the 3D Master Method)
Neckenich, Jonas; Winter, Roland; Vielhaber, Michael .................................................. 10-1

Generating Hybrid Geometry Models for More Precise Simulations by Combining Parametric CAD-Models with 3D Surface Scanned Geometry Inserts
Katona, Sebastian; Koch, Michael; Wartzack, Sandro .................................................. 10-11

Visualisation of Biomechanical Stress Quantities within CAD Environments
Krüger, Daniel Benjamin; Wartzack, Sandro .................................................. 10-21

Issues in Learning Engineering Graphics Fundamentals: Shall we Blame CAD?
Metraglia, Riccardo; Baronio, Gabriele; Villa, Valerio .................................................. 10-31

Analyzing the Generative Effects of Sketches with Design Theory:
Sketching to Foster Knowledge Reordering
Brun, Juliette; Le Masson, Pascal; Weil, Benoit .................................................. 10-41

A Sustainable Product Model
Vadoudi, Kiyan; Troussier, Nadège .................................................. 10-51

PLM Implementation: Case Study
Bojcetic, Nenad; Salopek, Damir; Marjanovic, Dorian .................................................. 10-61

Study of the Efficiency of Product Development Teams through Combined Virtual Communities of Practice, PLM and Social Media Technologies
Doumit, Nancy; Fortin, Clément; Huet, Gregory .................................................. 10-71

PLM-MES Integration to Support Collaborative Design
D’Antonio, Gianluca; Sauza Bedolla, Joel; Chiabert, Paolo; Lombardi, Franco .................................................. 10-81

Identifying Flexible Design Opportunities: Getting from a Procedural to an Execution Model
Allaverdi, David; Herberg, Arne; Lindemann, Udo .................................................. 10-91

Crowdsourcing for Search of Disaster Victims: A Preliminary Study for Search System Design
Burnap, Alex; Barto, Charlie; Johnson-Roberson, Matthew; Ren, Max Yi; Gonzalez, Richard; Papalambros, Panos Y. .................................................. 10-103

Strength Mapping Algorithm (SMA) for Biomechanical Human Modelling Using Empirical Population Data
Miehling, Jörg; Wartzack, Sandro .................................................. 10-115

Systematic Online Lead User Identification - Case Study for Electrical Installations
Pajo, Sanjin; Vandevenne, Dennis; Duflou, Joost R. .................................................. 10-125
Knowledge Management Tools and Techniques:
Extent of use in Organizations and Support for Modularization
Stenholm, Daniel; Rossi, Monica; Bergsjö, Dag; Terzi, Sergio ..................................................10-293

Proposed Evaluation of the use of K-Briefs for Knowledge Acquisition in KBE
Marthinusen, Ivar; Kalavrytinos, Christos; Sivertsen, Ole Ivar ..................................................10-305

Digital Repository for Design Knowledge Reuse
Firdaus, Mochammad; Wang, Hongwei; Qin, Hao; Liu, Yusheng .............................10-315

Approach for Modelling Knowledge Management Solutions within the Product Development Process using the ‘Knowledge Modeling and Description Language’
Laukemann, Alexander; Binz, Hansgeorg; Roth, Daniel ..................................................10-325

Design Knowledge Representation as an Integration of Functional Knowledge Modelling and Design Structure Matrix
Zhu, Guo-Niu; Hu, Jie; Qi, Jin; Gu, Chao-Chen; Peng, Ying-Hong .............................10-337

Knowledge Sharing in Heterogeneous Data Context: Application in PLM
Pham, Cong Cuong; Matta, Nada; Durupt, Alexandre; Eynard, Benoit; Ducellier, Guillaume ..................................................10-347
Design for Behavior Change: An Elaboration-Based Approach to Persuasion in Product Design
Montazeri, Soodeh; Panos, Papalambros; Rich, Gonzales .................................................. 11-1

The Use of Multisensory Feedback to Make Users Behave in a Sustainable Way
Graziosi, Serena; Ferrise, Francesco; Costanzi, Alessandro Achille Maria; Bordegoni, Monica ................................................................. 11-11

Support of the System Integration with Automatically Generated Behaviour Models
Kößler, Johannes; Paetzold, Kristin ................................................................. 11-21

Technology-Supported Design Research
Thoring, Katja; Mueller, Roland M.; Badke-Schaub, Petra ............................................. 11-31

Moving Targets: How Consumers Change Value Systems through Interaction with Designed Products and Other Consumers
Thomas, Russell C.; Gero, John S. ................................................................. 11-41

Developing a Framework of New Mixed Method, Social Networking Services Group Diary and its Application in Practice
Bae, Jieun; Cho, Kwangmin; Kim, Chajoong .................................................. 11-51

Physiologically Based Segmentation of Design Protocol
Nguyen, Philon; Nguyen, Thanh An; Zeng, Yong ............................................. 11-61

