DDUS Guidelines

design for dynamic and diverse use situations
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This workbook describes and explains a set of guidelines to deal with knowledge about the variety in use situations in which products are used in the design process. The ultimate goal of these guidelines is to support designers in creating products with a higher level of usability in intended use situations. The guidelines were developed iteratively by means of applying them to realistic design cases in two student projects. A further validation of the guidelines in design practice is needed to evaluate the usefulness of the guidelines for design practitioners.

“Guidelines to design for dynamic and diverse use situations”

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INTRODUCTION

As opposed to tailored products, industrially manufactured products are used by different users, for different purposes in different contexts. I call this dynamic and diverse use situations (DDUS, [1]). Dynamic use situations refer to the change of situations in time for one product, for example, one day you might use your bike to cycle to university to be in time for a lecture, while the next day you might use it to transport your groceries from the supermarket to your home. Diverse use situations refer to the change of situations in time and space for different versions of the same product. For example, someone else might possess the same type of bike, but only uses it for recreational purposes, for example cycling with friends.

Design for DDUS is difficult because it is hard to:

- predict the variety of use situations a product will encounter: use situation analysis
- anticipate what kind of issues will occur when the designed product will interact with these situations: use anticipation
- deal with conflicting requirements from the different use situations in one design: solution generation

These different aspects of design for DDUS are illustrated by the example shown in figure 1. Designers of smart phones will undoubtedly do a lot of research on who uses or would like to use smart phones for which purposes under which circumstances. Apple designers might have expected that people would use the iPhone outside, also in cold weather (use situation analysis). However, that Korean

Figure 1: design for DDUS consists of use situation analysis, use anticipation and solution generation.
people would consequently use sausages to control the phone (use anticipation), was probably unforeseen! In this way, each specific use situation can require different product characteristics. In this case, the problem can be solved by providing an accessory to the iPhone such as a special glove (solution generation).

Design for DDUS is not new in the sense that it recognises the difficulties of dealing with different users in different contexts, because this issue is mentioned in many sources (for example [2], [3]). However, those sources give little guidance on how to deal with this problem in design. Therefore I developed a set of guidelines to support designers in dealing with DDUS in the design process. The goal of these guidelines is to make designers more aware of DDUS, stimulate designers to analyse DDUS, explore the consequences of DDUS and apply the use situations consistently in the design process.

This is expected to improve both the usability of solution proposals as well as the decision making process with regard to choosing solutions and appropriate target use situations. Both factors influence the usability of the final product in its intended use situations. Apart from its short term effects such as improved safety and user performance, usability can give product development companies a competitive advantage through its influence on consumer satisfaction, brand perception and repeat sales [4]. It should be noted that the guidelines are not aimed at developing products with a diverse as possible use situation target domain.

This ‘workbook’ will explain the guidelines to design for DDUS. Examples of two student projects are used to illustrate the different elements of the guidelines. The first project concerned the redesign of a carrier bike (bakfiets), which in the Netherlands is mainly used by parents to transport their children. The second case concerned the design of an Airfryer, which is a deep fryer that uses air instead of oil to fry different kinds of food. Examples from different teams are shown in this document.

*Figure 2: the example products that are used to illustrate the guidelines in this workbook, a carrier bike (in this case with a hood to protect children) and the Airfryer (original design of Philips)*
BASIC GUIDELINES

The basic guidelines to design for DDUS are summarised here and further explained in the sections mentioned after the guidelines.

- Make all members of a design team aware of dynamic use and create a shared mindset by having members actively work with information about use (see: Envisioning Use workshop, page 20)

- Keep track of a consistent frame of reference with use situations and related use issues throughout the design process (see: the explicit frame of reference, page 8) by:
  a. Analysing current use: learn about future use situations from analysing the present (see external DDUS exploration, page 27)
  b. Exploring use issues related to chosen use situations (see internal and external exploration, page 22/27)
  c. Verifying assumed issues for current and future use situations (see external DDUS exploration and evaluation, page 27)

- Structure the frame of reference: connect use issues to the use situations in which they occur (see explicit frame of reference, page 8)

- Present: use a simplified, prioritised representation of the frame of reference to inspire solution generation and support team communication (see explicit frame of reference, page 16)

- Use scenarios to explore connections between use situations and use issues and to communicate those connections (see scenario analysis, page 25)

Apply the frame of reference in use evaluations:

- Use targeted use situations to set test conditions for use evaluations (external use evaluations, page 29)

- Use targeted use issues to set research questions for use evaluations (external use evaluations, page 29)

The ‘design for DDUS’ guidelines can be used to develop a design approach which consists of a number of activities that are performed around an evolving frame of reference of product use. This frame of reference contains the use situations that a product can possibly encounter and the use issues that occur in related use situations. This frame of reference can be used to design and evaluate solutions (figure 3).
ACTIVITIES IN DESIGNING FOR DDUS

We distinguish different groups of design activities to create and apply the frame of reference of product use. Since use anticipation and use situation analysis are strongly interrelated, they are not mentioned as individual activities, but they are part of the different types of analyses.

- External exploration and verification of current use, for example by means of user analysis or expert interviews
- External evaluations: confronting a solution to a use situation based on the frame of reference, for example by means of user tests
- Internal explorations and evaluations: exploring the relations between use situations and issues for both current and future solutions, for example by means of scenario analysis or the Envisioning Use workshop, self-evaluations or placing ideas in context
- Solution generation: creating solutions inspired by the frame of reference
- Decisions on target and solution: choosing an appropriate target and solution with a team or with the client

Internal activities concern activities in which no verification of information about actual use situation aspects takes place, for example evaluations that do not involve potential end-users or exploration of use issues based on assumptions. Evaluations that are executed opportunistically with people that are close to the development team (e.g. colleagues or family) are also considered internal activities when the selection of these test persons is not based on the defined target group. However, the area between internal and external activities contains a grey area, because in some cases an opportunistically chosen test person might also be an actual end-user of the intended target group.
Figure 4 shows the relations between the different activities and the two most relevant design materials in this approach: the solutions and the frame of reference of product use. The relations will be explained in the corresponding sections.

