From Directions to Actions – IT Support for Individual Mobility in Everyday Activities

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Abstract

Being mobile is a crucial factor for taking part in society and living an autonomous live. Nevertheless, the demographic change, more sparse infrastructures and an tendency to move to more urban areas challenges people's ability to maintain their personal everyday mobility options.

One group in society that is especially affected by these challenges are the elderly. While we do not claim that the elderly in general present a homogenous group, but instead represent a very heterogenous group with very different social backgrounds and individual experiences, they do have experienced various changes in their lives, such as retiring and changes in their financial situations as well as physical condition. These experiences made them reflect their current situations as well as anticipate future changes. Thus, working with older adults in order to understand how they decide on adapting to changes in their mobility is very promising.

This work, therefor, focusses on how the adoption of transportation opportunities for individual everyday mobility can be supported by using information and communication technologies (ICT). Based on empirical studies with older adults that were carried out in three consecutive Design Case Studies (DCS) in a larger living lab context, we present practice-based insights on how different means of transportation are seen from a user's perspective.

The first DCS represents an empirical framing of this thesis. The findings of that DCS show that the supporting the appropriation of different modes is highly individual, needs contextual adaptations and needs to take into account, that different modes of transportation do not fit all situations encountered by people. Considering this, the second DCS shows exemplary how ridesharing concepts could be altered to make them more suitable for everyday contexts. Specifically, the flexibility that our participants value during their everyday mobility needs to be preserved when engaging in ridesharing. The third DCS presents derives the technological implications from the preceding DCSs and validate the technological feasibility of the proposed ICT-based concept for everyday ridesharing support. The findings highlight that a suitable support for everyday mobility

should take into account far more than logistical factors, which play in important role but are highly influenced by routines and therefor presents only little opportunities to be changed. Instead, contextual information that can be derived from the activities that induce the transportation as well as personal meaningful historical information, such as informal naming, known landmarks or typical routes and routines provide opportunities to highlight the suitability of alternatives modes of transportation.

In addition, this work also presents a critical reflection of the methods used, especially looking at the role of users in defining the problem and the design space of ICT-based solutions.

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1 Introduction

Recent years have significantly changed the way we think about mobility and transportation. Increased affluence, improving infrastructure, changing work patterns, and population increases have all contributed to a significant shift in the number of trips people make and the length of these trips (Handke & Jonuschat, 2012). This has led to the recognition that resource constraints affect our ability to maintain and adapt transport infrastructures in a financially and environmentally sustainable manner. Use of non-individual transportation systems, such as public transportation or shared rides, depends on the availability of information. Riding a bus or train, for instance, is difficult without access to a schedule. Advances in information and communication technologies (ICTs) have arguably transformed access to information, enabling systems to better provide information related to transportation infrastructures. Especially for older adults, access to well-established transport services and the ability to use individual modes of transport available in their local communities is crucial to satisfy their basic everyday needs and foster well-being. In addition to their age-related problems (cognitive and physical impairments) their mobility profile is different from that of younger generations due to a more dynamic schedule with more leisure and charity activities.

There is a variety of new transportation modes based on sharing resources (referred to as "cooperative forms") that provide alternatives to existing concepts. Such systems (see http://dynamicridesharing.org/), e.g., flinc, FluidVille, ZimRide, and Car2Go, try to encourage resource sharing, yet struggle with problems of adoption on a regular or daily basis (Raney, 2010). In Germany, for example, there are 43 million privately owned cars compared with roughly 9,000 vehicles in the bus and tram network. Overall, there is significant imbalance between individual and public or shared transportation in Germany; 83% of 68.7 billion annual trips are taken in a private car (counting only those of drivers and not including passengers). In general, there seems to be a tradeoff between autonomy, flexibility, and comfort, on the one hand, and reducing environmental and financial impacts by sharing, on the other. In addition, the growing carbon output, increasing cost of gas, higher taxes, and overcrowded urban areas that make commonly used ways of moving inappropriate for various reasons, have established a general understanding shared by governments and society that a shift to newer concepts of travel is needed. However, individuals persist in habits and refuse to explore new modes, which especially holds true for daily transportation needs that are characterized by short, often recurring trips.

This lack of adoption might due to the fact that common tools supporting transportation provide unsuitable support for certain tasks. For the aging population, these issues are also connected to aspects of changing self-perception and public image. Focusing on this group's mobility provides the opportunity to understand what other issues concerning mobility, especially day-to-day mobility, are of relevance for the design of transport information systems. By placing the focus on the specific group of elderly users, who are anticipating a pending transition in their mobility, we hope to understand what challenges are not met by current ICT solutions.

Concerning open challenges, most of the literature concerning transport and mobility tries to provide solutions for one particular mode of transport, e.g. public transportation. Transportation is often decoupled from the activities that necessitate the trip (Brereton & Ghelawat, 2010; Mirisaee, Brereton, & Roe, 2011). The problem of mobility is dealt with in a somewhat functional and efficiency-oriented way. New approaches such as car- or ride-sharing, as well as classic ones such as public transportation and taxis care about the "where" (in terms of starting point, distance and destination) and the "when" (in terms of departure and arrival time) of traveling. However, looking at the "why," these approaches have in common that the design ideas are based on the backdrop of existing transport modes such as taxi, bus or car. Although the "where" and "when" play a prominent role in some situations, it remains clear that there are situations in which the destination (Brewer, Mainwaring, & Dourish, 2008) and the time (Wash, Hemphill, & Resnick, 2005) are of less importance.

To this end, we make the case for viewing mobility through a praxeological lens. Using this lens, the issue of transportation is seen from the user's perspective, which is a promising way to address transportation as a question of individual mobility, which in turn is always embedded in and dependent on the broader set of previous, concurrent and subsequent activities. Such a "practice-oriented" perspective allows identification of everyday practices that lead to transportation usage and facilitate exploration of multimodal and intermodal mobility.

This thesis is structured as follows. First, we provide an overview of the relevant work in the areas of personal mobility and transportation from the user's point of view, with a particular focus on elderly users. We complement this understanding with findings related to public transportation and cooperative forms of transportation. Second, we outline our theoretical stance and methodological background, which is based on practice theory and participatory design. After outlining the setting of the research, we present our methodological approach. We applied a long-term living lab-based approach, in which 19 elderly participants took part to explore transportation issues, co-design potential solutions and evaluate these in long-term appropriation studies. These activities were carried out within three design case studies (DCSs) that built on each other and iteratively narrowed the scope of the research.

The first DCS was conducted on the assumption that mobility is essential for taking part in society and a prerequisite for autonomous living. In later life, this participation and autonomy are challenged by various factors. With increasing age people are faced with changes in their daily lives, including losing their driver's licenses, forcing them to deviate from existing routines such as using the car to do the daily errands or visit friends. By providing users with an intermodal transportation system, we wanted to explore what factors influence their choices and how they assess the suitability of certain modes. The presented results have been previously been published at the ACM Conference on Human Factors in Computing (Meurer, Stein, Randall, Rohde, & Wulf, 2014; Stein, Meurer, Boden, & Wulf, 2017) as well as the Multikonferenz Wirtschaftsinformatik. (Meurer, Stein, Rohde, & Wulf, 2014)

The second DCS aims to address the question of why our participants hesitate to adopt ridesharing tools to address their needs. We present a study that reflects on the mobility-specific needs of our group of elderly users regarding ridesharing. Based on interviews and two co-design workshops, we explore technological opportunities for ridesharing that address the mobility needs of elderly users and overcome prevalent appropriation barriers.

In the third DCS, we present an application based on continuous location monitoring and local data processing (on the user's device). This lays the technological foundation for opportunistic ridesharing using frequent locations of users as an alternative to the classic "offer-request" concepts, which require actively specifying rides in advance. The prototype presents the consequential implementation of lessons learned from DCS 1 and the implications of DCS 2. The findings of this case study are currently under consideration for publication at the ACM Conference on Supporting Group Work.

Chapter eight discusses these findings by reflecting upon our praxeological stance, highlighting the importance of routines in daily life that often implicitly include choices of modes of transportation. We show how a specific understanding of the role of a transportation mode, in our case ridesharing, can lead to better concepts of ICT-based support.

Following the discussion of findings, we also reflect upon our methodological approach, with a particular focus on the different means of user involvement throughout the process. We draw conclusions about necessary staging to explore the design and problem space. The thesis ends with concluding remarks on transferability and future work. The discussion of our methodological approach is currently resubmitted as major revision to the ACM Transactions on Computer-Human-Interaction (ToCHI) journal.

2 Related Work

This section presents the relevant previous literature and outlines current works within several research streams. The main contribution of this chapter is providing an overview of the theoretical and technological contributions within the field of transport and mobility research.

2.1 Understanding of Mobility and Transportation

Looking at mobility research shows an understanding of the issue that is characterized by a focus on rational choice and individual scope. Various research areas, such as transportation studies, urban planning, and behavioral and social psychology, provide insights on how to influence people's transportation and mobility practices. As summarized by Ozenc et al. (2011), research can be divided into four perspectives with regard to modal choice in transportation.

- Decisions based on stress and coping mechanisms (Laurier, 2002; Lockton, Harrison, Holley, & Stanton, 2009)
- Decisions based on the person's attitude and norms, as well as the personal sense of control or autonomy (Aarts & Dijksterhuis, 2000; Bamberg, Hunecke, & Blöbaum, 2007; Meurer, Stein, Randall, et al., 2014)
- Decisions in support of societal norms and values such as environmental sustainability (Froehlich et al., 2009; Meurer, Lawo, Janßen, & Wulf, 2016)
- Decisions based on habitualized behavior against a background of situational and infrastructural conditions (Bamberg et al., 2007; Banister, 1978; Castelli, Stevens, Jakobi, & Schönau, 2014; Perry, O'Hara, Sellen, Brown, & Harper, 2001; Stein, Meurer, Boden, & Wulf, 2017)

In order to establish any new transportation option, e.g. ridesharing, in a sustainable way, the stakeholder's benefits from using the new option must be clearly visible. Research has shown that the perceived benefit cannot be reduced to financial interests, but also entails different dimensions such as environmental criteria (Nordlund & Garvill, 2003; Fatih Kursat Ozenc et al., 2011). These incentives are of crucial importance, as engaging in ridesharing, or in new modes of transportation generally, must challenge existing habits and routines (Klöckner & Matthies, 2004). Understanding why and how transportation modes are routinized, how they can be supported effectively, and why they are difficult to change is of the utmost importance (Aarts & Dijksterhuis, 2000; Aarts, Verplanken, & van Knippenberg, 1997; Banister, 1978; Verplanken, Aarts, van Knippenberg, & Moonen, 1998), especially for the adoption of new transportation modes (Goodwin, 1977). In this regard, economics and related research areas mainly address the issue as a standard consumer choice problem. Most works address the problem using time and goods as inputs and the traveler as a production unit (de Donnea, 1972; Gillen, 1975), resulting in a mathematical choice problem of alternatives or possible equal options (Banai-Kashani, 1989; Domencich & McFadden, 1975). This implies that mobility and the reasons for specific behaviors can be represented in a deterministic mathematical model, which due to its very nature must exclude everyday factors such as actual mobility experiences (for example, the aesthetic dimension). Further, it seems that technology supporting transportation uses relatively little information when dealing with routine trips (Aarts et al., 1997), although transportation mode choices are usually associated with travel destinations (Aarts & Dijksterhuis, 2000) and commitments (Banister, 1978).

It is clear that everyday mobility and the related transportation choices span several domains. Due to its individual habitualization and the heterogenous infrastructural and societal conditions most studies focus their interest in a narrow way. For example, Ozenc et al. (2011) provide a design concept addressing "three driving themes affecting people's commuting choices," namely "flexibility, cost and personal preferences." Although they summarize four different perspectives on mobility they "follow […one…] perspective and frame commuting as a habitual problem defined by situation, consisting of roles people perform and environments they inhabit" (Fatih Kursat Ozenc et al., 2011).

In the absence of a more comprehensive understanding, there seems to be a clash between the rich but complex concepts in the social sciences and philosophy (see, e.g., Urry, 2007) and their adoption in traditional positivist disciplines such as economics, computer science, psychology and human-computer interaction (HCI). However, in recent years, in the so-called "third wave in HCI," these concepts have gained popularity. In the context of this work, Harrison's and Dourish's concept of "spaces" and "places" is of particular importance (Harrison & Dourish, 1996).

"Physically, a place is a space which is invested with understandings of behavioural appropriateness, cultural expectations, and so forth. We are located in "space," but we act in "place." Furthermore, "places" are spaces that are valued. The distinction is rather like that between a "house" and a "home"; a house might keep out the wind and the rain, but a home is where we live" (Harrison & Dourish, 1996).

This perspective contains a multifaceted, socially constructed, but individually interpreted understanding of mobility as rooted in everyday routines. Such an exploratory approach touches on aspects of existing mobility research theories but also goes far beyond, requiring an understanding of "what an all-encompassing notion like 'mobility' might have to offer" (Brewer et al., 2008).

As a first step to addressing this issue, we do not try to limit our interest through a theoretical lens in advance, but instead look closely at a specific user group, i.e. the elderly. In doing so, the general challenge of introducing and successfully adopting new, potentially beneficial modes of transportation can be narrowed, as described in more detail in the following section.

2.2 The Mobility of Older Adults

The majority of older adults in Western countries will increasingly live alone in suburban or rural communities, and access to public infrastructure is becoming increasingly problematic for this group (Mollenkopf, Marcellini, Ruoppila, Széman, & Tacken, 2005). As a result, the private car continues to gain popularity as the mode of choice to maintain individual mobility (Fobker & Grotz, 2006). In addition, Fobker and Grotz (2006) point out that incomplete knowledge about public transport services is a significant barrier preventing older adults from using alternative transportation, and they also show why a good social network is of great importance to compensate for the absence of a car. Coughlin, for instance, discovered that older adults who are embedded in well-established social structures (e.g. many friends, strong family relationships, etc.) are more likely to give up driving because of informal ridesharing opportunities (Coughlin, 2001). In this context, Lord emphasizes the adaptation of lifestyle through “mutual aid” and “community-based” help (Lord, Després, & Ramadier, 2011), while Goswami et al. (2010) notes the possible benefits of social network systems. Others further argue that such structures should be institutionalized to increase the benefits (Dumbaugh, 2008; Silvis, 2008).

In any case, access to public infrastructure in old age must be preserved. On the one hand, this means providing physical access to the infrastructure, but on the other hand it also means providing access to information such that these infrastructures can be used. However, existing research tends to focus on the physical and cognitive impairments in later life that can cause difficulties in the basic mobility activities of daily life (Beswick et al., 2008). In particular, Rosenbloom criticizes the current research on older adult mobility for focusing too closely on those with the most obvious and severe disadvantages, those who do not drive or who are severely disabled (Rosenbloom, 2004). She shows that disability rates have in fact been falling among all cohorts of the elderly for decades, caused by a combination of good nutrition, improved health care, better education, and higher incomes. Most elderly people, she argues, will be in generally good health until they reach age 80 or older (apart from minor problems such as night vision, problems carrying heavy bags or negotiating crowded streets) (Rosenbloom, 2004). However, driving is still the easiest physical task for older adults. Long before they lose the ability to drive, older people may be unable to board or ride public transportation or to walk to a bus stop. Thus, it is not surprising that the fear of losing a driver’s license is widespread among older adults (Schwanen, Banister, & Bowling, 2012).

In summary, the research concerned with the transportation situation of older adults focuses strongly on typical deficits. Thus, we must take a step back and try to identify the relevant aspects of mobility in terms of a user-centric understanding of the concept. Such a perspective will help inform the design of new mobility support systems, since most current systems merely strive to retrieve information such as bus schedules or telephone numbers of taxi services. Interaction is mostly limited to requesting travel information. Now, more than ever, prompted by the emergence of concepts such as ridesharing (Avego, 2012; Flinc, 2012; Goloco, 2012; Wash et al., 2005), carpooling and multimodal commuting (Moovel, 2012; Zimride, 2012), it is necessary to overcome these legacy understandings.

2.3 Different Modes of Transportation

This section takes a more detailed look at the different modes of transportation. To illustrate the structure of this section, we present a schematic overview of the most commonly used modes (Figure 1).

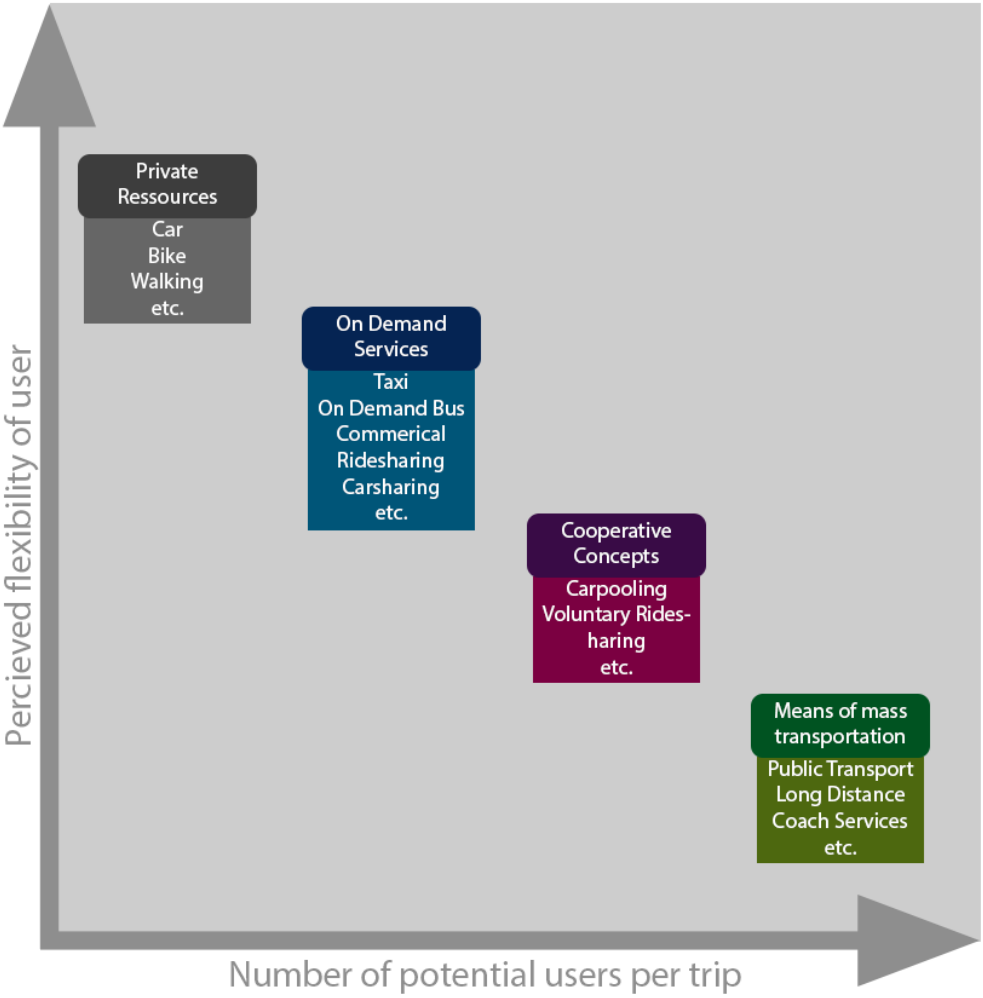

Figure 1: Schematic classification of modes

While this diagram presents a very simplified overview, and there are certainly examples that would be hard to fit into this classification, it emphasizes a typical tradeoff regarding transportation – flexibility vs. number of potential users (i.e. simultaneous users, thereby reducing the individual costs). Except for private resources all options entail another stakeholder's involvement and therefore are limited in terms of perceived flexibility.

It is beyond the scope of this work to give a comprehensive overview of the research focusing on individual transportation that has been conducted in both transportation research area and social sciences. We therefore focus on the advancements that have been made due to the introduction and advancement of ICTs supporting the use of different means of transportation. HCI research in this area is largely concerned with providing better access to certain transportation modes or easing specific tasks when using one of these modes. Most of the common modes of transportation have been researched, e.g. public transportation (PT) (Ferris, Watkins, & Borning, 2010; Foong, Diaz, Houssian, Huse, & Jamsri, 2007), walking (A. Kim et al., 2016), cycling (Reddy et al., 2010), motorcycling (Prasad, Taele, Goldberg, & Hammond, 2014), ridesharing (RS) and carpooling (Brereton, Roe, Foth, Bunker, & Buys, 2009; Glöss, McGregor, & Brown, 2016; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011; Tedjasaputra & Sari, 2016). Car navigation has been studied extensively (e.g. Forlizzi, Barley, & Seder, 2010; Knobel et al., 2013; Lee, Forlizzi, & Hudson, 2005; Leshed, Velden, Rieger, Kot, & Sengers, 2008). The focus of the studies within each mode varies greatly, but the various studies focusing on PT can be taken as an example (e.g. André, Wilson, Owens, & Smith, 2007; Baños, Aquino, Sernas, López, & Mendoza, 2007; Collins, Grude, Scholl, & Thompson, 2007; Ferris et al., 2010; Y.-T. Lin, Su, Lo, & Chou, 2016; Pritchard, Vines, & Olivier, 2015; Zimmerman et al., 2011). These address issues of payment (Pritchard et al., 2015), real-time information and waiting times (Collins et al., 2007; Ferris et al., 2010; Zimmerman et al., 2011), accessibility (Y.-T. Lin et al., 2016), and specific user needs (André et al., 2007) in order to increase the quality of service (Redman, Friman, Gärling, & Hartig, 2013). In many cases, the goal is to foster more sustainable behavior. In this regard, it should be pointed out that there are few studies in HCI that focus on behavioral change in transportation without being bound to a certain mode specifically. Hasselqvist et al. (2016) explore how people adopt more sustainable (car-free) transportation practices, while Meurer et al. (2014) identify motivations and barriers among the elderly to use different modes, but with a specific focus on RS. Of course, we do not limit our focus to works in HCI, but rather take into account results from the aforementioned works that provide additional insights about how and why people adopt and reject certain modes.

As outlined above, personal transportation is habitualized based on commitments, and the adoption of one mode depends on its advantages over other modes. For this reason, the car has become the mode of choice for personal transportation. 80.6 % of all trips are made using private motor vehicles. Thus, several works focus on ways to incentivize mode switching. Here we present various aspects of this focus that we found in the literature.

2.3.1 Attributes

Using individual means of transportation such as car or motorcycle is the preferred choice for most people, and thus these descriptions are limited to modes that struggle with adoption due to their imposed constraints (e.g. schedules in PT) or coordination overhead (e.g. matching rides in RS). Therefore, the following sections are generally concerned with the characteristics of and advancements in public transportation and cooperative modes.

Public Transportation

Various topics have been researched in order to understand when and why people use public transport and what circumstances cause them not to. With regard to incorporating quality improvements through shorter waiting times, reduced uncertainty, increased ease of use, higher willingness to pay, greater possibilities for the adjustment of travel behavior and more flexibility have been shown (Dziekan & Kottenhoff, 2007; Fellesson & Friman, 2012; Ferris et al., 2010).

Redman et al. (2013) undertook a systematic review of studies in order to determine attributes that define the quality of public transportation services. They also looked at the attributes that cause car drivers to switch to public transport. They distinguished “physical” attributes and “perceived” attributes. The former include mainly objective facts that can be easily observed or measured. The latter category instead encompasses the subjective experiences of the passengers.

Redman et al. pointed out the physical attributes that can be understood as more or less objective measures of public transportation. *Reliability* describes how well the services adhere to schedules, which also relates to the *vehicle's condition*, as delays might be due to breakdowns. The *frequency* of the service, meaning how often a PT service runs within a given period of time, also influences the quality. This is connected to the *speed*, i.e. the travel time between two points. In addition to these time-related attributes are others such as *accessibility*, meaning how many people can access PT with reasonable effort. Accessibility also depends on the *information provision*, as one aspect of it is the availability of information. Furthermore, people are concerned about the *ease of transfers*, which is characterized by the effort necessary to make a connection (including waiting times). Of course, all of these attributes are within the context of the service's *price* (the monetary fee for travel).

In addition to these physical attributes, Redman et al. also identified findings within the studies that were related to matters of perception. They included the *comfort that* a passenger experiences during travel, such as seat quality and the noise or handling of the vehicle. *Safet*y, i.e. how passengers asses the likelihood of traffic accidents or other threats such as violence, is also an issue, not surprisingly. Interestingly, the authors also described the attribute of *convenience*, which is clearly related to the physical attributes of accessibility, frequency, and reliability, yet also has a very individual aspect concerning how easy it is to integrate PT into one's mobility (e.g. by integrating ticketing systems to ease planning and coordination). Lastly, they also highlighted the *aesthetic* dimension in relation to the vehicle, routes, etc.

Based on these sets of attributes they also focused on works that highlight positive changes in the attitude towards adoption of PT modes. For example, they indicate that monetary factors (e.g. free PT, increasing the cost of private transportation) have an effect on the willingness to switch from private cars to PT (Fiorio & Percoco, 2007), yet these effects affect adoption only initially and other factors must be taken into account to sustain PT usage (Fujii & Kitamura, 2003; Sen, Tiwari, & Upadhyay, 2007; Thøgersen, 2009; Thøgersen & Møller, 2008). These include increasing the level of convenience, e.g. integrating a ticket system (Dargay & Pekkarinen, 1997), and shorter travel times / higher frequency (Eriksson, Friman, & Gärling, 2008).

Redman et al. (2013) conclude that, in order to foster the use of PT, a basic level of quality with regard to the physical attributes needs to be established in order to compete with private car usage. If this is not accomplished, private car usage presents the main hindrance to PT demand. They emphasize the need to understand the justification of private car usage, which can be more contextual and relates to perceived attributes (considering the specifics of that area).

Cooperative Modes

In this work, the term "cooperative modes" is used to refer to new transportation services that entail coordination with other passengers or drivers. These services include ridesharing services such as ridesharing.org or flinc (www.flinc.org), as well as carpooling services such as the RideNow project (Wash et al., 2005), which mostly aim at regular carpool arrangements for commuting. Although car sharing services (such as car2go.com) also involve sharing a resource with other system users, these services are not addressed in this thesis, as coordination efforts are typically limited to finding an available car and there is no need to coordinate with another person. Furthermore, ridesharing services (especially commercially successful ones) such as "uber.com" will be presented and discussed only briefly. Such services, though initially branded as ridesharing services, have transformed into what can be considered a classic provider/client concept and compete with classic on-demand services such as taxi cabs (see Figure 1). Therefore, the coordination effort is minimized, because the driver (as the service provider) aligns to the needs of the passenger (the client paying for the transportation service).

The focus in this work is instead on services that intend to leverage synergies of route convergence and are therefore based to a large extent on voluntary participation. A useful classification of the different kinds of ridesharing services can be found in Chan & Shaheen (2012) and is shown here in Figure 2.

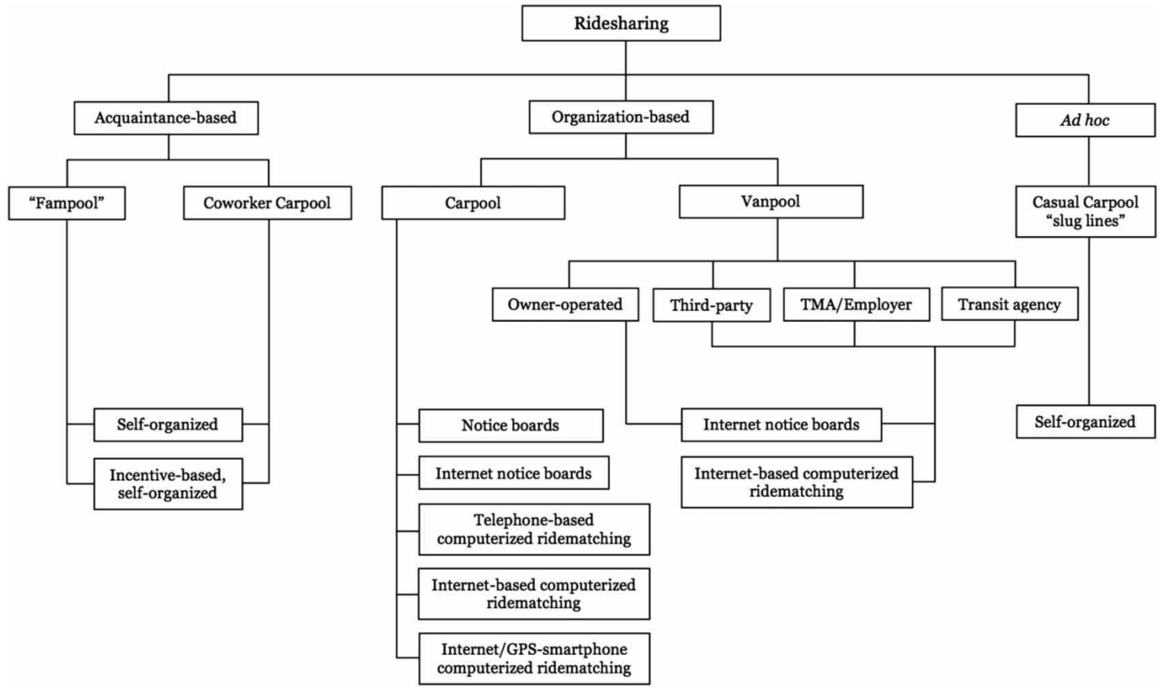

Figure 2: Classification of cooperative concepts (Chan & Shaheen, 2012)

Chan and Shaheen (2012) differentiate between "acquaintance-based," "organization-based," and "ad-hoc" ridesharing. "Acquaintance-based" ridesharing is self-organized and is usually based on the commitment of coworkers or acquaintances sharing a regular destination. "Organization-based" ridesharing is arranged by a third party. It can be further differentiated into carpooling and vanpooling, where vanpools are often organized by the vehicle providers such as transit agencies. We subsume these two forms under "classic" ridesharing. Classic ridesharing support focuses on commuting routines that require little coordination effort and do not generate high transaction costs (Handke & Jonuschat, 2012). In contrast to commuting, general ridesharing arrangements usually necessitate significantly higher coordination effort and costs. In the case of commuting, the time of travel and the destination, as well as the purpose of the ride, are essentially known. Yet even in this limited context, many systems failed to reach a critical mass of users (Raney, 2010), largely because of the planning overhead that was needed (Prost, Schrammel, Röderer, & Tscheligi, 2013). Drivers and passengers used different communication platforms (on- and offline notice boards, telephone, etc.) to retrieve information and negotiate pickup locations and times.

"Ad-Hoc" or dynamic ridesharing, as defined by Chan and Shaheen, differs from the two other categories, as coordination typically happens close to the actual travel event and is not carried out in advance (Kelly, 2007). "Dynamic" ridesharing differs from classical ridesharing in two aspects (Levofsky & Greenberg, 2001): 1) Every ride is a onetime event and driver and passenger do not settle on recurring destinations and pickup times or locations, and 2) possible ride matches need to be arranged on very short notice and travel plans require high conformity. Consequently, and to facilitate the necessary exchange, research on cooperative transportation has focused primarily on solving the logistical problem of finding and matching rides, aiming to reduce the time and effort necessary to make ridesharing arrangements (Handke & Jonuschat, 2012). With technological advancements, opportunities for new ridesharing concepts arose that allowed faster, more flexible matching concepts. These dynamic approaches have been complemented by opportunistic ridesharing concepts (Bicocchi & Mamei, 2014; Rigby, Krüger, & Winter, 2013; Xing, Warden, Nicolai, & Herzog, 2009), which try to further reduce "in-advance" coordination efforts, thereby extending the ridesharer's flexibility.

This work builds upon the classification of Chan and Shaheen, and also extends it, distinguishing between "classic," "dynamic" and "opportunistic" approaches. This approach is illustrated in Table 1.

Table 1: Different ridesharing concepts

	Classic	**Dynamic**	**Opportunistic**
Concept of coordination	Manual in-advance matching of offers and requests prior to actual ride	One-time ride matches close to departure; highly flexible	Opportunity-based or based on matching routines
Purpose of trip	Recurring events (e.g. commute) or special trips (e.g. intercity travel)	Intended for daily transportation needs, yet mostly used for longer distances	Spontaneous, everyday mobility, recurring events
Technological basis	Early concepts: Bulletin boards, SMS-based Newer concepts: Web-platforms, social network groups	Mobile apps, automatic route matching engines, ad-hoc communication channels	Location-based services, Mobile apps, location tracking technology, ad-hoc communication / information exchange

Commercial examples	Rideshare.org, Goloco, ZimRide	Flinc, carma, see dynamicridesharing.org	-
Exemplary Related work	(Raney, 2010)	(Fatih Kursat Ozenc et al., 2011)	(Bicocchi & Mamei, 2014; Rigby et al., 2013)

2.3.2 Information Retrieval and Coordination Support

Public Transportation

About two decades ago certain studies outlined possible improvements in public transportation trip planning that might result from using ICTs (Maclean & Dailey, 2002; Peng, 1997). However, it was shown that just providing more information at travel points does not contribute to the adoption of PT (Wall & McDonald, 2007), as this information does not influence the decisions of travelers. Today, with advanced tracking solutions, systems providing live information during transportation have become widely available. These make it possible to provide information that is more contextual and individual. For example, the prototype introduced by Hoar (2008) allowed users to create their own schedules, giving them direct access to the required information. More advanced approaches attempt to predict the required information by tracking past behavior (Foell, Rawassizadeh, & Kortuem, 2013; Patterson et al., 2004). Foell et al. (2013) argue that it is necessary to include more than just location information in order to understand where the user might be heading. They emphasize the necessity of taking into account personal and social behavior as sources of relevant information in order to create "personalized information spaces" (Foell et al., 2013). To enable this linkage, Hoar (2008) provided a representation of transportation information in a geographic system that utilized the user's knowledge of local landmarks. Additionally, Hightower (2003) and Lin et al. (2010) argue that semantically enhanced information helps fuse transportation information with personal activities. In summary, research on public transportation has developed from providing static schedule data to the inclusion of live and individually customized data, culminating in the incorporation of semantically meaningful data. It is evident therefore that transportation information systems (TIS) have been striving to adapt to user needs. Yet in computer-supported cooperative work (CSCW) and HCI, examples of research on public transportation usage are rare (Ferris et al., 2010; Foell et al., 2013) and deal mainly with information related to transportation, neglecting precisely the focus on practice we advocate.