Surprise as a Situated Phenomenon
Becattini, Niccolo; Borgianni, Yuri; Cascini, Gaetano; Rotini, Federico ...................... 11-71

Creativity Intervention: Using Storytelling and Math Problems as Intervening Tasks for Inducing Incubation
Al-Shorachi, Evan; Sasasmit, Koonlada; Gonçalves, Milene ................................ 11-81

Influence of Information Collection Strategy in Problem Formulation on Design Creativity through Mental Stress: A Theoretical Analysis
Wang, Xiaoying; Nguyen, Thanh An; Zeng, Yong ............................................. 11-91

Developing a Computational Framework to Study the Effects of Use of Analogy in Design on Team Cohesion and Team Collaboration
Singh, Vishal; Casakin, Hernan ................................................................. 11-101

Exploring Problem Decomposition in Design Team Discussions
Tobias, Connor; Herrmann, Jeffrey W.; Gralla, Erica ............................................. 11-111

Physiology and Sensorial Based Quantification of Human-Object Interaction – The QOSI Matrix
Balters, Stephanie; Bisballe Jensen, Matilde; Steinert, Martin ................................ 11-121
Provoking Iterations in Ideation Workshops – An Explorative Study

Heck, Johannes; Steinert, Martin; Meboldt, Mirko .............................................11-133

Novice Engineers’ Predisposition to Compassionate Design

Seshadri, Priya; Reid, Tahira ........................................................................11-143

Dynamically Capturing Engineering Team Interactions with Wearable Technology

Sjöman, Heikki; Steinert, Martin; Kress, Greg; Vignoli, Matteo ..............................11-153.

Design Questions for Life: Connecting Engineering Design, Appreciative Inquiry, and Other Question-Based Models

Liija, Johan; Hansen, David; Richardsson, Daniel ..................................................11-163

The Influence of Different Media Instructions on Solving a Procedural Task

Chirumalla, Koteshwar; Eriksson, Yvonne; Eriksson, Pelle .....................................11-173

A Sensor Design and Data Analysis for Automatic Drum Beater Winding

Zhao, Yuchen; Johnson, Teegan; Goh, Yee Mey ......................................................11-183

Barriers to Hinder Collaboration within Product Development Teams from Designers’ Perspective and the Development of a Method to Facilitate the Collaboration

Kim, Yeonghun; Kim, Chajoong; Cho, Kwangmin; Kim, Kwanmyung ......................11-193

A Comparative Study on the Role of Models and Prototypes in Human-Centered Design Versus Design-Driven Innovation Approaches

Isa, Siti Salwa; Liem, Andre .................................................................................11-203

Design As the Resolution of Paradoxes: An Exploratory Study

Morgan, Thea; McMahon, Chris ..............................................................................11-215

DESIGN EDUCATION

Academic Design

Koskinen, Ilpo K; Dorst, Kees ..................................................................................11-227

Guidelines for Competence Assessment in Engineering Education an Implementation in Project Nusal

Albers, Albert; Butenko, Viktoria; Breitschuh, Jan; Walter, Benjamin; Drechsler, Sandra; Burkardt, Norbert .................................................................11-235

A Case Study Exploring the Use of Journals to Support Student Engagement

Born, Werner Christian; Schmidt, Linda Catherine ................................................11-245

New Approaches to Teaching Design for Additive Manufacturing

Junk, Stefan; Matt, Rebecca .....................................................................................11-257

Do High School Students Benefit from Pre-Engineering Design Education?

Kannengiesser, Udo; Gero, John; Wells, John; Lammi, Matthew ..........................11-267

Concept and Structure of a New Master-Programm “Systems Engineering”

Paetzold, Kristin; Förstner, Clara; Tillmanns ............................................................11-277

New Ways in Education with Shape Design

Heimrich, Felix; Anderl, Reiner ..............................................................................11-287
A Design Course Combining Aesthetics and Engineering Knowledge in PBL Style
Chang, Hsiang-Tang .................................................................11-297

Advanced Business Coaching Approach in Combination with Systemic Constellation Work to Improve the Business Engineering Process
Burchardt, Carsten ................................................................11-307

Understanding the Characteristics Between Design and Non-Design Background Students in Product Development Process and its Implications
Kim, Chajoong; Kim, Yeonghun .............................................11-319

Interdisciplinary Learning through Design Activities Uniting Fundamentals of Engineering Curriculum
Fu, Katherine Kai-Se; Tan, U-Xuan; Teo, Tee Hui; Soh, Gim Song; Wood, Kristin L. ......11-329

Design Learning Mind-Sets
Hamat, Basyarah; Badke-Schaub, Petra; Eris, Ozgur .................................................11-341

Applying a Combined User-Centred Design Approach to Assistive Shopping Trolley Development in Design Education
Mengoni, Maura; Bevilacqua, Roberta; Peruzzini, Margherita ..........................11-351