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DESIGNING ON THE ROAD; EXPLORING THE WHO, WHERE AND WHY OF INDIVIDUAL MOBILITY DEVICES

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ABSTRACT
The aim of this study is to support designers in dealing with the variety of situations in which product are used, so-called dynamic and diverse use situations (DDUS). Dealing with varying use situations in the design process is difficult because it is hard to predict the situations in which a product will be used, to anticipate what will happen when the product encounters those situations and to generate solutions for conflicting requirements. A retrospective case study of three design projects in practice furthermore showed that knowledge of DDUS often remains implicit and is not shared between members of a product development team. We therefore developed a set of guidelines to support designers and design teams when dealing with DDUS in the design process. The basic principle of the guidelines is that existing design activities are used to create and apply an explicit ‘frame of reference of product use’ which makes DDUS and their relation to use issues explicit. In this paper we explain these guidelines and show its application to the design of an individual mobility device.

Keywords: dynamic and diverse use situations, design methods, user centred design, industrial design

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1 INTRODUCTION

In user centred design it is generally acknowledged that the user, goal and context of use of a product directly influence the usability and user experience of that product, and are therefore important to take into account in the design process (Nielsen, 1993; Fulton Suri and Marsh, 2000; Maguire, 2001). On the one hand many methods prescribe how to analyse the user, goal and context of use at the start of a design project, such as with observations, interviews or focus groups (e.g. Sharp, Rogers et al., 2007). On the other hand methods prescribe that test conditions of use evaluations should represent these parameters (Cushman and Rosenberg, 1991; Bevan and Macleod, 1994). However straightforward these prescriptions may seem, in practice the design process is seriously complicated by the fact that in reality many products are used by a wide variety of users, who have different goals and use the product in various contexts. We define this as 'dynamic and diverse use situations' (DDUS) (van der Bijl – Brouwer, 2012a). Dynamic use situations refer to the situations that change in time for one product, while diverse use situations refer to the variety of use situations between products. For example, for the Stokke Tripp Trapp chair dynamic aspects concern the different positions of the child during a meal and the different purposes for which the chair is used within one family, while diverse aspects concern the different dimensions of the primary user and different furniture arrangements in which the chair is placed in different families (Figure 1). Difficulties when designing these kind of products include how the designer or design team knows in which situations the product will be used in the future, how they know which consequences this has for usability or user experience, and how they come up with solutions for situations which lead to conflicting requirements.

Figure 1: the dynamic and diverse use situations of a Stokke Tripp Trapp chair.

In a previous study we analysed how designers deal with these difficulties in design practice (van der Bijl - Brouwer and van der Voort 2009). From this retrospective case study of three real product development projects we concluded that finding solutions for conflicting requirements is generally not a problem for designers. Solution principles we found included 'one size fits all', accessories, adjustable features and segmentation. The Stokke Tripp Trapp chair is an excellent example of a product that offers accessories and adjustable features to attune the product to various body positions, dimensions and purposes for use. Segmentation is applied in the colouring of the chair to allow the chair to aesthetically fit the users preferences. Furthermore we did not find a difference in the design process between how designers dealt with either dynamic or diverse situations. A problem we did find is that in current design practice, knowledge of the dynamics and diversity of users, contexts and goals often remains implicit and is mostly not shared. Members of one product development team would often be aware of the DDUS of the product and would have knowledge and assumptions about these situations based on both personal knowledge (e.g. based on self-experience or from family or friends) and knowledge retrieved within the company (e.g. based on user research). However, this knowledge was often not made explicit or shared. This lack of a 'shared frame of reference' of use situations and related use issues can have a negative effect on decision-making when design teams have to choose solution proposals. Furthermore an explicit frame of reference is needed to control the external validity and focus of use evaluations, since it defines the test conditions and questions for these tests. Our research was therefore aimed at supporting the creation and application of such a frame of reference.

Design for DDUS is not new in the sense that it recognizes the difficulties of dealing with different users in different contexts, because this issue is mentioned in many sources (e.g. Shackel, 1984; Green and Jordan, 2002). However, these sources give little guidance on how to deal with this problem in design. Therefore we developed a set of guidelines that support designers in dealing with DDUS. In this paper we will present a summary of these guidelines. We will particularly focus on the guidelines related to the creation and communication of the frame of reference and show their application to a case: the design of a new individual mobility device.