Cooperative Forms

Driven by a concern over the inefficient use of individually owned cars and the desire to foster ridesharing arrangements, new cooperative transportation modes have been proposed (e.g. Dailey, Loseff, & Meyers, 1999; Haselkorn et al., 1995). Classical approaches to ridesharing-related coordination tasks have often been found to be limited in terms of flexibility and expressive power compared to face-to-face interaction or Web 2.0 technologies, as they were based on early web technology and text messaging (Prost et al., 2013; Raney, 2010). These projects and many subsequent ones failed to reach a critical mass (Raney, 2010). Today, the introduction of smartphones with internet access has enabled systems that provide advanced solutions (Andersson, Hjalmarsson, & Avital, 2013). However, research on cooperative transportation continues to focus mainly on solving the logistical problem of finding and matching rides, thus aiming to reduce the time and effort necessary to arrange ridesharing (Handke & Jonuschat, 2012). The precondition for matching a driver with one or more passengers is that their mobility patterns be as congruent as possible, given travel time and route convergence. The prevalent research focus is on the challenge of finding appropriate algorithms for matching rides. While there is no standard method to determine the best ride-matching method, several approaches have been developed along different foci of activity-based behavior (Steger-Vonmetz, 2005; Teodorović & Dell' Orco, 2008). Meanwhile, agile and real-time matching have become key components for a successful ridesharing system. Location-aware internet-enabled mobile phones allow very short notice or even on-route notification. This constitutes the technical basis for flexibility among the dimensions of space, time, role and route (Handke & Jonuschat, 2012).

Another means to achieve intelligent matching operations is to improve the modal choice of transport (Steger-Vonmetz, 2005). Increasing attention is being paid to the question of how the use of online social networks can contribute to solving problems of coordination, logistics, and meeting potential sharers (Ghelawat, Radke, & Brereton, 2010; Mirisaee et al., 2011). For instance, Hansen et al. (Hansen, 2010) were successful in reducing the transaction costs generated by the complexity of coordinating meetings between ride sharers by simplifying the process. The selection of and navigation to meeting points has been streamlined using community-based toolkits and ICT. Similarly, focusing on meeting points, Xing et al. call for “multi-modal travel planning systems” to include public transport information to facilitate the choice of optimal meeting points (Xing, Warden, Nicolai, & Herzog, 2009). Another approach is used by Kamar and Horvitz (2009), who use GPS traces and calendar data to identify matching ridesharing parties based on time, fuel, environmental factors, and the cognitive costs of the arrangement. In this regard, Ozenc et al. (2011) compared different ridesharing concepts and found that people do not want to give up their flexibility by making a long-term commitment, and instead preferred dynamic information feeds. Regarding elderly people, a similar result was found by Meurer et al. (2014), who more specifically stress the importance of autonomy and independence. For example, Rigby et al. (2013) create immediate awareness about the available ridesharing opportunities by visualizing the potential pick-up time of available rides nearby. Users are thus free to choose the most appropriate option in their situation. Bicocchi and Mamei (2014) or Liu et al. (2013) use mobility traces based on cellular network information to identify patterns in the mobility of users. They then use this information to derive clusters and find patterns using a latent dirichlet allocation (Blei, Ng, & Jordan, 2003), treating each user movement as a word. The result of this analysis can be used to inform the user about suitable ridesharing partners. These opportunistic approaches try to lower coordination efforts and thus increase flexibility. Commercial examples such as flinc (https://flinc.org/) and carma (https://carmapool.com) offer real-time ad hoc solutions via mobile phone. For instance, they provide support for managing coordination, payment, and automatic posting of ride offers when starting to navigate (integrated with navigation solutions, e.g. Navigon). Another example is VilleFluid, which focuses on the reliability of rides (http://www.villefluid.fr). It suggests a ride only when a fallback ride is also available if the original arrangement falls through. It is important to note that these systems and their features have been developed based on commercial interest. No scientific studies of the users of these systems are therefore publicly available, which limits our ability to understand their impact on mobility practices. Thus, several subtle social challenges that may affect the adoption of cooperative transportation tools remain unaddressed. Several authors stress the importance of not separating the act of travel from the purposes and meanings associated with it. In this regard, pioneering works by Brereton et al. (2009), Ozenc et al. (2011), and Meurer et al. (2014) argue that such systems could achieve broader adoption if social challenges such as trust, privacy, independence, and autonomy are resolved.

2.4 Research Question

Research on cooperative transportation reveals a picture quite similar to that of public transportation. Owing to the technological limitations at the time, it started with data-driven approaches, attempting to improve access to static information. Further, the initial system design focused on optimizing the "fit between the physical and the mental state of the 'user' and the interface of the machine" (Kuutti & Bannon, 2014). Subsequent solutions advanced the capabilities to include live information and mobile access in order to improve flexibility and reliability.

In both cases – public and cooperative transportation – the incorporation of personal and/or implicit local knowledge (e.g. landmarks, parking situation, business hours etc.) is considered helpful to the transportation activity. Both research streams emphasize contextual and semantically meaningful information to improve each mode's ease of use and to connect the travel with the activity.

Various research approaches try to detect the context of the activity automatically (e.g. in ubiquitous computing (D. H. Kim, Hightower, Govindan, & Estrin, 2009; Liao, Fox, & Kautz, 2007) or in HCI (Zhou, Ludford, Frankowski, & Terveen, 2005). Taking contextual information into account allows systems to make more appropriate recommendations reflecting the characteristics of the travel options (e.g. costs, flexibility and decisional autonomy, reliability, environmental impact etc.). Ideally, this implies that systems incorporate information from several transportation systems. In this vein, Meurer et al. (2014), Szyliowicz (2003), and King (2006) argue for multi-/intermodal transportation solutions that allow combinations of transportation modes. Such multimodal solutions can address challenges not easily addressed by a single mode (Szyliowicz, 2003), thus supporting more flexible and nuanced decision-making and having a positive environmental impact (Steger-Vonmetz, 2005). However, most research on multi- or intermodal TIS is limited to optimization (Burmeister, Haddadi, & Matylis, 1997; Coffey, Nair, Pinelli, Pozdnoukhov, & Calabrese, 2012; Modesti & Sciomachen, 1998) and lacks approaches that identify and integrate contextual information relevant to the user (King, 2006).

As we see, there are various approaches to researching personal mobility and supporting personal transportation. The aspects that have been outlined above can be summarized as three different challenges:

1. **Logistical challenge**: Every time people engage in transportation they decide on logistical factors, such as destination or departure time. Depending on the mode these aspects can be very flexible (e.g. in the case of using one's own car) or restricted (e.g. adhering to the schedule of public transportation). Therefore, one area of research is concerned with optimizing routes, departure times, etc. to provide efficient services that are catered to users' needs. This also includes matching the routes of different people to facilitate ridesharing. For example, one could think of research on the traveling salesman problem to enhance the pick-up of passengers in ridesharing.
2. **Informational challenge:** To use any mode of transportation one always relies on a specific set of information. This information is necessary in order to use a service or a resource, be it one's own car or public transportation. Systems providing this information therefore need to be designed in a way that corresponds to user intentions. The focus of this area of research is not advancing the transportation act as such, but supporting the information retrieval process to provide support for the use of an infrastructure. For example, one could think of public transportation apps that include pedestrian navigation to enable non-regular public transport passengers to find bus stops easily.
3. **Situational challenge:** Since transportation is part of everyday life, people engage in transportation in various situations. Thus, decisions to use certain modes depend on various situational factors (regardless of the underlying rationale for how decisions are made: habits, rational choice, values, etc.). Again, this area of research does not advance the transportation act as such but is also not limited to retrieval of logistical information. The importance of including more information

has been foregrounded in recent years due to the changing demand in mobility (demographic change, declining (public) infrastructures especially in rural areas and the resulting emergence of diverse new modes of transportation).

The main contribution of this work is centered around the connection of the informational and situational challenges. Specifically, this work attempts to answer the following question:

What informational needs need to be considered to support everyday mobility of older adults that can be addressed by information and communication technology especially focusing on the adoption of unfamiliar mobility options?

To answer this question, we acknowledge both the situational and the informational challenge and use an exploratory, empirically grounded, action-research based approach. The research is based on the specific case of transportation practices of older adults in Germany. Our research is driven by a strong practical orientation, which makes it possible to understand the issues related to the research question from the user's point of view. Thus, before presenting our studies, we elaborate on the paradigmatic basis of our research approach, which provides the "sensitizing concepts" (Blumer, 1954) for our research.

3 Theoretical Framing

3.1 The Turn Towards Practice

ICT is increasingly integrated into the everyday life of most people and appropriated in highly individual ways (Pipek & Wulf, 2009). New means of interaction and integrated representation based on a user-oriented viewpoint can help inform users about the benefits of new types of mobility and can reduce prejudices against certain modes (e.g. the tradeoffs of using public transport). However, when it comes to the task of supporting people in everyday mobility, research struggles to find solutions that end up being widely accepted by users in their daily activities. In this sense, mobility-related activities are, like human activity in general (Ackerman, 2000), highly flexible, nuanced, and contextualized.

Thus, in order to provide adequate technological support, overcoming this "social-technical gap," technology must be equally flexible, nuanced and contextualized (Ackerman, 2000). While this understanding has been addressed in CSCW research (Ackerman, 2000; Schmidt & Bannon, 1992), it has gained more attention in HCI (Kaptelinin & Bannon, 2012; Kuutti & Bannon, 2014; Shove, Pantzar, & Watson, 2012) and gets addressed more explicitly in CSCW (Schmidt, 2014; Wulf, Rohde, Pipek, & Stevens, 2011) and IS (Rohde, Brödner, Stevens, Betz, & Wulf, 2016) recently. In line with the "practice turn" (T. R. Schatzki, Knorr-Cetina, & Savigny, 2001), understanding "normatively regulated contingent activity" (or practices) (Schmidt, 2014) as the central unit of research provides an epistemological alternative to existing approaches such as positivism or interpretivism (Rohde et al., 2016). Practice theory, as it is commonly known, is rooted in different streams of work. It builds upon concepts such as "habitus" (Bourdieu, 1979) or "discipline" (Foucault, 1972), which describe how individuals perceive their social surroundings and how they act with and in relation to it. The "theory of structuration" (Giddens, 1984) provides a further conceptual basis for understanding how practices not only result from principles of order but "reproduce" them when being carried out. Generally, practice theory builds upon phenomenology and hermeneutics (Garfinkel, 1984; Habermas, 1995; Schutz, 1960).

In an attempt to pinpoint the core aspects of these studies in a practice theory concept, Reckwitz (2002) describes a practice as "*a routinized type of behavior which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotions and motivational knowledge*." For Reckwitz, practices can be reduced neither to actions of the body nor to those of the mind. They possess inter-subjective meaning in the form of shared knowledge and understanding and are reproduced in physical and mental actions by incorporating things as essential parts of the practice itself. Thus Reckwitz extends Schatzki's "*temporally unfolding and spatially dispersed nexus of doings and sayings*" (T. R. Schatzki, 1996, p. 89) with things that are necessary for a practice to be practiced.

In this understanding, the design of "things" to support or even give rise to a practice must extend its focus from the artifact itself to its practical context of use. Understanding the user's practices *"should be not only helping designers create better artifacts, but also helping people themselves create better environments"* (Kaptelinin & Bannon, 2012). This includes taking into account the constant change of the use context (Goldkuhl, 2011; Kuutti & Bannon, 2014; Wulf et al., 2011), which necessitates that even artifacts designed for specific purposes must be appropriated by the user in order to become a "part" of a practice and eventually transform previous practices (Rohde, Stevens, Brödner, & Wulf, 2009). In this regard, Kaptelinin and Bannon (2012) introduce the concept of technology enhanced activity spaces (TEAS) and describe how the availability of technology can cause such transformations. They distinguish between extrinsic (induced by the external introduction of new tools, e.g. by designers or researchers) and intrinsic transformation (induced by the users themselves in order to address a concrete need, e.g. by adopting existing technology). This distinction highlights the two facets of technology-induced change (Orlikowski, 1992, 1996; Orlikowski & Hofman, 1996): anticipated (and externally induced) and emergent (intrinsically induced). By providing users with new tools, designers seek to transform practices extrinsically. However, for successful transformation "*[i]t is important to note that intrinsic and extrinsic types of technology-enabled practice transformation are not mutually exclusive or even competing; they rather represent two complementary, mutually dependent facets of the overall process of technology-enabled* *practice transformation*" (Kaptelinin & Bannon, 2012). As technological artifacts inevitably represent abstractions based on the contexts that determine their requirements, they can be understood as decontextualized. Intrinsic practice transformation, or "appropriation," represents the users' ways of incorporating these decontextualized tools into their infrastructure in order complete their tasks and achieve their goals (Pipek & Wulf, 2009; Stevens, 2009; Stevens, Pipek, & Wulf, 2010). Users meaningfully re-embed technologies in their contexts by using them for their situational needs. As this context inevitably differs to some extent from the context the designers imagined, practices emerging from the appropriation of the tool in the situated context can vary greatly and differ from the anticipated use (Orlikowski, 1992). The importance of the "situatedness" of use was highlighted by Suchman and Wynn (L. Suchman, 1982; L. Suchman & Wynn, 1984; Lucy A. Suchman, 1983; Wynn, 1979), who researched office automation systems and highlighted the deficiencies of standardized office procedures (Schmidt, 2000). In line with practice theory concepts and the "social-technical gap," Suchman (1987) particularly influenced how technology design is understood against the backdrop of social practices: she highlights the importance of the specifics of each situation, such as complex expectations and social relations that make a person's actions unpredictable (Rohde et al., 2016). Suchman outlines a "coherence of situated actions," which is "tied in essential ways not to individual predispositions or conventional rules but to local interactions contingent on the actor's particular circumstances." Technological artifacts, on the other hand, are based on models and deterministic sets of rules that, even if technologically feasible, fall short of modeling the complexity of these different situations.

Excursus on "Context" from a Technological Perspective

As technology becomes more integrated into daily lives, research has begun to focus on the potentials of "ubiquitous computing" (UbiComp). Since its beginning the main driver of UbiComp research has been providing people and environments with "computational resources that provide information and services when and where desired" (Weiser, 1991).

To this end, the recognition and interpretation of "context" is at the core of this research area (Abowd & Mynatt, 2000). According to Abowd and Mynatt (2000) answering the questions of "who is involved," "what do these users try to do," "where does this interaction take place," "when does the interaction take place and what historical events influence it" and "why are/is the user(s) doing this?" provides the minimum set of information that can be used to describe the context and make applications aware of it. In its first formulation, "context-awareness" described the ability of software, or ICT more generally, to adapt itself "according to the location of use, the collection of nearby people, hosts, and accessible devices, as well as to changes to such things over time" (Schilit & Theimer, 1994). While this early definition addresses questions of "where," "when" and "who," in contrast to Abowd and Mynatt's definition it largely neglects the "what" and "why." This may be due to the fact that Schilit et al. assumed that context-awareness is defined in relation to a system and its specific tasks. Generally speaking, there have been various definitions of context-awareness, most of which are too specific for general application (Abowd & Dey, 2000; Dey, 2001). A more general but "task-oriented" interpretation has been developed by Dey (2001):

"A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task."

It becomes clear when reading the definitions of context with regard to context-awareness that context seems to depend on the user's task. While Abowd and Mynatt (2000) point out how this captured context information helps to facilitate a richer interaction with systems based on more "natural interfaces" that leverage "the implicit actions in the world," framing the user's task in order to define its context remains an unresolved problem. Early approaches tried to create "stable representations of context," which were then used to "automate the capture of live experiences" (Abowd & Mynatt, 2000). These early research prototypes were mainly built to accommodate just one aspect of the context. Several examples continue to reduce context to one kind of information, such as location (e.g. Ley & Stein, 2010; Want et al., 1996; Want, Hopper, Falcão, & Gibbons, 1992).

This oversimplification of "context" in technology design has been addressed by several recent publications, in which these practice theory concepts served as a foundation to understand the situated contexts of technology usage (Kuutti & Bannon, 2014; Luff, Hindmarsh, & Heath, 2000; Schwartz, Stevens, Ramirez, & Wulf, 2013; Wakkary, Desjardins, Hauser, & Maestri, 2008; Wulf et al., 2011). In particular, Kuuti and Bannon

(2014) criticize research that focuses on technologically induced interventions and the "relation between humans and the computer" arising from the human information processing (HIP) approach. They depict the trajectory of HCI's theoretical concepts over recent decades; interest in HCI began with the human-computer-interface and gradually extended to include the contexts of interaction and appropriation of tools, culminating in understanding the practices of users (Wulf et al., 2011).

"*Practice can be interpreted as the ultimate context: practices are where interactions take place in real life. But there is also a gestalt shift involved: while formerly interaction is the foreground and context the background, with practices, interaction is no longer at the center, but is one aspect among many, serving its specific part in the performance. It can be studied and understood only through this whole performance, not separately*" (Kuutti & Bannon, 2014).

"Practice" here is clearly distinguished from and broader than interaction (as defined in Randall et al. (2007)). Interaction with the artifact is part of the practice's performance and introducing designing new technology that tries to support (transform) existing practices must be accompanied by "*(1) individual learning to acquire sufficient familiarity with the software to allow it to be used unreflectively (2) placing the new IT artifact within the practice holism by way of (social) sense-making, and (3) making IT part of the social identity of that practice so that using the new IT becomes 'what one normally does'*" (Riemer & Johnston, 2013). Not focusing on interactions or the specific necessities of a given problem (e.g. retrieving schedule information) allows designers to step back and question decontextualized data- and technology-driven assumptions. Yet understanding the technological artifact and the interaction with it as just one part of "the whole practice" requires a different understanding of how the suitability of technology and its design should be assessed, "[*b]ecause practices are contingent, mediated and cannot be understood without reference to the particular place, time and concrete historical context where they occur, they can only be studied 'close-up'*" (Kuutti & Bannon, 2014).

To draw upon these concepts as a frame of reference, it is important to take into account the systematic conceptual discussion that has been taking place in recent years, as outlined above. Within research on technology design, the conceptual work by Shove et al. (2012), which is based on concepts of practice theory by Schatzki (2002) and Reckwitz (2002), has become popular (e.g. Entwistle, Rasmussen, Verdezoto, Brewer, & Andersen, 2015; Wakkary et al., 2008). This work describes material aspects (in terms of things that are involved in the performance of a practice), aspects of competence (in terms of knowledge and shared understandings) and of meaning (in terms of the contextual, situated, future-oriented aspect of a practice's performance) as building blocks to describe practices. While the framework of Shove et al. is useful and has been applied broadly, Schmidt (2014) provides another conceptual outline of "practice" and related concepts. Both have in common that practices are understood as a specific category of activities and that activities represent the actual doing or performance of practices, entailing a specific start and end. Practices entail a set of normative rules established by practitioners on how to do things, which represent shared understandings and exist beyond the actual performance (or activity). These rules or shared understandings define the "sameness" of activities (Schmidt, 2014). When engaging in these various activities, actors require practice-specific skills and tools. Schmidt uses the terms "techniques" to refer to means that are applied (methods and tools), and "skills" to refer to one's capability or "know-how" (Schmidt, 2012) of applying techniques in order to engage in a practice. These terms overlap with the concepts of "material" and "competences" introduced by Shove et al. While Shove et al.'s distinction stresses the importance of things within practices (T. R. Schatzki et al., 2001), it lumps together "knowing in the sense of being able to evaluate and knowing in the sense of having skills required to perform" (Shove et al., 2012, p. 23). Understanding them as a resource that an actor potentially can make use of, they present interchangeable ways to perform practices. The third element introduced by Shove et al., that of meaning, describes the situatedness of practices and is implicitly present in Schmidt's concept, as the rules that a practice entails can be applied and may be altered due to variations in the circumstances.

Based on this understanding, the design of IT-artifacts that are intended to support people must always be considered from the user's perspective and with regard to its implication on the (organizational) context in which the artifact will be used (Wulf & Rohde, 1995). Therefore, the design of such tools must take into account the fact that the requirements on which a system design is based are not stable and may be altered by the introduction of the tool itself (Kaptelinin & Bannon, 2012). Addressing this issue, within this work we use the design case study framework (Wulf et al., 2015). Iteratively combining activities of context study, co-design and appropriation study makes it possible to take into account the user's perspective on the design goals and reflects the appropriation of the tools in practice, ultimately allowing their suitability and exploitation of emergent changes to be tested. In this sense, the framework goes beyond the design of the tools and focusses on the transformation of practices. Since the framework builds upon strong user involvement to explore design opportunities and gain insights from actual long-term usage of tools, it is necessary to plan user involvement systematically. This especially holds true for users who have little experience with technology, including many older adults who did not encounter ICT tools in their work life.

3.2 Involving Elderly Users in the Design of ICT Solutions

Introducing technology to elderly users is becoming more and more important for both sides, the elderly as users and the technology vendors who want to target the growing group of elderly users. As users demand solutions that fit their needs, designers have developed several methods to craft tools that fit those needs. In software design, one way to address this challenge is the involvement of users in order to fit systems to their needs (Bodker, Kensing, & Simonsen, 2004; Finn, Jesper, & Keld, 2004; Kaptelinin & Bannon, 2012; Kensing & Blomberg, 1998). However, existing approaches such as "user-centered design" (UCD) and Participatory Design (PD) adopt very different stances on how to involve users in the design of systems and enable them to influence the development.

3.2.1 User Involvement in Design

UCD has become a popular conceptual framework in HCI research (Kaptelinin & Bannon, 2012; Kuutti & Bannon, 2014; Norman & Draper, 1986; Vredenburg, Mao, Smith, & Carey, 2002) and the industry (being standardized in the ISO standard 9241-210) for eliciting user requirements and creating more usable products by iteratively attending to users' needs. While the goal of the UCD process is to create fine-tuned artifacts that are based on the user's language, skills and knowledge, the UCD-model follows a "designer-driven" process, putting the designer in charge of 1) understanding the context of use, 2) specifying the user requirements, 3) producing design solutions and 4) evaluating these solutions (based on ISO 9241-210). The users themselves remain passive, mostly being responsible for introducing the designer to the context of use and providing information about tasks and procedures to define the problem space.

PD, in contrast, aims at giving more control to the target users during the design process, as "[i]t assumes that technology-enabled […] development can and should be driven by the users themselves, rather than initiated and accomplished solely by designers" (Kaptelinin & Bannon, 2012). Thus, PD research offers ways of involving future users in a design process, giving them a voice and empowering them to influence the design of their own future tools (S. Bødker, Ehn, Knudsen, Kyng, & Madsen, 1988; Greenbaum & Kyng, 1991; Muller & Kuhn, 1993; Schuler & Namioka, 1993). Here, users are actively involved in the development process as a key group of stakeholders. "Participatory design studies are not a 'listening tour' in which researchers hear the concerns of users, then go away and design a solution; they are participatory top to bottom and must include verifiable, regular avenues for group interaction and definite routines for ensuring that users' concerns are methodically addressed in the resulting design" (Spinuzzi, 2005). Ideally, the users identify with the intended tool and oversee and approve the content, choose the look and feel, decide on functionality and may even create the content or parts of the system themselves through co-design activities. Historically, the involvement of users had a political dimension (Beck, 1996; Gärtner & Wagner, 1996) and tried to foster a democratization of the workplace. In more recent works, PD is mainly understood as a design approach used in industry and research (Bodker et al., 2004; Muller, 2003).

A key challenge when making use of a PD-oriented approach is overcoming the "asymmetry of knowledge" or "symmetry of ignorance" (Fischer, 2000; H. Rittel, 1984) and creating a "symmetry of knowledge" (Fowles, 2000) between the designer/developer, who is aware of the "design space," and the involved users, who are aware of the "problem space." Creating this symmetry requires a process of mutual learning (see, e.g., Béguin, 2003; Bjerknes & Bratteteig, 1995; S. Bødker et al., 1988; S. Bødker & Grønbæk, 1991; Greenbaum & Kyng, 1991; Kyng, Bjerknes, & Ehn, 1987; Muller, 2003; Robertson, Leong, Durick, & Koreshoff, 2014; Stein, Boden, Hornung, & Wulf, 2016). The goal is to create a shared hybrid space, or "third space" (Bhabha, 1994), extending both the design and problem space with regard to the design goal. By creating this hybrid space, developers and users learn from each other and question their own assumptions (Bhabha, 1994; Muller, 2003).

According to this notion, designers must understand the **“problem space”** of the users by becoming aware of key aspects, necessary information and crucial requirements for a successful design. Users, on the other hand, must learn about the **“design space”** in terms of technological potential in order to become “fully empowered participants” in the design process (Muller, 1991).

Our research group has a long tradition of applying different forms of PD in various contexts. One aim is to design technology for elderly users, focusing on enabling wellbeing and supporting autonomy in later stages of life. Working with older adults who lack experience with technology, opening and exploring this design space can be especially challenging (Bratteteig & Wagner, 2012; Essén & Östlund, 2011; Östlund, 2011). This issue is exacerbated by recent trends in technology that have led to increased complexity of ICT, rendering technologies more and more invisible, networked and adaptable, and making it harder to envision potential solutions. Instead of envisioning a mobile app or a single artifact, users must now grasp potentials of whole infrastructures and understand their relations at least enough to provide informed feedback. Thus, the implementation of PD requires a complex understanding of how technologies of different kinds (sensors, computers, mobile phones, data sources, etc.) must be combined to meet a given design challenge, which might be challenging for ICT novices such as many elderly people. The following section gives an overview of research addressing these issues.

3.2.2 The Problem and the Design Space

Design from a PD perspective begins not with a pre-defined solution in mind, but with the framing of a problem space. This usually entails the combination of developing a deep understanding about current practices and co-developing technological interventions regarding these practices (Blomberg & Karasti, 2012; Spinuzzi, 2005). Ethnography and ethnomethodology provide a rich set of proven fieldwork methods for exploring the problem space and developing a contextual understanding of what one is designing for (Blomberg & Karasti, 2012; Crabtree, 1998; Hughes, Randall, & Shapiro, 1992).

Originally, these methods were intended not to inform design, but to provide "detailed descriptions of the lived social experiences and social activities of social actors within specific contexts" (Hughes et al., 1992), with no intention of implementing changes. Findings generated by these methods must therefore be carefully considered with regard to their design relevance and adapted to make them appropriated for matters of design and engineering (Hughes et al., 1992; Randall et al., 2007). Nevertheless, for both design practitioners and field workers, combining fieldwork methods with co-design approaches has proven useful for both exploring the problem space with design intent (e.g. K. Bødker & Kensing, 1994) and iteratively introducing informed designs to the field (e.g. Blomberg, Suchman, & Trigg, 1997; L. Suchman, Blomberg, Orr, & Trigg, 1999). Emphasizing the design intent, PD aims at the active involvement of "users" defined as recipients of the "technology to be designed." Fieldwork can play an important role in getting a first impression of the context and providing initial insights into the problem space, allowing researchers to engage with the envisioned users and starting to create third spaces for ongoing collaboration.

Within the last two decades, the relevance of ICT has reached far beyond "controlled" settings such as the workplace. With ICT increasingly permeating the everyday life of users, and as result of the rapid technological development that affects very different areas of human life, PD researchers and practitioners are dealing with new, more complex, or at least less defined tasks that are subject to constant change. ICT has become an infrastructure in everyday life that is characterized by high complexity and multiple interdependencies (Forlizzi, 2008; Jung, Stolterman, Ryan, Thompson, & Siegel, 2008). As such, it cannot be reduced to a matter of technical design, but instead needs to be reflected in actual context ("in the wild"), in connection to other technologies and against the backdrop of individual appropriation (Kuutti & Bannon, 2014). While this has long been acknowledged by empirical technology research (e.g. Wittel, 2000), it has been argued that this effect is exacerbated by the latest trends in technology (Stein et al., 2016).

As an essential infrastructure for users, ICT is moving more and more into the background. This makes it visible, and addressing it in PD can be hard despite, or in fact because of, its ubiquitous and pervasive character. Due to this crossing of borders, the question of how to design such systems reaches far beyond the level of the interfaces and applications, extending to the underlying infrastructures (Stevens, Pipek, & Wulf, 2009), which in turn are the embodiment of how we deal with problems individually, as groups or as a society (L. Suchman et al., 1999). While at its inception concepts such as Gärtner's and Wagner's (1996) arenas of 1) the individual project, 2) the company and 3) the political, helped to frame PD processes, the entanglement of different areas of life through technology and thereby the interdependence between the different arenas has increased. This entanglement poses new challenges to the researchers, including:

- Understanding the problem space, including anticipating changes of technological interventions, is becoming increasingly hard because the intervention influences more than just one area such as the workspace (Robertson et al., 2014; Stein et al., 2016).
- Specific design choices have broader impacts and are subject to what has been called "context collapse"; e.g. people use a work calendar for private events and reject sharing calendar information (Palen, 1999) or use social network sites differently when they span various contexts (Skeels & Grudin, 2009) .
- Different stakeholders have different scopes of solutions. For example, funding agencies require broad general solutions, companies involved in projects seek economic advantages, and single participants look for increased ease of use or new solutions to personal problems (Dachtera, Randall, & Wulf, 2014; C. Müller, Hornung, Hamm, & Wulf, 2015).

As various types of technologies are already playing a role in the practices of users, it will be necessary to acknowledge them in PD, pushing the issues outlined above even further. While it is helpful to keep in mind the different arenas and their interrelations and interconnections, these issues are often relational in the sense that they only unfold in use time and cannot be fully anticipated by means of ethnography or PD, for instance (Kaptelinin & Bannon, 2012; Kuutti & Bannon, 2014; Wulf et al., 2011). Approaches are needed that are able to address such issues explicitly and adequately (Liegl, Boden, Büscher, Oliphant, & Kerasidou, 2016; Rohde et al., 2016).

This is of special importance when dealing with user groups that lack experience with technology and therefore struggle with using, let alone designing, new technology. PD must therefore be designed as a staged approach (S. Bødker & Iversen, 2002), allowing designers to systemically frame the problem and users to explore suitable design solutions.

In the case of elderly users, Güldenpfennig and Fitzpatrick (2013) and Müller et al. (2015; 2012; 2014) argue in favor of a focus on exploring the design space beforehand by introducing market-ready standard solutions before involving elderly users in the design space. Güldenpfennig and Fitzpatrick root their argument in a "research through design" approach (Zimmerman, Forlizzi, & Evenson, 2007). They argue that certain practices that can potentially provide benefits and should be supported must be evoked by introducing the technology first (Güldenpfennig & Fitzpatrick, 2013).

Conversely, Coleman et al. (2010) argue that the limited experience of the users can lead to more creative designs. To leverage this fact, Östlund et al. suggest "to study and use methods that reveal the sources of innovations behind their [elderly people's] expressed problems and lifelong habits as users of technology" (Östlund, 2011). In this regard, Vines et al. (Vines et al., 2012) highlight critique as a design resource to pinpoint such innovative design elements. They examine the transformation of banking practices. The ongoing digitalization of these processes challenges existing routines of technologically inexperienced users. They found that the elderly people they worked with opposed new tools and processes. To deal with this issue, they employed the user's critique of existing solutions to identify potential design solutions. When designing an online banking system for elderly users, this critique helped Vines et al. (Vines et al., 2012) understand the aspects of payment checks that elderly people particularly valued, such as tangibility or limited use. Thus the critique helped conceptualize "digital" checks that reproduced these aspects.

Generally, the exploration of both the design and the problem space is challenged by the increasing gap between available technological opportunities and awareness about and experiences with these opportunities (Stein et al., 2016). As technology plays an integral part in an increasing number of daily situations, the scope of the problems that technology affects becomes broader and is harder to grasp for developers and designers. Addressing these more complex problem spaces has resulted in adaptable, learning and connected technological infrastructures, which in turn are very hard to grasp for regular users.

Attempts to invoke an innovation process have taken different forms:

- *Future Imagination*: Innovation in approaches that argue for introducing technology beforehand stems from participants leveraging insights on new technology to recompile bits and pieces of this technology to create new technological artifacts that fit **future practices.**
- *Retrospective Innovation*: Innovation in approaches that argue for not introducing technology in advance stems from **retrospectively** understanding practices that have not been aligned to technological support and therefore make it possible to freely explore and find the most suitable design options.

While we do not claim that each individual PD project fits perfectly into this dichotomy, we argue that this categorization can help systematically develop the PD process with regard to the intended goals of extending the problem and/or the design space. To better understand this conceptual approach, we compare two design projects that involved designing complex technologies for technologically inexperienced elderly users. The two design studies were situated in the same project context but followed different design approaches (one followed the "future imagination" approach and one the "retrospective innovation" approach). The case studies are interesting for further engaging with the questions of the users role in the design process especially regarding the exploration and framing of the design and problem space.

4 Research Framework

The methodological context of our work is a Living Lab (Ogonowski, Ley, Hess, Wan, & Wulf, 2013). The Living Lab was set up within the “S-Mobil 100” project to create a long-term participatory design environment consisting of researchers, developers, public institutions, and end users. Within this process, we applied qualitative and quantitative methods to explore innovative socio-technical solutions to support transportation.

During the research in the Living Lab setting, various studies were conducted using the design case study (DCS) framework introduced by Wulf et al. (2011). They address the design of innovative technological artifacts created in the context of existing social practices and, due their iterative, participatory design approach, take into account the interdependence between the evolution of these practices and the availability of technology.

A DCS typically starts with a context study for the purpose of exploring a field of application. The aim is to understand current practices, relations between actors and organizations, the current use of technology, as well as potential areas for improvement. Second, based on these insights, socio-technical solutions are designed, typically involving a participatory design-oriented approach. Third, the appropriation of the solutions in real settings is studied in the long term. This third step looks at how behavior or practices changed after the new (ICT) artifacts were introduced. Therefore, its aim is not to “confirm” concepts or features of design, but to provide a detailed understanding of how existing practices have been disturbed and altered by the introduction of technology, thereby deepening the researchers’ understanding of the practices themselves (Rohde et al., 2016). It is therefore crucial to document emergent changes that might not have been anticipated (Orlikowski & Hofman, 1996).

In this regard, it is important to point out that the phases of DCS are not necessarily sequential, but rather cyclic, interwoven and overlapping, each informing the other. Development of socio-technical artifacts can start during the initial empirical investigations and even facilitate the context study, e.g. by using methods such as technology probes (Güldenpfennig & Fitzpatrick, 2013; Hutchinson et al., 2003). Studying the appropriation of technology can also point to other opportunities for innovative design solutions. In this sense, DCSs build upon each other, and reflecting on each phase helps to build the knowledge base necessary to provide practical solutions (Rohde et al., 2016), taking into account the practice theory considerations outlined before. It is important to note that there is an ongoing discourse regarding practice theory concepts. This work does not attempt to contribute to this discussion and the outline of concepts above only serves the purpose of providing "sensitizing concepts" (Blumer, 1954) that illuminate certain aspects in the data analysis. Thus, based on this approach, we present our findings on the role of transportation as an embedded part of situated practices and the influence of these practices as a context for interaction with transport systems.