The frame of reference has a dynamic character, it evolves during the design process. In the beginning of a design process, assumptions need to be made about what the target use situations are and what the desired use issues for these situations are. During the design process, when analyses of the use situations and evaluation of solutions reveal new information, the frame of reference needs to be updated. In some cases this concerns an addition or removal of information, in other cases it concerns an adjustment of the target.

The activities are not meant to replace current design processes. On the contrary, they refer to activities that mostly already occur in practice. The added value in design for DDUS is that their relation to the frame of reference with dynamic and diverse use situations becomes more apparent. For internal explorations we developed a specific technique, the Envisioning Use workshop, which can be used as a good starting point for the design process.

Since the target group and therefore target use situations are usually defined before the actual design process, the guidelines are applicable to both predevelopment phases and later development phases. In the predevelopment phase the guidelines
can be used to set the target use situations and issues for the design brief or development proposition.

In the following section I will firstly describe the content of the frame of reference. The subsequent sections will describe the different types of design activities.

THE FRAME OF REFERENCE OF PRODUCT USE

In the frame of reference we basically distinguish two types of information: information about the situations in which products are used and information about the interactions between products and these use situations. Figure 5 shows how use situations are related to use issues. When a product with certain characteristics encounters a use situation, this will result in an interaction with certain qualities: the use issues. The frame of reference contains information about use situations and use issues. Besides these types of ‘use knowledge’ it contains a prioritised target which defines which use situations and issues will be taken into account in the design process.

USE SITUATION ASPECTS

With a use situation we mean a certain user with a certain goal in a certain context. Several aspects of this use situation will have influence on the use of the product. For example for the design of a carrier bike (bakfiets) product use will be influenced by where it is used (on the road, in the park, on the beach), what people want to transport (groceries, children), why people buy and use a carrier bike (environment, costs, health) etc.

Characteristics of the user can relate to mental characteristics such as knowledge, experience and cognitive characteristics. Furthermore they can relate to emotional

![Figure 5: relation between use situations, use issues and product characteristics](image-url)
characteristics or physical characteristics (dimensions, sensory aspects). All aspects can have a temporal (moods, fatigue) or a more firm character.

The goals of the user can be divided in motivations (why someone uses/buys a product), practical goals (for which practical purpose the product is used) and preferences of use (how someone wants to use the product).

Aspects that concern the context include environmental characteristics (weather, busyness, lightness, and loudness), objects in the environment or tools that are part of the interaction and events that can occur during the interaction.

INTERACTIONS AND USE ISSUES

When a product encounters the use situations as described above, an interaction between those situations and the product can occur. This interaction will have certain characteristics and qualities, which are defined as use issues. Those use issues include performance aspects (how well the goal of the user is achieved), usability (the effectiveness, efficiency and satisfaction of the interaction) and user experience (a person’s perceptions and responses that result from the use or anticipated use of a product). Use issues can also concern safety. An example of use issues is that one aspect of the carrier bike is that older children like to explore the world around them (goal aspect). Resulting use issues could be that when seats are positioned forward (product characteristic) older children are happy because they can look around (use issue) (figure 6).

Relations between use situations and use issues can also be viewed holistically presented in stories or scenarios.

The frame of reference can be based on assumptions and facts. Ideally information on use situations and use issues is based on reliable sources such as a user analysis. However, in design practice, it is impossible to work without assumptions to make steps forward. Therefore, use issues can have different status. They can be defined as the characteristics and qualities of the interaction that can, could or should occur between use situations and a current or future product. The differences between the three is illustrated by the example of the Airfryer in which issues are connected to the use situation of cooking with children around presented in figure 7. The issues indicated in red are assumptions (the interactions that could happen). When they are verified they can be transferred into facts which are indicated in black. Assumptions and facts are thus different formulations for different status of the same issue. It is not recommended to use the different formulations next to each other, but to formulate them according to the appropriate status. When introducing new solutions, such as the child lock, a new issue could be formulated next to the related issue of current use, because a new product essentially introduces a new interaction. Introducing solutions can also lead to new issues which are not
related to preceding issues, such as ‘the child lock is not visible for young children’ which was found out after evaluating the design for the child lock.

Often, it is not clear which aspects of the use situation influence certain use issues. For example, if a certain feature of a product is not understood by most users, the issue mostly occurs independent of the user. These issues are defined as

**Figure 6: example of 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.**

**Figure 7: use issues can be based on facts or assumptions.**
‘independent issues’ and can be positioned in the frame of reference, independent of use situation aspects.

In the frame of reference, use issues and use situations should be kept together as much as possible. This ensures that the people who are working with it know where a certain issue comes from. Product characteristics are not part of the frame of reference, because desired use issues can often be achieved by different solutions. For example, looking around in the carrier bike during rain can be achieved by means of a transparent rain hood, a rain hood that is open at the front or having the children wear a waterproof outfit. However, in some cases a use issue might become more clear when an example of a solution is mentioned. For example, children should be given the same view of the environment as with a rain hood of type X. Figure 8 shows an example of a frame of reference of product use for the design of a carrier bike.

Next to the structured part of the frame of reference, which includes the above mentioned connections between use situations and use issues, it should also contain a general description of the target user, goal and context, for example by means of a scenario. How to represent this general target was not explored in this research yet.