2 GUIDELINES TO DESIGN FOR DDUS

2.1 Method of development of the guidelines

The guidelines were developed in multiple iterations. Based on literature analysis and the above mentioned case studies in design practice a first set of guidelines was developed, and evaluated in a student project (van der Bijl – Brouwer 2011). Four teams of five students applied the guidelines to the design of a carrier bike (a bicycle with a large box in the front which in the Netherlands is mainly used to transport children), for a real client. Based on this evaluation a new set of guidelines was developed which was evaluated in another student team project concerning the design of a kitchen appliance (van der Bijl – Brouwer, 2012a). This led to a final set of guidelines that we partly present in this paper.

2.2 Conceptualisation of the support

As mentioned above our research was aimed at supporting the creation of an explicit frame of reference of DDUS and its application in team decision-making and use evaluations. In the conceptualization of the support we particularly paid attention to the support's flexibility. According to Stolterman (2008) it is important for those who produce support for design practitioners to make the 'incorporation' into the designer's own approach possible. We therefore developed guidelines instead of a step-by-step method. The guidelines could thus assumingly support multiple design activities in a complete design process.

Next to the guidelines we developed a technique that was explicitly aimed at gathering implicit knowledge of product use in design teams. This Envisioning Use technique is a half-day workshop in which design team members come together and share their knowledge and assumptions of product use. This technique was successfully evaluated in multiple real product development projects (van der Bijl - Brouwer, Boess et al., 2011).

2.3 Summary of the guidelines

A workbook was generated which included all the guidelines and their explanation (van der Bijl – Brouwer, 2012b). In this paper we summarize these guidelines:

- Make all members of a design team aware of DDUS and create a shared vision on product use by means of the 'Envisioning use technique'
- Keep track of a consistent explicit frame of reference with use situations and related issues throughout the design process
- Create this frame of reference by means of exploring use issues related to chosen use situations
- Apply the frame of reference in use evaluations

This frame of reference is an overview of all relevant use situations that a product can possibly encounter and also lists the use issues such as usability or user experience issues that occur when a user and product interact in those specific circumstances. The frame of reference can have the format of scenarios, a mind map or other structure preferred by the design team.

The shared vision on product use

Creating a shared vision on product use means that all members of a product development have the same mindset or 'implicit frame of reference' of relevant use situations and related use issues. These implicit frames of reference should be aligned with each other and with the explicit frame of reference. The best way of achieving this is to create an explicit frame of reference of product use together, as we propose to do within the Envisioning Use technique. In this paper we will not further elaborate on the team activities of designing for DDUS.

The explicit frame of reference of product use

The explicit frame of reference includes two types of information: information about the diverse situations in which products are used, and information about the interactions between products and these use situations. Figure 2 illustrates this information by means of the example of a carrier bike. When a product is part of a specific use situation, this will result in an interaction with certain qualities: use issues. Use situation aspects concern user characteristics, their goals and the context of

use. For the carrier bike this concerns physical characteristics of the cyclist, why the cyclist prefers a carrier bike to a car, types of luggage or passengers, road conditions, weather conditions etc. Use issues can be related to performance, usability, or user experience. For example, if the box of the carrier bike is large enough to bring all preferred luggage (performance), if the rain hood is easy to adjust (usability) or if the children are happy to sit in the box (user experience). Besides this 'use knowledge' the frame of reference contains a target that defines which use situations and issues will be accounted for throughout the design process.
Since the frame of reference can consist of a large collection of use situations and issues, it can easily contain too much information to deal with in communication or solution generation. We therefore propose to use different views: a complete view which can be used as a check list in use evaluations, and the simplified priority view which shows the most important situations and issues on one page, and which can be used to support communication and inspire solution generation. In the presented case in section 3 we will give examples of these two views.