For this project, we wanted to initiate a PD process with elderly participants from the area. This required finding relatively technologically inexperienced participants with a certain level of skills to cope with the envisioned technology in ways that were meaningful for them and, perhaps more importantly, to get over their skepticism and anxieties regarding these new technologies. Addressed consistently as important members of the project, holding the status of experts regarding their own practices and important contributors, the users started to see themselves as members of the project and as a part of a mutual learning process. The general idea of this approach is to enable users to participate in development of technology throughout the process and influence its direction. Different methods are applied during all phases to ensure empirical grounding, such as interview studies, workshops, focus groups and observations, as well as to keep the design concepts aligned to these findings, including participatory design workshops, focus groups, usability tests, rapid prototyping, and creative workshops.

An overview of the steps we took to initiate the PD process with the elderly is shown below in Figure 3.

Figure 3: Stages of the PD process with elderly users

4.1 Recruitment

The participants were initially contacted through various local senior organizations. From the beginning, we tried to establish a trusting atmosphere by leveraging existing networks (German Red Cross, senior computer clubs, municipal organizations, etc.) and by establishing a presence in the local communities. Through activities like giving talks and promoting dialog with potential participants, we were able to contact roughly 50 persons that were interested in participating in the project. Our call for participation was not focused on predefined issues or deficits. Instead, we tried to explain the opportunities we wanted to provide, trying to focus on positive experiences and following the suggestions made by Davidson and Jensen (2013) and Convertino et al. (2005). This strategy helped us negotiate the boundaries of our work. The users were sure to address their individual issues, but we also made very clear that the focus was on new ICT development. We selected a group of seniors (N=19) that was heterogeneous with regard to gender, age, local infrastructure, and transport systems typically used, in order obtain a wider range of ridesharing and mobility experiences. At the beginning of the project in 2012 the older adults were aged between 57 and 81 with a median age of 65. All of them were involved in the project from the beginning to the end and had no technical skills regarding new media. Thus, they were quite skeptical, and also somewhat anxious to learn about new technology.

4.2 Setting up Infrastructure for PD-Oriented Work

To start working with the elderly participants, infrastructure played a significant role. This includes issues such as identifying the smartphone that was easiest for the elderly to handle. After deciding on a model, the recruited participants were equipped with Android devices in May 2012. Additionally, we had to set up infrastructure at the people's homes. As some users did not have Wi-Fi, we established such connections at all users' homes. All users received an iTV set-top box installed in their living room.

After this appropriation phase, weekly meetings were held in order to conduct co-design workshops (more than 40 workshops involving 6-10 participants), which we documented with audio recordings and supplementary note taking during and after each session.

4.3 Support and Motivation

One issue was to keep the training sessions interesting for the users. Therefore, we tried to orient towards the wishes and needs of the elderly. In a series of 10 sequential weekly meetings, we supported the participants in appropriating the devices for basic tasks (using it as "daily device" for tasks such as calendar management, messaging, transportation, calling, etc.). We also considered what kind of apps or functions might be of interest for the users. Examples include photo functions and options for synchronization with their PCs or laptops, deleting and downloading new apps, information about security issues, and so forth. Generally, the training workshops provided an open, welcoming space where everyone was given the opportunity to express an opinion. We had always coffee and refreshments to make the elderly people feel comfortable, and we organized occasional social events. These events were crucial for long-term motivation and the creation of an open space for exchange, as also found by Newell et al.(2007) and Müller et al. (2012).

This work presents three DCSs, the first of which is based on active participation by the users to combine the problem space and the design space, in which the designer acts as a mentor providing innovative stimuli. The second and third DCSs are critique-based, building on the user's involvement to define the problem space, yet leaving it to the designer to introduce new designs and define the user requirements.

4.4 Context of the Research

This section outlines the context of the various studies. Most of the work was carried out within the nationally funded project "S-Mobil 100," which is described in the following chapter. The area in which the research project took place will also be described to highlight the specific challenges that might not arise in more rural settings.

4.4.1 The S-Mobil 100 Project

The project "S-Mobil 100" began in February 2012 with funding from the German Ministry of Education and Research (Bundesministerium für Bildung und Forschung, or BMBF). The project's scope was to identify opportunities to support the mobility of older adults using new ICT. The main idea behind using ICT to enhance mobility was the fact that ICT can be introduced and scaled to a broader audience more easily than infrastructural changes. Of course, it was taken into account that the intended target group is not always entirely familiar with new ICT. Thus, the targeted outcomes were twofold: 1) With regard to mobility, the project aimed at providing a new conceptual approach to maintain and extend mobility in rural and semi-urban areas. 2) Regarding the target group, the project also intended to provide the necessary socio-technical infrastructures to allow older adults to engage with new ICT and make use of the services developed. To operationalize these aims the consortium consisted of partners from research institutions, industry, NGOs, and public administration. Within a period of three years, eight organizations had the following tasks within the project:

1. German Red Cross Siegen (GRC)-Wittgenstein (NGO)
   Coordinator of the project. The GRC had the largest professional transportation service at the time the project started. In addition, the GRC as an institution has a good reputation within the target group and access to a large network of volunteers.

2. University of Siegen (Research)
   The department of Information Systems and New Media was responsible for setting up and coordinating empirical studies focusing on mobility with the aim of generating design concepts.
3. University of Heidelberg (Research)
   The department of Gerontology was part of the project to assess the older adults' attitudes towards technology and the acceptance of platforms on a large scale by applying quantitative measures.
4. Infoware GmbH (Industry)
   Infoware GmbH was responsible for developing productive solutions based on the concepts derived from the empirical studies.
5. City of Siegen (Public administration)
   The city of Siegen was involved in establishing a trusting relationship with the older inhabitants of Siegen and gaining access to public infrastructures, as well as existing initiatives.
6. District of Siegen-Wittgenstein (Public administration)
   The district was involved in the same capacity as the city of Siegen. The involvement provided the project with access to infrastructures and potential users in more rural areas. The district was also responsible for the public transportation infrastructure.
7. BAGSO Service GmbH (Industry)
   BAGSO was responsible for ensuring the project's compliance with general accessibility guidelines with regard to elderly people and to further develop these guidelines, e.g. with regard to new devices such as smartphones.
8. International Institute for Socio-Informatics – IISI (NGO)
   The IISI was responsible for fostering the community-building process within the target group that was deemed necessary to achieve some of the intended goals. The institute developed means to manage this process.

During the project, several other institutions were involved in certain phases of the project. For example, within the first year a school [1] and a local community of seniors learning new

[1] http://www.gymnet.de/schuler/neuland-schuler-unterrichten-senioren/

ICTs[2] were involved in supporting the project participants. Later, public transportation agencies and larger networks focusing on standardization of transport solutions were involved.

In this thesis, most of the work described was part of the University of Siegen's sub-project. The relevant details are described in the method description of DCS I (see section 4.5.1).

4.4.2 The Area of Siegen-Wittgenstein

Demographic change presents one of the greatest challenges in modern societies. The rural exodus, growing cities and of course the aging of society challenge today's infrastructures and social structures. The area of Siegen-Wittgenstein is no exception and, as most semi-urban areas, faces decreasing public infrastructures in rural parts of the area (see surrounding municipalities in Figure 4).

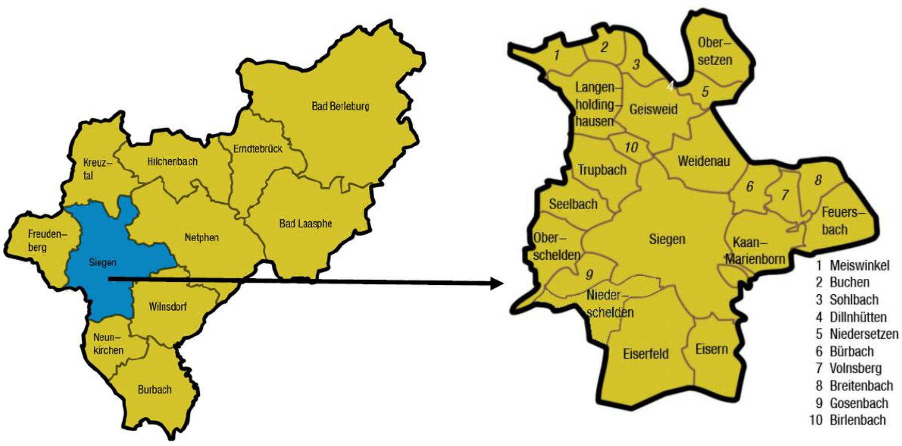

Figure 4: The Area of Siegen-Wittgenstein and the City of Siegen

The city of Siegen has roughly 100,000 inhabitants, while the area of Siegen-Wittgenstein has about 275,000 inhabitants (IT.NRW, 2011). Compared to other areas in North Rhine-Westphalia, the situation in Siegen-Wittgenstein is even more challenging. The population density of the area (244 inhabitants per km^2) is roughly half as high as the average population density in the county (518 inhabitants per km^2) (IT.NRW, 2015). Thus, it is

[2] http://www.senioren-siegen.de/

even more critical to sustain public infrastructures due to the greater distances and the smaller number of people.

This very open area combined with the hilly terrain makes it still more difficult to establish a dense public infrastructure. In terms of social structure, 20% of the inhabitants are of retirement age, and this share is expected to increase by 6% before 2030. This distribution is not homogenous, and the share of elderly people is higher in the surrounding rural areas.

From an infrastructure point of view, the area lacks freely accessible infrastructure items such as meeting points and event centers, which are necessary to engage in volunteer activities and foster communities. It is necessary to extend the socio-cultural offerings within the area, as well as create awareness about existing initiatives and events.

4.5 Methodological approach

The data used in this thesis was gathered on the basis of design case studies (Wulf et al., 2011) that followed a participatory design-oriented approach (S. Bødker & Grønbæk, 1991; Ellis & Kurniawan, 2000) consisting of an initial context study, an intervention phase (introduction of a technological artifact) and an appropriation study. Twenty-one participants took part in the initial context study and 19 took part in the subsequent long-term participatory design process.

Participants were between 58 and 80 years old (average: 69/71 years). Most owned a car (context study n=17/appropriation study n=15); only five used public transportation and nine/seven engaged in ridesharing on a regular basis (e.g. going to the theater together or to regular club meetings). Among the participants, the number of urban (n=11/10) and rural (n=10/9) residents was roughly the same. The participants are generally in god health and quite active. Some of the female interviewees have no driver's license, and all participants anticipate the loss of their driving ability or privilege due to future impairments. These current and future limitations were one of the main motivations for taking part in our study.

To collect data, we conducted 40 interviews in total. Twenty-one interviews were conducted in the participants' homes in advance (initial interview study), which also served as the source data for the ensuing DCS. Nineteen interviews were conducted after we developed our prototype (appropriation interview study). Two participants in the initial interview study did not take part in the later phases of the project (co-design and evaluation). Two other participants dropped out during the project and were replaced by others. The interviews were audio-recorded and then transcribed. After transcribing the interviews, we conducted a content analysis (Mayring, 2000) to identify significant themes based on the research focus of each DCS. The duration of interviews was dependent on the preferences of the interviewees and thus varies in length from 45 minutes to 2.5 hours. The interviews in the initial context study were used in all three DCSs and iteratively (re-) analyzed as appropriate to the focus of each DCS.

Between the two interview studies we engaged in more than 40 co-design workshops with the participants (see Figure 6) in order to conceptualize and design tools supporting the mobility of our participants. This included the design of mobile, web and iTV applications for integrated transportation information services within DCS 1, a second prototype for an alternative ridesharing concept in DCS 2 and a third prototype focusing on context-sensitive mobility support in DCS 3. The first workshops were mainly used to introduce the participants to the devices. After this “Basics - appropriation support” phase (Figure 5), we conducted the workshops to understand how an integrated transport information system might be designed. In the beginning, the workshops focused on existing practices related to different transportation modes. We further introduced available tools, such as flinc for RS or DB-Navigator for PT (official app of the German Railway System).

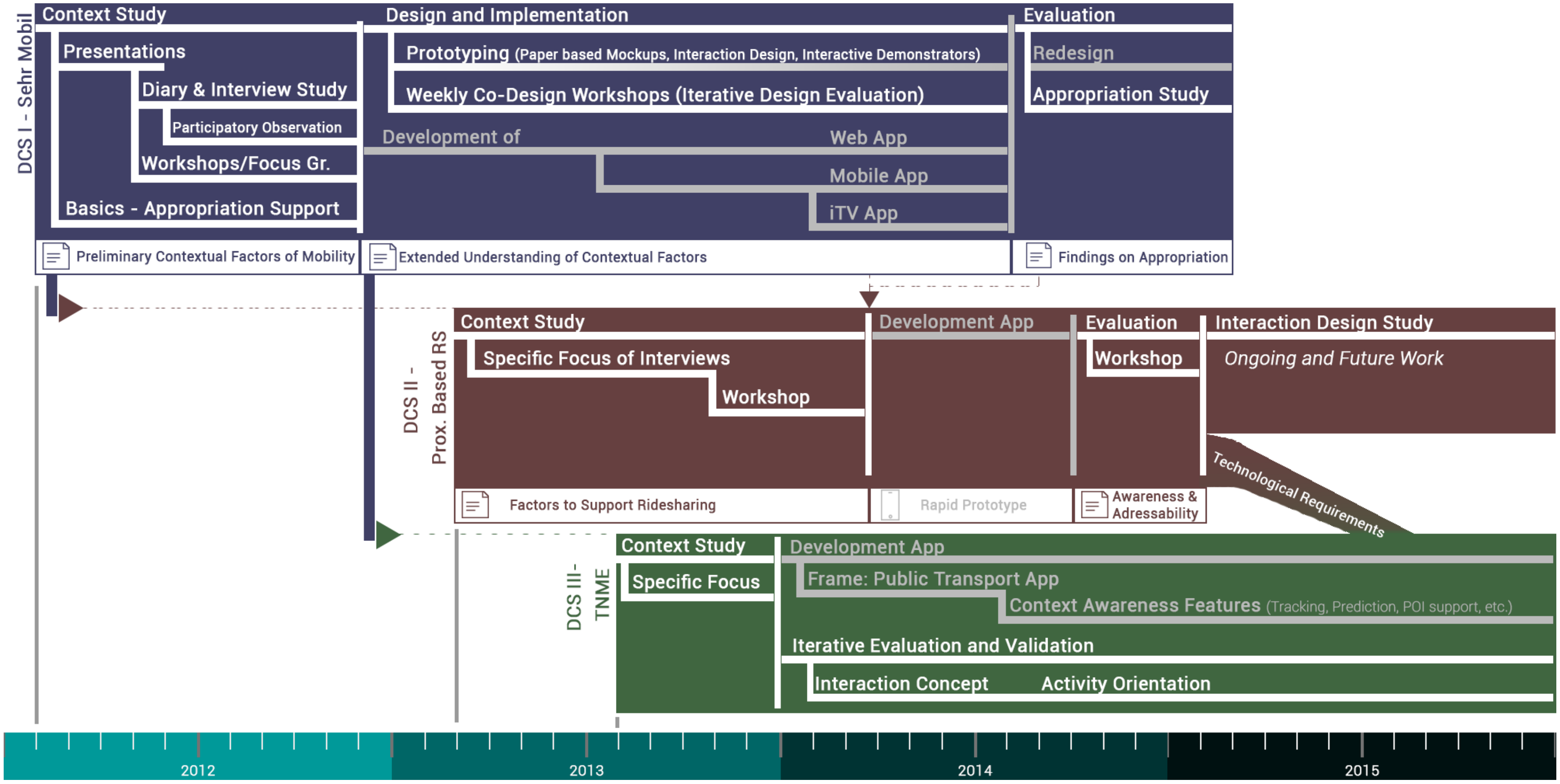

Figure 5: Approach Overview

4.5.1 Design Case Study 1 - Sehr Mobil

	Context Study	***Evaluation Study***
Number of participants	21	19
Age distribution	Min:58 Max:80 Average:69	Min:60 Max:82 Average:71
Mode usage (multiple)	Car: 17 PT: 5 Ridesharing: 9	Car: 15 PT: 5 Ridesharing: 7
Area	Rural:11 Urban: 10	Rural: 10 Urban: 9

Table 2: Details of User Sample

Within this DCS the initial interviews were conducted and analyzed focusing on different aspects. Generally, the interviews emphasized problems regarding the elderly's transportation habits. We initially focused on the opportunities and obstacles of the various transport modes and specifically on why our participants preferred certain modes over others. In the second phase, we revisited the data and chose a more design-oriented focus to look more closely at how transportation is routinized and the reasons why people deviate from these routines. In this phase we were especially interested in the organization and planning of the interviewee's daily transportation to understand how they think about transportation opportunities to reveal potentials for ICT-based support. The analysis resulted in different codes, which were collectively clustered into several topics, such as "usage of transportation modes," "planning of transport," "cooperation in mobility," and "self-perception of abilities in age." Based on these, we further developed the categories described below.

In the evaluative interview study focusing on the appropriation of the tool, we focused on the integration of the prototype into the participants' daily lives. While we had the chance to see routine use during the weekly meetings, since we iteratively developed the applications, we conducted a second interview study at the end of 2014 to ask about the influence of the prototype from the participants' point of view. We identified the situations and tasks in which our applications were deemed useful, as well as situations where participants stuck to their existing tools and routines or situations in which they made use of other tools that they became aware of after the smartphones had been introduced. The long-term involvement of the users in the design process allowed us to build a trusting relationship (C. Müller et al., 2012) and further enabled us to observe the appropriation of our (and other) applications over time. This helped us understand the situations and issues participants described during the second study.

Figure 6: Participants design the iTV-interface

Based on these steps, we first developed paper-based mockups, which we discussed with participants. Partly due to the complexity of the system, we provided initial ideas and conceptual solutions and used their critiques as a resource for further designs (Vines et al., 2012). In other cases, we conducted workshops and asked the user to design interfaces. For example, we conducted one co-design workshop to design the layout and select the functionality of the iTV application, one to test different interaction prototypes to negotiate RS arrangements, and another on privacy, using card sorting to identify relevant information structures and sharing preferences.

4.5.2 Design Case Study 2 – Proximity Based Ridesharing

The data gathered and used in this DCS was gathered in part from 1) project activities and 2) more focused activities. The study is based on a participatory design-oriented approach (S. Bødker & Grønbæk, 1991) and used data gathered during the initial interview study (n=19), assistive sessions, and two other co-design workshops (n=8, n=7). The participants in the first workshop did not take part in the second workshop. All workshop participants took part in the initial interview study. In parallel, we initiated weekly meetings at the university, typically lasting between 90 and 120 minutes, which were initially used to support the users in appropriating the devices and were later used in the iterative design and evaluation of new concepts. This resulted in a total of more than 40 assistive sessions. While some of the materials used for this DCS were collected in this broader project context, in this DCS we report on findings stemming from a specific investigation of the interview data and supplement the material with the aim of developing alternative concepts for integrating ridesharing into everyday mobility.

Our participatory design process was structured in such a way that each step informed the next one, critically revisiting and expanding our findings from previous iterations, all the while evolving empirically grounded design implications for ridesharing support in later life. Details on how the different steps from the initial interviews to the two co-design iterations were organized in terms of empirical inquiry and analysis are presented in the following sections.

Interview Study – Understanding the Specifics of Informal Ridesharing Practices

We revisited the initial interviews focusing specifically on the participants' experiences with various ridesharing situations in their daily mobile life. We looked for detailed descriptions about the setting, organization, meeting procedure and related ritualized habits, challenges, and critical situations that might require re-organization.

For our analysis, we coded the data with regard to the planning activities involved, including "intention of mobility," "cooperation," "circumstances of mobility" (e.g. weather conditions), "logistical issues" (e.g. being on time for fixed appointments, etc.), but also more subtle issues such as "duties when engaging in ridesharing," "shared destinations," "moral obligations," "trust/mistrust," "motivations for sharing rides" and other more general codes with regard to means of transportation and related issues. The results of the analysis provide an understanding of mobility issues as well as common insights for potential support of such situations, centered in particular on the concept of proximity-based support for transportation sharing.

The findings were extremely helpful for understanding the situations in which ridesharing occurred and the reasons why elderly people engage in ridesharing. Since ridesharing seemed to be an established practice among the participants, we were curious about the reasons for reluctance to use existing tools on the market, and we used the weekly assistive sessions to further elaborate on this issue (see section 5.2). Based on these user studies we co-developed use cases for more appropriate support in which co-location or proximity is leveraged (first workshop in section 5.3) and validated our support concept (second workshop in section 5.3).

Assisting Sessions – Exploration of the Existing Solution

To support our participants in becoming familiar with the devices, we offered weekly sessions to answer initial questions and to provide support regarding configurations and basic features (calling, messaging, taking photos, etc.). We also encouraged them to use existing transportation applications and services and asked them to reflect on how these technologies influenced their mobility. Over time, the participants became aware of several apps, including messaging tools, cameras, commercial ridesharing tools, public transportation apps, and games. They made frequent use of WhatsApp and other communication tools. Based on the understanding we derived from the interview study, we were able to suggest existing apps and discuss their technological capabilities. In particular, we discussed existing ridesharing applications such as flinc, ridesharing.org, Uber, etc. (not all services are available in the area of our study, but we were able to discuss their concepts and their strengths and weaknesses). We also considered applications that seemed useful as part of the task of arranging rideshares, such as WhatsApp and Facebook (e.g. to ease communication).

With regard to existing ridesharing applications, we decided to focus most closely on flinc as a technology probe to explore current limitations of ridesharing tools in the context of everyday mobility. Flinc (www.flinc.org) is a dynamic ridesharing tool. It provides automatic matching of drivers and passengers based on route convergence and is integrated into navigation solutions allowing flexible on-route notification about potential ridesharers. Flinc was the most well-established platform in our area (Uber is not available at all in the study location) and the most suitable for everyday mobility because it aims at dynamic short trip matches (ridesharing.org and similar tools only focus on long-distance, intercity trips). We therefore asked our participants to install this application. We also created a group on the flinc-platform so that all members of the group would be aware of other members' offerings. In the following two months, the weekly sessions themselves served as a recurring reason to engage in ridesharing. After the two-month testing phase, we used consecutive sessions to discuss their experiences. Probing an existing, well-established solution was helpful to understand what features are welcomed and to what extent existing shortcomings lead to the rejection of tools. Further, at a later phase, these insights helped us reflect on statements that our participants made with regard to a rapid prototype that we introduced.

Co-Design Workshops

Based on the results of the interview study, we organized the first workshop to co-develop ideas and designs for ICT-based tools that facilitate the sharing of transportation opportunities. The participants (n=8) in this workshop were also involved in the preceding interview study and the weekly meetings. The workshop consisted of three parts. First, participants were asked how they plan and organize individual or group trips. Second, they were introduced to possibilities for detecting and communicating with devices in close proximity by presenting some sample applications, giving the participants the chance to comment on existing tools and highlight their strengths and, more importantly, their limitations. Thirdly, they were asked to reflect on specific situations in which proximity-based approaches could be useful and to suggest concrete use cases and user needs for possible support tools. We initiated this process by presenting scenarios based on the interviews and in which people might benefit from ridesharing. Subsequently, we prompted them to discuss how they would proceed in these situations by asking them to reflect on their usual coordination tasks, as well as the tools and people involved when planning trips or activities, with the aim of identifying potential areas for ICT support. Based on the insights from the interview and the flinc study, we focused on future joint activities and immediate travel opportunities.

Based on the outcomes of the first co-design workshop, we developed a prototype that is described below. This prototype was used to detail the concepts and ideas that were co-developed with the users during the first workshop and open them up to critical investigation. As such, we used this prototype in a second workshop to illustrate the design space and the technical possibilities more clearly. The participants in the second co-design workshop (n=7) also participated in the initial interview study but did not take part in the first workshop. We chose to work with new users for two reasons. First, our decision was due to pragmatic reasons, allowing all participants of the interview study to take part in the workshops (for reasons of group dynamics). Second, we hoped that involving new users would lead to a more critical reflection on the results from the first workshop (as the users would not be arguing for their own ideas).

The second workshop aimed at identifying the potential of proximity for supporting the necessary steps to engage in ridesharing. Again, especially with proximity-sensing technologies, the participants lacked experience and required an introduction in order to understand the conceptual approach and its technological potentials and limitations. Thus, as an introduction to this second workshop, we briefly outlined the outcome of the first workshop. We proceeded by introducing our prototype and let the participants explore it. Furthermore, we asked them to perform tasks, such as searching for other users nearby, offering and searching for rides or tickets, forming a group for carpooling, and exchanging messages within that group. The goal was to reflect the core features identified in the first workshop and to envision interactions with the proximity-based tools. We decided to test the prototype in a workshop for several reasons. First, our main interest was introducing the proximity-based concept in a more tangible manner to trigger more detailed reflections of the idea. The workshop, co-locating the participants, provided a means to "simulate" serendipitous meetings which were hard to observe "in the wild," as they would require a critical mass of users which is far beyond the scope of our study.

4.5.3 Design Case Study 3 – Transiit&Me

In order to validate the technological concepts developed to support opportunistic ridesharing, we deployed the prototype publicly. The basis for the validation test was a public transportation information app that we created based on the concepts discussed above and that is publicly accessible in the Google Play Store. The application can be used to retrieve schedule information for buses, trams, trains, etc. It also adjusts to the user's movement patterns by suggesting probable destinations.

As the application usually does not allow us to access the data from the locally performed analysis, we looked for users who would be willing to share their location information with us for research purposes. This included installing a modified beta-version of the application that would send us logs containing the collected locations and analysis results. We focused specifically on two different aspects: 1) the amount of data collectable while minimizing power consumption, and 2) analyzing the collected data on the device of the users (with limited computational power).

To recruit users, we used mailing lists, personal contacts and existing contact groups from previous research projects, resulting in 15 users installing the beta version of the application without compensation. We did not ask them to change their settings in any way and explained that the application would collect and share their location information with us. Before any upload, users had to give their consent to share their data by acknowledging an information dialog during the first launch of the application. Within the application, users were also able to see the results of the clustering and were provided with a specific "Location History" – GUI to explore the tracking data shared with us.

Five of the participants contacted us during or after the collection to ask questions about the collected data. They were curious about what the data would be used for specifically. In these cases, we showed them their data, including visualization, as presented below. Discussing the visualization with them allowed us to further interpret their data.

5 Design Case Study 1 – Sehr Mobil

5.1 Motivation for the Case Study

The assumption underlying the first design case study is that mobility is essential for taking part in society and maintaining an autonomous life. In later life, this participation and autonomy are challenged by a number of factors. With increasing age people are faced with changes in their daily lives, such as losing their driver's licenses, forcing them to deviate from existing routines like using the car to do daily errands or visit friends.

At the same time, existing and new alternatives that may compensate for lost possibilities must be appropriated. If such transitions are enforced, however, the adoption of alternative modes might be limited or even fail for certain kinds of activities (even at younger ages (Hasselqvist et al., 2016)). This may be due to the perceived restrictions on one's wellbeing in later life (Nordbakke & Schwanen, 2014) or simply due to lacking knowledge of how to retrieve the necessary information (Mollenkopf et al., 1997). It is therefore necessary to understand what drives older adults' willingness to use a certain transportation option or, conversely, what hand prevents it. Works in gerontology or social science (Mollenkopf et al., 1997; Ziegler & Schwanen, 2011), HCI (Hasselqvist et al., 2016; Meurer, Stein, Randall, et al., 2014), and especially transportation research (Nordbakke & Schwanen, 2014; Redman et al., 2013; Schwanen et al., 2012) provide insights on the reasons for switching between modes, preferences that influence this switching, and drawbacks of specific modes that prevent people from switching. In this DCS, we follow an approach of integrating various transportation opportunities into one intermodal transportation information system to ease the switch between modes, potentially extending one's set of commonly used transportation options. In doing so, we hope to lower the impact of losing one mode due to aging, allowing older adults to maintain or even increase their wellbeing in later life. The importance of such multi-/intermodal transportation solutions is expected to grow due to continuing urbanization and the pressure of environmental concerns (Behrisch, Bieker, Erdmann, & Krajzewicz, 2011; Meurer, Stein, Randall, et al., 2014; Szyliowicz, 2003).

5.2 Initial Context Study

The study took place at the beginning of the project as described in section 4.5.1 and the results have been published previously (Meurer, Stein, Randall, et al., 2014; Meurer, Stein, Rohde, et al., 2014; Meurer, Stein, Wulf, & Rohde, 2014). The participants identified the different modes they used for daily mobility. They elaborated on the advantages and disadvantages of each mode used. It became clear that, regarding their decisions and their daily transportation needs, two prominent aspects influenced their choice: being independent and retaining decisional autonomy. The following sections show to what extent these factors play a role in the different modes of transportation and why neglecting their importance can hinder the adoption of new transportations modes. The analysis will also demonstrate how interviewees describe informal strategies to deal with issues related to these factors.

5.2.1 Independence and decisional autonomy

Independence and decisional autonomy were not the specific focus of any question in the interviews. Nevertheless, all interviewees at some point justified or explained their transportation choices using these concepts. This was especially interesting, as every interviewee had his/her own way of describing these factors although they used different modes of transportation and lived in different parts of the area. For example, the independence provided by public transportation was described by Female 7 as follows:

> *"It [mobility] means being very independent and able to go places. The bus services up here are really good and I'm really happy and that is important. You don't need anybody because the [bus] connections are excellent and you can get anywhere you like really quickly. That is very important for me. Yes, this is really very important to me" (Female7, 78).*

She is widowed, does not have a car, and lives in a suburb. Thus, the spaciousness of the area (see section 4.4.2) issues a challenge to Female7. Still, she does not want to address this challenge by just any means, but only if she is capable doing it without relying on external help. This relates particularly to cognitive and physical abilities. The issue of being independent may be more prominent for elderly, as they already struggle with the prejudices of a stigmatizing, deficit-oriented understanding of aging. It might be due to this very prominent understanding that most of the interviewees feared losing their independence even though they were in a generally healthy state.

In contrast to this actual independent usage of a specific transport option, decisional autonomy refers to one's available options, even those that are not used or needed in a given situation:

> *"Yes, a great deal, [mobility means] everything. Everything… the decision too, just the thought of it even I CAN go, if I want… that is so important, you know? Even if I might not actually go anywhere but just… yes, just to know that if I wanted to go anywhere, I can just go to the garage, get in my car and drive off… and yes, I am scared of the day when that might not be the case anymore", (Female14, 77).*

Female14 (married; living in a rural area of Siegen-Wittgenstein) emphasizes her desire for flexibility, meaning to go where she wants, when she wants. This finding supports those of Urry, who also highlights mobile autonomy as a key aspect to the perception of freedom (Urry, 2007). In this regard, all interviewees shared Female14's demand of autonomy.

5.2.2 Independence and Decisional Autonomy within Different Modes of Transportation

Having briefly introduced the both concepts, this section outlines specific issues and characteristics for each transport mode that the interviewees used. Both concepts are deeply interwoven and often come into play jointly in daily transportation tasks. Thus, the following paragraphs also describe the mode-specific implications jointly for each mode.

A privately-owned car was understood as a means to foster independence and maintain decisional autonomy. Compared to the car, both concepts were interpreted more negatively for cooperative modes such as ridesharing. Compared to PT, the car is favored by the interviewees, as PT clearly limits decisional autonomy, as described by Male1:

> *"Of course, I always go by car. It means a lot because it means I'm able to get out when I want. Although the bus stop is right before our house, the bus stops only twice a day if we are lucky [smiling]. You need a car in order to do all the daily errands or if you want to get out in an emergency or anything like that, or go out to the theater" (Male1, 81).*

The car was described as a means to extend one's activity radius, meaning that it allows the interviewees to reach destinations that they would not be able to reach using other modes of transportation. It even compensates for the physical decline associated with aging and thus serves to maintain one's personal independence. As described by Male1, the car also allows people to go wherever they want whenever they want, which fosters decisional autonomy. Although several interviewees also described PT as positive when it comes to being independent, it was striking to see how clearly interviewees pointed out the drawbacks of PT with regard to decisional autonomy compared to the opportunities offered by the car:

> *"When I use public transportation, I have to plan ahead. I have to look up how to do things. When I take the bus, oh God, I always think: 'I have to get going. The bus is coming in 10 minutes'. And with the car, this doesn't matter. I can go now or in half an hour. I do not really NEED the car and I don't use it every day but I want to have it right in front of my door if I need it. It gives me some sort of independence. (...) The car provides me with some degree of freedom" (Female13, 75).*

As mentioned before, PT was criticized for limiting flexibility due the its schedule-based services, yet it also was highlighted as a means to foster independence. Of course, this notion was more prominent in interviews with non-car-owners. It is interesting to note how interviewees described their relation to PT, as on a very basic level it implies using a service offered by an external organization and thus is comparable to cooperative modes. However, people see PT as an infrastructural right. As such it does not imply any reciprocity in terms of feeling obligated to "return the favor," which is the most critical drawback of cooperative modes with regard to independence. Nevertheless, the car was the only mode that allowed completely spontaneous, independent, self-controlled transportation.

As implied before, cooperative modes such as ridesharing represent an even more challenging scenario when it comes to addressing independence and decisional autonomy. Above, we have seen how decisional autonomy is affected by PT schedules. In cooperative modes, this decisional autonomy is also influenced externally. One's flexibility (even for the ride-offering party) to alter plans is immediately limited as soon as one agrees to share a ride. Although one might come to terms by renegotiating the specifics of a ride, it still necessitates a certain amount of prior coordination. Typically, these coordinating negotiations follow some implicit rules, as highlighted by Female4:

> *"[With ridesharing] you've just got to follow suit, no matter how or when she's driving. I have to watch what someone's doing, I can't look (when shopping) where I want and how long I want and what I want. Thus, I prefer*

to do it alone, you know […] That's all those things, no, well it is (on my own) more independent" (Female4, 73).

The quote exemplifies a common understanding of the relationship between driver and passenger among all the interviewees. As a passenger, one does not expect the driver to align to the passenger's schedule or other needs. Nevertheless, as highlighted by Sherlock (2001), these ride sharing arrangements imply a "host-guest relation," and as such in many cases the host feels obligated to be a "good host" and take into account the needs of his/her guests. Thus, the independence and flexibility of the host is also affected by the arrangement. Even more importantly, the interviews revealed that the negotiations and their subtle social rules are not generally codified, and thus a certain amount of uncertainty remains when making arrangements to share a ride. These uncertainties present a strong barrier to formal engagement in ridesharing (e.g. by publicly posting an offer). It was thus interesting to see that ridesharing seems to be very common among the interviewees in more informal settings (outside of formally organized arrangements such as ridesharing platforms). The following sections present the interviewees' strategies to compensate for loss of independence and decisional autonomy. These strategies have very high practical relevance and have proven successful in overcoming the barriers that prevent ridesharing arrangements. Thus, they are a good starting point for designers, developers, and researchers to create ICT-based ridesharing support.