TARGET
The frame of reference can give a very broad view on use situations and issues related to current products and prototypes. However, it is often not desirable to develop a product that fits all use situations and issues. Cooper [5] states for example

![Image of a frame of reference for the design of a carrier bike for families (left) and a closer look of the part of the frame of reference related to the design of the hood (right).]
that you will find that the product features that please some users will interfere with the enjoyment and satisfaction of others. Trying to please too many different points of view can kill otherwise good products. Therefore the use situations and use issues that should be taken into account should be clearly targeted. The target is divided in two types of elements:

1. The use situations that the product is aimed at. These use situations will serve as test conditions in use evaluations (see chapter external evaluation).
2. The desired use issues such as the desired level of performance or the desired user experience.

Targeting is a decision making activity and should therefore be done in consultation with team members and the client. Motivations for a certain target can be market potential (no competitor product aimed at a certain domain of use situations), technical opportunities or other commercial or ideological goals. Cooper (1999) furthermore proposes to focus at ‘daily use’ and ‘necessary use’, which are the most frequently occurring and most important use situations. Other ‘edge case scenarios’ need not to be taken into account in the design process.

The target can be indicated in the frame of reference by means of a separate ‘tag’ such as shown in figure 7. The issue can then be translated in a description of the desired use, the interaction that should occur. These formulations of the desired situation can be integrated in the frame of reference, for example such as presented in figure 7.

WORKING WITH A FRAME OF REFERENCE OF PRODUCT USE

The frame of reference can have both an explicit and an implicit character. Explicit versions of the frame of reference concern digital or analogue representations. The implicit version of the frame of reference is the knowledge in the heads of the team members. An explicit frame of reference is theoretically easy to share and to reflect on while the implicit frame of reference benefits from always being available to a designer and therefore being easier to apply in reflection on solutions. In a development team it is important that team members have a shared frame of reference, both implicitly and explicitly (see figure 9).

Design for DDUS implies that the frame of reference is a very broad collection of use situations and use issues. However, for certain design activities it is not desirable to work with the complete collection. For example, in generating solutions and team communication, a simplified version of the frame of reference is more appropriate (see representing the frame of reference). In other activities, for example, doing a user test, the complete frame of reference is necessary to check if all necessary
issues are tested and to set up the user test. Moreover, during the design process, new insights or decisions can result in a change of the frame of reference. In that case, the irrelevant situations and issues should be removed. Keeping them in a ‘recycle bin’ preserves that data for reuse. For example, one team of the carrier bike project started off with a bike for parents to transport their children, but decided to reset their target to professional transport at holiday parks. They could discard many of the firstly generated parents-children issues. However, when they found out through verification that the professional transport was not an appropriate market, they changed to renting facilities on holiday parks. For this type of use, the parent-children issues became relevant again. Summarising, there are three views on the frame of reference: the complete view of all relevant information for the chosen target, the recycle bin with non-relevant information and the simplified view which shows just the priorities of the complete view (figure 10).

Each design activity requires a different view on the frame of reference and a specific kind of representation. Table 1 shows the four main categories of frame of reference presentations and their relations to the design activities. The following section will explain the explicit representations in more detail.

REPRESENTING THE FRAME OF REFERENCE

THE COMPLETE FRAME OF REFERENCE

Content
The complete target frame of reference contains all relevant use situation aspects and related use issues. Furthermore the priority is indicated in this view and it
can contain the questions that need to be answered. Since many elements in this frame of reference are interrelated, different categorisations can be made to structure the information. It is up to the development team to choose a workable structure. At this stage of this research process it is not clear yet what the best types of categorisations are. Figure 13 and table 2 show two examples of possible categorisations: a categorisation in use phases, a categorisation in use situations: user motivations, user types (ages of children) and contexts and a categorisation in issue types: ergonomics, safety and functionality.

Facts and assumptions should be distinguished in the frame of reference. This division makes it clear which data need verification. In the Envisioning Use

<table>
<thead>
<tr>
<th>Representation</th>
<th>view</th>
<th>activity</th>
<th>benefits</th>
<th>limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>The implicit frame of reference</td>
<td>No</td>
<td>Always available in the mind of the team member</td>
<td>Solution generation and reflection</td>
<td>Create a shared view, always available</td>
</tr>
<tr>
<td>The priority view</td>
<td>one page overview</td>
<td>Always visible: target/ priorities</td>
<td>Solution generation and choosing/ communicating target, solution and process</td>
<td>Easy to remember, easy to communicate</td>
</tr>
<tr>
<td>The complete view of target use situations</td>
<td>Mindmap, table, product use mindmap, structured overview</td>
<td>Hidden: visible on request: evaluative data</td>
<td>Setting external evaluations and external DDUS explorations/ verification Internal DDUS exploration and evaluation</td>
<td>Complete overview, logical categorisation, distinguishes assumptions and facts</td>
</tr>
<tr>
<td>Recycle bin</td>
<td>All above mentioned representations</td>
<td>irrelevant data</td>
<td>For reuse after target change</td>
<td>Prevents redundant researches</td>
</tr>
</tbody>
</table>

Table 1: four categories of representations of the frame of reference and their benefits and limitations
workshop the division is made visible by writing facts in black and assumptions in red.

**Working with different representations for the complete frame of reference**

The first version of the frame of reference can be made in the Envisioning Use workshop (see page 24). The frame of reference there takes the format of the ‘product use mind map’ consisting of sticky notes on flip-charts (see figure 11). Preferably these flip-charts are used throughout the design process. However, they are not very portable. The flip-charts could therefore be digitised by making photographs or translating them in a digital representation such as a digitised mind map, a table or a website.