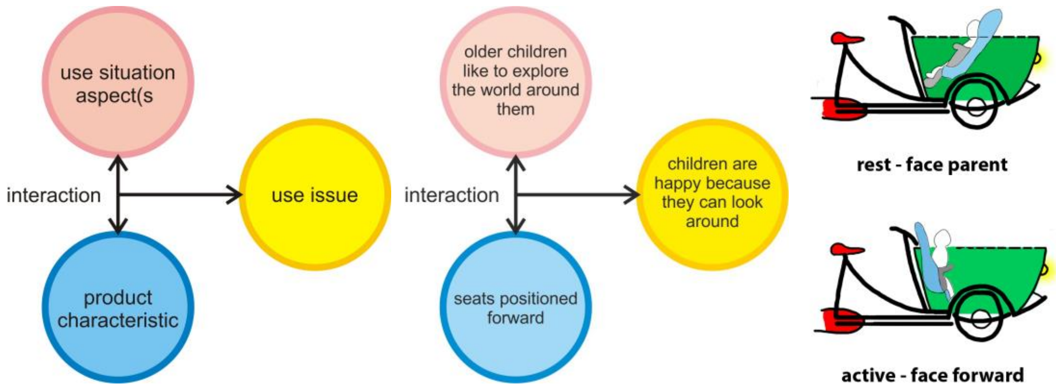

Figure 2: the frame of reference contains information about use situation aspects and use issues. The example shows how a use situation aspect (older children like to explore the world around them) relates to a use issue (children are happy because they can look around) for a carrier bike design which allows seat adjustment to the age of children. The lower design shows the solution for the older children.

Creating the frame of reference

To create and update a new frame of reference, teams can employ different design activities. We distinguish internal activities, aimed at exploring how use situations relate to use issues based on assumptions, and external activities, aimed at exploring factual use situations and evaluating solution proposals in those use situations. Internal explorations include techniques like self-testing design proposals, scenario analyses and the aforementioned Envisioning Use technique. Internal explorations are important because they can easily be applied in an iterative design process: a solution can be created, explored quickly as to how it relates to different use situations, adjusted etc. Another benefit of internal exploration is that it guides the external activities by making gaps in factual knowledge or product use explicit. External explorations are activities aimed at gathering insights in the relevant use situations and issues for comparable products, for example by consulting online reviews or observations of use of comparable products. These explorations of current use lead to insights that can be extrapolated to future use.
Finally, evaluations of design proposals in probable use situations can give insight in factual use issues. Since each activity can be used to add, verify or remove information on product use, the frame of reference evolves in the course of the design process.

Applying the frame of reference in use evaluations

The main advantage of a complete explicit frame of reference is its application in use evaluations. Targeted use issues in the frame of reference can be translated into research questions for use evaluations. For example, a question for the design of the carrier bike could be: 'Can children explore the world around them sufficiently while seated in the box?'
The most important function of the frame of reference when planning use evaluations is that it helps to set proper test conditions. To increase the external validity of use evaluations, the test conditions of these evaluations should reflect actual use situations as much as possible (Jordan, Thomas et al., 1996).

The frame of reference should give insight into what these actual use situations are. For example in the case of the carrier bike, it makes sense to invite children of varying ages for a user test because their needs for communication with parents while seated in the box can be assumed to differ.

Process model of design activities surrounding the frame of reference

As mentioned above different design activities are input to and output of the frame of reference. Figure 3 visualizes how these activities surround this frame of reference. Note that the guidelines do not prescribe new design activities, but indicate how current design activities can be employed to generate and apply a frame of reference of product use.