Creating a Reciprocal Arrangement

To decrease the perceived loss of independence when agreeing to join a ride as a passenger, our interviewees describe gestures of appreciation in order to return the favor. This is very much in line with Mauss's (1990) concept of gift giving. People perceive the ride offer as a gift from a driver and they look for a suitable mechanism to return the favor in order to establish reciprocity. This was a common theme in the interviews and different ways of balancing the relationship, such as altering the roles (alternating driver/passenger) or through small signs of appreciation, as described by Female15:

"To square things you can take some flowers or a plant to say thank you now and again. They [the drivers] don't want anything but just to say thank you, you can get some flowers. Just a little plant. But I don't do it so often

because they don't want you to. Like they say, it doesn't matter whether three people are in the car or four" (Female2, 64).

This quote highlights the subtle challenges that accompany ridesharing arrangements. The "reimbursement" for the ride offer is not necessary as a means to compensate for efforts spent, from the driver's perspective (because the driver does not demand any compensation), but is a way reducing the perceived dependence. In the quote above it becomes clear that the gift is not actually asked for and perhaps not even welcomed. The quote also highlights how the social setting determines appropriate means of compensation to create reciprocity. In the quoted case, the passenger and driver are friends and know each other and provide a gift from time to time. In other cases, where driver and passenger might know each other not very well or not at all, financial reimbursement is a common way to deal with the issue. Generally, we see how neglecting these social structures can lead to conflicts, e.g. if one party (or a tool used to arrange the ridesharing) enforces financial reimbursement. Thus, flexible ways of creating awareness about expected compensation methods and social structures are crucial.

Finding Potential Drivers

The interviews made clear that interviewees sought to balance giving and receiving favors. Thus, while most were not in favor of asking for a ride too often, they showed great willingness to offer rides to others. This is partly due to the reciprocal relationship of driver and passenger and stems from the desire to owe nothing to someone else. This is especially true for social structures, such as those within the family, in which the driver may perceive some degree of obligation not to turn down a ride request. It was more common to ask friends or acquaintances that might have a shared interest in going somewhere together:

"Some people offer me a lift sometimes. But there are not too many people that I would actually join, because I know what this would imply. I know the feeling, if you asked someone to join you on a ride, you feel obligated to do so every time. Thus, I try to ask as few people as possible for rides. Mostly acquaintances who have a similar schedule" (Female11, 78).

This quote shows a strategy to find a suitable driver that was quite common among the interviewees. Instead of asking a person who might feel obligated, such as a family member, one tries to ask people that are going to a destination anyway, thus limiting the additional effort. People also try to distribute their requests across their network to lower the burden on each person in the network. This clearly presents a strategy to reduce costs (in terms of informal economies) and serves the purpose of reducing the "debt" within the reciprocal relationship of driver and passenger.

Finding Shared Mobility Routines

It is rarely enough just to find a suitable ride to a destination, and one must also make sure to have a travel opportunity to return home. Therefore, our participants often sought others with similar travel routes. Coordination in these cases is usually done prior to the travel itself. Thus, our participants specifically picked shared routes (e.g. going to a computer club) for ridesharing, as this neither restricted their own independence or autonomy, nor did the ride offering cause additional effort for the driver:

> *"Well yes, they're fixed… well, there's a group of us who do things together… sometimes we drive to the cinema … and yes, then you just ask, do you want to go this evening or maybe tomorrow and then one person says, yes, listen I'll drive or [someone else says] I'll drive…That's what it's like" (Female2, 64).*

Such frequently shared activities, such as theater visits, also provide a set frame for the coordination, as the starting time, the specific destination and often the time of return are already established.

5.2.3 The Opportunities and Challenges of Integrating Different Modes

To understand the challenges of integrating various means of transportation we must reflect on the results of the interview study with regard to different transport modes. The selection of modes for consideration is based on the selection integrated into the later prototype. Of course, this selection is not complete, but it allows us to transfer certain aspects from mode to mode, e.g. issues regarding buses can be compared to issues with trains, trams, cable cars, etc. to the greatest extent.

Privately owned car
The car has essentially no restrictions when it comes to choice of route, departure time, or

distance to cover in the context of everyday mobility. However, the car also requires financial resources and a driver's license (which is not commonly available among females in older generations).
Independence As long as one is able to drive a car on his/her own, the car provides the most independent means of transportation. The car is even more resilient to certain geographical and seasonal specifics such as altitude or, in the case of elderly, slippery/icy roads or hot temperatures.
Decisional Autonomy Flexibility is not limited in any way by using one's own car. Instead, it extends the radius one is able to cover and compensates for physical decline (e.g. reducing walking distances by choosing parking lots close to the departure point and destination).

Public Transportation
Public transportation is understood as a public infrastructure that can be used freely and thus does not depend on favors from any social ties. It is seen as an infrastructural right that one can make use of, as the compensation model is taken care of by ride fares and taxes.
Independence Public transportation allows people to move independently. Thus, people relying on it feel a similar sense of independence as those who use their own car.
Decisional Autonomy A downside of public transportation is lack of flexibility with regard to schedules and destinations. As such, public transportation affects one's decisional autonomy is correlated

to its (perceived) quality of service.

Individual Transportation Services (Taxi, patient transport, etc.)
Transportation services such as taxis allow users to adjust the routes and travel times according to their own schedules. They also always entail a service fee as compensation for the service, thus typically requiring financial resources.
Independence Transportation services typically do not conflict with the feeling of independence as they are not understood as asking for help, but rather as buying a service. It is interpreted as a classic business transaction and as such deemed more desirable by the involved stakeholders than asking for help. However, due to higher marginal costs (compared to PT or private cars) services may not be suitable for every instance of transportation.
Decisional Autonomy Transportation services provide a degree of flexibility that is comparable to privately owned vehicles. There are minor disadvantages when it comes to planning, as these services usually require notification prior to the actual trip (meaning the passenger is, e.g. not standing in front of a taxi).

Ridesharing
Ridesharing is associated with subtle social negotiations and predispositions. It is seen as a useful option when there are matching activities or at least destinations and time frames. However, ridesharing involves reciprocity and thus goes along with the need to create an equilibrium of giving and taking.

Independence
Ridesharing entails the necessity of relying on someone else’s service (if one is the passenger). While ridesharing does not conflict with the independence of the offering party, it evokes feelings of “asking for help” from a passenger’s perspective (at least for non-compensated rides).
Decisional Autonomy
With regard to the limitations that ridesharing places on the ridesharers’ flexibility, drivers and passengers feel restricted. Even if the driver has a stronger negotiation position and the passenger feels obligated to adhere to the driver’s plans, both must inform each other about changes of plans, making the alteration of trips/destinations more difficult and cumbersome.

In this direct comparison, it becomes clear that, in order to create better support for transportation, systems must first challenge the assumptions people have developed based on their experiences and ideas with regard to different modes. Specifically, this leads to different conceptual implications that appropriate technological support for transport needs must provide. Thus, below we outline various issues that were taken into account when developing our prototype.

1. **Increasing the perceived quality of service**
   The car was clearly described as the mode of choice for most of the interviewees, largely due to the flexibility and self-determination it provided. Nevertheless, even the car imposes restrictions that lead to cases in which people make use of supplementary modes such as public transport or taxi services (e.g. “Park+Ride,” intended consumption of alcohol, etc.).
   In other transport modes such as PT or RS the quality of service depended on the flexibility that was established by the number of travel opportunities (e.g. frequency of a PT service) and the reliability these services provided.

2. **Support the identification of suitable transport opportunities and create awareness in different situations**

Typically, people have a certain set of transport choices that they can make use of. However, the information they use to decide which opportunity is the most suitable is incomplete or not up to date. Thus, technological support should provide general information, such as costs, trip duration, alternatives, etc., but also ride-specific information, such as intermediate stops in PT, as well as reasons for a ride in the context of RS.

3. **Enable individual information retrieval to accommodate personal preferences and capabilities**
   The information people require in order to use a service varies depending on the person and his/her experiences. Thus, technology must be adaptable in order to account for the preferences of users and their physical and cognitive capabilities. Furthermore, it must take into consideration that there are mismatches between publicly available information and personally meaningful information (e.g. knowing where to go without knowing the specific address or bus stop).

5.3 Extended Context Study

The focus in this extended study is on the user's reasoning about daily travel decisions in order to understand how such decision situations can be better supported. To structure the presentation of our findings, we use the categories proposed by Shove et al. (2012), i.e. material (see section 5.3.1), competences (section 5.3.2) and meaning (section 5.3.3). Each of these categories has its idiosyncrasies in the case of everyday transportation, as is described below.

5.3.1 Resources at One's Disposal

To understand how people make decisions about everyday transportation, we must be aware of the opportunities that infrastructures or resources create. Our participants expressed different mobility strategies that highlight how transportation infrastructures (of different modes) form resources for mobility:

> *PT - "As long as I can still walk to the bus stop, I use the bus, I'm happy. It's my independence. I'd like to remain independent actually. And for me*

that means the bus. Not the car, because I don't own one" (Female1, 73, PT).

Own Car - "I have to admit, it [the car] needs to be parked at my door. More or less. […] I do a lot of things on foot, even walking to town, but it is reassuring to know the car's in the garage at home" (Female2, 64, CAR/PT).

Ridesharing - "I'm lucky to have the children around, at least some of them live here. And if I call them, they take me where I want if they are available" (Female3, 73, PT).

Commercial Services - "If it is late [and there's no more public transport] I can still go by taxi or just walk home" (Female1, 73, PT).

These quotes highlight the importance of infrastructural resources such as the availability of a car or PT for one's mobility. Social resources were important too, as people without cars mentioned the transportation opportunities afforded by having car-owning relatives and friends.

Particularly given the participant's age, physical abilities (or lack of disabilities) formed another important resource in daily mobility. Commonly mentioned physical limitations were impaired vision, slow reaction time, and fatigue. A comment by one of our participants highlights that he is not able to use PT but instead uses the car to reach certain destinations that are not in close proximity to a bus stop.

[Talking about the ticket fees in PT] For me the decisive factor is 'where does the bus stop?' and 'how far do I have to walk to get to the destination?' This is due to my problems with walking. I might walk 500 meters or even a kilometer but I think there is more to it. It's just getting worse with walking" (Male1, 81, CAR).

His physical abilities were insufficient to cover distances by foot that the PT infrastructure usually necessitates. These issues are especially critical in the area the interviewees live, which has a hilly terrain. This was also mentioned by another participant in a similar way:

"As long as I can get to the bus stop, catch the bus […] oh, and ride my bike…. walking is getting more and more difficult, walking to the center of town, and then you've got maybe one or two bags to carry all the way back home. That's really quite a burden" (Female3, 73, PT).

Thus, physical ability can be considered a resource of at least equal importance to that of infrastructure. Physical abilities are described as necessary to use a car or PT. As described above, resources used within certain practices can be understood as (material) things that are interwoven with the performance of a practice (Shove et al., 2012) or as techniques that require skills in order to be applied (Schmidt, 2014). These skills in particular turned out to be another key aspect of the ability to make use of certain modes and thus take them into account when deciding on a transport opportunity.

5.3.2 Know-How To Use Transportation

The above section outlined various transport infrastructures as resources that our interviewees utilize to engage in travel that is necessitated by a performed practice. For understanding transport modes as techniques that are available for the performance of various practices (such as visiting a friend, going to the gym, doing errands, visiting the doctor, etc.), it is also necessary to look at the routines and skills that one must have in order to make use of each mode.

Switching to other transportation modes, especially over the long term, was rarely mentioned. Participants would rather maintain familiar routines and available resources. This especially holds true for car owners. Few of them consciously deliberated on whether to take the car, rather treating it as the default option. Only one participant anticipated switching to public transportation to save money and time. However, this potential switch was likely influenced by this participant's upcoming move close to the city center, providing access to "denser" PT infrastructures that require less planning and therefore less effort and knowledge to access information (due to better infrastructures such as live monitors, etc.). Feeling confident using PT would then allow the interviewee to change modes when engaging in certain practices.

In the interviews, we identified two kinds of knowledge that enabled or eased the use of specific modes. The first is the actual "know-how" (Schmidt, 2012) that people need in order to do something instead of just understanding or recognizing it (playing the piano vs. recognizing someone playing piano), and the second relates to the meanings of places and spaces, which also has been highlighted by Harrison and Dourish (1996) and Dourish (2006).

Mode-specific "know-how" was of crucial importance for the interviewees to make use of certain transportation opportunities; alternatively, if they lacked this know-how they were not able to integrate a particular mode into their daily activities (or more generally, they lacked skills that kept them from using a certain technique (Schmidt, 2014)). For example, car owners often stated a lack of experience with public transportation. However, even regular users of public transportation mentioned situations in which they encountered for reasons such as changes in schedules, which caused them to work out informal strategies to verify information:

> *"There's often a change, just a couple of minutes, and when you're going out, you think 'Oh yes, you still have time' but then you see there is nobody standing at the bus stop. And you think to yourself 'has the bus already left?'" (Female3, 73, PT).*

The second kind of "know-how" became apparent when people spoke of destinations or described locations using landmarks. They used personally meaningful expressions such as "to my brother's place," "*the* supermarket" (having a specific supermarket or a set of supermarkets in mind) or names that were known to people living the area and differ from official names. In some cases, this knowledge was derived from the history of the place. For example, a participant referred to a shopping mall by the name of the store that used to be in the building several years ago. Other place references are personally or socially constructed and imply a certain understanding about destinations and activities such regular meeting points with friends (e.g. people mentioned "the computer club" when talking about a course on computers for seniors that takes place weekly in the area). One participant, for example, referred to the gym as "doing sports." Typically, these personal or unofficial labels must be "translated" into a meaningful input for a given transport mode, and thus potentially valuable information gets lost (e.g. by referring to the university with its address instead of the course a student is going to visit, the information about the start time gets lost). In other words, places are closely tied to personal and social meanings. Such references to places or landmarks occurred frequently in the interviews. The name served the dual purpose of underscoring the personal utility of the place and describing the activity connected with visiting the place.

5.3.3 Reasons for (Re-)Scheduling Transportation

The previous sections discuss resources and competences that people rely on when making decisions with regard to transportation. This section explores the intentions and situational influences when settling on a transport option, distinguishing between external factors, temporal and spatial factors, and social aspects.

External Factors

While people usually adhered to certain routines, they also occasionally rescheduled trips, altered destinations and switched modes. For example, participants refrained from driving or formed ridesharing arrangements when they intended to consume alcohol. Mode switches also occurred when an alternate mode offered specific advantages. For instance, taking the bus to the city center eliminated the need to search and pay for a parking space. Generally, we found that our participants showed a strong interest in structuring their days efficiently and avoiding redundancy. Thus, engaging in ways of scheduling transportation was quite common:

> *"We [Male2 and his wife] try to get organized. We don't go out to buy bread at 8 o'clock and then go out the same morning to buy something else at 10. We try to combine things so we don't have several trips to make because that pushes costs up" (Male2, 64, CAR).*

Participants also described more dynamic, serendipitous instances of rescheduling in the event of unexpected changes. This was typically indicated by remarks such as "since I'm already in the city center" or "since I'm taking the car/bus anyway." Participants outlined how they opportunistically combined or postponed activities based on the situation at hand.

> *"If you're going on the bus anyway [instead of walking], you might as well buy groceries before you go home" (Female4, 73, PT).*

Most participants reported that they would continuously (re-)compile their "personal schedules." As a consequence, the transport modes chosen must meet the requirements of these (newly) scheduled practices. Due to the continuous nature of this scheduling, the suitability of mode is assessed situationally, taking into account various (external) factors:

> *"Imagine it's winter; snow outside. I would still drive. Not a problem. But if I'm not sure about [my ability to handle] a situation, I'll take the bus. We've got an excellent bus service here" (Female5, 75, CAR/PT).*

> *"I quite often combine things. Say it's chilly outside and I'm working until 2 pm, I can run my errands afterwards. But if the car has been sitting around in the hot sun, I wouldn't carry raw meat in a hot car" (Female6, 60, CAR / PT).*

In the first quote, the participant would switch to public transportation when the situation made her unsure about her own ability to drive in difficult winter conditions. While the quote shows that a change of context can render a transport mode less desirable (weather challenging the car as mode of choice generally), these changes of context might also only affect the suitability of a certain mode with regard to certain practices. The second quote highlights how a transport mode (the car in this case) becomes inappropriate for the practice of going to the butcher shop. One may consider using a PT as alternative in this case, as buses may be air conditioned. Generally, the quotes show how the circumstances and the requirements of a specific practice must be aligned based on the situation at hand, which might alter the user's plans. These changes in context increase the difficulty of adhering to schedules.

Temporal and Spatial Flexibility within Practices

A common issue that our participants face is that certain activities cannot be scheduled precisely in advance. Sometimes the practice itself is accompanied by vague restrictions on time and destination, entailing a certain degree of temporal flexibility, as the following example shows:

> *"We can't do it all today, there isn't enough time. […] You simply do the rest the next day. You plan things ahead and it works out. And even if it doesn't work out, you just say so – but we have more time than younger people anyway" (Female1, 73, PT).*
>
> *"You can just sit in the bus shelter or whatever – you're sure to see a neighbor passing by, purely by chance. You strike up a conversation and time flies when you get chatting. […] It sometimes happens that we're so immersed in conversation that you completely forget the time… And when that happens, I just catch the next bus" (Male3, 66, CAR/PT).*

These quotes demonstrate that the participants anticipate deviations from schedules. People engage in different kinds of activities that imply different levels of temporal precision. For instance, the examples above describe very loose time constraints. Such activities can easily be incorporated in the schedule and can easily be rescheduled, but this is only possible if the temporal shifts caused by the rescheduling can be met by the chosen mode of transportation ("just catch the next bus"). The need to be temporally flexible goes along with the fact that certain activities do not require a specific destination. From a practical point of view, certain practices might be carried out at different locations, resulting in an interchangeability of destinations:

> *[Explaining how she plans trips in her leisure time] "It could be that we meet at the bus stop at 9 a.m. and we don't know where we are heading. So we go to the station and just say 'let's take this train.' It doesn't matter where it's going"(Female2, 64, CAR/PT).*

While the above situation is perhaps uncommon and limited to very few situations in leisure time, participants described several situations in which no specific location had been chosen in order to carry out a certain practice:

> *"I just check out all the little stores and it doesn't matter to me which kind of store it is. As I said, I buy my groceries at the stores that I think have what I need" (Female5, 75, CAR/PT).*

Another participant mentioned a situation where *both* time and spatial flexibility come into play:

> *"Sometimes things are already planned [in terms of having fixed appointments such as visiting the dentist]. You know you are going to a certain place, so you know things that can be done there. For example, at the town hall I can drop things off there or whatever. It's natural to do things like that" (Female1, 73, PT).*

This respondent used the town hall as a reference location to consider possible activities. In this case, the town hall is located within the city center, where several other stores are located, as well as the post office, where *"*one can drop things off." This shows that spaces do not always determine activities, or vice versa. For instance, instead of using one's usual post office, one may mail a package from a post office near the town hall in order to combine the mailing activity with the town hall errand. Because of temporal and spatial flexibility, an activity may be associated with several locations, and vice versa.

Social Triggers of Scheduling

In addition to these circumstantial factors, we also found the social context to have an impact on transportation-related decisions. As expected, some situations were regarded as "personal" (e.g. a visit to the doctor), with no desire to involve anyone else.

> *"I take my time and I like to browse. I look here and there, remember things I had forgotten to look for, and so on. That's why I prefer to be on my own" (Female3, 73, PT).*
>
> *"I am a sociable person, but with some things I'm better off on my own. Okay, if someone asks if I want to go to town, that's different. That's a different case entirely and I'd be putting my coat on to join him" (Female5, 75, CAR/PT).*
>
> *"I've already been there several times and it was interesting. Places that would otherwise be out of reach. And it's more fun when you go with a group" (Female3, 73, PT).*

As the examples illustrate, interviewees preferred different levels of social engagement based on the type of activity. Hence, shared activities can provide advantages such as a shared theater experience. A travel invitation from another person can mean that people take part in an activity they might otherwise have skipped. Moreover, sociability offered benefits such as cost sharing and entertainment. Several participants stated that they were interested in sharing rides mainly because of their desire to meet people curiosity about experiencing something new. Thus it became clear that social considerations were an important trigger for mobility and the motivation to engage in shared travel activities.

5.4 Participatory Created Design

This section presents the prototype and its design based on the empirical results.

5.4.1 Iterative Interaction and Visual Design

Based on the results of the context study we engaged in several design cycles. The aim was to incorporate the issues, detailed above, that must be reflected in various potential solutions. In order to do so, the first step was to generate visualizations or concepts. These early sketches were not intended to provide detailed requirements, but rather should be understood as starting points for discussion. One example of such a sketch is shown in Figure 7. It illustrates a sketch which is projected on a whiteboard and includes hand-drawn additions that resulted from the ongoing discussion.

Figure 7: Example of sketching first ideas

These design sketches were developed based on underlying use cases, which were derived from the stories told by the interviewees and from typical use in existing applications. On a general level, the use cases can be differentiated with regard to their goal: offering or searching for a transportation opportunity.

Searching for a transport opportunity depends heavily on the intended mode of transportation. For traditional transportation modes such as PT or taxi services, the user only engages in information retrieval tasks, such as looking at a bus schedule or retrieving contact information for commercial transportation services.

These cases of *pure information retrieval* are characterized by one of the following criteria.

- The user fully aligns his needs with the available service and its timetable and/or route (in cases such as PT)

- The transport service is completely flexible and accommodates the user's needs in terms of time and route (e.g. taxi services)

If the search for transportation opportunities involves *forms of collaborative transportation*, such as ridesharing, the user and the provider of the ride opportunity typically engage in some kind of negotiation. As described earlier, logistical details must be settled in these negotiations (e.g. pick-up and drop off times and places), but it is also necessary to determine other potential mismatches, such as a pet owner offering rides to an allergy sufferer, or reasons to rideshare (e.g. to establish new social contacts vs. the utility of the ride). Depending on the "first mover" (accepting an offered ride vs. requesting for a ride) within these collaborative cases, there are different social dynamics to be considered in the design process. For example, in terms of autonomy people stated that it is easier to accept an offered ride than to ask for one (see section 5.2.2), yet the general opinion among the interviewees was that the offeror is typically in a stronger negotiating position.

Consequently, the other use cases for the design sketches focused on the offeror. Either the driver offered the ride beforehand and a potential driver wanted to join the ride, or the driver became aware of a ride request and reacted by offering the ride.

Taking these different perspectives into account, a first concept of the application was developed and iteratively redesigned together with the participants in the Living Lab. For example, early wireframes (e.g. an initially anticipated contact view within the prototype in Figure 8) were presented to determine what functionality should be focused on. These wireframes mainly highlighted the structure and allowed us to build a shared understanding of the system.

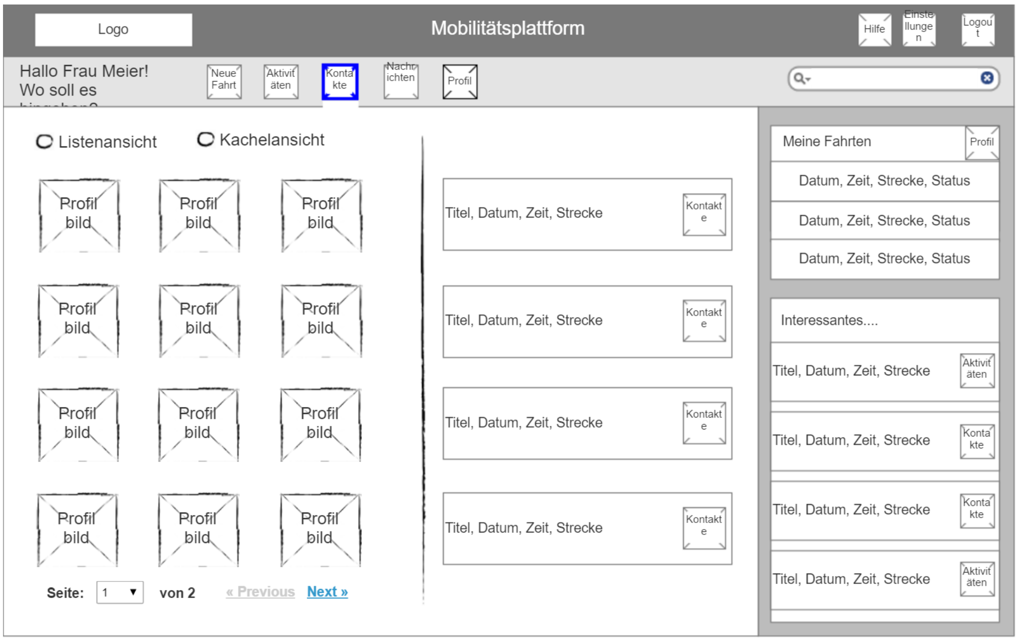

Figure 8: Early wireframe of the desktop application

In later phases, we also discussed various interaction flows (see Figure 9, for example). Discussing these flows helped create a holistic overview of the system and illustrate which steps are necessary in order to perform certain actions within the application. These flows were created for every task that a user might perform within the application.

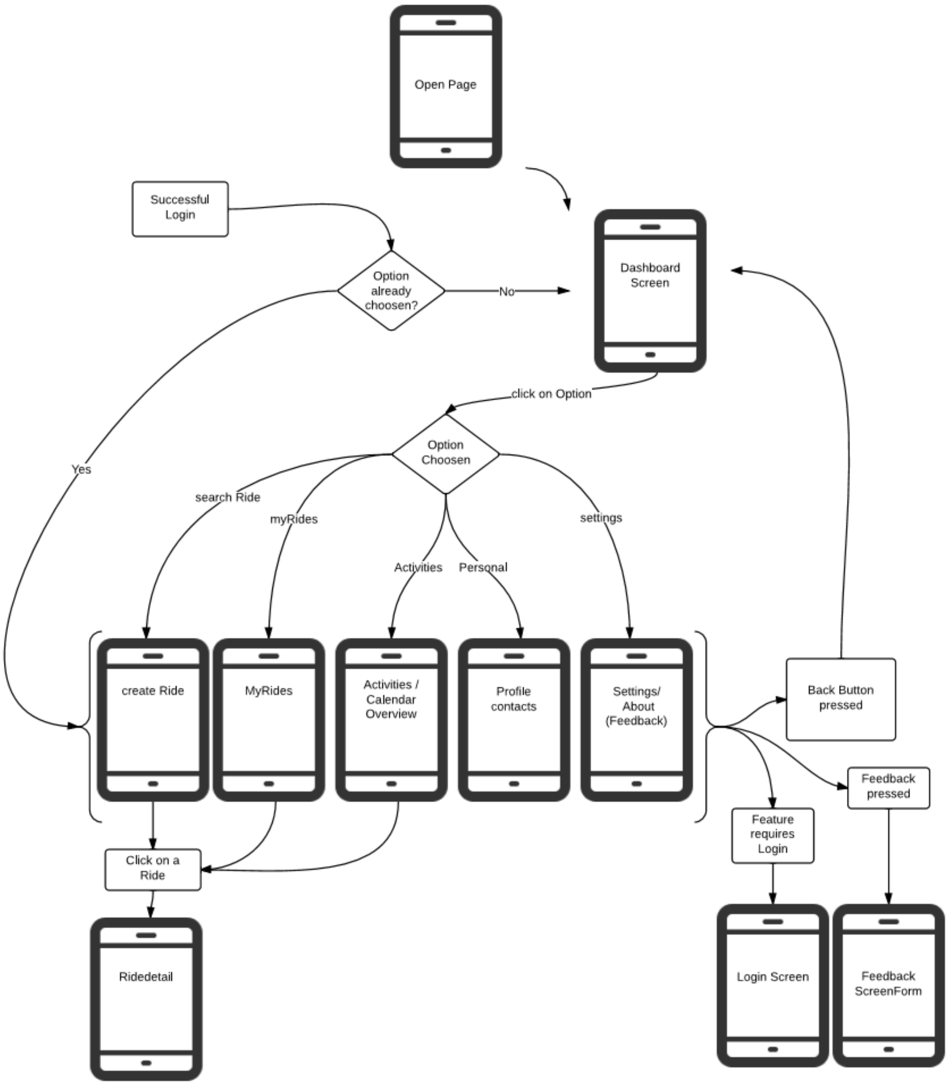

Figure 9: Sample interaction flow of the mobile app

5.4.2 Implementation

This section outlines how we intend to address the requirements above and present our prototype of an integrated transportation system. The system consists of a server application and client web-application for regular desktops, mobile clients and iTV clients.

As one outcome of the empirical studies, we found a mismatch between the current TIS and users' needs, especially when dealing with unfamiliar modes. These issues force users to take on unnecessary and often cumbersome tasks, such as comparing transport opportunities and searching for alternatives. Due to the iterative nature of the empirical process, several issues arose only after we implemented and introduced certain features. Thus, not all issues could be addressed in an optimal way. This prototype therefore serves as the first step or as one approach demonstrating what an implementation of the identified requirements might look like. The system is split into server and client applications. The server is written using the Java Spring Framework and clients are implemented as HTML5 web pages. We chose web pages as the front end on the client side in order to guarantee high cross-platform compatibility and easy portability of new features to all devices. On the mobile device, the web page is wrapped in a native Android application in order to provide more comfort features that require access to the device's sensors.

Server Side - Architecture of an Integrated Transport Information System

Figure 10 shows the architecture of the server application. The system consists of various modules to ensure scalability and flexibility during the development process. The different modules were developed by a project partner that already had solutions providing standard functionality with map and routing services. The MapSuite (MS) shown in Figure 10 consists mainly of these solutions and allows switching of the underlying map source.

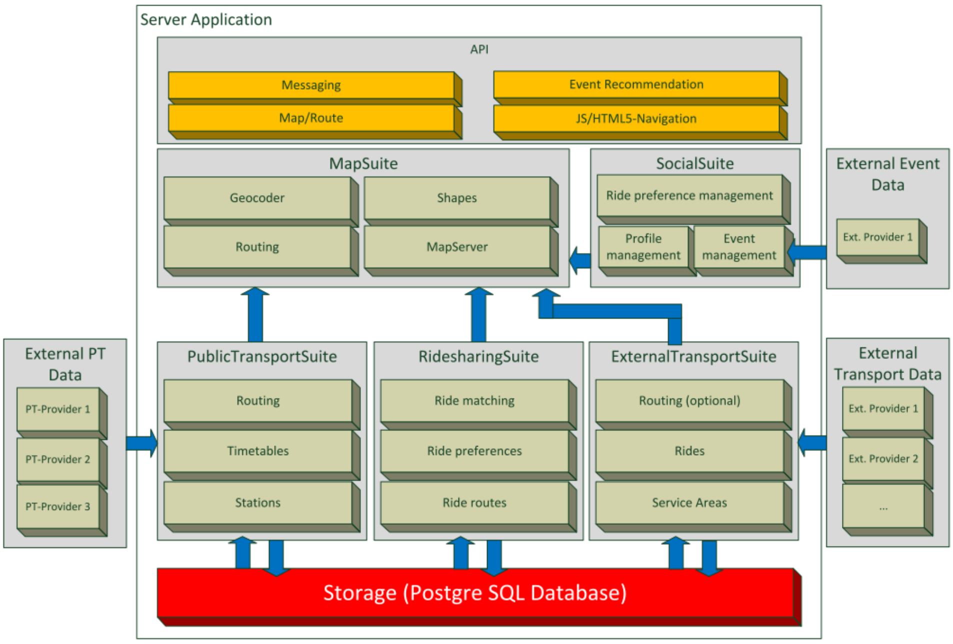

Figure 10: Architecture of server application

The PublicTransportSuite (PTS) was developed to integrate the data of different PT service providers. It allows services providers to supply either station, schedule and line data, or calculated routes ad hoc. In the first case the PTS will calculate the shortest PT routes based on the user's input. This is a crucial precondition for PT providers servicing smaller, often rural, areas (e.g. the area where we developed and tested the prototype), which might not provide online services themselves (e.g. via web service) but only deliver their data to larger integrators. For large service providers, we also implemented features to query external routing services ad hoc. During this project phase, we integrated three PT service providers, two of which provided data sets and one of which provided an external routing service. The format of the data sets is based on a standardized data format for public transportation data (VDV452).

The RidesharingSuite (RSS) was developed to address issues related to sparse public transportation, especially in rural areas. Users can enter offers and requests for rides. These are matched based on spatial and temporal criteria and on personal preferences, such as smoking, permission to take pets in the car, required space, and the need for assistance during rides.

The ExternalTransportSuite (ETS) was developed to provide other transport service providers with the opportunity to integrate their services. These service providers can either state the areas they service in general (e.g. cab services) or provide specific kinds of transportation services (for example, transportation services for handicapped persons). The prototype also offers routing for these rides (calculating fastest routes, ride duration, etc.), which means that users can retrieve routes and durations even if this information is not supplied by the providers themselves.

PTS, RSS and ETS provide their data to the MapSuite (MS). The MS is responsible for integrating the information from the other suites and providing this information via API, from which the information can be accessed by client applications.

Further, we added a SocialSuite (SS), which is responsible for managing the user profiles and the individual ride preferences (e.g. walking distances, exclusion of specific transport modes, personal interests, etc.). This data is used by the MS to offer individual transport options. In addition, the SS is able to retrieve event data from external sources, including schedules of local cinemas and other events in the user's area. Furthermore, the SS can recommend upcoming events based on the user's interests.

Based on these suites, the server application allows the API to access the services described. Clients can make use of APIs for messaging, routing and map services, event recommendations, and HTML5-based navigation for support during transportation.

Client Side – User Interfaces

We developed a new interaction concept to retrieve information and offered various options for data input. This section explains those parts of the client applications that specifically address our requirements. The visualization provided typically contains German entries, as the system is designed for older adults in Germany (parts of the images have been translated).