Working in a team with these digital overviews can be difficult, because you can only see a part of the frame of reference at a time on a computer screen. Moreover it is difficult to view and adjust a digital representation together. Therefore it is advised to assign one team member with the role of ‘managing’ the digitised frame of reference. This task includes updating the data and informing team members about the changes in the complete representation.

Figure 13 shows an example of how an explicit frame of reference can evolve during the design process. Different use situations and issues are added and removed as new information becomes available or different targets are chosen. The members of this design team had difficulties in working with the vast amount of use issues in the mind map. They preferred working with a simplified priority view and implicit frames of reference in workshops. Figure 12 shows an example of a part of the

![Figure 11: example of a product use mind map generated in the Envisioning Use workshop. The green post-its show questions, gaps in the frame of reference.](image)
The complete frame of reference is built bottom up to make it possible to check completeness and to add structure, which is needed to use the frame of reference in evaluations. The priority view of the frame of reference serves as inspiration to solution generation and as a means to communicate the target within the team. The priority view can furthermore be used in team communication to decide on which steps to take. A priority view on the complete frame of reference is necessary, because the bottom up approach of the complete view can contain a lot of information and is therefore difficult to take in at a glance (see the examples). Therefore a representation is needed that shows the target in one view, for example by printing it on one A3. The priority view should represent the most important target situations the product is aimed at and the most important use issues related to those situations. Examples of priority views on the frame of reference are:
Figure 13: example of a complete digitised mind map: different coloured lines indicate different relevant sections during the design process. The right part of the mind map shows a categorisation in use situations: user motivations, user types (ages of children) and contexts; the left part shows a categorisation in issue types: use phases, ergonomics, safety and functionality.
Table 2: example of a part of a complete frame of reference in a table format for the design of a carrier bike for renting purposes. The categorisation is based on use phases. It should be noted that the column ‘possible solutions’ is not part of the frame of reference, but is here added to show the connection of the frame of reference to possible solutions.

<table>
<thead>
<tr>
<th>situation</th>
<th>issue</th>
<th>possible solutions</th>
<th>target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading/ unloading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensions box</td>
<td>Doing groceries</td>
<td>Bringing a large load in volume and weight</td>
<td>Test target: is it possible to adjust loading space compared to passenger space</td>
</tr>
<tr>
<td></td>
<td>Taking heavy load out the box</td>
<td>High wall makes it heavy to lift</td>
<td>Test target: are walls not too high, or is the box too deep</td>
</tr>
<tr>
<td></td>
<td>Opening box</td>
<td>When raining, water can get into the box and seats can get wet</td>
<td></td>
</tr>
<tr>
<td>Parking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small space</td>
<td>Difficult to manoeuvre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little parking space</td>
<td>Carrier bike obstructs other parking users</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaving load in the carrier bike</td>
<td>Luggage should be protected against vandalism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Getting on and off bike/ walking next to bike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusting bike</td>
<td>Seat and steer are not adjusted correctly</td>
<td>You cannot cycle comfortably</td>
<td>Should be easily adjustable without tools TARGET: bicycle should be adjustable without tools</td>
</tr>
</tbody>
</table>

- A mind map representation of the five to seven most important issues with connected use situation aspects.
- Scenarios with explicitly mentioned use issues. Scenarios combine the prioritised target use situation aspects in stories or storyboards. Different representations for scenarios can be applied from simple narratives to complete digital animations (see figure 14).
User profiles can be used when other situation elements (environment, goal) are clearly related to specific types of users. As with scenarios, the user profiles should also mention the most important issues.

Creating a shared vision of product use

In a design project, the team members should preferably have the same idea about the users, contexts and goals they are designing for and the relevant issues that should be solved. In other words, they should have a shared vision or common frame of reference. A shared vision is necessary to be able to make design decisions. An explicit frame of reference can help to create and communicate such a shared vision. Ideally team members then build an idea of this frame of reference in their heads which they can use in discussions about design decisions or in creating and reflecting on solutions. However, during the design process, new information
about product use will come forward. Consequently the frame of reference will need adjustment and all team members need to be updated on the newly gathered information. Basically there are two means to (re)create a shared vision. The first way (see figure 15) is that the team member who has gathered new user insights updates the explicit frame of reference and sends the updates to the other team members. The second way is to organise a meeting in which the information is shared with the other team members and the information is added to the explicit frame of reference in that session. The Envisioning Use workshop can be applied for this goal. The main advantage of sharing information in an interactive meeting is that team members actively work with the data and therefore will more easily remember the data. The downside is that organising such a meeting will cost more time.

In one of the carrier bike projects a team had an idea to develop a box that can easily be adjusted to different aged children. This has both physical as well as emotional constraints and opportunities (for example small children want to look at the parent, while older children want to look outside). These age specific characteristics were gathered by two team members by means of literature. Then they organised an envisioning use workshop to update the other team members with this information. Because the other team members had very little experience with children, the workshop worked very well in anticipating together how children would react in different situations.

![Figure 15: two means to update team members with newly gathered information: through the explicit frame of reference and through an envisioning use workshop](image-url)
UPDATING AND TIMING THE FRAME OF REFERENCE

As mentioned in the basic guidelines, different activities can be used to update the frame of reference. An internal exploration, for example an Envisioning Use workshop, can be used to gather implicit knowledge and explore relations within the frame. External explorations of current use can be used to gather or verify information about users or contexts for example by means of interviews or online reviews. External prototype evaluations can be used to verify use issues.