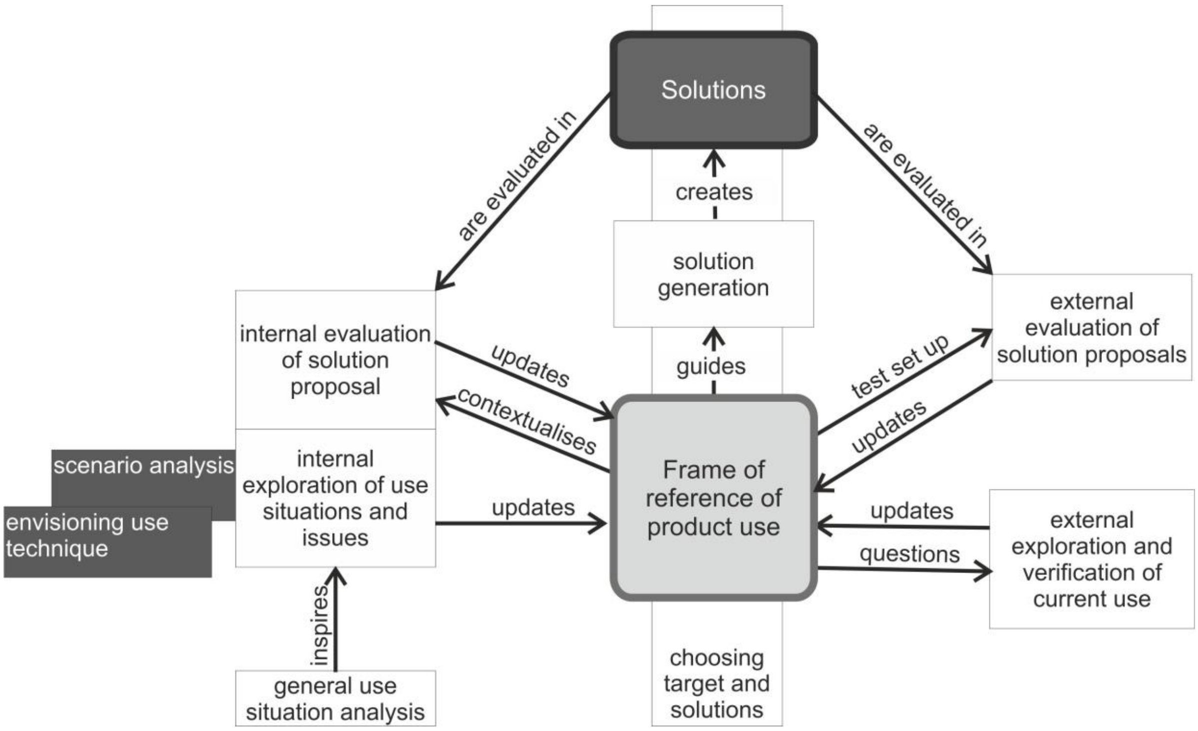

Figure 3: the different design activities to create and apply the frame of reference of product use

3 CASE: DESIGN OF AN INDIVIDUAL MOBILITY DEVICE

The guidelines were evaluated in the aforementioned student projects of the carrier bike and kitchen appliance. These evaluations showed that the guidelines proved to stimulate the creation of an explicit frame of reference of product use which could give the required focus to use evaluations and also proved that they can be used to set-up externally valid test conditions (van der Bijl – Brouwer, 2012a). However, these student projects were relatively short in the sense that they had to be carried out within the time frame of a course of 5 European Credit points (140 hours) per student. This meant that the teams had limited time to execute the design activities. In this paper we present the application of the guidelines to a more extensive design project: the design of an individual mobility device by a master student for a real client. This project was executed within a timeframe of 9 months and covered 45 EC. This project is particularly a good example of how the explicit frame of reference can be created iteratively by means of various internal and external design activities. The project also allows an evaluation of the guidelines in an individual design project.

3.1 Design of an individual mobility device

The case concerns the design of a new individual mobility device for people with impaired mobility (van der Molen, 2012). The assignment was executed by a graduate student Industrial Design Engineering for a company that produces mobility scooters. The motivation for this assignment was that the market of mobility scooters is changing from a business-to-business into a consumer market. As a result the critical consumer will soon have more opportunities to choose and acquire his own individual mobility device, instead of getting one assigned by a care institution or the municipality.

This means that consumer needs are becoming more important. The focus of the assignment was therefore on exploring user needs for this type of products and resulted in a set of 'design directions' for new individual mobility devices. Three concept designs were presented as a proof of principle of these design directions. Since an individual mobility device is a product with very diverse and dynamic use situations, the designer chose to apply the guidelines to design for DDUS in this project.

3.2 Creating a frame of reference of product use

As explained in section 2, both internal and external activities can be employed to create the frame of reference. The internal explorations are based on assumptions and allow to explore interesting combinations between use situations and use issues that can be targeted in the design process. The external explorations allow gathering factual knowledge with regard to how users currently experience the use of mobility scooters in diverse use situations. This includes a validation of the assumed relations between use situations and use issues that were found in the internal explorations.

Internal design activities

In this project internal explorations included executing the Envisioning Use workshop with employees of the scooter company, a self-evaluation and scenario analysis. The Envisioning Use workshop made it possible to gather all the knowledge and assumptions with regard to the use of mobility scooters that was already available within the company. In a self-evaluation the student used a mobility scooter herself in several situations. For example she did groceries on a mobility scooter in the supermarket to explore which use issues could occur in these situations. Finally scenario analysis allowed a further exploration of what could potentially occur in different use situations. This scenario format was also used to represent the frame of reference. An advantage of scenarios is that they do not only support exploration, they are also a very useful tool for communication as stated by Rosson and Carroll (2002, p23): "Scenarios use a universally accessible language. All project members can 'speak' the language of scenarios". Therefore they could directly be used as a communication tool when verifying the scenarios with end-users. For example, in the supermarket the student ran into several problems with regard to storing the groceries in or on the mobility scooter. By explaining this in later external design activities by means of scenarios to end-users, they could confirm if this was a relevant issue or not.