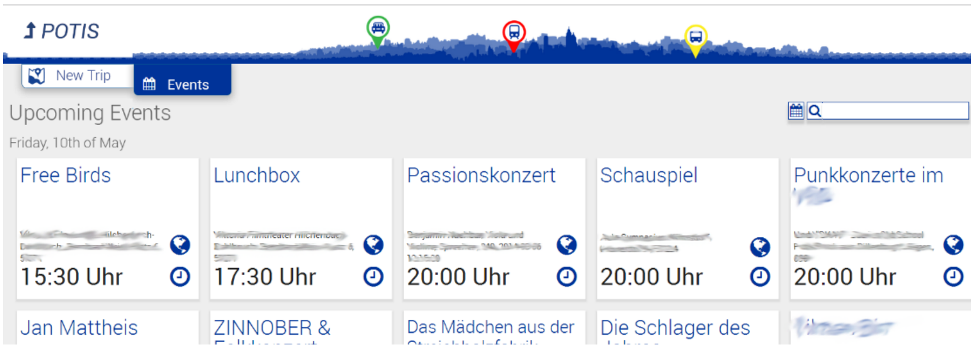

Figure 11: Event page to search for rides (translated and anonymized)

Figure 11 shows the event page included in our system, which is available in every client application. This event feature has been implemented as the first step towards a more activity-oriented method of retrieving transportation information. The data is retrieved from public calendars hosted by the various municipal administrations of the test area. Users can browse the list of events, get more detailed information and, if they are interested in participating, look for transport options to get there, offer a ride to the location, or just save the event to a personal calendar. If they offer or look for a ride to the event, the ride is connected to the event. This means that if the user decides to cancel his participation in the event, he is also able to cancel the ride. We also implemented infinite scrolling on the event page, as users tended to browse through the events to look for interesting activities. This serves as a first approach to make people aware of possible activities and others who might join them.

We found that, depending on the transportation mode of choice, our participants had different needs concerning the possible use of supplementary modes. For example, frequent and infrequent PT travelers have very different needs when it comes to accessing travel information. We created a search flow that differs from standard interfaces by providing a unified interface for the context of frequent travelling or infrequent travelling. Figure 12 shows our interface, where (1) shows the information presented without any input made by the user, (2) shows the visualization with destinations entered, and (3) shows the picker we developed to choose a destination.

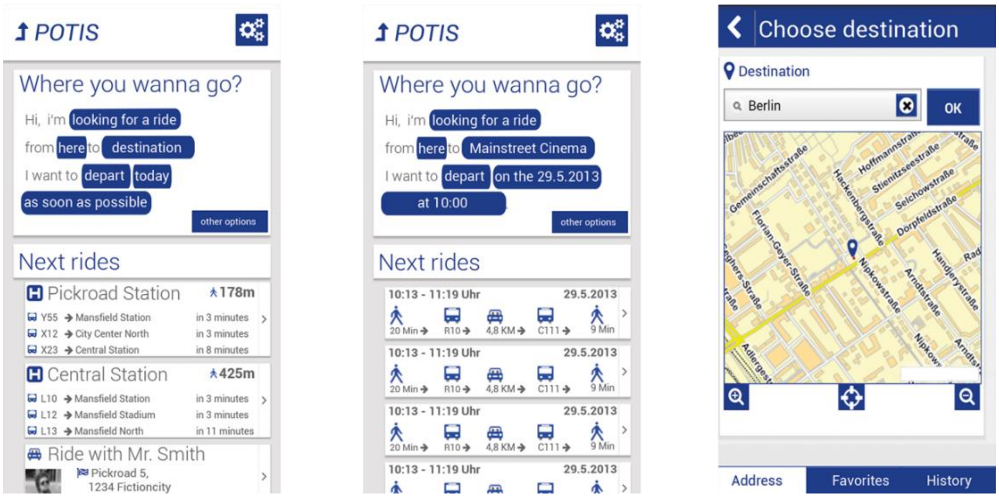

Figure 12: Search for a ride - (1) without entering destination (2) with destination entered (3) destination picker (translated and anonymized)

Firstly, the retrieval of information is iterative, meaning it provides more precise results with each input made instead of asking for all input up front. In conjunction with the visualization on the map, the user can control the filtering of information based in his interests and knowledge. For example, frequent travelers on public transportation looking for the timetable of the nearest bus stop do not need to enter any input to get the relevant information, as the system automatically provides them with the timetable of stations nearby using GPS. Furthermore, they are also able to provide only the input relevant to their requirements, e.g. they can adjust the departure times, thereby querying all buses leaving from the nearest station within the specified time. In contrast, infrequent travelers can input more information, such as their intended destination, to access more detailed results, such as directions to the closest stop, travel times or intermediate stops.

Secondly, because information is provided step by step and from different sources (PT, ridesharing, transport service providers), the user is made aware of his options and this enables him to explore alternative modes more easily. Further, since the results change directly according to his input, it becomes easier to assess the suitability of each transport opportunity for the user's own needs. This way of retrieving information supports complementary use of different transport modes.

Thirdly, we offer various input mechanisms. In addition to the interface shown, which suggests personal destinations to the user through the functions "history" and "favorite," we also implemented voice input and point-of-interest searches, which enables the direct choice of destination. The voice input accepts natural-language sentences and recognizes patterns for time and date input. Further, the entities recognized in the sentence are geocoded if they are addresses, or matched against various POI services (Open Street Maps, Google Places and Foursquare).

Limitations of Implementation

In its current state the search interface of the prototype is still based mainly on geographical locations as inputs. For stricter activity-orientation, the search must derive all possible locations based on the user's task. For example, the system should provide transportation information for rides to all possible supermarkets if the user intends to go shopping.

During the iterative development of the system, we had to decide on certain specifics of the system that made it more cumbersome to implement the activity focus that was discovered later. Due to resource and time restrictions, we were not able to make use of more powerful hardware or focus on approaches to reduce the server load, nor could we restart the development process to reflect the insights found later. Nevertheless, we explored further ideas for integration of event/activity data by enhancing the system through user-generated events. This makes it possible to include individual private events, which may be shared with a specific group of users. In this regard, it is worth mentioning that Facebook and other social network sites (SNS) already provide functions for creating personal events. It might therefore be worthwhile to integrate the system with SNSs, especially since the participants initially rejected the idea of integrating social network features directly into the prototype. As it later turned out, the rejection of such features mostly stemmed from a lack of experience with such SNSs or communication tools. After being exposed to such tools, the participants appreciated their functionality and even suggested integrating them. However, looking at the broader target audience, this user group is typically not registered on social network sites and does not use such communication tools. The integration of SNSs is a feature worth considering in future iterations of the software.

5.5 Evaluation

This section outlines interesting observations that arose while our users appropriated the prototype "in the wild." The users were free to use whatever tools they liked and we did not limit our observations to the successful appropriation of our prototype, but looked more widely at the appropriation as it emerged after the new technology had been introduced. The study revealed blind spots in the existing literature that stem from a strong focus on (mode-specific) transportation aspects. This causes situational aspects of the framing activity to get lost. The appropriation study helped us understand to what extent increased awareness, better access to relevant transport information, and extended (contextual) information influenced the participants' willingness to adopt new or different transport options.

5.5.1 Reducing Uncertainty

Generally, the prototype was welcomed enthusiastically. The participants especially liked the regional focus of the tool, a perception when using the tool that was mainly established by the local event calendar and certain design elements (such as the header image), which resembled landmarks of the area. As most of the participants used no ICT-based tools to support their transportation (except for car navigation systems) before the project, we were interested in which situations and for which tasks they would adopt any transportation tools. One interesting point was the time of usage and the incentive to use the app. We expected that users would appreciate the mobile app's ability to obtain information on the go. To our surprise, they pointed out that they use the mobile device to carefully plan trips in advance:

> *"I occasionally check departure times when lying in bed late in the evening or early in the morning. I think you [addressing the interviewer] have a different way of doing that. Rather off the cuff" (Female4, 73, PT).*

The quote illustrates that checking in advance was used as a means to reduce the uncertainty caused by a lack of experience with the device (as she points out, the interviewers can do this task more spontaneously). However, the mobile access to such information also reduced uncertainty with regard to one's mobility. For example, Female11 *(PT, 82 years)* compared two situations before and after becoming familiar with various apps. She found herself lost at an intermediate train stop, helplessly trying to find an alternative connecting train after arriving late. Now, as she points out, *"the phone provides [her] with security"* when she is disoriented; she tells the story of how she managed to find the way back to her hotel using her phone to find an alternative route because the streets had been closed due to construction. Generally, several participants outlined how easy access to information helped them to verify trip information:

> *"Sometimes you have to change buses in between. Then you check if there is a better connection" (Female4, 73, PT).*

It became clear that people appreciated the ease of information retrieval using ICT, which allowed on-route information access. But the mobile app was also used within the users' existing routines of planning things in advance.

> *"I won't always bring the smartphone in the future. I don't need it. I'm happy having it at home, especially to access the internet and when I want to check things such as buses. Or events. That is really great in our app" (Female7, 78, CAR/PT).*

It was surprising how strongly the "always on" characteristic of the mobile devices was highlighted. The mobile phone and the app provided easy and spontaneous access to transportation information and therefore were used more than the desktop web application. Generally, by extending the participants' access to information, they were made to feel more aware of opportunities and more confident in finding suitable options.

5.5.2 Situated Exploration of Opportunities

Introducing the technology turned out to influence the participants' (perceived) flexibility. While the prototype sometimes blended in with existing routines, it also became clear that the appropriation of the tool(s) and the influence it had on existing routines was very different depending on one's prevalent transportation usage. Participants who mainly used PT for their daily trips reported greater benefits from using the technology for assistance. Even in the case of very regular PT users, the application helped to create better awareness of the available opportunities:

> *[Talking about search results containing various alternatives for going to the city center from the participant's home that were not expected by the user]*
> *Interviewer: Why do you think this result is wrong?*
>
> *Female3: This connection is not heading to the city. It ends up in [Village Name]. [Female3 recognized that this bus is just the first part of the whole trip]*
>
> *Female3: …Then I can board Line 555 in order to get to the cemetery. AND [recognizes that the connection is a suitable alternative] this is important to know, that there is an alternative to the main connections. It's really interesting that this information is programmed into the application. Very nice! (Female3, 73, PT).*

Based on the prototype, the users established new ways of retrieving information, abandoning tools that they used before, such as writing down departure times before going somewhere. The prototype enabled more flexible scheduling within their daily tasks.

> *[Talking about getting PT information]*
> *Interviewer: Did you use the paper book before?*
>
> *Female3: Yes, I always wrote down the departure time before I went out.*
>
> *Interviewer: And now you check the time on the go?*
>
> *Female3: Yes, you do not necessarily know when you will go back in advance. If you have an appointment or just stroll around the city.*
>
> *Interviewer: And how did you deal with that before you had the phone?*

> *Female3: I always wrote down several alternative departure times to go back (Female3, 73, PT).*

The two quotes highlight how the application helped extend flexibility within daily activities, on the one hand by providing more information *("…this is important to know, that there is an alternative to the main connection...*"), and on the other by easing access to this information (using the phone instead of writing down departure times in advance). This interest in information that provides new opportunities in a given situation was not limited to PT users, and extended to car users in particular. Although car users rarely used other modes, they reported instances of information retrieval, such as looking for events to visit, POIs or PT connections and RS offerings out of curiosity:

> *Male4: [Being asked if he uses the prototype for PT] Rarely, since we usually take the car. But that doesn't mean that I never use it for that purpose. Just recently, we went on a trip to [City Name] and we liked it there. So I thought about going there again and checked out how to get there using buses and trains. […] At that time I used the app of the German railway system because I knew that one from the computer. But I used our app when we visited our children. I wanted to know how the PT situation was over at their place. Even there [He emphasizes the fact that information is available because the children live in a very rural area] our app tells where the next bus stop is and how to get there (Male4, 71, CAR).*

What is interesting about this quote is that, although he did not actually use PT, the app allowed him to retrieve the information that was necessary to make use of PT in the situation he found himself in. We found that participants were generally interested in exploring their opportunities, in terms of both available transport options and potential destinations. In this sense, the integrated calendar provided a strong incentive to use our app. Thus, the inclusion of "mode-independent" complementary information can serve as a starting point to become aware of other mobility issues. All participants highlighted the prototype's event calendar in this context. Most of our participants pointed out how they just opened the application to look up interesting events and simultaneously were made aware of alternative transport options.

> *[When browsing events in the event calendar] "And the app provides me with alternatives to get there and I can think about using the bus or the car" (Female8, 65, CAR).*

The extent to which the calendar was used and reported as a central part of the application was unexpected, but highlights how browsing for opportunities might lead to experimenting with unfamiliar transport opportunities. Therefore, while it was necessary to integrate various transportation information in great detail, additional information for certain activities can indicate the suitability (or even advantages) of alternatives for a certain activity. For example, one user thought about using PT to visit her sister in the hospital after becoming more familiar with our app, because of limited parking. In this case, for example, the suitability of PT could be highlighted by providing schedules alongside the visiting hours of the hospital.

5.5.3 Integrating Transportation and Daily Activities

As shown above, the participants in our study regularly described situations in which they (routinely) made use of options because it was suitable for their intended activity. In this regard, participants described situations where the shortcomings of our prototype highlighted how they explored their opportunities and pinpointed the importance of detailed information in order to assess the suitability of the ride.

> *[Talking about the details provided regarding a connection. She requested more information, but the application did not provide further information about the route at this point] "I wanted to see the whole route of the connection. See which way it goes, because that would be interesting. For example, if I get on bus 333…it is also heading to the city center…yet it takes a detour through another part of the city. If I take this one… tough luck! So it is interesting to know which route it takes" (Female7, 78, CAR/PT).*

This quote makes it particularly clear that the necessary information is not limited to a level of detail that enables the interviewee to get to the desired destination, but rather extends to information that enables her to maintain flexibility and expand her opportunities within her daily activities. In this regard, PT users reported employing different applications for different contexts, e.g. they used the official application of the German Railway Service for longer travels, but our app for traveling within the city. Although both applications provide the same PT information, they integrate different additional services (e.g. ticket reservation in the official app and POI services and local events in our app). The example of the event calendar showed that the information our participants made use of was not limited to "logistical" information bound to a particular mode. We expected POI information to have a similar incentivizing effect, yet the users cared much less about POI than about events. When we asked for reasons, it turned out that most of the categories within the POI databases consist of venues that the user already knew. As a result, browsing the POIs was not as good of an incentive to use the application as the events were. Nevertheless, POIs turned out to be of value to the participants, yet in a situated way, with a very specific focus on the utility of places.

> *"So, I really would like to see information on toilets being integrated into the application. Information like this should be available. That's quite useful for elderly people like us. Especially some years ago, that issue was quite challenging in the city" (Female10, 63, CAR).*

Here we see emphasized the situated value of the transportation information and how it renders an infrastructure or destination suitable (the ones close to public or accessible restrooms). Clearly, the availability of contextual information when determining whether to take into account a certain mode when engaging in a certain activity is crucial. In another example, a participant outlined which modes she considers and how this is influenced by the availability of information.

> *Female7: "For example, when my sister is visiting me. We typically go to Italian restaurants. And then I look where the closest Italian place is."*
>
> *Interviewer: "Are you looking for the closest?"*
>
> *Female7: "If we walk, I will look for the closest. But she also has a car, so I can look for places we can drive to." […Talking about how to choose the best venue…] "I would choose the venue close by. Or… I mean..., if it is easy to reach, why not get on the bus and walk a few meters. This thing [the app] is quite helpful" (Female7, 78, CAR/PT).*

The quote describes the situation of a family visit, when POI information may be useful. In this case, the participant and her sister have no particular preference for an Italian restaurant, and therefore several destinations are interchangeable. Compared to the example provided by Female10, which shows how information on specific POIs (such as toilets) can render certain routes (and therefore modes on those routes) inadequate, the example of Female7 shows how information about the reachability of POIs influences which destinations and modes people consider in the first place when deciding on trips. As we see, the POI information (including its reachability) serves as a situated utilitarian means to an end, allowing participants to explore their options in terms of destinations and transportation.

This focus on the situational use of the system becomes even more critical with regard to RS. The RS feature of the application was used rarely, resulting in no matching of offers and requests even after the system was made available publicly. We asked why this feature within our app was not used. In many cases, people complained about the necessity to plan and enter trips in advance in order to publish the request or the offer. This caused issues of critical mass that rendered the RS feature not very useful.

> *"I seldom use the app. I sometimes open it out of curiosity, but I've never needed it. I like how it is designed and that I can see the PT connections. But you will start using the ridesharing as soon as you can be sure that someone answers. It's a dead end right now" (Female9, 60, CAR).*

In cases where we were able to observe RS (e.g. when people shared a ride to visit our weekly meetings), people preferred to use a messenger, as this allowed them to offer a ride more spontaneously. Employing an informal messenger as the tool of choice for RS highlights how participants sought to maintain flexibility while extending their RS network (which was previously mostly limited to family members and close friends). We expected people to adopt RS because of the increased awareness caused by its being presented alongside other transport modes. Our concept for RS, however, was not suitable for the participants' everyday transportation demands. It mostly followed existing concepts of established long-distance RS platforms. For this reason, it was inappropriate for daily short-distance travel, requiring people to plan ahead, which caused conflicts with regard to independence and decisional autonomy (Meurer, Stein, Randall, et al., 2014).

5.6 Discussion

Based on the literature and context studies we expected our participants to appreciate the integration of different transport information types into one system. We anticipated that expanded awareness about travel options would increase flexibility. As the literature has shown (Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011; Redman et al., 2013), the flexibility provided by a transport option is crucial to its adoption in daily life. We found that constant access to detailed information can reduce uncertainty, thereby fostering independence and increasing autonomy (Meurer, Stein, Randall, et al., 2014). It allowed the participants to assess the suitability of transport options for certain activities and personal preferences (e.g. finding the shortest connections and not being "trapped" on a bus taking many detours). The rejection of our RS feature highlighted the importance of this fact. The users saw greater potential in messengers for supporting their current RS practices (e.g. using group chats to offer rides). In this regard Wash et al. (Wash et al., 2005) have argued in favor of informal RS communication. These tools allow users to easily negotiate details and spontaneously offer rides and can therefore be integrated more easily into daily routines (Redman et al., 2013). Thus, they place fewer restrictions on one's decisional autonomy (Meurer, Stein, Randall, et al., 2014) and allow them to leverage existing social structures (Brereton et al., 2009).

Nevertheless, our study makes it particularly clear that fostering the adoption of new transport modes, not only the incorporation of transportation information but also the addition of complementary situated and contextual information, proves to be beneficial. For example, the event calendar provided updated information about upcoming events. The event calendar information provided reasons to look for transportation options and served as a "hook" to present alternative modes of transportation. The recognition of alternative modes of mobility can be seen as a first step towards challenging routinized behavior (Aarts & Dijksterhuis, 2000; Aarts et al., 1997; Banister, 1978; Goodwin, 1977; Verplanken et al., 1998). The POI information, on the other hand, became relevant within a given situation in which specific needs arose (e.g. finding the closest toilet or a restaurant). This is in line with arguments made by Redman et al. (2013), stating that the ease of integrating an option into one's daily activities is of utmost importance for switching to it and sustaining its adoption. It is also in line with existing findings concerning specific modes such as PT (Foell et al., 2013; Redman et al., 2013) or RS (Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011; Wash et al., 2005).

The findings from the appropriation study help more clearly explain the aspects identified in the context study and in the existing literature and prioritize them from a user's perspective. They indicate that it was not necessarily a question of being aware of all options (as shown in Fobker & Grotz, 2006; Mollenkopf et al., 1997; Redman et al., 2013), but rather of being aware of information that highlights the situated appropriateness of an option in a given context. Focusing on the situated appropriateness of options instead of simply creating awareness of all the options addresses a common problem of "mode-oriented" concepts that merely focus on infrastructural and logistical aspects. Modes are not simply interchangeable, but, as Hasselqvist et al. (2016) showed, transportation routines are established in relation to specific activities (e.g. daily errands, visiting friends, etc.). Therefore, concepts aiming at the adoption of various modes must support establishing new routines for certain activities instead of simply providing alternative logistical information. While existing concepts focusing on single modes take into account personal needs (e.g., in PT, Foell et al., 2013; Hoar, 2008) or provide more situated approaches (e.g., in RS, Rigby et al., 2013), they remain "mode-bound," including all the concomitant limitations. Our study showed that making use of transportation options is highly situated and is affected by all these limitations in the context of the intended activity. From a user's point of view, providing relevant information to emphasize the suitability of different options in a situated way facilitates development of robust strategies and routines (Aarts & Dijksterhuis, 2000; Aarts et al., 1997; Banister, 1978; Goodwin, 1977; Verplanken et al., 1998), including opportunities to suggest deviations from established routines.

5.7 Extended Design Implications

Table 3: Summary of Design Implications

#	Empirical / Literature finding	Design Challenge	Design Implication
Activity-based focus			
A1	Elderly choose/describe destinations based on intended activities instead of locations.	The design needs to provide search mechanisms that incorporate activities as input, e.g. going to a restaurant or doing daily errands.	Systems need to be able to detect the intended activity or at least provide input mechanisms for activities. For example, systems should incorporate existing point-of-interest databases.
A2	Elderly expend high effort in scheduling their daily trips according to their activities in advance, especially when combining activities.	The design should assist activity-based planning by understanding and utilizing the information, e.g. location and dates that go along with activities.	Systems need to take into account the details of the activity, e.g. start and end times and relevant places, or even filter results based on constraints. Such information can be extracted, e.g. from calendars or social network sites.
A3	Elderly deal with certain activities that can be carried out at different locations and at different times.	The design should incorporate alternative transportation opportunities. The design needs to take into account the task at hand may not be bound to a specific destination or time. Alternative trips may fit the needs of the user. Each of these alternatives may have different destinations and times.	Systems need to provide serendipitous opportunities while people are on the go, e.g. they should highlight chances to visit places/get things done when people pass certain places. This might even be supported through automatic (re-)scheduling of trips.

Coordination and context of information retrieval			
C4	Elderly struggle with unanticipated events that force them to deviate from existing plans	The design needs to allow spontaneous rescheduling of activities due to a change of agenda without disrupting existing plans and necessitating planning from scratch.	Systems need to work while the user is on the go and thus should also be provided as mobile solutions. By doing so, systems can provide features based on the current situation, such as trip information to relevant destinations based on the user's current situation. For example, systems might provide a "get me home" button or suggest destinations based on the transportation patterns of the user.
C5	Elderly have varying knowledge and skills that are developed based on their experiences and are utilized to plan trips.	The design needs to allow different methods of input that are adaptable to the ways information is presented, filtered and accessed.	Systems need to provide different input modalities to access information. Further relevant information needs to fit the person's situation and his/her intended goal. For example, they should make use of landmarks (e.g. by providing map interfaces), allow speech input for complicated terms or queries, etc. (especially to support orientation or provide additional information in unfamiliar situations).
C6	Elderly already engage in ridesharing arrangements, but they hesitate to use technological support.	The design needs to compensate by decreasing the efforts (e.g. arranging meetings) and restrictions (e.g. fixed appointments) that result from engaging in cooperative modes of transportation. Systems need to have certain activities suggest undertaking the necessary ride cooperatively when the framing activity is social (e.g. a club meeting) or of shared interest (e.g. going to work) (see also Finding A3).	Systems need to provide ways to engage in cooperative transportation that do not limit people's flexibility. In cooperative modes binding the trip to a particular activity reduces the coordination effort of all parties. For example, sensor and historical information can be used to ease coordination based on the current context.

Social and personal motivations			
S7	Elderly seek to preserve/extend their autonomy and independence in their mobility (Meurer, Stein, Randall, et al., 2014).	The design should not imply that one person is asking for a ride in terms of receiving a favor, but rather incentivize offerings, highlight win-win situations (shared costs, more entertaining rides, etc.) and show possible alternatives to highlight opportunities.	Systems should provide multi- and/or intermodal transport options enabling people to make more flexible decisions, to reduce the dependence on others, and to create awareness about joint travel opportunities at the time people are looking for travel opportunities.
S8	Elderly engage in certain trips because of social connections or out of curiosity to (passively or actively) get in contact with others (empirical).	The design needs to take into account the social outreach of certain trips and take sociability into account as a criterion for deciding on transport opportunities.	Systems should provide information about the trips of people within one’s social network or generally interesting travel opportunities (such as public events etc.). Typically, social network systems or calendar applications can be used to collect this information.

Based on the results of the context and literature study, several design implications arose that we verified by testing our prototype “in the wild.” This appropriation study partly confirmed, corrected and added certain design implications. We want to discuss each of these implications to outline their relevance for the design in light of further research and developments. We clustered these implications into the topics “activity-based focus,” “coordination and context of information retrieval,” and “social and personal motivations,” each of which provides a different angle on the results of the DCS.

5.7.1 Activity-based Focus

A1, A2 and A3 highlight the issue of translating the transportation requirements that arise from the intention to carry out certain activities into spatial and temporal information that is understood by existing systems. While the calendar-based input in our prototype was a first step towards a more activity-oriented input mechanism, as it took into account the date and time of the event, for example, it only covered “exceptional” events, which rendered it less useful for everyday mobility. Further the POI-based search could be used to find alternative destinations, and the evaluation highlighted that this information should be integrated with information regarding accessibility. In addition, the activity focus, in contrast to a decoupled route orientation, highlighted that temporal and spatial criteria cannot always be presumed in advance, which necessitates features that support rescheduling or put more focus on in-situ arrangement of transportation.

5.7.2 Coordination and Context of Information Retrieval

In addition to the problems with advance planning of certain activities, coordination is made more complicated by unanticipated events that force people to reschedule. While systems can provide simple support for standard tasks, such as finding directions home, they should reflect the context and the user’s personal experiences or knowledge. For example, systems might highlight or indicate familiar or well-known locations when people are trying to orient themselves, or assess the suitability of transportation options (e.g. by indicating that a bus stop is near a friend’s place to give a rough understanding of where a route is going). Further, with regard to certain transportation opportunities (e.g. a shared ride), systems should provide fallback options, e.g. by integrating this information with other modes or by highlighting these as serendipitous options.

5.7.3 Social and Personal Motivations

Systems must consider the various motivations people have when choosing certain transportation options. One key aspect is preserving flexibility throughout the day to deal with unexpected issues. This includes flexibility in the sense of the autonomy to decide on which trips to take, and also in terms of doing this independently, which is often difficult when involving other people or resources they do not control (such as public infrastructure or other people's property). On the other hand, certain trips are taken as, or in the context of, social activities. Systems should be sensitive to these different situations and provide means to support them, such as detection of group events.

To address and extend these issues, the other two studies were conducted with consideration for these implications, and looked more closely at the issues raised by DCS 1.

6 Design Case Study 2 – Proximity-Based Ridesharing

6.1 Motivation for the Case Study

The previous design case study has shown that ICT-enabled carpooling and ridesharing services, in particular, conflict with the desire to be independent and maintain autonomy in later life (Meurer, Stein, Randall, et al., 2014). Although older adults tend to engage in "informal ridesharing" arrangements (about 50% of rides are shared with at least one person (Schwanen et al., 2012)), they seem reluctant to use existing ICT-based solutions, as these services are often criticized for being inflexible and complicated to use. In this DCS we use the term "informal ridesharing" to indicate the existing ridesharing practices of our study participants. Those practices are not supported by any specific technology or organizational structures, such as existing ridesharing systems or carpool infrastructures. Rather, "informal ridesharing" refers to situations in which participants intentionally and/or often serendipitously shared rides as a result of informal arrangements.

In this DCS, we aim to address the question of why our participants hesitate to adopt ridesharing tools in order to address their needs. We present a study that reflects on the mobility needs of a group of elderly users with regard to ridesharing. Based on interviews and two co-design workshops, we explore technological opportunities for ridesharing that fit the mobility needs of elderly users and overcome the prevalent appropriation barriers.

Particularly, in this DCS we found awareness, defined as being informed about the travel intentions of others, and addressability, in the form of providing a ticket-to-talk for approaching a potential ride sharer, to be crucial aspects of more suitable solutions. More precisely, our empirical results highlight physical proximity or co-presence as a promising means to reduce coordination efforts. Subsequently, we provide implications for the design of mobile tools that enable elderly users to participate in sharing in the context of transportation.

6.2 Context Study

This section presents the findings of the interview study and the two workshops separately. We show how we used the results to inform the design of our ridesharing support prototype. We start by presenting the informal practices of ridesharing, followed by the scenarios derived on the basis of these practices, and conclude by presenting concrete design and functional aspects for such applications (names have been altered to preserve anonymity, but we indicate whether the quote is taken from the interview session as "IS" or the Flinc session as "FS").

Our interviews and discussions during the sessions, especially concerning the flinc ridesharing application, revealed that the informal ridesharing activities in which the participants engaged usually take place in specific situations. In particular, we found that most of the arrangements were either *regular joint activities* or based on *opportunities (serendipities)* that arose unexpectedly. In these cases, ridesharing was understood as a supplementary mode of transportation as part of daily mobility. This became particularly clear when participants provided feedback on the Flinc ridesharing tool.

> *For example, it's Friday and I'm looking for a way to get to the soccer game that weekend in [a city about 100 km away]. PERHAPS [emphasizing that it's unlikely] someone is going to the game as well. It's different if I plan a trip several months in advance, then this is a long period, during which I would expect there will be someone who also wants to go there eventually. If I plan a trip for tomorrow it's more critical. I might look if someone is already offering a ride [instead of making a request for a ride] … if so, lucky me. It would save me the trouble of buying a train ticket (Male2, 64, FS).*

> *Coming back to the hospital story. You can stay in contact with the person you gave a lift to and also go back together even though you might do different things at a destination, e.g. using SMS or Whatsapp. Arranging the ride back might work out just fine, but as a passenger you might just look for alternatives, such as trains, if it doesn't work out. You just try to see if schedules match. But the passenger should align (Female10, 63, FS).*

Ridesharing was accepted either in the context of an explicit, often regularly shared activity that would require only initial coordination, or because it provided serendipitous advantages of some sort in the specific situation (e.g. a lift offered by a neighbor). In both situations (regular and serendipitous), physical co-location turned out to be an important enabling factor: people are either coincidentally at the same location at some point (serendipitous arrangements) or they identify a mutual interest in the current location, as they visit it regularly in order to engage in a certain activity.

The following section describes these cases and gives examples of how direct physical proximity turned out to be an important enabling factor.

6.2.1 Regular Joint Activities

Supporting the existing literature, our interviewees expressed a great affinity towards informal ridesharing for regular joint activities due to the low coordination costs, as the following quotes demonstrate:

> *"It [current informal ridesharing practice] is much simpler [than flinc]. For example, you work at the university and you go to lunch with your colleagues. They know where you live and thus just ask if you want to share rides when appropriate. It simply evolves that way. It is the same with the choir, for example. We also do carpooling. Same for going to the gym" (Female13, 75, FS).*

> *"I have this friend who always picks me up for theater. […] We both have a season ticket and she has to drive past my house to get there anyway, so she picks me up and takes me back home again afterwards" (Female4, 73, IS).*

We found that the most common ridesharing arrangements occurred in such a planned, regular way, e.g. going to the same gym or attending an internet course. Furthermore, the interviewees named several advantages for ridesharing in regular settings. In particular, they described benefits in the coordination effort, as Female2 elaborates in the following quote:

> *"Well yes, they're fixed… well, there's a group of us who do things together… sometimes we go to the cinema … and yes, then you just ask do you want to go this evening or maybe tomorrow and then one person says, yes, hey, I'll drive or [someone else says] I'll drive…That's what it's like" (Female2, 64, IS).*

> *"Everything is much faster when you know each other. You just say, I'll drive and it is not as anonymous as Flinc. And then you can just say that you won't be able to drive next week" (Female13, 75, FS).*

This quote illustrates that the fixed rules and arrangements are an advantage of such settings. Routines to reach the shared destination can be established around these existing structures. For example, going to the theater implies that people agree on which shows to visit, which provides a certain context as given and shared. Thus the date, pick-up times, who is the driver, how often to go, etc. do not have to be negotiated anew each time. If the arrangements are set, they can be easily re-used or modified in later ridesharing situations. Even in cases of unforeseen circumstances (e.g. sickness), users reported that the coordination could be easily adjusted. In some cases, the negotiation extends beyond the travel arrangement to include settling on shared activities/events as the group planning to attend the event had already been formed (e.g. because of previous events).

However, although such regular meetings were likely to entail ridesharing, we observed that users avoided existing ridesharing services in these regular informal ridesharing situations, and instead used alternative, more informal types of communication. WhatsApp was frequently used, as the following quote shows:

> *"I don't like to fill out the input fields in ridesharing tools. It is too much preparation work from my point of view, and I often forget it. To go to our common training sessions, I prefer WhatsApp, for example. It really seems to be less work and effort to me to offer a ride or ask for one. It is also more direct. I do not feel the pressure to make the appointment long before the trip" (Male4, 71, IS).*

> *"For our group, flinc seems inappropriate. The Whatsapp group is better. It's the easiest thing in the world to write "who can give me a lift" there. Using Flinc in these cases – dear me – who wants to join, who does not!" (Male6, 77, FS).*

Although Male6 was not critical towards ridesharing in principle, Male4 described the static concept of offering and requesting in flinc as being inflexible and time-consuming in use and instead highlighted easy group communication as an important resource to initiate ridesharing in an informal way. In the informal, regular settings, the general details of a trip were clear for all members; therefore, there was no need to make them explicit for each trip (low coordination efforts), as would have been required by most ridesharing services. Even in the case of flinc, which already provides different technical tools to ease coordination, our participants complained about the necessary effort in other "non-regular" situations.

> *"If I want to join a ride, I always have to get to the pickup location. No one passes my place by accident. […] And if I want to go somewhere spontaneously… before this whole mechanism is set up and ready to go, the appointment is long, the reason you wanted to go in the first place might already be past. Perhaps with pre-planned appointments such as a doctor's visit. But actually, in this case, I might just take the bus or a taxi. Entering everything into Flinc does not seem practical: Entering it, waiting for responses, getting in contact. It just doesn't seem appropriate" (Male5, 69, FS).*

The quote above shows that even for cases in which the travel could be planned in advance (e.g. a doctor's appointment), using existing ridesharing tools is too cumbersome compared to other modes or even too restrictive (cf. Meurer et al. (2014)).

> *"Being dependent annoys me. I've often thought about entering information for regular rides, e.g. when I pick up my grandchildren from school. I would be open to sharing the ride. But I'm a spontaneous person, so I always end up saying no – you might do something else prior to the ride. I usually come up with these things right before the trip and in these cases, I would feel obligated to the potential passenger. You lose your flexibility" (Female12, 63, FS).*

Clearly, regular joint activities are a prominent reason for the interviewees to engage in ridesharing arrangements. They highlight that these arrangements often had a specific destination, were of a recurring nature, and the people involved already knew each other. In terms of coordination, these arrangements were very similar to ridesharing in commuting settings, as highlighted by, e.g. Dailey et al. (1999).