The similarity between current use and future use defines the extent to which the external explorations and evaluations can be used to build a relevant frame of reference of product use. The frame of reference is relevant when it represents real-world use situations and connected use issues. These real world situations consider the situations for the to be developed product. In other words, they consider future use. Because future use cannot be predicted, it needs to be anticipated indirectly by either extrapolating knowledge about use of comparable products and situations or by evaluating solution proposals in intended use situations. However, when there is a large difference between the to be developed product and/ or its intended use situations and the current product and use situations, it is not likely that insight in current use will lead to relevant knowledge with regard to future use.

This was for example the case in the carrier bike projects in which students chose a completely different target use situation domain (use by employees of a holiday park to transport tools) than the current domain (use by parents to transport their children). The insights they gathered in external explorations with regard to transporting children, gave very little insight in relevant issues for holiday park employees. Therefore evaluations of the carrier bike in the new use situation were necessary to gather this information and build a more relevant frame of reference.

The following question is when to do what? When to organise a workshop, when to do an external analysis or evaluation to verify assumptions, and when to create an explicit frame of reference. At this moment there is not enough experience with working with the frame of reference of product use to motivate the best approach, but some general remarks about timing can be made.

Firstly it is good to start a project with a workshop in which all available knowledge is gathered and the first target is set. When team members don’t have any experience with the product it will be necessary to do some research (external exploration of current use) before the workshop, for example by means of gathering online customer reviews. An internal evaluation of existing products can also be used to get insight in the use of the product. Another possibility is to invite an expert on the topic in the workshop. The workshop then results in questions for further analysis which can be verified in external analyses or evaluations. To prevent working on irrelevant problems, it is important to verify assumed issues as soon as possible, particularly issues that are part of the priority view! If these analyses
result in a lot of new information, a new workshop might be necessary to recreate a shared vision. If the analyses are mainly a verification of assumptions from the workshop, the results can then be used to directly update the frame of reference. When the choice is made to create a digitised explicit frame of reference, this should preferably be done after the first verification in case of a frame of reference with a lot of assumptions. This prevents doing a lot of unnecessary digitising work.

When the project is aimed at a new or unfamiliar market, a scenario analysis (see internal explorations) might be necessary to explore relevant use issues. This analysis can be executed individually or in a workshop. At each stage in the design process at which a lot of new user insights are gathered, a new workshop or other type of meeting might be necessary to align the mindsets of the different team members.

The different representations of the explicit frames of reference should preferably be adjusted each time new information is available, but at least be updated when they are needed for other design activities. When the complete explicit frame of reference is needed to steer external analyses or evaluations, it should be checked if it is still up to date. When a meeting is planned for decision making on solutions or when solutions are created, the simplified frame of reference should be adjusted to support those activities. One should make sure that the different representations of the frame of reference are updated in the same way. A balance should be found in spending time on managing the information on product use and actually using the information.

The following sections will describe the different types of design activities and how they relate to the frame of reference.

**INTERNAL EXPLORATION**

Internal exploration considers all those activities executed within a design team aimed at gathering implicit knowledge about product use, exploring relations between use situations and use issues, and analysing gaps in available knowledge. This can be aimed at both current and future use. The Envisioning Use workshop is a means to achieve those goals in a team. Another way to explore issues is scenario analysis which can be executed both individually and in a team. Both methods will be explained at the end of this section. The gathered knowledge can be used to update or create the frame of reference of product use (figure 16).

When internal explorations are aimed at a design proposal, they have an evaluative character. In those evaluations, no potential end-users are involved, but evaluations are executed by the designers themselves or opportunistically with people in their direct environment such as colleagues, friends or family. Although this type of
evaluations is less valid than an external evaluation, it has the advantage of being much faster. Therefore they can be more easily integrated in an iterative design process. For example, a designer can make some quick mock-ups of his or her ideas, test them with colleagues and make design decisions based on this evaluation. Thus, explorations, evaluations and solution generation can be combined in one ‘session’, for example in an Envisioning Use workshop. Therefore they are not presented as separate activities.

Exploring and evaluating solutions can take place in different forms:

- representations of the solutions can be compared to the explicit frame of reference such as the product use mind map or scenarios in a thought experiment
- drawings of solutions should be placed in context, which means the drawings should contain a presentation of the user (e.g. by drawing hands) and a presentation of the environment. Preferably they should be presented in a storyboard to show the complete use situation.
- in internal tests with mock-ups the test persons can be presented use scenarios or user profiles and they can be asked to imagine they are the actor in the scenario.

Figure 16: the relation between activities that concern ‘internal exploration and evaluation of dynamic use situations’ and the frame of reference of product use
In all cases, the explicit frame of reference can be used to ‘contextualise’ the exploration, which means the frame of reference is used to set criteria or test conditions.

INSPIRATION AND REFLECTION IN SOLUTION GENERATION

In internal exploration and evaluation the implicit frame of reference (the ideas about use situations in the head of the designer) can also be used as a reference. These kinds of reflections can therefore occur throughout the creative process. A designer makes a sketch, reflects on it by thinking about its application in the intended use situations, adjusts it etc. In this process it is particularly important that the designer has a valid image of the frame of reference (see ‘creating a shared vision’). A simplified priority representation of the frame of reference can be used to inspire the creative process. (see ‘representing the frame of reference’).

GENERAL USE SITUATION ANALYSIS

A separate activity is ‘general use situation analysis’ which is an external activity aimed at gathering insight in possible use situations in which the product will be used. As opposed to external explorations, which will be explained in the following section, use situation analysis are activities which do not explore how use situations are connected to a product and resulting use issues. Instead these type of activities can be used to inspire internal explorations by giving insight in general characteristics of the target users or target contexts. For example, the section on the shared mind set explained that one of the teams executed a literature analysis on physical, cognitive and emotional aspects of different aged children. This data in itself cannot be used in the frame of reference, because it does not relate the data to specific issues. An extra internal exploration of this data, in this case by
means of an Envisioning Use workshop, linked the characteristics of children to
desired use issues with the carrier bike.