External design activities

External explorations in this project included literature analysis, ethnography, expert interviews and probes. In probing, potential users are given probe packages which they can use to capture their use experiences by means of materials such as a diary, disposable photographic camera, audio recorder and question cards (Gaver, Dunne et al., 1999; Wensveen, 1999). Probes allow for a longer-term exploration of use situations and related use issues, thus giving more insight in the dynamics of the use situation. In this case the probes were handed out to users of mobility scooters who were asked to record their experiences for several weeks. For this project the probe included a workbook in which the user was asked to answer questions about their use experiences and to execute some cut-and-paste assignments (Figure 4a). They were asked to tell about their day, what they did, how they felt, but also where they (did not) like to go and what their ideal mobility scooter would look like. Four users completed the probe and an additional interview was held to discuss the results. Although the probes gave deep insights in the dynamics of use situations and related desired use issues, additional research was necessary to gather knowledge of the diversity of use situations between users. For this purpose an ethnographic study and expert interviews were conducted.

Ethnography is aimed at understanding people's everyday activities by gathering information in the settings in which the activities of interest normally occur (Blomberg, Burrell et al., 2003). In this case it was important to involve a large group of users to cover the diversity of use situations. This was achieved by contacting mobility scooter clubs. People of these clubs were observed and interviewed while using the mobility scooters (Figure 4b).

A third important source of external information was the consultation of experts. With regard to design for DDUS the advantage of consulting experts over end-users is that experts can give a large insight in the variations between use situations. Four dealers of mobility scooters and seven other experts such as an ergo-therapist and a mobility scooter technician were interviewed because they have so much contact with (potential) users, and therefore have a broader perspective on the subject.

Figure 4a: the probe and Figure 4b: ethnographic study with the scooter club (design student drives the first mobility scooter)

use situation aspect | use issue

1) John drives in his mobility scooter to the supermarket. When he is inside, he goes straight to the bread department. His favorite whole bread lays on the bottom shelf. He gets out of his scooter and grabs the bread from the shelf. He thinks he is lucky he can still stand on his legs; otherwise he wasn't able to get the bread himself.
Source: self-evaluation

2) Next, John drives to the cash desk. Here he is glad he sits on his mobility scooter and not in a wheelchair. His mobility scooter makes him high enough to normally communicate with the cashier behind the desk.
Source: user story ethnography

Figure 5: two examples of scenarios and their source

Visiting someone or something

For this theme, driving is mostly done for functional reasons, only to travel from one place to another. Easy to park and being weather proof while parking, are two important aspects when visiting.

Side by side

Driving with others, whether they walk, cycle or drive and interacting with them while driving are important aspects for this theme. Ease of operation is included for easily adjusting to others while driving.

Figure 6: two examples of a 'design theme card'. The upper theme is based on the use situation 'visiting'. The lower theme is based on social use issues.

3.2 Creating overview in the frame of reference

Based on aforementioned activities 85 scenarios were generated that each showed a particular use situation and one or two use issues related to that situation (Figure 5). To define starting points for the design of new individual mobility devices and to discuss this with the client a different view on this frame of reference was necessary. In the guidelines this is called a 'simplified priority view', as opposed to the 'complete view' that contains the 85 scenarios. After studying these scenarios the design student discovered three main categories of use situations. The first category is grocery shopping in which the user drives to the store, goes into the store with the mobility scooter, collects groceries, pays and drives back home. The second category is visiting in which the user drives to the place to visit such as family, friends, the doctor, the church and so on, parks the device, and gets in and out of the device. The third category of use situations consists of driving tours in and around town, alone or with others. Although these use situations are interesting to get an idea for which purposes the scooter is used, they do not give any insight in what consequences these situations have for the use of the device. Therefore use issues were added to the cards and an additional categorization was made with regard to the use issues. Desired use issues were called 'user needs' and connected to specific use situations. For example, one category considered social issues of the device when driving around with others. When driving around with someone who is on a bicycle it was for instance important for the users of the mobility scooters that they could easily communicate with this person and consequently that there would not be a too large difference in height between the scooter and the bicycle. Subsequently each use situation and issue category was translated in a 'design theme card'. Figure 6 shows two examples out of in total 15 theme cards.