6.2.2 Serendipitous Arrangements

In the previous section, the arrangements described were based on regular encounters and shared interests. Aside from these cases, we also identified a second type of situation in which ridesharing was likely to occur. Participants mentioned situations that were unique, spontaneous, and serendipitous. The challenges in serendipitous settings were different from those in regular joint arrangements. While the coordination effort was low due to the regularity of these arrangements, serendipitous ridesharing arrangements were not planned in advance but arose as a spontaneous reaction when one person became aware of another's intended (potentially shared) destination. In most cases, these situations involved just two people. The following quotes illustrate such behavior:

> *"Here in [name of city] I sometimes see people at the crossing nearby, holding a sign in their hands reading 'church' for example. Then everybody knows, ok, this person wants to go that place and I can give them a lift" (Male1, 81, IS).*

> *"In the city center or the theater, it happens quite often to me that I think, boy, it would be great to know who else has the same way home. Just, you know, to share the rides and get in contact with some new people" (Female9, 60, IS).*

Both examples illustrate the general interest in ridesharing opportunities and the challenges of making intentions visible for both drivers and passengers. Compared to the arrangements involved in regular group activities, the spontaneous arrangement of ridesharing opportunities is dependent on sharing information about destinations in situ*,* making people aware of immediate opportunities close by. In this regard, the quotes illustrate that, although there was an interest in exchanging information with people close by about shared destinations, a subtle barrier prevented participants from engaging in ridesharing with others without being aware of shared intentions. In other words, there was an issue of *addressability* of strangers in such serendipitous situations. While in the first quote addressability was established through the sign, in the second Female9 hesitated to approach strangers because she was unaware of their intentions. Another participant, Male6, also mentioned the social barrier of getting in contact with people:

> *"Yeah, there are these two ladies, and it's not an issue, you have to be accessible to them. By being accessible to people I mean being open, you have to be able to ask the question. If you just think someone will not give you a lift, you might even not ask in the first place" (Male6, 77, IS).*

The most prominent challenges in these situations were identifying and approaching possible ridesharers. As described by the interviewee, the challenge in such cases was to identify ridesharing opportunities as they arose. In this regard, we also asked about the usefulness of existing ridesharing platforms but participants preferred a very spontaneous uncomplicated way of organizing ridesharing.

> *[Researcher explaining ridesharing platforms, where people enter their ride offerings and requests in advance] "Yes, but they could just call me to do that" (Male3, 66, IS).*

This example highlights that people preferred to react spontaneously to needs and offer their services accordingly. It also emphasizes the focus on sharing rides with people who know each other (as they should "just call" him, which presupposes that they have his phone number), although we also found a general willingness to engage in ridesharing with unfamiliar people who happened to take part in the same activity or something close by, as outlined above.

The following section describes our approach to exploring both types of situations – regular and serendipitous – in more detail in the context of the co-design workshops. In doing so, we explore which specifics it takes people to engage in within these situations and what an appropriate ICT-based support mechanism would have to cover.

6.3 Results from the First Design Workshop—Scenarios for Ridesharing Support

In the case of regular ridesharing arrangements, some degree of commitment to the group was shown. Since regular arrangements require a long-term commitment, participants in these arrangements showed awareness about the social setting and tried to establish fair conditions for everyone. For the case of serendipitous arrangements, these factors play a less important role, as each arrangement was a unique, one-time event. There was no coordination necessary regarding what to do, where to go to, exactly when to set out, or who is going to drive, as these aspects were usually predetermined by the situation in which the spontaneous ridesharing opportunity arose. For our participants, the benefit of getting from their current location to the intended destination was sufficient for them to be interested in engaging in the serendipitous arrangement. In both cases, being at the same location was a critical factor in establishing useful ridesharing arrangements. In the case of regular arrangements, being at the same location enabled people to identify the shared interests (e.g. as they regularly meet at the theater). For serendipitous occasions, the shared location was the point of departure for ridesharing opportunities.

6.3.1 Scenarios for Ridesharing Support

To frame the discussion in the workshops, we introduced four sample scenarios, which were variations of situations that participants had mentioned in the interviews. For example, we based the first regular scenario on anecdotes presented by various participants about regular computer club visits, which made them board the same bus repeatedly. The second scenario reflects where our participants typically engage in group activities. For example, they formed groups to go the theater or they just established a group with people from the neighborhood who regularly engage in activities such as going to the movies. The serendipitous cases stem from situations, as reported by the participants, in which they got lost at a train station due to a delay and missed their connection. In this case, people were looking for help and spontaneously contacted other passengers who also missed the connection. The second serendipitous example describes a common practice between neighbors, who pick each other up when they see their neighbor walking along the street heading home.

However, these situations served as a starting point for the discussion and participants were free to reflect upon their own experiences. The situations introduced can be assigned to the two categories of regular and serendipitous arrangements:

On a regular basis:

1. Being on the bus/at the bus stop – People become aware of others they have already met when they frequently ride the bus and thus may have shared destinations (e.g. going to university).

2. Being at a group event/regular appointment – People may engage in cooperative trip planning activities or agree on ridesharing arrangements for future meetings.

On a serendipitous basis:

1. Being at the bus stop – People may ask other people at the bus stop if they would like to buy a joint ticket, or may ask for help to board the bus. People may also share a taxi instead of using public transportation.
2. Being at the supermarket – People may unknowingly pass by others who have the same end destination, e.g. going in the same direction after finishing their errands.

Based on these empirically derived scenarios, participants came up with several tasks that they had already engaged in or at least observed in one of these situations. The tasks were discussed in order to discuss the ones that might be supported with ICT, such as the joint use of public transport tickets (e.g. buying group tickets), asking other people for help (e.g. assistance to board the bus), sharing trip plans (assisting in new and unfamiliar situations such as finding the schedule for a bus that someone is riding for the first time), or planning joint activities (e.g. browsing upcoming events). The tasks identified also included offering/asking for rides (sharing a ride to the supermarket) and establishing ridesharing arrangements with people at the same location/activity (e.g. being at the same board game club meeting). We also asked the participants to rate the importance of these tasks from their own point of view. Creating regular arrangements of sharing/offering rides proved to be the most desirable features, as was often highlighted in the discussion on informal ridesharing practices. Creating regular arrangements necessitates features that allow for the planning and coordination of joint activities, while sharing single rides generally necessitates awareness of relevant trips.

Based on this selection, we implemented a prototype that provides the user with the means to create ridesharing arrangements and offer/search for rides. The prototype mainly takes into account the above-mentioned prerequisites, i.e. making the arrangement of ridesharing opportunities easier in both regular and spontaneous situations. The implementation of a prototype to embody these requirements is described below.

6.4 Functionality and Design

For the initial, conceptual testing we tried to keep the prototype simple. The interface provides access to the main functions of the prototype (see Figure 13-Figure 17):

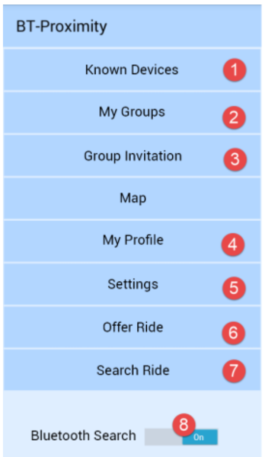

Figure 13: Main Menu

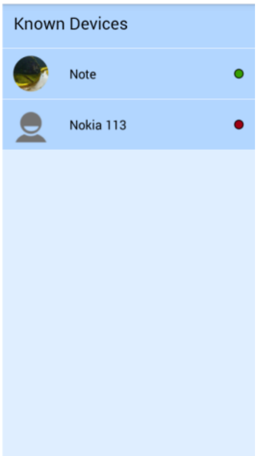

Figure 14: Known Devices

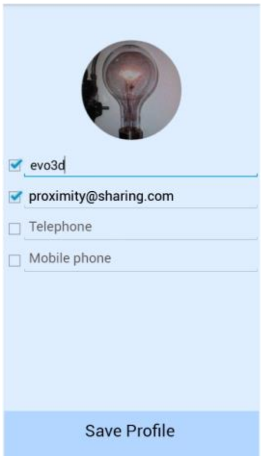

Figure 15: Edit Profile

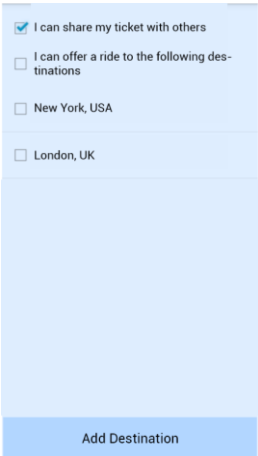

Figure 16: Offer Ride

Figure 17: Map Picker

- Known Devices: User can access the list of devices already encountered (offline) or those which are currently in proximity (online). Identifying a device as currently available (in proximity) red and green indicators are shown after the names. In this list the profile picture and the username appear as soon as the devices exchange profile information.

- My Groups: User can join/create groups to plan and coordinate joint activities such as ridesharing arrangements. A group chat is provided to ease the communication necessary for coordination. Groups can be created when users are in proximity to each other. However, the communication within the groups is based on a classic server-client-architecture in order to support coordination tasks even when users are at different locations.

- Group Invitation: User can accept or decline invitations to groups. Open invitations are displayed in this section.

- My Profile: Users can provide profile information (see), which will then be used in the prototype and, if checked, can also be exchanged with other users of the application when they are near each other. The information provided here is accessible to others via the ‘Known devices’ screen. The information is transferred via Bluetooth connection, thus exchanging profiles does not depend on internet connectivity.

- Settings: The settings allow users to choose whether or not they wish to stay logged on to the platform (backend for group communication services), to set the radius for matching destinations of rides and to set the interval at which the profiles of nearby are checked and refreshed.

- Offer Rides: Users are given the opportunity to offer rides to other users. They can provide the application with locations they visit or pass regularly. If they check a location in the interface (see Figure 5) these locations are used to search for matching search requests placed by other users. These destinations are compared as soon as the user searching for a ride comes close. Further, the user has the opportunity to flag himself as a ticket provider. Thus the application also provides matches based on whether someone is willing to share a joint ticket. This feature was implemented only as an initial test. Thus sharing/searching for tickets currently neglects the destinations provided by a user. Locations can be provided via map interface as shown in Figure 6. Further locations can also be removed using this interface.

- Search rides: The ride search function was designed to be analogous to the offering of rides. Thus users provide locations and activate them by checking in the same way as offering them. It is important to note that the matching of rides is always initiated by the device of the user who is searching for a ride. As soon as a user is searching for (or offering) a ride, a Bluetooth service ID is registered on the user's device. This allows users who are offering or searching for rides to be identified without actually transferring data beforehand. The devices only need to invoke a service discovery. If a searching user discovers an offering user, the searcher's device will start transferring its currently activated search destinations. The offeror's device will check for matching destinations and send those to the searching device if destinations were matched. In this case the searching user will be notified that a ride match has been found and/or that someone is willing to share a joint ticket.
- Switch off service – As the search for available Bluetooth devices is processed in a background service, the user must be able to turn this service on or off as needed. The application provides a switch for doing so at the bottom of the top level menu.

6.5 Evaluation

In the second workshop, we used the prototype described above to implement and evaluate the concepts we derived from elderly people's ridesharing habits and preferences, which indicate the suitability of opportunistic ridesharing concepts for everyday mobility. Using the prototype as a starting point for discussion, we were able to outline opportunities for potential support in a very specific and tangible manner. Within the second workshop, users were first asked to freely explore the prototype and then to perform specified tasks. These tasks included 1) entering profile information (picture and name, as depicted in Figure 3), 2) entering locations they frequently visit, including one destination that we asked them to enter in order to generate matches (see Figure 4), and 3) get in contact with matched users through the chat feature of our application.

After users performed these tasks, they were again free to explore the application and ask questions to clarify features. After that, we engaged in a group discussion about the advantages and disadvantages of the concept. The results of this discussion are presented below.

6.5.1 Supporting Serendipitous Arrangements

Generally, participants had a positive overall impression of serendipitous support opportunities. They immediately saw the benefits of the proximity-based approach and identified situations in which this support would be useful. One participant, for example, reflected on the usefulness of the prototype as follows:

> *"The question is, when will it be of interest to me? I know the people in this group [the group members all took part in the three-year research project and thus knew each other], I don't need a cell phone to ask: 'Do you want to come, too?' It gets interesting when I'm at the cinema or I've just come out of the theater and want to go home, or again 'Sunday afternoon I was at the soccer stadium and I watched them lose. After that, I wanted to go home'" (Male4, 71).*

Male4 clearly described situations in which he would use such a tool to find suitable rides spontaneously. In later parts of the discussion Male4 and others (e.g. the quote below from Female5) highlighted the importance of information such as profile pictures to have a clear reference to the "real," physical world: *"You need the picture because you don't want to ask people randomly" (Male4).* He highlighted that using a chat feature to contact people through the app first was too cumbersome. Users' interests in such very spontaneous arrangements of rides were also mentioned by Female4 and Female5:

> *"I can be in an Internet café, for instance, and afterwards I want to go home. It would be no problem at all for me to give someone a ride who wanted to go in the same direction, for example to [name of town; anonymized; another town that will be passed on the way to participant's home]" (Female4, 73).*

“It’s all about simplicity! 1 or 2 clicks. Everything needs to be easily accessible. It is not as if I was sitting comfortably in an armchair. I’m on the road or at the bus stop and potentially stressed out” (Female 5, 75).

The quotes highlight situations in which the awareness that can be provided by the prototype would facilitate serendipitous ridesharing arrangements, but in which appropriate ICT support must leverage the context of the given situation through easy and fast (potentially face-to-face) interactions. Interestingly, although most participants were car owners, they still appreciated how useful it would be to share a ticket for public transportation:

“Bluetooth is really interesting [in contrast to general online solutions]. There I am at the bus stop and there are 20 other people. Three of them have got one of those ‘Nice Day Tickets’ [group ticket for up to five persons with a fixed price, regardless of the actual number of travelers] that they’re not using to full capacity. They could just say ‘you could share my ticket.’ Or if I’ve got one of those tickets I’d take another two people with me” (Male4, 71).

By talking about a specific public transport ticket, which was actually available to buy, people were already envisioning concrete situations in which the prototype would be beneficial. They also envisioned other transportation-related use cases in which awareness of others close by could be helpful:

“I’m thinking about parking tickets. Sometimes, e.g. after visiting someone in the hospital, you paid parking fees in advance and you still have 1.5 hours left on you ticket. If someone close by is getting a ticket on his own you might just offer yours” (Male5, 69).

Another interesting point was the issue of addressability. Although people in principle could easily just talk to everyone at the station about their willingness to share the ticket, having a tool that would clearly identify people interested in sharing travel opportunities was deemed helpful to lower the social barriers and “invite” an approach, as described by Female5:

"I don't know if I would just write someone just because I can see an offer close by. It would be different if this person would actively say 'Yes here I am' […] Or if I could see the picture. Then I would address the person. I really need a clear reference such as a person's face to be sure whom to address. I don't ask haphazardly. I want to know who is getting in my car" (Female5, 75).

Summarizing the participants' feedback, awareness support for serendipitous arrangements could help to extend established tools for transportation (e.g. ridesharing applications or public transport information systems).

6.5.2 Supporting Regular Arrangements

As with support for serendipitous arrangements, support for regular arrangements was also deemed useful. However, as participants were aware of other tools supporting group chats, it was unclear to what extent our prototype would provide additional benefits:

"Basically, it's certainly not wrong for smaller groups. In this group, for example, or in my family circle it's quite interesting" (Male4, 71).

Furthermore, the coordination feature was considered to be similar to familiar applications:

"It's pretty much like our WhatsApp group, or that other thing [Telegram]. Everyone gets the same message" (Female10, 63).

Nevertheless, participants saw the potential of forming regular ridesharing arrangements based on regular encounters at specific destinations:

"If I go to that place all the time, e.g. to the gym. Other people at the gym might ask themselves 'Why do I drive on my own? I'd rather ride with him.' Or the other way around. You just start exchanging information. And if I would become aware about him going from X to Y always at the same time, he might just pick me up at Z because it's on his way" (Male5, 69).

Participants also requested online features, consisting of a search for regular ridesharing arrangements by browsing events or destinations (e.g. theater, cinema, gym, etc.).

The feedback on coordination support for regular arrangements made clear that existing tools already provide sufficient support. While using proximity as support for forming groups was deemed useful, it should be incorporated into existing tools instead (e.g. messengers or online social networks).

6.5.3 General Remarks on Proximity-Based Ridesharing

Compared to classic static approaches, there were two advantages of our proximity-based, opportunistic approach, which participants specifically discussed in addition to the feedback concerning the various situations. The first advantage relates to privacy concerns when sharing location information via ridesharing applications. One participant highlights how the use of Bluetooth implies a maximum (physical) radius in which the location is shared, thereby creating more willingness to share his location (which would be necessary to arrange ridesharing):

> *"[Talking about sharing his location online] Not necessarily, I am a bit more careful. With Bluetooth, that's just a handful of people who are standing nearby. They can see, can't they, that I'm waiting for the bus" (Male4, 71).*

Furthermore, participants stressed that making use of physical proximity increases their flexibility because there is no need to actually search or offer anything:

> *"When I use the other ridesharing app, I have to open the application to get the information. With this app (our rapid prototype) it happens without even having to search for anything directly" (Male4, 71).*

Thus, it becomes clear that proximity-based solutions can foster ridesharing arrangements. The effort to input trips and search for trips, as well as the necessity to commit to a trip up front, can be minimized.

6.6 Discussion

Our study investigated the ridesharing practices of the elderly participants with the aim of better understanding the paradoxical relationship between engaging in informal ridesharing and their reluctance to adopt ridesharing applications. Our study confirmed that, while informal ridesharing was a quite common part of their daily mobility, existing ridesharing applications imposed certain constraints on their mobility, resulting in the rejection of those applications in their daily routines. Most importantly, our study showed that ridesharing in everyday mobility, unlike the private car or public transportation, *is not a "default" mode of transportation, but rather complements those default modes in specific serendipitous situations or regarding specific regular activities*. Hence, prior coordination is seldom necessary, mostly due to the fact that the people are or have been co-located. Existing applications generally ended up failing to leverage those situations, requiring users to input ride demands and offers in advance.

Our findings thus indicate a need for alternative strategies to support ridesharing in everyday mobility, where the perceived benefits of ridesharing arrangements do not outweigh the coordination efforts of arranging the ride, as is the case with long-distance travels (e.g. due to shared costs). Based on the informal ridesharing practices of our participants, we suggest supporting the creation of awareness and addressability in situations where people are already co-located. The prototype we presented to the users further leverages the complementary nature of ridesharing and supports the creation of awareness and addressability, as discussed in more detail below.

6.6.1 Taking Advantage of Proximity to Support Ridesharing as a Complementary Mode in Daily Transportation

Previous attempts at organizing and optimizing ridesharing have dealt mostly with improving the underlying ICT, especially regarding logistical issues. We found that for successful support of ridesharing, it is promising to focus on creating awareness of shared places and/or destinations and making potential nearby ridesharing partners addressable. In this way, the people's flexibility is preserved, as they are already at the same location at the same time, which presents an opportunity to coordinate joint activities (Licoppe & Inada, 2008) without substantial effort in preparation or commitment (cf. Terveen & McDonald, 2005). This facilitates ridesharing arrangements and carpooling groups, since the otherwise problematic "online" coordination—which hinders the adoption of such tools—is left to the "physical world," as *"fill[ing] in the input fields in ridesharing tools [...] is too much preparation work,"* and people have already established practices to successfully coordinate such arrangements.

We also explored the specific benefits of proximity to enhance ridesharing among elderly people. In this respect, proximity serves two purposes: a) It can be used to create awareness about possible ridesharers, and b) it can be used to make oneself addressable by others nearby. Both aspects are strongly interwoven, but while the former deals mainly with providing information about someone's intention (e.g. his or her destination), the latter provides legitimation to approach someone. We consider both of these purposes in more detail below.

6.6.2 Being Aware of Other Ridesharers

We found that a lack of awareness seems to be one of the main barriers for successfully establishing ridesharing arrangements with unknown persons. As our participants mentioned: "*It would be great to know who else has the same way home,"* as it would make it possible to overcome the anonymity of the public space by allowing the sharing of mutual interests or destinations. This would enable users to engage with strangers in a similar fashion as with familiar persons, e.g. friends, neighbors or relatives.

In the literature, several authors have discussed the concept of co-presence, understood as two or more people being in proximity at a given time. For example, the concept is used for dating applications (Beale, 2005; Birnholtz, Fitzpatrick, Handel, & Brubaker, 2014; Blackwell, Birnholtz, & Abbott, 2014) and meeting applications (H. Müller, Fortmann, Timmermann, Heuten, & Boll, 2013) that provide new and improved opportunities for urban, social interaction (Paulos & Goodman, 2004; Sutko & Silva, 2011) (examples include Grindr, Tinder, or Lokin). Other approaches employ proximity-based affordances for enabling exploration (Hornecker, Swindells, & Dunlop, 2011) or gaming (Falk, Ljungstrand, Björk, & Hansson, 2001) (e.g. Ingress by Google, where local teams cooperatively solve tasks). Most of these approaches have in common that they try to create awareness about nearby opportunities, e.g. for dating, places of interest, or other players of a game. In the case of ridesharing, people in our study highlighted the same interest: awareness. They described existing mechanisms to create awareness (e.g. signs reading "church"), but also envisioned the usage of proximity-based applications to become aware of jointly usable public transport tickets, as well as potential carpooling partners for regular events. Hence, awareness is crucial to take advantage of opportunities as they arise. This, in turn, is one way to address the challenge of limited independence and decisional autonomy that goes along with pre-planned ridesharing (Meurer, Stein, Randall, et al., 2014; Stein et al., 2017).

6.6.3 Being Addressable by Other Ridesharers

Awareness is only one side of the coin. In addition to being aware of other people offering or looking for rides, it is also necessary to enable users to make themselves addressable to potential ridesharers. One participant sums this up as follows: "Y*ou have to be accessible to them. Accessible to people, being open, you have to be able to pose the question."* This openness is challenged by Milgram's concept of *familiar stranger*, which is used in the HCI context by Paulos and Goodman (2004). Familiar strangers are people that happen to be at the same place at the same time, e.g. on the same bus, but show no awareness of common interests or shared goals, and thus do not normally establish contact with each other (Bandura, 1982). They are characterized more, in Goffman's terms, by "civil inattention" (Goffman, 1972). This describes how people demonstrate awareness of each other in public spaces without overstepping personal boundaries by staring at the other person or imposing a conversation, for example. As such it enables privacy in public spaces, but can also cause feelings of loneliness and invisibility (Moretti, 1996), which underlines how this mechanism also contributes to lacks of awareness and addressability.

We found that proximity can be a key to address this challenge, as shared physical places act as social filters and attract certain people (Brown, 2014; Jones, Grandhi, Whittaker, Chivakula, & Terveen, 2004), imply certain roles (Messeter, Brandt, Halse, & Johansson, 2004), and encourage or discourage certain types of activities (Blackwell et al., 2014; Harrison & Dourish, 1996; Jones et al., 2004; Sutko & Silva, 2011). In this regard Messeter et al. (2004; 2008) emphasize that technologies are used differently in different social contexts. Making tools aware of these social contexts makes it possible in certain contexts to adapt to the interaction (or prevent it completely). Hence, proximity-based solutions can overcome the challenge of civil inattention between strangers that shapes behavior in public spaces. Instead of just acknowledging the presence of strangers or being acknowledged by strangers, they provide opportunities to engage with each other, which are terms “tickets to talk” in other contexts (Draxler, Stevens, Stein, Boden, & Randall, 2012; Svensson & Sokoler, 2008). In the second workshop, we found that having and using an app can serve as a means to make oneself addressable. The app implies a kind of membership and willingness to share rides (to the group of ridesharers) and thus signals a willingness to legitimize the initiation of contact.

However, to be addressable in the context of ridesharing one must also address issues such as trustworthiness. As described by several authors (Ghelawat et al., 2010; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011), trust is a critical challenge, as users hesitate to reveal their destination or location to all and sundry. Toch & Levi (2013) show that people using proximity-enabled applications use co-situatedness as a trust-building mechanism, allowing a bridge between the virtual and physical world (Toch & Levi, 2012). Our findings support these assumptions, as we found that the elderly participants had a more positive attitude towards the concept of proximity-based information sharing than to general sharing of information online; as one respondent put it, “*that’s just a handful of people who are standing nearby.*”

Thus, understanding the informal practices of older adults’ ridesharing practices reveals why they approach certain people for ridesharing and what the common barriers are. It allows designers to provide tools to make people addressable more broadly and more aware of opportunities.

6.7 Implications for Design

This section provides concrete design implications derived from our study and the discussion. The implications for design that we suggest are meant as examples, but we are confident that their empirical grounding makes it possible to draw more general conclusions for a variety of other use cases and user groups.

In general, creating awareness and legitimating the addressing of relevant people must be supported throughout the design of ridesharing services for the elderly. To do so, proximity-based solutions seem promising, but they need to fit both the virtual and physical world; in other words, they need to provide the information necessary to identify, find, and contact people physically. Furthermore, concrete addressability mechanisms, for example in the sense of "tickets to talk," must be provided to the involved parties. Our study provides clues to the design space of such awareness and addressability mechanisms, as described in more detail below.

6.7.1 Minimize Planning and Pre-Ride Coordination

Users should only have to set up the tool once by providing profile information and locations to which they offer rides or destinations they would like a ride to. The relevant destinations may even be gathered automatically by tracking the users' frequently visited locations (as also suggested by Kamar & Horvitz (2009) and Liu et al. (2013). However, the user needs to be able to control the sharing of rides if desired. The rationale behind this implementation is to eliminate any a priori efforts to plan rides. Users (with the tool running in the background) should continue, e.g. doing their daily errands, as usual. Coordination work should only be required if the user actively triggers actions or when the opportunity to share a ride arises because another user is close. This ensures the flexibility, which is crucial to establish independence and autonomy in later life, as users do not need to plan a trip beforehand or commit themselves to a specific time, and date in advance. Rather, they are free to decide whether to share or accept rides when the opportunity arises.

6.7.2 Integration with Other Transportation Services

Due to the coincidental nature of the proposed concept, proximity-based ridesharing can be used as a supplementary feature in existing applications such as navigation solutions and public transportation information systems. Having ridesharing as a complementary mode of transportation supports intermodal approaches, as suggested by Meurer et al. (2014) and Stein et al. (2017), but also addresses the issue of critical mass (Raney, 2010), as it allows slowly building a group of users around existing transport modes and infrastructures. For instance, our concept would build upon existing meeting points such as bus stops or frequently visited locations, as also highlighted by Hansen et al. (2010) and Xing et al. (2009). Thus, the proximity-based approach for creating ridesharing arrangements as an adjunct to existing tools seems promising.

6.7.3 Opportunities for the Integration of Established Routines

Systems to support informal ridesharing by elderly people should not enforce things like confirmations, structured information about rides, or a priori commitments unless absolutely necessary. Our study showed that even simple communication support is sufficient to enable informal coordination (as suggested, for example by Wash et al. (Wash et al., 2005)). However, compared to current approaches, our tool was seen to be more flexible and less cumbersome, since no planning was required in advance, and shared rides were arranged spontaneously and in-situ. Even so, the benefits provided by the proximity-based concept were clearly established in principle. In relation to the process of establishing groups who might wish to undertake regular activities together, proximity seemed to work well to identify potential group members when compared to existing (group) messenger systems. Nevertheless, people already make use of existing structures to coordinate with each other, e.g. social networks (Brereton et al., 2009) and informal means, as outlined in our study. In the sample design mockups, we would require users to input favorite locations only once to perform the matching. Thus, the user would not have to alter his/her behavior, e.g. enter requests or offers in advance.

7 Design Case Study 3 – Transiit&Me

7.1 Motivation for the Case Study

Ridesharing has the potential to provide benefits addressing several prevalent issues, such as reducing road congestion, working around sparse public transportation infrastructures, and optimizing of the use of resources. While these opportunities have been recognized by politics (e.g. by the introduction of “high-occupancy vehicle” lanes) and industry, a lack of critical masses prevents practical, broad uptake (Raney, 2010) outside of metropolitan areas. Since most of the past, present, and probably future concepts of ridesharing rely heavily on ICT when matching and coordinating drivers and passengers, research in HCI and CSCW can contribute to finding solutions addressing the issue of critical mass and/or finding promising alternatives approaches that foster ridesharing.

In this DCS chapter, we present a technological foundation based on continuous location monitoring and local data processing (on the user’s device). This provides the technology for opportunistic ridesharing using frequent locations of users as an alternative to the classic in-advance, “offer-request concepts” (as an alternative approach to DCS 1 and in extension to the results of DCS 2) for ridesharing where users must explicitly plan ahead. Established commercial examples such as Uber, Lyft, flinc, and carma already provide support for managing coordination, payment and automatic posting of ride offers when starting to navigate. However, these approaches are strongly characterized by an inherent commercial logic that is trying to offer a critical mass of users relatively inexpensive alternatives to existing transportation services, and few studies provide insights into the user’s perspective (Brereton et al., 2009; Glöss et al., 2016; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011). Thus, existing systems do not try to reduce coordination efforts caused by advance planning, but rather compensate for them by providing monetary incentives. Opportunistic forms of ridesharing (Bicocchi & Mamei, 2014; Rigby et al., 2013) offer a promising alternative approach, as they try to decrease these efforts. However, they are hardly in the interest of the established services due to unresolved technical and conceptual challenges.

In this DCS, we first identify these design challenges based on a literature review, including the practicability of the required location tracking, the user’s location privacy interests, and the meaningfulness of such tracked data. Second, we present our prototype that addresses these challenges and then we discuss the potentials of our concept for new forms of ridesharing.

To do so, we first revisit the material gathered in DCS 1 and build upon the results of DCS 1 and 2 to outline the challenges of ridesharing systems. We subsume the requirements with regard to ICT-based support for the elderly that we identified so far. Subsequently, we derive practical challenges that need to be addressed in order to track users' locations to enable such approaches (section 3). We then present our approach and discuss how it meets the identified requirements. Using this prototype, we test the data collection (section 4) and discuss the potentials (sections 5 and 6).

7.2 Rethinking Ridesharing – a New Design Concept for Sustainable Integration of a Transport Mode

Compared to the research presented in chapters 5 and 6, this study highlights technological challenges that stem from the requirements based on the empirical insights of the previous chapters. If the first DCS is understood to represent the broad frame of our interventions, the second DCS narrows down this frame to the more concrete problem of ridesharing in everyday situations. The following study, then, presents the step subsequent to the second DCS, as it specifies concrete technological requirements that must be met to implement the concept as described previously.

Before presenting the details of the prototype and its evaluation we summarize our findings so far and discuss them in the context of the existing literature. As a result we highlight the technological challenges that go along with the suggested concept of everyday ridesharing.

7.2.1 More than Logistics

In addition to the logistical issues, there is also a subtler challenge of matching people based on their social preferences and attitudes. Most people would like to choose with whom they share a ride, implying a certain importance of issues such as trust, privacy, independence, and autonomy. Pioneering works by Brereton et al. (2009), Ozenc et al. (2011), and Meurer et al. (2014) argue that such systems could achieve broader adoption if these social challenges were resolved. These works further stress the importance of not separating the act of travel from the purposes and meanings associated with it. As the authors point out, ridesharing usually entails interacting with unknown persons, which can cause feelings of social awkwardness, as one is forced into a very narrow space (the car). The chemistry between the driver and passengers must be right, in terms of things such as expectations with regard to cleanliness, driving styles and habits, and willingness to chat and interact with each other during the ride, as well as many other issues (Joireman, Van Lange, Kuhlman, Van Vugt, & Shelley, 1997; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011; Van-Lange, Van-Vugt, Meertens, & Ruiter, 1998). These issues can affect the adoption of cooperative transportation tools, yet they still remain largely unaddressed when it comes to designing ridesharing tools.

7.2.2 Providing the Right Incentives - Overcoming Routines

To establish ridesharing, or any new transportation mode, in a sustainable way, each party's benefits from sharing must be readily apparent. Research has shown that the perceived benefit cannot be reduced to financial interests, but also entails other dimensions such as environmental criteria (Nordlund & Garvill, 2003; Fatih Kursat Ozenc et al., 2011). These incentives are of crucial importance, as engaging in ridesharing, or in new modes of transportation generally, must challenge existing habits and routines (Klöckner & Matthies, 2004). Understanding why and how transportation modes are routinized, how they can be supported effectively, and why they are difficult to change is of utmost importance if they are to be adopted (Aarts & Dijksterhuis, 2000; Aarts et al., 1997; Banister, 1978; Verplanken et al., 1998), and this is especially true for the adoption of new modes of transportation (Goodwin, 1977). Further, it seems that technology supporting ridesharing uses relatively little information when dealing with routine trips (Aarts et al., 1997). Typically, choices of transportation mode are automatically associated with travel destinations (Aarts & Dijksterhuis, 2000) and commitments (Banister, 1978).

7.2.3 Threats to Voluntarism in Private Ridesharing

Overly systematical support of ridesharing through organizational and technological concepts also endangers the voluntary nature of participation in ridesharing. The monetary interests of platform providers in particular can cause a drift of commitment (Wash et al., 2005). An example from Germany is "mitfahrgelegenheiten.de" (a major ridesharing platform), which introduced a mandatory fee for each brokered ride. This made several users shift to other platforms (e.g. "blablacar.de"), where no such fees were required. In addition to these "provider-introduced" fees, users also recognized financial benefits and "commercialized" their engagement. They offered rides for highly frequented routes to earn money instead of leveraging route synergies. Platforms mainly utilizing financial incentives therefore provide limited complementary additions to existing transportation services, as seldom used routes (e.g. in rural areas and/or short distances) are underserved. Platforms reacted to users exploiting the platform for commercial reasons with specific filters (e.g. bessermitfahren.de), that removed users who offered too many rides. Uber represents an example where users exploited ridesharing infrastructures as a source of income, to the point that Uber now competes with traditional taxi services (albeit in a form intended by the platform provider) (Glöss et al., 2016).

7.2.4 Opportunistic Approaches

As indicated above, matching a driver with one or more passengers is mainly based on their mobility in terms of routes and travel times. The prevalent research focus emphasizes the challenge of finding appropriate algorithms for matching rides (e.g. D'Andrea, Lorenzo, Lazzerini, Marcelloni, & Schoen, 2016). While there is no standard method to determine the best ride-matching method, several approaches have been developed with different focuses related to activity-based behavior (Steger-Vonmetz, 2005; Teodorović & Dell'Orco, 2008). Agile and real-time matching have become key components, allowing the emergence of dynamic ridesharing systems (Agatz, Erera, Savelsbergh, & Wang, 2012).