THE ENVISIONING USE WORKSHOP
The Envisioning Use workshop is aimed at creating a shared vision on product use
by gathering and sharing all available knowledge on product use at a certain stage
in the design process (see figure 17). It results in both a shared implicit frame of
reference and (an update of) an explicit frame of reference. The main part of the
workshop is spent on exploring the relations between use situations and use issues
and indicating gaps in the knowledge. This ‘internal exploration of dynamic use
situations’ can be combined with solution generation (the envisioning step) and
targeting. The different steps of the workshop are described in the manual of the
Envisioning Use technique.

The first steps of the workshop are Remembering (gathering stories of product
use), Imagining (imagining other future situations and exploring related use
issues) and Experiencing (role-playing future situations). These steps are aimed at
exploring relations between use situations and use issues. If the workshop is aimed
at exploring and gathering knowledge about current use, more time will be needed
for remembering and the scenarios played in experiencing will be current scenarios.
If the workshop is aimed at exploring future use, more time will be needed for
imagining and the scenarios played in experiencing will be future scenarios.

In the questioning step, gaps in the product use mind map are explored and
questions about product use are formulated. The Questioning step is always a good
step to wrap up the workshop, because it can be used to define next steps in the
development process with regard to product use.

SCENARIO ANALYSIS
A part of the Envisioning Use workshop is aimed at exploring unknown use
situations in relation to the design project at hand. This is done in the Imagining
step and can also be part of the Experiencing step. In Imagining this is done by
stimulating participants’ imagination by providing them with associative materials.
They then think up scenarios and tell them to the other participants while writing
the most important issues and aspects on post-it notes. The scenarios in this case
are not recorded. Another way to do imagining is quickly generating scenarios
together. However, since scenario generation is a relatively slow process to do in a
workshop and is difficult to do in a large group, working with explicit scenarios on
paper in the workshop will result in less breadth in the results compared to working
with implicit scenarios (in the heads of participants and in the stories that they tell)
and associative materials. Scenario analysis is therefore a technique which can be
best applied as a separate activity. The advantage of scenario analysis compared to
‘imagining’ in the Envisioning Use workshop is that the situations can be explored more deeply and the results are recorded during their creation.

A scenario is a description of the hypothetical use of product [6]. Scenario analysis is a holistic approach which considers use situations as a whole instead of a collection of individual use situation aspects. The scenario allows for exploration of what could happen if a certain solution encounters that situation. The solution can be an existing product, a black box idea for a solution or a more developed concept design. The scenario should contain information about the user (the actors), setting (environment and persons or objects in it), the goals of the user, actions of the user and external events. The scenario can be completed with statements about the quality of the user-product interaction: the use issues.

A scenario can be completely based on imagination or can contain different elements that are based on facts that are gathered in previous analyses. For example the user characteristics can be based on a real user, while the solution and the use environment are based on imagination. In scenario analysis, the goal is to explore relations between a certain use situation and resulting use issues for a certain solution. Those use issues will therefore be based on assumptions. In later design stages these assumptions can be verified.

Scenarios can be represented in different ways such as narratives (figure 18), storyboards, movies or a role-play. For the goal of exploring use situations and issues, narratives are an efficient means to represent the scenarios. For communication purposes it is often useful to add visualisations to the scenario.

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**Figure 18:** this scenario was created to explore the use of an Airfryer (here called AirCooker) by a user of the target group ‘social climbers’ in a specific shopping situation. Different scenarios were created for different shopping and cooking rituals.

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**Scenario 2**

Loes is travelling homewards by train after a long day of work. She is too tired to put much effort in cooking for herself only, but she still wants to cook something healthy and delicious. So she gets her laptop and looks at the AirCooker recipes on the internet and selects one with chicken, potatoes and cauliflower, together with a cheese sauce which she can put in the microwave. When she arrives at the train station, she goes to the local supermarket on her way home and buys the ingredients. At home she takes the AirCooker from the shelf, puts it on her counter top and looks at the recipe again for the preparation time and which compartments to use for the food. When she is done, she starts the machine and finds herself ending up watching Sex and the City on television. When she hears the signal she shakes food and continues to watch television. The food is ready and she puts the sauce in the microwave before putting the food on her plate. When she finishes the plating, she gets the sauce out of the microwave, pours it on her food and eats the dinner in front of the television. When she is done, she puts the dirty stuff in the dishwasher and puts the AirCooker on the shelf again.
This section described how internal activities can be employed to explore relations between use situations and use issues. This will lead to assumptions about use. The next section describes how assumptions with regard to current use can be verified and further explored externally.

EXTERNAL EXPLORATION AND VERIFICATION OF CURRENT USE

Relations between use situations and use issues can be analysed internally or externally. Internal explorations will mostly lead to a lot of assumptions about product use. However, to be able to make more successful design decisions, it is necessary to base them on facts. These facts can only be gathered by doing external analysis on real end users in real settings. External DDUS exploration and verification is aimed at current solutions. Based on knowledge of use situations and issues of comparable products, use issues and use situations of future solutions can be anticipated. As opposed to evaluations of future solutions in design proposals, they can be used to gain valid insight in actual use. Those analyses can be explorative or structured. In the last case the analyses are steered by questions and can include the verification of assumptions that were defined in internal explorations (figure 19). The questions are drawn from the frame of reference. In the first case the analysis is more open and situation aspects or issues can arise that were not considered before in the frame of reference.