3.3 Targeting and solution generation and evaluation

Since the diversity of use situations and related use issues was so large, the student and client agreed that it seemed most wise not to search for a 'one size fits all' solution, but to explore different segments. Each segment would need to target specific use situation – use issue relations and would need to attract a certain target group of consumers. For this reason several 'design directions' were defined. For each design direction a selection of design theme cards was brought together to define the most important use situations and issues that would be targeted in that specific design. For each design direction different solutions were defined. This was an iterative process aimed at exploring and discovering interesting combinations between solutions on the one hand, and use situations and related use issues (here represented in the collection of theme cards) on the other hand. As mentioned in the introduction, this phase was mainly used to show how the gathered insights with regard to DDUS, represented in the theme cards, could be used. It was not an end-result in itself. Therefore it is not further presented in this paper.

Finally the solutions were each represented by means of a storyboard to show how the solution would work in the defined scenarios. The scenarios were then shown to potential end-users to ask their feedback.

3.4 Evaluation of the approach

The student was asked to reflect on the application of the guidelines and indicated that the guidelines helped her to explore different aspects of the use of mobility scooters in different ways. Many activities were employed to gather information about DDUS – use issue relationships. The explicit frame of reference represented by means of the scenarios provided a means to connect these activities.

It provided a means to structure the large amount of information gathered. Moreover, it helped her in keeping focus on what was important while designing the new types of mobility scooters. It can therefore be concluded that in addition to the successful application of the guidelines in design teams, the guidelines are also useful in individual design processes.

Two views were used to represent the frame of reference. The complete view of 85 scenarios was useful as a representation of the gathered information and served as a checklist for the design process itself. Each solution could be compared to these scenarios to reflect on the appropriateness of the solution. Furthermore assumed scenarios based on internal explorations could be used to focus external explorations by setting questions. The simplified priority view in the 'theme cards' proved to be a very useful format for the communication process with the client and other stake-holders. The cards could be talked about and categorized easily in this group process.

What was a difficult part of this design process was to define useful segments for the design directions. The guidelines do not support this aspect of the design process. This issue is further discussed in section 4.3.

4 DISCUSSION

4.1 Creating a frame of reference of use situations and related use issues

In this case we showed how exploring the relation between use situations, product characteristics and use issues is a useful way to create focus in a design process for products with DDUS. It is important to explore which use situations are meaningful to the design process in the sense that they lead to use issues that need to be solved (if they are negative) or enhanced (if they are positive). Just randomly listing use situations does not guide the design process. For example, it would not have been very useful to ask users of mobility scooters to list all the places where they use the mobility scooter without asking them which consequences each place has or could have for the use of the scooter.

Although we encourage to do a user analysis at the start of a design process, we argue that these analyses are only useful when they lead to insights in useful use situation – use issue relationships. In the case of DDUS an internal exploration can assist in adding more focus to these external user analyses. In the mobility device case for example, questions could be formulated for the probes based on potential interesting use situation – use issue relationships found in the Envisioning Use technique and self-evaluations. Moreover, techniques were applied that were particularly appropriate to gather insights in these relationships, such as the ethnographic approach. By interviewing the user while using the mobility scooter it became immediately apparent what the relation between a certain use situation and issue was.

4.2 Flexibility of the support

We deliberately developed a support that could flexibly be applied in existing design processes. The activities for internal and external exploration of DDUS are not meant to replace current design activities. On the contrary, they refer to activities that often already occur in practice, such as the techniques shown in the example in this paper. The added value of design for DDUS is that the relation of these activities to the frame of reference with DDUS now becomes more apparent. This allows an easy incorporation in existing design approaches.

A downside of flexibility is that 'the higher the degree of freedom for the user as to how the support can be used and the more the support allows for different interpretations, the more difficult it will be to ensure that the support will be effective and efficient' (Blessing and Chakrabarti 2009, p160). In the several evaluative studies we have done so far we experienced that the guidelines' flexibility indeed in some cases led to an unsatisfying level of application. In the individual mobility device case we for example experienced that initially the theme cards with regard to the use situations 'shopping', 'visiting' and 'driving tours' were not explicitly connected to useful use issues, as advised in the guidelines. Since the student was guided actively by one of the researchers this problem could easily be solved. This raises the question how the guidelines can appropriately be introduced to their users. They are now presented in a workbook format. However, the design student had also participated in the earlier design course in which the student teams designed the carrier bike. In combination with the researcher's supervision this means that the student received a far more extensive introduction to the guidelines than just by means of the workbook. Since the ultimate aim of this research is to support design practitioners in designing for DDUS, and since these practitioners probably will not be able to invest in following a complete course on the university, future research will include the development of an efficient means of introduction to design practitioners.