In addition to these dynamic approaches, opportunistic ridesharing concepts have been suggested that try to reduce "in-advance" coordination efforts. For example, Rigby et al. (2013) create immediate awareness about the available ridesharing opportunities by visualizing the potential pick up time of available rides nearby. Users are thus free to choose the most appropriate option for a given situation. Bicocchi & Mamei (2014), as we have seen in Chapter 2, use mobility traces based on cell network information to identify patterns in the mobility of users, in which they then find patterns using a latent dirichlet allocation (Blei et al., 2003), with each user movement as a word. This can then be used to inform the user about potential ridesharing opportunities. It further addresses the issue of commercialization or loss of voluntarism: one cannot simply offer a ride, but matching is based on the serendipity of two persons having shared past locations. Taking this work further, we are interested in the potentials of location-aware internet-enabled mobile phones to create awareness about immediate ridesharing opportunities. Their ability to provide very short notice and even on-route notifications constitutes the technical basis for flexibility in terms of space, time, and social dimensions (Handke & Jonuschat, 2012). The next section goes more deeply into this kind of ridesharing approach by exploring the potentials and challenges of utilizing historic location information for opportunistic ridesharing.

7.2.5 Design Challenges

Information about people's whereabouts may prove beneficial for opportunistic ridesharing concepts, as it reduces coordination efforts and requires no planning in advance, but instead creates awareness about immediate opportunities. Further, this awareness about existing ride opportunities derived from historic location information renders the classic offer-request-concept obsolete, thus making it more likely to reach a critical mass. Nevertheless, the question remains as to whether and how data can be gathered in a way that is both technologically feasible and acceptable to the user.

For our study, we were interested in realistic tracking data to estimate its potential for real-life opportunistic ridesharing. While it is theoretically possible to retrieve a very dense profile of users' mobility, there are practical limitations to tracking, such as the battery life of the devices (e.g. smartphones), power to process the data (see implementation section), user preferences, and unresolved technical challenges such as deriving meaningful information from logged data. To obtain an overview of these issues, we examined the existing literature and identified three key design challenges (see Table 4) which are discussed in the following sections.

Challenge	Key Aspects	Selected References
Suitability for daily use (practicability)	Continuous tracking for long-term analysis, Energy consumption, Computing power, Analytical methods	Abowd & Mynatt, 2000; Dax et al., 2015; Froehlich et al., 2009; Kjærgaard, Langdal, Godsk, & Toftkjær, 2010; Luimula & Kuutti, 2008; Meurer et al., 2016; Ramos, Zhang, Liu, Priyantha, & Kansal, 2011
Privacy	Sharing control, Data usage transparency, Data transmission and access control	Brush, Krumm, & Scott, 2010; Patil, Norcie, Kapadia, & Lee, 2012; Tang, Keyani, Fogarty, & Hong, 2006; Toch, Cranshaw, Drielsma, et al., 2010, 2010; Toch, Cranshaw, Hankes-Drielsma, et al.,

		2010; Wood, 2012
Meaning and enrichment	Semantic meaning of data, Enriching contextual information, Implicit knowledge	Barkhuus et al., 2008; Harrison & Dourish, 1996; Iachello, Smith, Consolvo, Chen, & Abowd, 2005; D. H. Kim et al., 2009; Simperl, Cuel, & Stein, 2013

Table 4: Design Challenges

Suitability for daily use (practicability)

Collecting location information has been at the core of ubiquitous and context-aware computing from the start (Abowd & Mynatt, 2000). While some research focuses on temporary collection of data (e.g. Dax et al., 2015) or on creating awareness of specific topics, such as environmental impacts (Froehlich et al., 2009; Meurer et al., 2016), other research streams are interested in providing the technological means to enable monitoring of locations (e.g. Kjærgaard et al., 2010; Luimula & Kuutti, 2008; Ramos et al., 2011). One key challenge when it comes to providing such means is their practical feasibility, e.g. through energy efficiency (Kjærgaard et al., 2010; Ramos et al., 2011).

When analyzing the data on the user's devices, approaches can be divided into two different categories: 1) Using a stream-based or event-driven approach (for example, see Dax et al., 2015), each location is analyzed immediately, taking into account information for a given timeframe. For example, Dax et al. (2015) used complex event processing, which has advantages in terms of required computing power and in-situ reaction. However, this requires prior configuration. To address these configuration tasks, such as defining the radius of visited locations to detect people staying at or leaving from a location, they proposed a system to dynamically set and adjust the respective boundaries. 2) Alternatively, all collected information is processed in batches (for example, see Ashbrook & Starner, 2003; M. Lin, Hsu, & Lee, 2012), e.g. once per day. As a batch of data becomes completely available before the processing starts, it is possible to analyze the data before actually processing it, find optimal parameters, and even choose or develop appropriate algorithms to derive such parametric information, for example (Birant & Kut, 2007; Zhou, Frankowski, Ludford, Shekhar, & Terveen, 2007). For example, Lin et al. (2010) extracted 403 visited locations based on nearly 120,000 “raw” locations. They used the tracking data of 26 study participants over two weeks, each of whom visited on average 15.5 locations. However, due to the amount of data, this processing can require substantial computing power, limiting the possibilities for analysis on the user’s devices.

Location Privacy

In addition to the technological means, other requirements result from user’s preferences, particularly those concerning privacy. In this regard, users show a specific interest in protecting the data that is collected around private locations (Brush et al., 2010; Wood, 2012) compared to commonly frequented public locations (Toch, Cranshaw, Drielsma, et al., 2010). Further, conveying location information often “serves as a means toward achieving a higher-level interactive goal such as sharing a positive experience at a place or ‘appearing cool’” (Patil et al., 2012), or as a way to socially interact with a known or specific group of people, such as one’s family or friends living in a specific city (Patil et al., 2012).

These aspects are subsumed under the concept of “location privacy,” which Duckham and Kulik define as “a special type of information privacy which concerns the claim of individuals to determine for themselves when, how, and to what extent location information about them is communicated to others” (Duckham & Kulik, 2006). In this sense, for the purpose of opportunistic ridesharing, there is a difference between the amount of information that must be retrieved at frequent locations and the amount of information shared to establish an agreement to share a ride. Studies show that people are concerned about who has access to their location (Tsai, Kelley, Cranor, & Sadeh, 2010), yet Brush et al. (2010) found that people are willing to share their long-term location data for personal (e.g. traffic information) and community services (e.g. traffic jam reports) if they benefit from doing so. Such anonymous services can use high precision without interfering in one’s privacy (Tang et al., 2006). Nevertheless, Brush et al. (2010) emphasize the participants’ high interest in privacy with regard to their location data, especially when data is uploaded, as users fear unauthorized access to data and usage without their consent. In this regard, Tang et al. highlight the importance of generating and processing the location data on the user's device, accepting it as the only trusted device (Tang et al., 2006). Based on these prior works, it is worth considering having the data analyzed on the device itself instead of uploading it to a server.

Meaningful Data Collection and Enrichment

Understanding the intention of users and the meaning of places or any automated data collection is an ongoing topic of research (D. H. Kim et al., 2009; Simperl et al., 2013). To utilize location data for opportunistic ridesharing and lower coordination efforts, the main challenge is to understand the meaning of each individual place (Harrison & Dourish, 1996). Iachello et al. (2005) found that when the sender and receiver of a location share a context (e.g. in the case of a couple) the location information is enriched with implicit knowledge (e.g. "I'm at the bus stop" is interpreted as "I'll be home in 15 minutes" at a certain time of day), as also pointed out by Barkhuus et al. (2008). In these shared contexts, Barkhuus et al. highlight the coordinative advantage of sharing locations with others. They further present four different types of location labels that participants used to refer to or describe locations: (1) geographic references, (2) personally meaningful place, (3) activity-related labels, and (4) hybrid labels. According to Barkhuus et al. the first category of labels is common for unfamiliar places and consists of landmarks, street names, etc. The second category of labels consists of generic labels, such as "restaurant," which only make sense in a specific (shared) context. The third category refers to activity labels, which do not describe a location but rather an activity that is carried out there. The last category consists of labels that are hybrids of the first three categories, such as "university introduction to computer science," which consists of a place label combined with the activity of attending a class. With regard to labeling places, Zhou et al. (2007) emphasize its dynamic nature, meaning that a place can have multiple labels. Lin et al. (J. Lin et al., 2010) identified two different ways of generating labels for places. The first is based on computational models that analyze location data and generate hierarchical structures. These methods cover geographic properties but fall short at generating semantic properties (J. Lin et al., 2010). The second approach is based on "grassroots" labeling, where users are asked to enter the information of locations they visit.

7.3 Architecture and Implementation

In this section, we outline the architecture of an application for tracking user location information. This was developed as part of a user study in which we wanted to explore the potentials of using location data to enable opportunistic ridesharing in practice. Since tracking the users' location data can reveal very personal and sensitive information, our architecture makes sure to maintain the privacy of the user. All data stays on and is processed on the user's device. The core tracking and analysis concept is shown in Figure 18. Our tracking component is based on the Android OS and registers itself as the location receiver using the available Location APIs (we use Google Play Services, but the component can also be implemented using the basic Location API of the Android OS). Our component consists of collecting and processing services. A continuously running service collects locations passively and triggers other relevant processing services, which process batches of data and terminate after completion. After the service has registered itself (see Figure 18, Step 1), the component receives future location updates. If another application requests a location update (see Figure 18, Step 2) the OS sends an update to the requesting application (see Figure 18, Step 3) and to other applications registered for updates, including our component (see Figure 18, Step 4). This passive collection causes very little additional battery consumption (in fact, no additional consumption was reported by the Android OS during testing). We also actively requested location updates every 10 minutes (resulting in a minimum of six locations per hour). We collected these locations actively to determine whether and for how long location services had been disabled by the user. The active requests caused no noticeable battery drain according to the devices' battery measurements (less than 1%). Using this approach, it is not possible to determine how many location updates are available, as all location updates are published to the component. On the other hand, it provides a realistic picture of general collected location information, which can be taken into account for further analysis of the data.

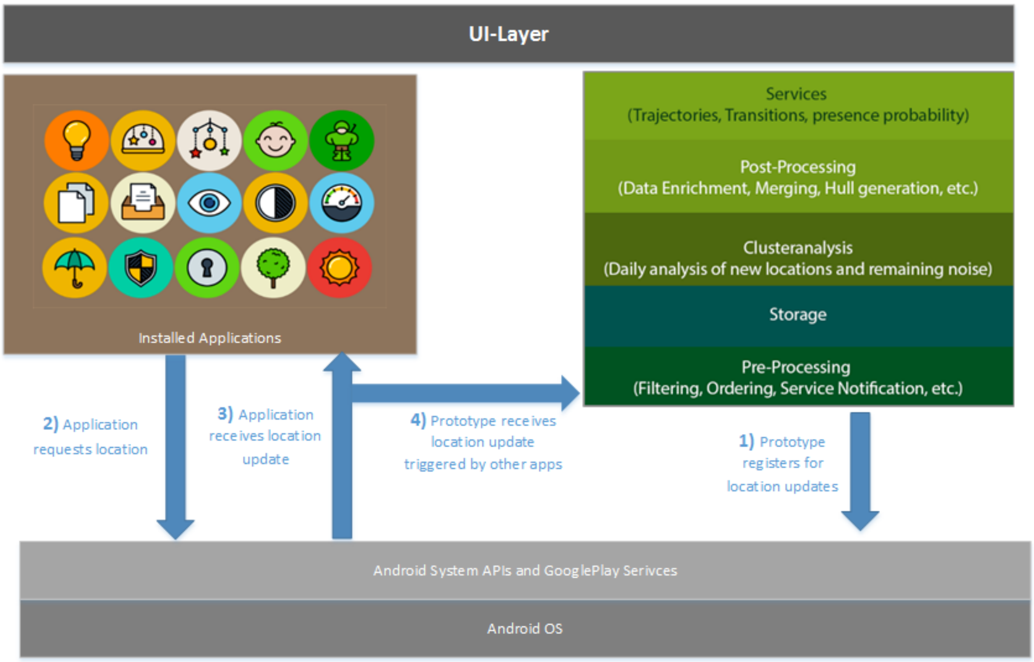

Figure 18: Basic data collection and analysis concept of the prototype

7.3.1 Implementation

We wanted to create a prototype that was used in realistic settings to evaluate whether the collected data could be used to identify relevant and meaningful locations for opportunistic ridesharing.

Pre-Processing of Location Data

As a first step of the data collection, the location data received is pre-processed. This was necessary mainly to address limitations with regard to computing power and to ease the ensuing analytical steps. When a location update is received, the component decides whether the update is accepted or not. We implemented this measure based on the criteria described below.

First, we require a certain degree of accuracy. In our initial tests, we set an accuracy threshold of 1000 meters. The value for the accuracy of the location measurement is provided by the Android OS and is defined as a 68% chance that the "real location" is within "*value of* *accuracy"* meters of distance from the measured position. We introduced this assessment as we ran into error-prone or inaccurate measurements that negatively influenced the validity of the data.

Second, we introduced a time threshold. The component only accepts location updates every 30 seconds. We introduced this assessment as certain use cases (such as navigating using the phone) turned out to produce substantial amounts of data that typically provided no additional value for our goal of identifying visited locations. Further, additional filtering strategies would be necessary when analyzing the data.

The time and accuracy thresholds are easily configurable in order to support requirements of unanticipated use cases. In addition to these filtering mechanisms, the pre-processing can also notify other services (see "Services" section) that require live location updates, such as "geofencing," which allows the system to handle the arrival to and departure from previously tracked locations.

Storing the Data

Accepted location data is stored *locally* for batch processing once per day. We considered other approaches such as complex event processing, but processing the data in batches turned out to produce better results and was more reliable with regard to different users and scenarios (we tested alternative implementations in other settings, but describing these is not within the scope of this thesis). For this purpose, each location is stored including its latitude and longitude values, a timestamp and a cluster id, which is used to mark a location as part of a cluster after the cluster analysis is complete (see following section).

In addition to the pre-processed location data, cluster data is also stored, consisting of the *cluster id* (which is used as reference in each raw location), the *type of cluster* (see following section), a *timestamp when the cluster was found*, a *timestamp when the cluster was last visited*, *latitude* and *longitude* of the cluster's center and metadata, such as the cluster's *spatial hull* (fencing all tracked locations belonging to the cluster), a *count* of how many days the cluster has been visited, a *user defined label* and *category* describing the type of venue (such as "restaurant").

Both, cluster and raw location data are automatically deleted after a configurable amount of time to control the memory usage of the component (for testing we collected data over a timeframe of two weeks). Clusters edited by the user (see "Post-Processing" section) are never deleted.

While it is possible to delete the locally stored raw locations after a batch has been processed, retaining the raw locations is required, as some analytical tasks require all the tracked data. At no point in the processing is the data uploaded and processed remotely.

Cluster Analysis

We implemented automatic analysis of the location data using a batch processing approach. Processing the location information as a live stream of updates, e.g. by detecting stops and the resumption of walking, is a generally promising alternative. However, the fact that we cannot estimate the number of location updates that will be received (if any) renders stream-based processing inadequate.

We used DBSCAN (Ester, Kriegel, Sander, & Xiaowei, 1996), a density-based cluster algorithm commonly used for location analysis (Birant & Kut, 2007; Zhou et al., 2007) and proved to be more scalable than other more complex machine learning techniques (Zhou et al., 2007).

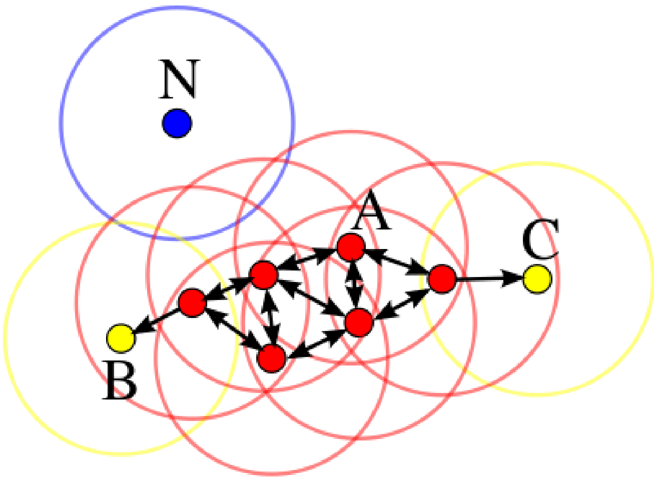

Figure 19: Example of density based clustering (taken from de.wikipedia.org/wiki/DBSCAN)

This is of crucial importance due to the computational limits of mobile phones. One important property of DBSCAN is its capability to produce clusters of arbitrary shapes, which can allow very precise specification of the spaces people visit. Figure 19 illustrates the core concept of DBSCAN. The algorithm expects two parameters – *Eps* and *minPts.* where *Eps* represents the distance criteria (the radius of the circles drawn around each point in Figure 19). If at least *minPts* are in an *Eps*-distance of a point A, A becomes a core point of a cluster. DBSCAN is capable of filtering "noise" (Point N), which means that not all locations are assigned to a cluster (as is the case in other algorithms, such as "K-Means"). DBSCAN thus compares all points with each other, resulting in a runtime behavior of $O(n^2)$. This doubles the locations to analyze and quadruples the required processor time.

To reduce processor time and preserve battery life, we processed the tracked location data once per day, which means the devices needed to process a maximum of 2880 locations (given the time threshold of 30 seconds) in one daily batch. Since we cannot rely on a steady stream of updates, this approach can cause problems with detecting specific places. For example, locations visited regularly, but only for a very short amount of time (for example bus stops, bakeries, etc.), might be not detected, as there are not enough locations collected on a single day to meet the *minPts* criteria.

To address this issue, we perform a second analysis of the collected location data. To this end, we selected all locations that were classified as noise. We can easily identify these as they are stored with no reference to a cluster (see "Storing the Data" section). Since we may now need to process a batch of locations of an unknown size (which also grows over time, as new noise locations are found each day), we selected roughly 2000 locations of the data set (proportionally distributed across the sequence). This analysis of the noise data is also performed on a daily basis.

Each day after the new locations and the existing noise locations are processed, the center of each cluster is calculated. For our study, we tested several values for *Eps minPts,* where *Eps* = 25 meters and *minPts* = 10 turned out to produce promising results. We must emphasize that, of course, clusters with higher density (meaning the average *Eps* < 25 meters) would also be covered by this set of parameters.

Post-Processing

Post-processing consists of automatic and user actions. The automatic actions are performed on a daily basis after the cluster analysis is completed. The results from the cluster analysis are enriched automatically by specific data. One important piece of information is the hull that a cluster is covered by. It describes a fenced area that contains all locations belonging to the cluster. We calculate the (convex) hull of each cluster using the Graham Scan algorithm (Graham, 1972). The algorithm takes the cluster's locations and sorts them based on the angle and distance of each point to the "smallest point" (lowest y-coordinate; if there are more than one lowest-y-coordinate locations, the lowest x-value is used). After sorting, the sequence is traversed, always comparing three points N_i, N_{i-1}, N_{i-2}. The algorithm checks whether N_i is on the left or right side of the Vector $\overrightarrow{N_{i-1}N_{i-2}}$. If left-sided, point N_i is added to a stack of preliminary corner points of the hull. If N_i is right-sided of $\overrightarrow{N_{i-1}N_{i-2}}$ (or collinear), N_{i-1} (which is on top of the preliminary corner points stack) is removed and the left-sided check is repeated for Vector $\overrightarrow{N_{i-2}N_{i-3}}$. When all points have been processed, the stack contains the points of the convex hull for the processed cluster. Sample results are shown in Figure 20. Hulls must be generated in order to analyze the similarity of regularly found clusters. Due to the daily batch processing, frequently visited places (such as home or work) are found several times. By checking whether the hulls of newly found clusters overlap with previously found clusters, we can merge those clusters. If a new cluster overlaps with an existing one, they are merged and the metadata is updated, such as the number of visits, the timestamp of the last visit, and the center of the cluster (see markers in Figure 20).

Figure 20: Hull examples

The center of these clusters is further used to reverse-geocode the coordinates and retrieve an initial address for the location that can be presented to the user. This information is also stored.

In addition to this automatic enrichment, we also implemented a means for the user to annotate and label the locations. The interface shown in Figure 21 for the annotation process only serves to demonstrate the basic idea.

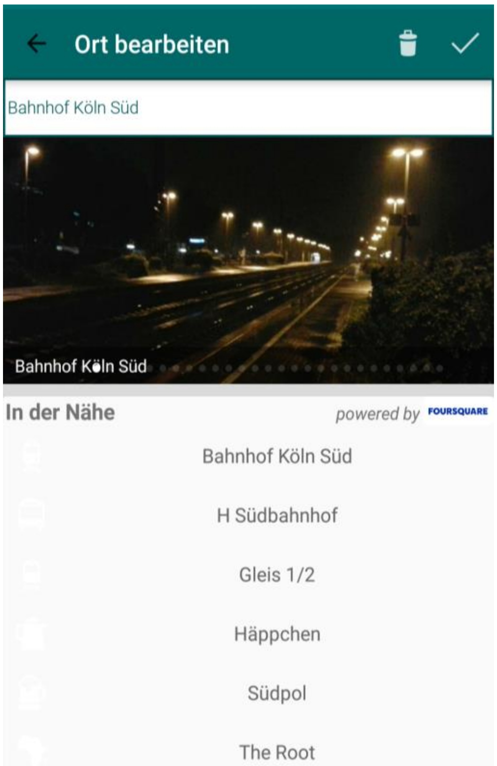

Figure 21: Interface for labeling clustered locations

The user annotation feature is provided to allow users to assign meaningful labels to the locations. Aside from the option to provide their own label, users can select suggestions based on nearby venues. For this purpose, we decided to use the foursquare API, as it is based on user-generated content, which includes informal names for locations that might be more meaningful to the user than the official names. However, our tracking component is able to use various POI-providers, allowing us to compare different ones (Open Street Maps, Google Places, Yelp). When the user selects one of the suggested labels, the category of the venue (e.g. "train station" in the above example) is automatically added to the cluster's metadata. Last but not least, users are able to delete a detected location to exclude it from any further analysis and services.

Sample Services

This section presents examples of potential services that can be realized based on the collected information. We present two services that we implemented as a proof of concept for enabling opportunistic ridesharing. The first service uses the collected data to extract trajectories and the transition probability between detected locations. The second service generates a weekly probability of presence, which can be used to estimate rough departure and arrival times, or in combination with the first service to estimate probable destinations.

Trajectories and transitions can easily be extracted from the gathered and enriched data. We used the trajectory information to provide the user with a "location history" that allowed him or her to see which data was gathered and how it was analyzed. Based on this location history, we generated first-order Markov chains for each clustered location to determine the probability of users transiting from their current location to any other location they had visited before. In our public transportation prototype, we used this information to suggest potential destinations as soon as the app was started (see Figure 22).

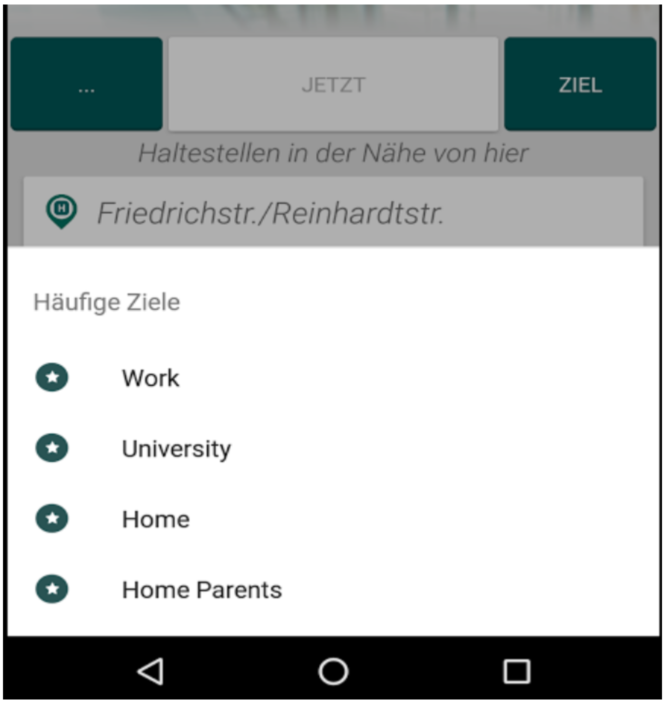

Figure 22: Sample recommendations

The service is provided with the updates collected by the continuous collection service (see section "Pre-Processing of Location Data") and uses existing hulls to determine which of the current clusters the user is currently located in.

To estimate the probability of presence for each day of the week and each hour of the day, we determine the share of tracked locations for each cluster compared to all locations collected in that hour on that weekday (see Figure 24). This data can be aggregated to retrieve the probability of presence for a location at a given time of day (see Figure 23). In combination, the both services make it possible to create a detailed profile of the user's whereabouts, including typical times at which the user arrives at certain locations and then leaves again.

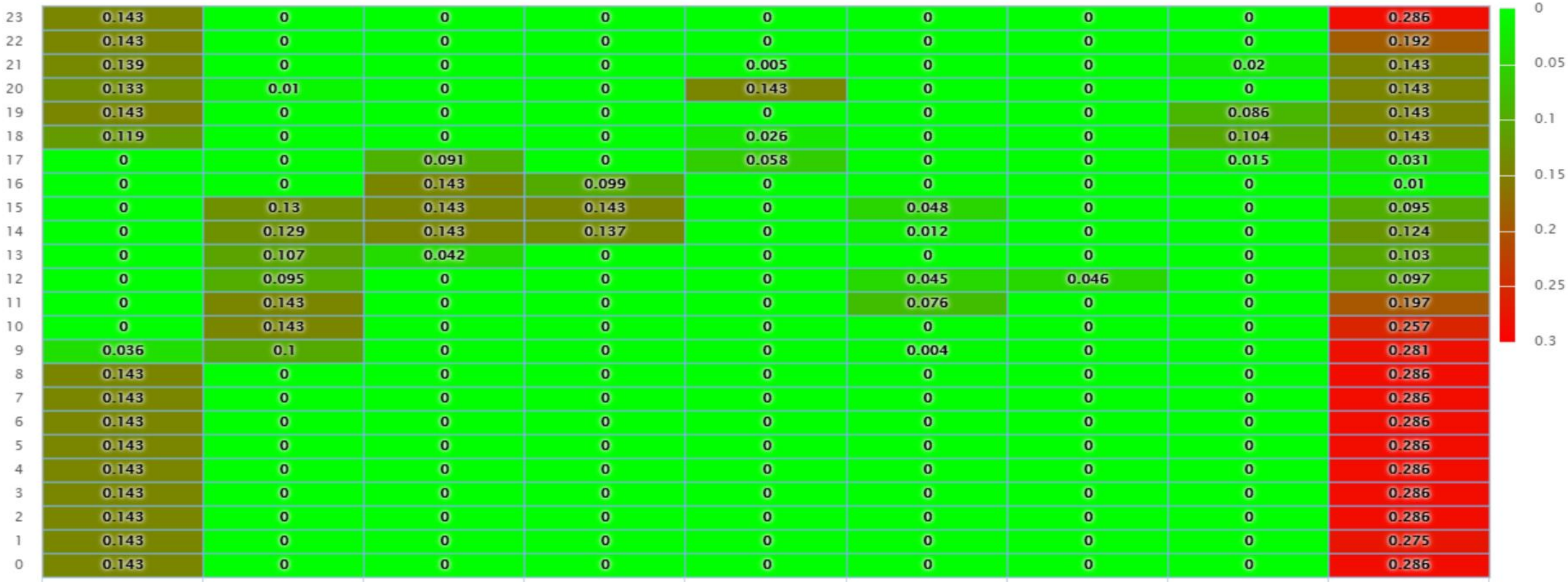

Figure 23: Probability of presence across tracked whereabouts; y-axis contains hour of day, x-axis contains 9 different locations (left blank for anonymity)

Figure 24: Probability of presence for a "home" location; y-axis shows day of week (Sun-Sat), x-axis shows hour of day

7.4 Testing the Potentials for Opportunistic Ridesharing

This section outlines the results from the two-week collection phase. Of course, the number of users in our study places certain limitations on the validity of our findings, but they allow us to better understand the impacts and limitations of our design approach, and particularly to assess the potential of collected tracking information for opportunistic ridesharing.

7.4.1 Results of Data Collection

The prototype we presented focused on two different aspects: 1) monitoring the user's location with minimum impact on power consumption, and 2) analyzing the collected data using only the device's computational power.

In total, we collected 60,959 raw locations from the 15 users (mean: 4,063; min: 238; max: 13,514). Based on these locations, 239 clusters were calculated (mean: 15.9; min: 3; max 49).

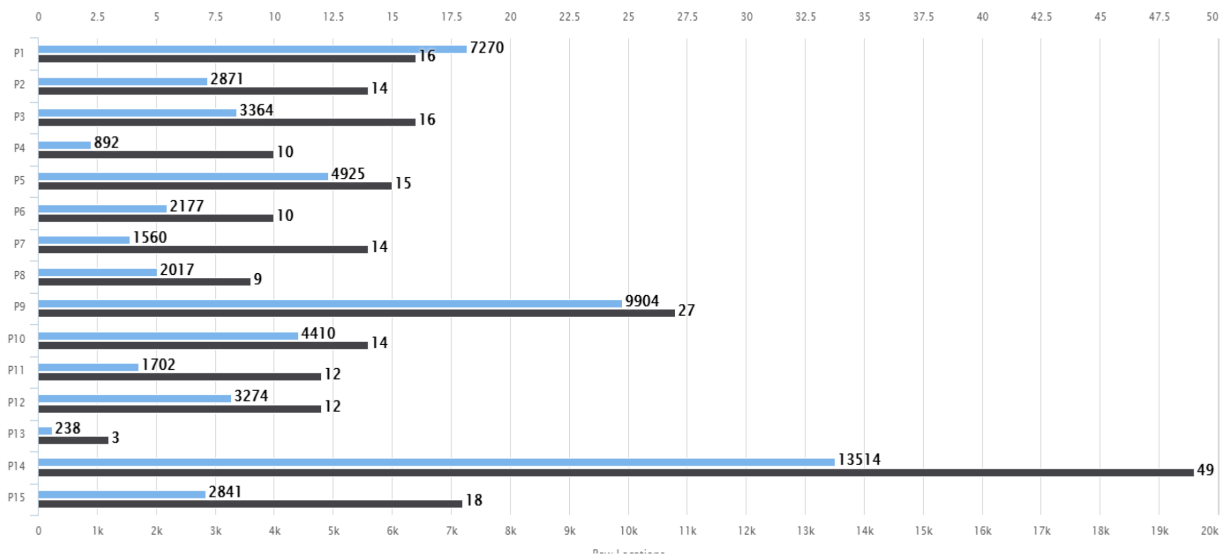

Figure 25: Raw locations (blue) and clusters (black) per user

The distribution of the users is shown in Figure 25.

In terms of power consumption, it is important to note that our approach expects users to have turned on location services on their devices anyway (at least for a large part of the time). We did not check whether the users enabled location services just for our study, which may cause additional power consumption compared to regular use. During and after the study, no participant contacted us to complain about additional consumption caused by our application. While this does not prove that there was no impact on the battery consumption, the impact was at least imperceptible. When testing the prototype on different devices in the lab (using three different smartphones and two tablet computers), our app caused no noticeable battery drain (per the Android OS battery measurement).

Since our approach was to analyze the data on the user's device (mostly for privacy reasons), we had to employ means to lower the computational requirements to meet the devices' capabilities. This was necessary to avoid harming the user experience due to a high computational load and to reduce power consumption. Compared to other studies, such as Lin et al. (2010), our results seem promising, as our analysis revealed a similar number of locations (15.9 on average compared to 15.5 in the study by Lin et al.). Given our sample size, we removed P14 as an outlier (having significantly more clusters than the other users), reducing the number to 13.6 locations on average. We had the chance to contact P14 (P14 was a participant in a previous research project), and it turned out that this participant was on vacations, engaging in sightseeing, which produced more clusters than usual.

We further checked if users repeatedly visited the detected locations. Figure 26 gives an overview of how many clustered locations were visited only once, twice or multiple times. While on average we found that users visited several locations at least twice (4.13 locations

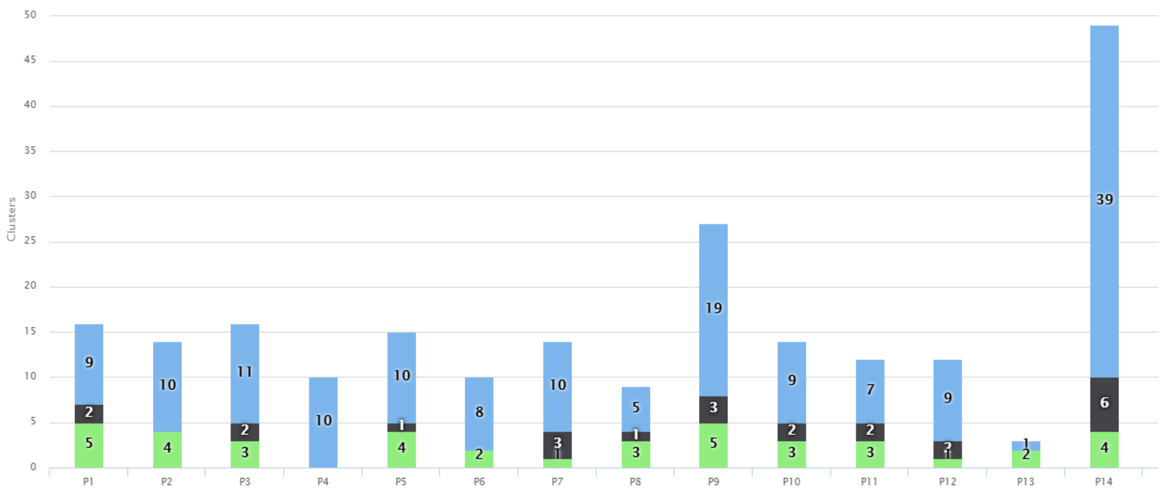

Figure 26: Number of clusters visited once, twice or multiple times; Multiple visits (green), visited twice (black), visited once (blue)

on average), it is interesting to look at P4 (no locations visited two or more times) and P14 (with the highest number of detected locations). We looked more closely at the data of P4 and found that most of the time no locations were collected at all. Looking more closely at the trajectories of this user, most of the locations that were collected resulted from car trips, using the phone as a navigation system. These locations do not fulfill the criteria for clustering (because they do not meet the density criteria). Interestingly, most of the detected clusters (8 out of 10) in the case of P4 covered no area (see "Hull Generation" in section "Post Processing") but were clustered because multiple location measurements (more than *minPts* threshold) had exactly the same latitude and longitude values. It turned out that, except for occasional task of navigating, P4 had turned off GPS localization, only relying on assisting localization features (such as Wi-Fi and Bluetooth localization), which might have caused these issues. Since the clusters did not cover any area, no overlaps could be detected when the user visited the same location again, resulting in no recurring visits. On the other hand, the example of P14, the user with the most locations, shows how the number of visits to a certain location can help filter detected clusters and identify more relevant ones (10 of 49 visited more than once).