![Figure 19: relation between activities that concern ‘external exploration and verification of current use and the frame of reference of product use](image-url)

Figure 19: relation between activities that concern ‘external exploration and verification of current use and the frame of reference of product use
Results from the external analyses can be used to update the frame of reference (figure 19). This can only be achieved when use situations are connected to use issues. When use situation aspects are not connected to what this means for the product, they first need to be explored internally, as explained in the previous section. Assumptions can be verified and converted to facts and new situation aspects or use issues can be added. External analyses might also lead to new assumptions, when an analysis of use issues of a current solution gives input to assumptions about use issues of a new solution. In that case predictions about future use are based on extrapolations of analyses of current use. Table 3 give examples of different techniques which can be applied to conduct external analyses.

VALIDITY OF DATA

When verifying assumed issues, one should take care of the external validity of the gathered data. The validity concerns the extent to which the data can be generalised to real world situations. When a user is observed when using a current solution in daily life, the validity of the information is high because a real world interaction can

<table>
<thead>
<tr>
<th>Type</th>
<th>Benefits/ limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert interviews</td>
<td>Experts have a broad knowledge about users, contexts and issues. The expert is not always the end-user.</td>
</tr>
<tr>
<td>Online: internet fora, reviews, YouTube</td>
<td>Broad variety of stories is available, in case of movies with visualizations. Reliability cannot be inspected. Very often only extreme cases and problems are shared.</td>
</tr>
<tr>
<td>Observation of current use</td>
<td>Observations can give direct insight in context characteristics. One cannot observe what goes on in the user’s head. Longer observations necessary to analyse dynamic use.</td>
</tr>
<tr>
<td>End-user interviews</td>
<td>To get insight in user goals. To achieve breadth in results many users should be interviewed.</td>
</tr>
<tr>
<td>After sales feedback [10]</td>
<td>Depending on the way the after sales feedback is retrieved, a broad variety of issues can be analysed.</td>
</tr>
<tr>
<td>Use evaluations of current solutions</td>
<td>Explore the use of existing solutions in new use situations. Does not give insight in actual use, as opposed to above mentioned techniques.</td>
</tr>
<tr>
<td>Analysing catalogues</td>
<td>Particularly anthropometric data are commonly available, but also other use situation aspects can be found in reports or catalogues. However, this data is mostly not connected to specific use issues.</td>
</tr>
<tr>
<td>Standards and legal requirements</td>
<td>Norms often mention the test conditions (=use situations) that are used to evaluate products for a specific norm.</td>
</tr>
</tbody>
</table>
be observed. When users are interviewed about how they would use a current solution, without actually having done so, the validity is of course a lot lower. But also observations of first time use (presenting a current solution to a user and having it used) has a lower validity, because it does not give insight in how the user would apply the product in daily life. For example, in the Airfryer project different users were asked to try out the current Airfryer while being observed. Although this led to very valuable data, the observation was not completely valid with regard to how users would integrate the use of the Airfryer in their actual daily cooking rituals.

HETEROGENEITY OF THE TARGET GROUP
When a target group is not homogeneous with regard to a certain important use situation aspect, this heterogeneity should be made apparent in the frame of reference. Figure 20 shows an example of one of the teams who worked on the Airfryer, in which a graph format is used to represent the diversity of the target group with regard to a seemingly relevant use situation aspect. However, this representation does not indicate if this leads to different issues. At this moment, no examples are available of how heterogeneity and more specifically the quantitative spreading of a certain use situation aspect can be represented in the frame of reference. More research is needed to gain insight in this issue.

EXTERNAL EVALUATIONS
In external evaluations, generated solutions are evaluated on their interaction qualities such as usability, user experience and performance with potential end-users. The frame of reference can be used to set the test conditions and the research questions (figure 21). The more realistic the test conditions, the more valid the results will be for predicting future use. The results of the external evaluation can be used to update the frame of reference.
OBJECTIVE AND RESEARCH QUESTIONS

The objective of the use evaluations should be clearly related to use issues that are part of the frame of reference. For example one group in the carrier bike project developed a concept for a box that is more attractive for children so parents will be tempted to rent the bike in a holiday park (figure 22). This concept contained small steers for the children and had the appearance of a comic train character. Some of the issues that they assumed would be important with this concept were:

- Children are attracted to the carrier bike when they see it for the first time.
- The children like to play with the steers, but there might be a difference between girls and boys.
- The steers might make it more difficult to get into the box.

These issues defined what the research questions were, for example: do children show enthusiasm when they see the carrier bike, do children like to
play with the steers and is there a difference between girls and boys and do children have any trouble in getting in the box?

Use evaluations usually also have an explorative character, because not all use issues can be defined in advance. For example, one unexpected use issue in this case was that for some children the steer was positioned too close to their body to be able to steer comfortably. To allow these explorations, higher level questions should be asked as well, such as: ‘how do different children behave in the box?’

DEFINING TEST CONDITIONS/ SAMPLING

In designing for DDUS it is important that test conditions in use evaluations represent as much as possible the targeted use situations of the frame of reference. When the frame of reference is complete and it is clear which use situation aspects will influence the use issue that will be tested, the selection of participants and other test conditions can be based on these aspects. For example, in the above mentioned carrier bike project, it was important to involve both boys and girls because it could possibly influence the extent to which they liked playing with the steers. However, when it is not clear what ‘discriminating use situation aspects’ are, random test participants and environments should be chosen. Discriminating use situation aspects are the use situation aspects that influence the use issues that need to be verified, in this case girls and boys. These aspects are connected in the frame

![Diagram](image)