4.3 Targeting use situations and use issues

An important challenge while designing for DDUS that became apparent in this design project was the definition of appropriate targets for different segments. The student struggled with finding solutions and related targeted use situations that would appeal to a specific segment of the market of mobility scooter users. The guidelines do not support this part of the design process. The studies in design practice did not show that this segmentation process was a problem. Segmentation and selecting a corresponding product differentiation strategy is a well-known principle of product marketing (for example Kotler and Craven, 2003). Both the relatively low level of design experience of the student in comparison to practitioners and the fact that segmentation is more a marketing than a design task could have caused the difficulties of the student with regard to this issue. Since both choosing a successful target and choosing an appropriate solution depend on more criteria than just usability and user experience, it was chosen to not further support this activity in the guidelines. However, connecting this marketing process to design and product use is an interesting area for future research.

5 CONCLUSION

In this paper we presented guidelines to design for DDUS. These guidelines showed how different design and research activities can be employed to create and apply an explicit frame of reference of product use. This frame of reference represents the dynamics and diversity of use situations and how the situations relate to use issues. As an example we presented the application of these guidelines to the design of an individual mobility device by a graduate student Industrial Design Engineering.

The guidelines have proved to be successful in both design team projects as well as individual projects executed by students. Future research will be aimed at developing an introduction of the guidelines to design practitioners and evaluating if the guidelines can successfully support designers in dealing with dynamic and diverse use situations.

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SEOUL
ICED13

The 19th International Conference on Engineering Design

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Sungkyunkwan University, Seoul, Korea
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'Design for Harmonies'

- Harmony of Products and Services
- Harmony of Old and New
- Harmony of Culture and Technology
- Harmony of East and West

PROGRAMME & ABSTRACT BOOK

the Design Society
a worldwide community

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SUNGKYUNKWAN UNIVERSITY

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Creative Design Institute

SEOUL

ICED13

The 19th International Conference on Engineering Design

19th-22nd August 2013
Sungkyunkwan University
Seoul, Korea

Organised by
the Creative Design Institute
and the Design Society

PROGRAMME & ABSTRACT BOOK

Edited by
Udo Lindemann
Srinivasan Venkataraman
Yong Se Kim
Sang Won Lee

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Preface by the Conference Chair

Welcome to the 19th International Conference on Engineering Design 2013 (ICED13), and its conference proceedings. The theme of ICED13, Design for Harmonies, is well reflected in the programme and papers of the conference. As design practice and research make progress, integration and incorporation of diverse viewpoints take more essential roles. ICED13 will make its mark in the history of ICED and the Design Society as an important cornerstone for harmonies in design.

Increasing numbers of presentations in topics like human behavior in design and product, service and systems design indicate that issues of harmonies of products and services and those of human-centered views and technology support are at the core of design research. With continued excellence in the topics of design methods and tools, design information and knowledge and design processes, strong research foundations of design have been confirmed in the programme. Presentations in design organisation and management, design for X, design to X, and design theory and research methodology also demonstrate the leadership of the Design Society community in these important issues. Design education is yet another important area where new needs and requirements appear as the roles of design become broader. As Seoul is the very first Asian city hosting ICED, more papers from Asian countries appear in ICED13. This reflects harmonies of East and West being strengthened in design research. ICED13 will make a good transition for drawing more such harmonies.

In addition to a technical programme of keynote, podium and discussion sessions, ICED13 has organized a few special events such as the Young Members Event. Ten selected presentations by young designers and design researchers will address the Future of Design. This event is open to the (young) public so that diverse harmonies can be achieved by the attendees. With opening and closing ceremonies and receptions as well as a conference banquet, diverse opportunities for cultural harmonies are prepared. For example, Korean traditional culture experiences are available for conference attendees and accompanying guests together with old Korean traditional buildings in order to draw harmonies from the Old and the New. The optional Gangnam-Style tour will introduce modern Korean culture as featured in the world hit music video.

We hope you enjoy ICED 13 and have the fun and excitement of Design for Harmonies.

Yong Se Kim
Conference Chair

Sang Won Lee
Assistant Conference Chair

Welcome to the ICED13 Proceedings!

We welcome you to the proceedings of arguably the biggest conference on engineering design: 19th International Conference on Engineering Design (ICED13) held in Sungkyunkwan University, Seoul, Korea!