*Figure 23: discriminating use situation aspects in the frame of reference should be used to set the test conditions for usability evaluations. Realistic, random use situation aspects should be chosen to complete the use situations where necessary.*
of reference to the target use issues. Even though an evaluation might have a more evaluative than explorative character, more aspects of the use situation should be considered in the test conditions than just the ones that are in the structured part of the frame of reference. During the evaluation it then becomes clear what discriminating situation aspects are and they can be added to the frame of reference for later evaluations. Therefore, the test conditions should be completed with realistic, random use situation aspects that are part of the general target use situation, to allow for this discovery of new discriminating use situation aspects. At least the user (respondent), goal (tasks) and context of use (test environment) should be included in a test plan. For example, In this case it was not clear if the weather would have any influence on the use of the steers, but to set up a complete realistic use situation the test was executed outside while the weather conditions were left to chance, but not extreme. This planning of test conditions is shown in figure 23. Discriminating use situation aspects and realistic, random use situation aspects together are used to define complete realistic situations in which the product is evaluated. The discriminating use situation aspects are needed to verify assumed issues and possibly discover new issues, the random part of the test conditions can possibly lead to the discovery of new issues and new discriminating use situation aspects. In the case of the Airfryer project, none of the teams conducted their usability evaluations in a kitchen environment, because it was not indicated as a discriminating use situation aspect in the frame of reference. However, evaluating the appliance in a kitchen environment instead of evaluating it in a less realistic environment such as a living room or office, might have led to new unexpected issues or relevant use situation aspects.

SIMULATIONS VERSUS ACTUAL USE SITUATIONS
The external validity of use evaluations is highest when both the product and the use situations (reflected in the test conditions) are realistic. Therefore the most valid results come from after sales feedback: ‘test results’ from completed products that are introduced to the market. However, during the design process this type of feedback cannot be generated. The product will be represented by a mock-up or prototype and several elements of the use situation need to be simulated. One needs to make a choice for which elements will be simulated and which will be actual elements. For example actual end-users can participate in an evaluation but a designer or researcher could also choose to ‘simulate’ the user in a role-play (in that case it is an internal use evaluation). The (practical) goal of the user is often simulated by giving the participant a task. Personal goals can be real when actual end-users are selected based on motivation. The environment can be actual in an in-situ evaluation or it can be simulated by means of for example a lab, miniature environments, drawings, animations or virtual reality. Complete use situations can also be represented in different types of scenario representations. For example, in the case of the carrier bike for a holiday park, the prototype was not tested in
a holiday park, but at a school. Parents were shown the scenario of the holiday park rental, so they could be asked to imagine if they would rent the bike when they would stay at a holiday park. When it is not clear yet what discriminating use situation elements are (see ‘defining test conditions) testing in actual use situations will give more insight in what these elements are.

INTERNAL EVALUATIONS OR EXTERNAL EVALUATIONS?
As mentioned above, use evaluation can consider both external evaluations (elaborate, formal evaluations such as user testing with multiple end-users) and internal evaluations (more informal or ‘discount’ evaluations such as self-testing quick mock-ups or testing with colleagues or family or friends). Formal user tests have the advantage of being more reliable while designers executing informal user tests benefit from being much faster to organise and execute. The latter type of evaluations can be easier integrated in an iterative design process.

These internal evaluations are also very useful for discovering independent use issues. These are use issues that are independent of the use situation, and can occur in any situation. This means they do not need to be evaluated under specific test conditions. For example, a user interface might not give enough feedback for people to understand what to do. By testing internally early in the design process, these types of issues can be discovered and solved quickly.

GENERAL REMARKS ON USER TESTING
Nielsen advises to conduct multiple user tests with approximately five test persons ([11] and [12]). More background information on executing use evaluations can also be found in these sources.

TARGETING
Targeting is the act of defining which use situations and use issues the solution will be aimed at (figure 24). All members of the development team, including the client, should agree on what the target is. Therefore this activity is a team activity. It can be done as part of an Envisioning Use workshop or done separately.

To discuss the target it is necessary to have a visualisation of the different options. To ensure overview during the discussion a priority view of the frame of reference might be appropriate. However, in some cases it might be necessary to define the target in more detail and a visualisation of the complete frame of reference might be necessary to go through it.

Criteria to choose a certain target are usually of a commercial nature. Analysing what competitors do in a certain market might give appropriate input to decide on a target. Often it is unknown if a potential target will be successful or not. The development team then has to make an educated guess and explore the potential
fit between a solution and targeted use situations as soon as this is possible. For example, the team that wanted to design a carrier bike to rent to parents at a holiday park (target), checked if parents would be interested in this kind of service by interviewing parents and showing them drawings of a possible rental bike. They also checked if holiday parks were interested and analysed what the use issues of competitor rental bikes were. This gave them enough information to motivate the choice for that market to the client. Targeting an unknown market includes more risks because more knowledge has to be gathered about these use situations. A risk analysis can be executed to help in deciding on the appropriateness of a certain market. However, since these are marketing tools, they are not further described in these guidelines.

CONCLUSIONS

This workbook described guidelines to generate a design approach which takes the dynamics and diversity of use situations into account. The guidelines describe how this issue can be catered for in different design activities by making use of both an explicit frame of reference of product use and a shared, implicit frame of reference of product use. We expect that the application of the guidelines will make members of product development teams more aware of DDUS, stimulate designers to analyse DDUS, explore the consequences of DDUS and apply the use situations consistently in the design process.
FURTHER RESEARCH

The current guidelines were evaluated in student projects. Evaluation of the guidelines in business settings will lead to conclusions on the appropriateness of the offered guidelines for design practice. Issues that need to be investigated further in those evaluations are firstly the connection of the frame of reference of product use proposed in this workbook to currently used representations of target use such as user requirements and representations of the design problem with regard to technical or marketing specifications. Secondly more explorations and evaluations are needed of appropriate ways to organise the frame of reference. Finally it should be explored how the guidelines can be integrated in current design processes.

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