This proceedings is a compilation of the 342 peer-reviewed and accepted papers submitted to ICED13. The proceedings is published in different forms: a book of abstracts, a soft-copy of proceedings on a USB-based memory device and a hard-copy of proceedings, which is available via a print-on-demand supplier. All these different forms of proceedings are numbered against both Design Society and ISSN referencing to allow wider access, better referencing and improved citation in the near and distant future. All the accepted papers are divided among the following 9 themes: Design Processes; Design Theory and Research Methodology; Design Organisation and Management; Products, Services and Systems Design; Design for X, Design to X; Design Information and Knowledge; Human Behaviour in Design; Design Education; and Design Methods and Tools. The hard-copy of the proceedings is in turn divided into 9 volumes where each volume comprises papers from a theme. All the accepted papers are presented in podium or discussion sessions in the conference. It is important to make it explicit that all the accepted papers have successfully cleared the criteria for acceptance in ICED13. The division into podium and discussion sessions is solely based on grouping similar papers so as to allow relevant, connected, lively and stimulating presentations and discussions. For this year's conference we have introduced a number of novel schemes to reduce the bureaucratic load for authors and organisers and, it is hoped, to increase the quality of the conference. To name a few: (i) automatic production of the cover page of papers based on title of paper, details of authors, abstract and list of keywords in the Conference Management System, (ii) electronic acceptance of terms and conditions in copyrights, (iii) feedback of acceptance and quality of reviews to reviewers from authors, etc.

This proceedings is a consequence of dedicated efforts of many people, namely, the authors, the reviewers, the chairs and associate chairs of the various themes, and the members of the Programme Committee. The Programme Chair on behalf of Programme Committee would like to acknowledge the contributions of: (a) Authors for submitting papers, (b) Reviewers for providing timely comments and feedbacks to improve the quality of papers, (c) Chairs and Associate Chairs of themes for assisting in selection of reviewers, providing directions for improvements to papers with the status of major revisions, and helping in the final decisions of papers.

We hope that you enjoy the programme of ICED13 as much as we have enjoyed creating and organising it.

Udo Lindemann
Programme Chair

Srinivasan V
Assistant Programme Chair

Preface by the Design Society President

The2013 International Conference on Engineering Design (ICED) will be the nineteenth held since the conference series was inaugurated in 1981. It will also be the sixth held under the auspices of the Design Society, an international society founded in 2001 to develop an understanding of all aspects of design. The previous five conferences have been in Stockholm, Melbourne, Paris, Stanford (California) and Copenhagen, and by holding the conference in Asia for the first time it is surely established as a truly world-wide event. The 2013 conference continues the tradition of holding the conference in an exciting location with a vibrant design research community and for which design is important to local industry and commerce. Seoul is exceptional in this regard, the dynamic heart of the world's second largest metropolis whose success is built on great design and engineering.

ICED13 also continues the format, established in 2009 and continued in 2011, of a conference programme made up of plenary sessions, podium presentations, discussion sessions with focused debate and workshops led by the Design Society's Special Interest Groups. We hope that this varied programme, combined with extensive opportunities for networking, will provide an exciting opportunity for researchers and practitioners to learn about the latest developments in design research and practice.

Organising an international conference takes an enormous amount of work, and I would like to express the thanks of the Society to the great team that has worked over many months to make the Conference a success. Especially I would like to thank Yong Se Kim, Sang Won Lee and colleagues at Sungkyunkwan University for their great work in the Organising Committee, and Udo Lindemann, Srinivasan Venkataraman and the Programme Committee for bringing together such an excellent programme. Of course, their work would be in vain without the fantastic contributions of the authors, reviewers, theme chairs and session chairs, and the thanks of the Society are due to all of them.

Chris A McMahon
Design Society President

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On behalf of the entire community we would like to express our gratitude to the work performed by our scientific committee. The reviews of the scientific committee were used by the programme committee to make informed accept/reject decisions for each submission and by the authors to make the appropriate amendments to their papers.

In addition, the reviews also allowed the programme committee to acknowledge the top 10% of papers based on the scores given by the reviewers; look out for the following emblem throughout the abstract book:

Reviewers' **Favourite**

Themes and Theme Chairs

The ICED 13 program committee organises various topics that cover substantial, original and previously unpublished research. The ICED 13 sessions are composed of plenary sessions, podium sessions, discussion sessions and workshop sessions from both academia and industry based on rigorous analysis or argumentation in the following themes.

Design Processes

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Design Theory and Research Methodology

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Product, Service and Systems Design

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Design for X, Design to X

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Design Information and Knowledge

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