7.5 Discussion - Potentials of Location Monitoring for Ridesharing

This section discusses our design in the context of the design challenges we identified in the literature. Addressing these challenges is, from our point of view, crucial to establishing opportunistic ridesharing systems that address prevalent issues with existing ridesharing concepts.

Ridesharing poses more than a logistical question, since it is based on cooperation and collaboration. Several works emphasize that subtle social issues must also be resolved (Brereton et al., 2009; Ghelawat et al., 2010; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011) in order to ease coordination between driver and passenger, increasing the willingness to adopt ridesharing as a daily transportation option. Our design could make a contribution to resolving these problems, insofar as it relies on matching and coordination mechanisms based on shared whereabouts. Shared physical places are known to act as social filters, attracting certain people (Brown, 2014; Jones et al., 2004) and implying certain roles (Messeter et al., 2004). Furthermore, these places encourage or discourage certain types of activities (Blackwell et al., 2014; Harrison & Dourish, 1996; Jones et al., 2004; Sutko & Silva, 2011). These activities are of crucial importance as they form the context of the ridesharing arrangement (Brereton et al., 2009; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011; Stein et al., 2017). As the sample services further indicate, it is possible to derive temporal patterns of presence that would even make it possible to distinguish between different activities carried out at the same location (e.g. working a daily 8-hour shift at the university vs. visiting a weekly 90-minute class at university), providing a more meaningful context for the information.

At the same time, our design allows us to replace the explicit prior offering and requesting of rides by an implicit matching of current locations and probable destinations, reducing the effort required to engage in ridesharing. Such implicit, crowd-based concepts require users to be physically present and are thus harder to exploit for individual financial interests. However, their implied focus on routinized destinations and the implicit, opportunistic nature of the concept suggests that they can be offered as a complementary mode alongside existing services, such as public transportation, cab services or as an addition to existing ridesharing concepts in order to maintain and extend flexibility and independence (Meurer, Stein, Randall, et al., 2014; Szyliowicz, 2003). Generally, the concept we suggest and technically support is promising for more voluntary contexts, such as neighborhoods in rural areas, which are often outside the scope of existing commercial platforms.

A critical issue to consider when approaching ridesharing, as we propose it, is the user's privacy. We were able to show that the necessary collecting and processing of the data are feasible while adhering to the guidelines proposed in "privacy by design" research (Langheinrich, 2001), and more specifically with privacy concerns of location sharing such as those raised by Tang et al. (2006), Tsai et al. (2010) and Brush et al. (2010). The concept we propose keeps sensitive information exclusively on the user's trusted device (Tang et al., 2006), also making it possible to delete all or certain locations to remove sensitive locations (Brush et al., 2010; Toch, Cranshaw, Drielsma, et al., 2010; Wood, 2012). Regarding location sharing and related privacy considerations, storing and processing the data locally allows more transparency and user control over data usage (informed consent) before actually uploading any data.

7.6 Design Implications

This chapter presents a design example to outline the supported use cases more clearly. To do so, we describe a hypothetical scenario and present mockups that illustrate the interactions involved.

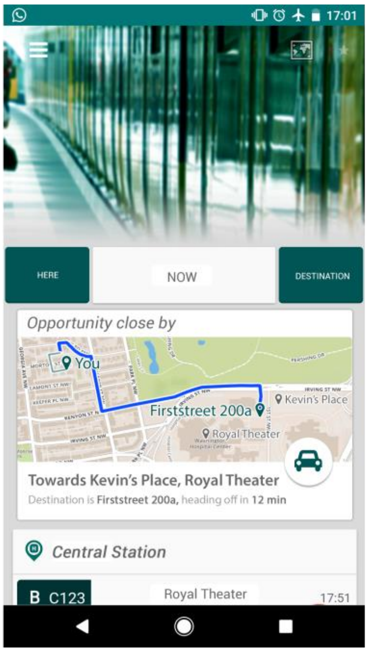

Figure 27: Making a passenger aware of a nearby opportunity

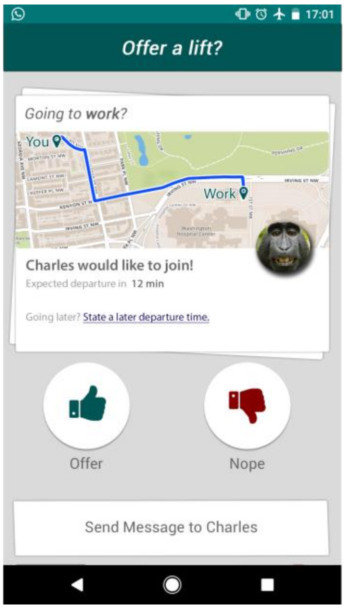

Figure 28: Driver's view to offer or deny a ride

The system detects when a user is entering one of his common locations, and thus does not require any interaction apart from selecting the location to be shared, thereby minimizing the efforts to offer or search for rides. When a user arrives at one of his detected locations (e.g.

university or supermarket) or opens the app, e.g. to retrieve information about public transportation, the system updates the user's location and retrieves and compares the shared locations of other users who happen to be close by. If any ridesharing options are available (meaning someone with a shared location is close by) the user is made aware of them through the application (Figure 27). The user (in this case the passenger) can now use the car symbol on the card to indicate his interest in the ride. If the user is not interested, he can still use public transportation (default transport mode), about which information is provided below the ridesharing offering.

If the user wants to join the ride, the driver is notified and can decide to offer or deny the ride (Figure 28). He is also free to suggest another departure time or send a message to the potential passenger.

8 Discussion – Embedding Transportation in the Context of Everyday Practices

We argue that a practice-based analytical stance is a useful perspective for understanding transportation in its embeddedness in everyday activities. As pointed out in the introduction of this thesis, a praxeological stance allowed us to contextualize transportation as a challenge of organizing and meeting individual mobility demands. This approach thus provided a fruitful extension to the usual focus on directing the user from an origin to a destination, which is grounded more deeply in the everyday tasks and restrictions of our participants. This chapter highlights how looking at transportation from a practice-based perspective helped us to provide novel and arguably better ICT support. To do so, we first provide a brief summary of the three DCSs and subsequently present the lessons learned with regard to transportation support for the elderly.

8.1 Design Case Study 1 – Sehr Mobil

This DCS outlined the findings of our context study and provided insights into the benefits of increased awareness about options, the consideration of personal knowledge and ability (e.g. in terms of "personal information spaces" (Foell et al., 2013)) and the importance of situated reasoning (e.g. taking into account contextual information (Hightower, 2003; J. Lin et al., 2010)). However, the results of the appropriation study also stress how the relevance of information for the user depends on his/her situated context. Based on the user's activity (or intention), different kinds of information are required, including non-transport related data such as weather, alternative destinations, or activity-related restrictions and implications (e.g. movie times when going to the cinema). In addition to logistical information and transportation infrastructure, the findings of the DCS suggest a need for an integrated understanding of transportation and the user's practical intentions. A concern facilitating the adoption of different transport options, taking into account the user's intention serves two purposes: 1) it provides opportunities to create awareness about existing alternatives, and 2) it highlights the necessity of providing information that allows users to assess the suitability of options. Therefore, based on the findings we argue that future support for transportation should be integrated more strongly into the activity that necessitates the transport. Future research and system design should thus focus on the requirements of intended activities, which might entail the unification of information across various modes, but more prominently requires integration into calendar systems or other third party services, as well as existing routines (e.g. opportunistic approaches for ridesharing in everyday settings). To address this, in the second DCS we explored the potentials of transport information systems that leverage the situational context.

8.2 Design Case Studies 2 and 3 – Opportunistic Ridesharing Based on Systematic Location Analysis and Co- Presence

Based on the findings of DCS 1, DCSs 2 and 3 revisited and extended the initial analysis of older adults' ridesharing practices and derived design implications to inform the development of appropriate technological support. We re-analyzed the data in order to understand the role of proximity for ridesharing practices. In particular, we were curious about the reasons for the user's reluctance to adopt existing tools, which became the topic of an additional study about the ridesharing application flinc. This study revealed a clash between the necessary prior planning in flinc and the desire to maintain flexibility throughout everyday mobility. All participants further agreed that, while the general idea of flinc (or ridesharing in general) can be very beneficial, the way it is currently designed better supports long-distance trips and necessitates too much planning to be used in more spontaneous, everyday trips. Participants backed up their comments by outlining how the use of informal messaging applications (Whatsapp) provides more adequate support for arranging joint rides and reported on illustrative situations in which offering or requesting a ride restricts them in rescheduling events throughout their day. The evaluation also highlighted that awareness and addressability are crucial aspects that must be supported in order to overcome civil inattention in public spaces, which prevents private ridesharing arrangements from broadening into ridesharing with strangers.

The key finding of DCS 2 and 3 was the complementary nature of ridesharing in older adults' everyday transportation. Ridesharing was not seen as a "default" transport mode, but rather as something that complements other preferred modes (such as the car or PT). More specifically, we found that ridesharing was mainly used in two different contexts. The first was serendipitous meetings, e.g. meeting a neighbor at the supermarket who offers a lift home, which happens to be more comfortable than using the bus. The second context was “regular meetings or events”, e.g. people started sharing rides to the gym or choir practice, as it allowed them to save money or was perceived as an extension of a social activity that was happening anyway. Both cases highlighted that a shared physical space or co-location played an important role in coordinating and arranging the ridesharing, either since people were serendipitously co-located and spontaneously joined a ride or because they regularly go to a shared physical space. As many of the commercial ridesharing tools are including more and more features to foster ridesharing on short notice, we wanted to explore whether the lack of adoption of such tools was simply due to being unaware of them or for other reasons such as conflicts with existing ridesharing practices.

8.3 Lessons Learned – Designing Practice-Oriented Systems for Everyday Mobility

In the beginning of this work we outlined several concepts related to decision-making regarding transportation:

- Decisions based on stress and coping mechanisms
- Decisions based on the person’s attitude and norms, as well as the personal sense of control or autonomy
- Decisions in support of societal norms and values, such as environmental sustainability
- Decisions based on habitualized behavior against the backdrop of situational and infrastructural conditions

Following a practice-oriented approach, instead of committing to one of these concepts beforehand, we tried to understand the decision-making inductively. We did this because our main interest was to understand transportation and the factors influencing decision-making from a user’s point of view without forcing specific presuppositions onto the empirical data. As expected, aspects well covered by the different concepts turned out to be of relevance, such as routinized behavior, coping mechanisms, and personal values. However, the practice orientation allowed us to understand transportation and mobility as being embedded in everyday practices, thereby outlining the interconnectedness of the various aspects, and ultimately the interconnectedness of these theoretical concepts. Building on very concrete cases of older adults' mobility in a (semi-)rural area, it further allowed us to *iteratively* build up an understanding about transportation. This understanding was not theory-driven, but rather stemmed from iterative reflection of empirical data in the context of our design intent. Thus, within this iterative reflection, the DCSs were conducted with a broad initial problem scope, but gradually specifying different problems and potential design solutions.

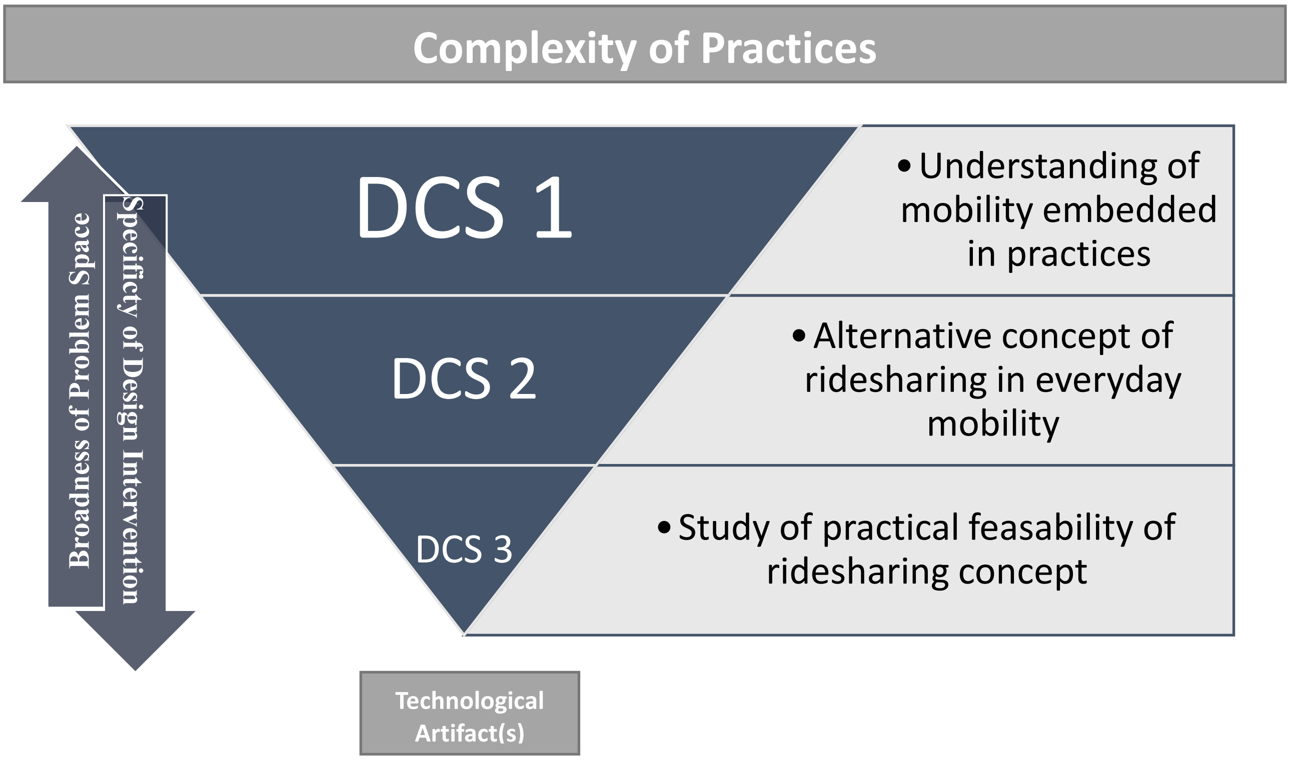

Figure 29: Interdependence of the three DCSs

As Figure 29 indicates, the different design studies that were conducted are not independent but rather informed each other in sequence. Within each DCS, findings that had been made previously in the other DCS(s) were taken into account. Generally, the process reported in this work can therefore also be understood as various cycles of a larger iterative design and development process. We therefore discuss the results of the DCSs in a more synthesizing, integrated manner, highlighting how their results build upon each other and how the combination of all three studies provides an example of design in a practice-oriented way.

Taking into consideration the three DCSs it became clear that while all addressed very similar issues, they strongly differed with regard to how the problem was framed (broad vs. narrow scopes). In line with these varying problem scopes, they also resulted in very different technological artifacts, which either supported a broad range of features (DCS 1) or represented a solution for a very specific problem (DCS 3). The process of honing in on specific problems and specific technological solutions emphasizes how the process of supporting practices, and therefore translating very complex issues into very strict (technological) models, necessitates a staged and iterative design process (Rohde et al., 2016; Wulf et al., 2015). The sequence of DCSs in our study can therefore also be understood as a "drill down," during which a very specific technological problem was addressed (DCS 3 – continuous location monitoring) in order to provide support for a practical task (DCS 2 – supporting ridesharing on an everyday basis), which is one issue in a broader set of complex problems (DCS 1 – inter-/multimodal mobility). In this regard, the concept of practice guided the research process in its various aspects, firstly by providing a suitable unit of analysis to explore everyday transportation empirically, secondly by highlighting technology appropriation and co-design as source of innovation, and thirdly by contextualizing ICT design within real-world problems.

Nevertheless, it is important to emphasize that we applied the concept of practice to the case of transportation not primarily to extend the concept of practice, but to outline an understanding of transportation that is driven not by mode-specific or direction-oriented intentions, but by the participants' practices.

8.3.1 Understanding of Transportation Embedded in Practices

Earlier in this thesis we pointed out that the literature, for the most part, suggests that people often use specific transportation modes for specific goals and tend to follow routine transportation habits (Aarts & Dijksterhuis, 2000; Aarts et al., 1997; Banister, 1978; Goodwin, 1977; Verplanken et al., 1998). While the results of DCS 1 generally support these findings, the study also revealed implications for the design of transportation systems that better contextualize the logistical factors of transportation, which are currently at the center of most designs. DCS 1 in particular highlighted how decisions in transportation are made based on the user's intended activities. Many of these activities are performed on an everyday basis, and thus can be understood as "*normatively regulated contingent activity*" (Schmidt, 2014) or practices.

These practices provide the context for the transportation activity and have varying implications on the transportation requirements (e.g. doing errands vs. having doctor's appointment), e.g. regarding the degree of spatial and temporal flexibility. As a result, people routinize their mobility within the context of *and* as parts of these practices.

For the case of practices that entail transportation activities, the first DCS highlighted that more than just logistical support is required (Awareness, Figure 30). From a practice-oriented standpoint, one can argue that this awareness – which might be created by ICT-based tools such as apps or websites providing information about transportation opportunities – indicates "potentially useful, usable and efficient functions" (Rohde et al., 2016), but only through appropriation of the technology (Stevens et al., 2009, 2010) are specific practices transformed (Kaptelinin & Bannon, 2012) and the use of the new tools is routinized (Riemer & Johnston, 2013).

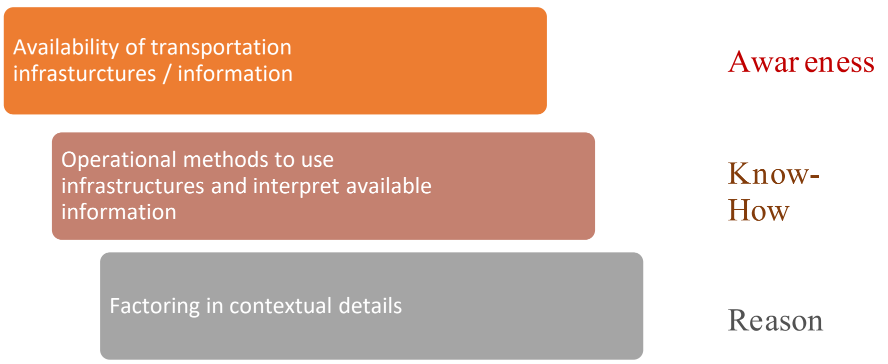

Figure 30: Levels influencing flexibility

Thus, to facilitate these appropriation processes, DCS 1 highlighted the necessity of designing systems in a way that suited our participants' *abilities* in terms of knowledge of the operational methods required to use means of transportation and their ability to apply existing knowledge (e.g. knowing and providing relevant (location) names as information for activities). Few participants were able to see the benefits of new tools and provided information based on their existing know-how (Schmidt, 2012), and they appropriated these tools and established new practices (Know How - Figure 30). The "new practices," as indicated above, entail an act of transportation but are not limited to it. Quite the contrary, from a user's point of view the act of transportation in some cases (e.g. going out for drinks) represents only a small, utilitarian act in the performance of the contextualizing practice. As a result, *reasoning* (Reason, Figure 30) about the suitability of transportation options always takes place in the context of the performed practice. As these typically constitute routinized behavior, they imply a "default modal choice." In this sense, contextual factors play an important role regarding the decision on a "default mode." If they change (situationally), this can cause deviations that lead to switching the mode of transport. Looking at these various dimensions – awareness, know-how, and reason – we see that aspects influencing transportation activities also cover the aspects of "material," "competences," and "meaning" (Shove et al., 2012), or "skills" and "techniques" (Schmidt, 2014), highlighting the link with the major practice theory concepts (Kuutti & Bannon, 2014; Reckwitz, 2002; Rohde et al., 2016; T. R. Schatzki, 1996; Schmidt, 2014; Shove et al., 2012; Wulf et al., 2015), and indicating their relevance as "sensitizing concepts" (Blumer, 1954).

This understanding has fundamental implications for the goal of designing inter- or multimodal transportation information systems:

1. Inter- or multimodal transportation systems should consider that mobility behavior is routinized, and this includes modal choices. Therefore, not all available transportation options are assessed for each trip, but only if circumstances force users to deviate from existing routines; this illustrates the importance of (non-logistical) context information. Especially in these situations, users benefit from the awareness of *suitable* transport opportunities or combinations thereof, thus providing a better understanding of the use cases for multi- / intermodal solutions, as suggested in the literature (Meurer, Stein, Randall, et al., 2014; Szyliowicz, 2003). Regarding the suitability of modes, other studies have highlighted how specific knowledge is necessary to make use of or ease the usage of different modes, e.g. for PT (Ferris et al., 2010; Peng, 1997; Redman et al., 2013) and ridesharing (Brereton et al., 2009; Ghelawat et al., 2010; Meurer, Stein, Randall, et al., 2014; Fatih Kursat Ozenc et al., 2011). This must be considered when integrating these various modes.
2. The focus of transportation support systems should be not solely on the act on transportation, but rather on supporting the contextualizing practice. As pointed out by Kuutti and Bannon (2014), this in turn shows that it is not the interaction with the system that is in the foreground, but the performance of the practice. This relation between the act of travel and the performed practice is comparable to that between

places and spaces (Harrison & Dourish, 1996). As Dourish (2006) explains, space is understood as “a natural fact” and place as “a social product.” A collective understanding of spaces is connected to the practices of the people within them (Dourish & Bell, 2007). In the case of mobility, the *act* of travel constitutes physical movement from an origin to a destination but the *characterization* and implied requirements of the act focus on the *goal* of the travel. Harrison and Dourish (1996) described this distinction as follows: “space is the opportunity; place is the understood reality.” In a similar vein, we argue that a system for accessing transportation information needs to provide not only schedule information, but also functionality to support the users in assessing the suitability of the transportations services in the context of their activities, e.g. visiting the cinema by providing information for the return trip or alternative destinations (other cinemas).

3. For the goal of facilitating mode-switching, our results highlight that multi- or intermodal systems that focus on the transportation-related information have only a limited potential to influence mode choices, as these are typically routinely set. Instead, based on the user’s intentions, transportation information must be integrated with systems and information supporting the framing practice (e.g. a hospital visit) in order to highlight the suitability of particular modes (e.g. providing public transport to the hospital due to limited parking there). Further information on routines could be leveraged to highlight (one-time and regular) opportunities.

8.3.2 Alternative Concept of Ridesharing Support in Everyday Mobility

Building upon the understanding that transportation routines are established with practices, the example of ridesharing demonstrates how the understanding of existing practices helps to establish new support concepts for specific transportation modes such as ridesharing. In this sense, the exploration of alternative concepts for ridesharing was carried out in order to understand situations in which ridesharing is a suitable mode of transportation, thereby informing the design of ridesharing tools that address everyday transportation.

While studies looking at the attributes of specific modes (e.g. Redman et al., 2013) highlight important issues such as frequency of service, reliability, comfort, etc. they remain descriptive and limited to objective measures. Taking a practice theory stance allowed us to explore specific modes, in this case ridesharing, from a user's perspective and in the broader context in which it takes place. Very similar to the study conducted by Vines et al. (Vines et al., 2012), we explored current instances of ridesharing to understand advantages and disadvantages in situations in which it was preferable to make use of this mode. Such informal ridesharing coordination is not leveraged by existing tools. The proximity-based concept we provided allowed users to employ these existing procedures in terms of know-how (Schmidt, 2012) or competences (Shove et al., 2012) and did not require them to switch from their default mode, building on the supplementary and serendipitous use of ridesharing as mode of transportation within the participants' daily mobility.

Further, the informal negotiations that users already conducted when sharing rides with others provided represented very flexible means to deal not only with logistical coordination, but also with issues that typically arise with the introduction of ICT-based ridesharing tools, such as trust (Brereton et al., 2009; Ghelawat et al., 2010), reciprocity (Meurer, Stein, Randall, et al., 2014), and others. This flexibility often is restricted by the formalized interfaces in existing tools (Wash et al., 2005), highlighting a clash between design concepts (or plans) and the required situated actions (Lucy A. Suchman, 1983).

8.3.3 Practical Feasibility of the Ridesharing Concept

Understanding ridesharing from a user's perspective resulted in the development of a new concept for technological support. This new approach was based on a more contextualized method of interaction. While other works have highlighted the importance of including various types of data to provide better information retrieval for decision making, e.g. using maps (Hightower, 2003; Hoar, 2008), social networks (Brereton et al., 2009), or personal routines (Foell et al., 2013; D. H. Kim et al., 2009), these approaches have been based largely on classical or dynamic ridesharing approaches (see section 2.3) and tried to leverage other tools, such as social networks or applied optimization, to address issues such as critical masses and planning efforts.

Our concept differed from existing ridesharing technology by orienting along our understanding of existing practices that already entailed ridesharing. It therefore avoided most of the problems that existing ridesharing tools face by leveraging existing informal coordination. However, its practical feasibility remains unclear. As outlined by Wulf et al. (2011), to develop systems and conduct research in practice one must consider real-life circumstances as well as the restrictions that often go along with additional efforts. In the case of our concept, testing its practical feasibility meant taking into account people's privacy concerns regarding location monitoring, as well as practical issues such as power consumption.

In order to address these challenges and systematically develop our concept it was necessary to make decisions with regard to various technological matters, and also design questions. While we relied partly on quantitative data such as usage logs and tracked GPS data, we further informed our design process by including the participants in the design activities. This participatory design approach comes with certain advantages and disadvantages that we reflect on below.

9 Methodological Critique - PD Processes within Design Case Studies

Above we presented the findings from the participatory design approaches which we implemented within the DCS framework (Wulf et al., 2015). These studies included three intertwined phases: an *intensive pre-study* to gain comprehensive insights into the practices of the empirical object under investigation; the *development of a prototype* of a technical device based on the findings of the pre-study; and the *evaluation of this prototype* in practice. Each phase used diversified and integrated qualitative empirical methods, such as ethnographies, participant observation, interviews, biographical approaches and methods, cultural probes, analysis of pictures and videos, etc., as well as participatory design workshops with potential end users and other relevant stakeholders. Therefore, the aim was not to "confirm" concepts or features of design, but to achieve a detailed understanding of how existing practices had been upset and altered by the introduction of technology, thereby deepening the researchers' understanding of the practices themselves (Rohde et al., 2016). It was therefore crucial to document any changes that might have not been anticipated (Orlikowski & Hofman, 1996).

Hence, we introduced two different approaches within the three DCSs that were conducted in parallel in order to explore the main research goal: *Maintaining and extending older adults' mobility by integrating complementary modes of transportation using ICT*. However, while all DCSs had the same overall goal, they followed different design approaches and resulted in different outcomes with regard to the ICT solutions. The different designs turned out to have their advantages and disadvantages, and to varying extents resemble existing solutions or support existing practices. We argue that these differences were related to the design process and, more specifically, to the user's role in defining the design space, the problem space, or both. To illustrate this, we revisit how we proceeded in each DCS. Based on these descriptions, we reflect on the evaluation results to draw conclusions about which steps in the design were helpful at the various stages of the process. The strong distinction between the two approaches is mainly for the purposes of analysis, readability, and structure. Since the same participants took part in both approaches and since all DCSs overlapped in practice, they also interfered with each other. We elaborate on these interferences and possible implications (and limitations) for our arguments in later parts of this chapter.

The most prominent distinction between the two approaches was that they were based on a somewhat different understanding of user involvement. In the first case, *Sehr Mobil*, the users took part in all design activities. They not only participated in framing the problem space, but also envisioned features and actively took part in co-design activities, such as defining use cases, designing interface layouts, and suggesting and selecting features. For the purpose of our later analysis, we characterize this form of collaboration as **future imagination** through co-design**.**

In the second case, *Opportunistic Ridesharing*, the involvement of the users was limited to the definition of the problem space and focused on the critique of a particular design prototype that we had developed. The subsequent research and development were informed by the insights of this critique, but the users did not actively take part in framing the design space. We would characterize this form of collaboration as **retrospective innovation** utilizing design critique.

As indicated above, the clear distinction between the two cases is for analytical purposes. Of course, on a practical level, the insights gained in each of the processes also informed and thus influenced the ongoing process of the other process.

9.1 Sehr Mobil - Future Imagination by Involvement through Co-Design

This DCS concerned development of the main prototype of the project. We included users in each step of the design process. Due to the long-term nature of the design process, we tried to establish an equal relationship between the participants and us as the researchers or designers.

9.1.1 Understanding the Problem Space: Analysis and Supplementation of the Initial Interview Data

Initially, we conducted an interview study with all the participants. We were especially interested in problems regarding the elderly's transportation habits and the organization and planning of their daily transportation. The underlying motivation was to understand how users reason about transportation opportunities to reveal potentials for ICT-based support. The initial analysis resulted in several codes which were clustered into topics such as "usage of transportation modes," "planning of transport," "cooperation in mobility," and "self-perception of abilities in age."

In addition to the interview study, six participants agreed to document their daily trips in a diary over a period of four weeks. The diaries were then used to identify routines in everyday life and to gain a better understanding of how participants referred to different types of destinations. We also engaged in observations of their public transportation and ridesharing arrangements to identify common problems. A focus group was conducted to explore existing transportation tools. Participants were asked to write down typical routes, travels, and cancelled trips. They were also asked to describe the means used to make the trips and think about tools they would have liked to use. A second task of the group was to choose and test a tool from a set we provided and discuss its suitability for planning a later trip. Available options were a paper public transport schedule, a navigation system, a public transport service webpage, and Google Maps.

Using these different approaches and methods, we gained a rich contextual understanding of personal preferences (e.g. preserving decisional autonomy and independence), the resources our participants have available (infrastructures, bodily abilities, social ties), their knowledge and skills when looking for transport opportunities (regional knowledge, mode-specific experiences such as counting people at the bus stop to determine whether the bus has left), as well as situational factors that may have an impact on their mobility decisions (such as weather, coincidental meetings, or opportunities such as doing the daily errands when on a trip anyway).

Based in these initial insights, we developed use cases that were inspired by anecdotes told by the interviewees as well as from typical use cases in existing applications that we discussed with the participants during the weekly meetings and that served as a starting point for the design conceptualizations.

9.1.2 Exploring the Design Space: Iterative Co-Designs

Our intention was to provide participants with the opportunity to explore the design space on their own. Thus, we wanted to facilitate reflection on the potentials of existing technologies and leverage participants' knowledge of the problem space to co-design a well-suited transportation information system. To do so, we included the participants from the beginning by discussing uses and how they would imagine the system. This section briefly describes the steps we took and summarizes the results.

Based on the results of the context study, we conducted several design cycles. The aim was to incorporate identified issues that should be reflected in the various possible solutions. We did so by starting at a high level of abstraction and slowly discussing each detail of the application (Figure 8).

As a first step, we started by creating conceptual flows. To do so, we asked the participants what they would expect from the application step by step. Discussing these flows helped us gain a better overview of the system and illustrate which steps are necessary in order to perform certain actions within the application.

The second step was to hold co-design sessions to create the first mockups of each step within the application. For example, we projected empty templates of websites and apps on a whiteboard and hand-sketched additions based on the ongoing discussion. In cases where there was no consensus about a design alternative, mockups were created by the researchers and discussed at the following meetings.

Further, as a third step we also tested the interaction flow of the application by providing the participants with clickable prototypes (first low-fidelity prototypes and later high-fidelity prototypes) to make the specific design alternatives more tangible.

During the design phase we encountered several issues that made it necessary to conduct more specific activities regarding certain issues. For example, we conducted a focus group to explore the privacy concerns of users. We printed various parts of the users' profiles on cards and had them sort these in order to understand which information would be shared under which circumstances.

In summary, the design approach we followed in this DCS required active participation by the users. From the beginning, they were in charge of conceptualizing the features and design. We supported this process mainly by moderating the discussions, bringing in feature and design ideas, and preparing designs based on the participants' ideas.

9.2 Opportunistic Ridesharing - Retrospective Innovation by Involvement Through Critiquing Design

For DCSs 2 and 3, we chose a different approach, aiming at obtaining a deeper understanding of the factors that motivated or prevented our participants from sharing rides. We particularly wanted to use the participant's input to understand the situations in which they already engage in ridesharing without additional technological support, and found that those typically happen in one of two cases, both involving physical proximity. The first case was serendipitous meetings, e.g. a neighbor happens to be at the supermarket at the same time and offers a lift, which happens to be more comfortable than using the bus. The second context was regular meetings or events, e.g. people began sharing rides to the gym or to choir rehearsals, as it allowed them to save money or they perceived it as extension of the social nature of the activity. The key finding was the supplementary nature of ridesharing (in terms of filling gaps with regard to preferred transport modes) in older adults' everyday transportation (see Figure 27 and Figure 28 as examples of ridesharing integrated with public transportation).

9.2.1 Understanding the Problem Space: Revisiting Interview Data and Evaluating Existing Solutions

As a first step, we re-analyzed the interviews from the pre-study with a special focus on situations in which our participants already engaged in ridesharing. The results of this analysis were an initial understanding of mobility issues as well as common insights for proximity-based support for transportation sharing. The findings of these interviews were extremely helpful, as they allowed us to understand the situations in which ridesharing occurred, as well as the motivations of the elderly people to engage in it. Since ridesharing seems to be an established practice, we were curious about the reasons for reluctance to use existing tools.

As many of the commercial ridesharing tools included an increasing number of features to foster ridesharing on short notice, we wanted to explore whether the lack of adoption of such tools was simply due to being unaware of them or for other reasons that conflict with the existing ridesharing practices. Thus, we introduced a commercial ridesharing application called flinc (www.flinc.org). We used the flinc application as a probe, because it was one of the few applications that was used in our test area and it also included more advanced features that allowed fast and easy coordination of rides. For example, flinc includes automatic payment features, is integrated into existing navigation systems (automatically offering a ride when a user starts navigating), and matches users automatically based on route congruence. During the two-week exploration phase, testing flinc helped us to understand welcomed features, as well as shortcomings and inadequate design concepts. All participants agreed that, while the general idea of flinc (or ridesharing in general) can be very beneficial, the way it is currently designed rather supports long-distance trips and necessitates too much planning to be used in more spontaneous, everyday trips.

9.2.2 Exploring the Design Space: Offering Alternatives to Existing Solutions

To deepen our understanding of the role of co-presence and flexibility in the user's current ridesharing practices that were characterized by spontaneous or regular arrangements, we conducted an exploratory workshop. The workshop's focus was the topic of co-presence or co-location as a means to support ridesharing in a more spontaneous and less restrictive way. In the workshop we provided a brief introduction to co-location-based technologies by presenting existing apps (such as messengers, games, and dating apps that scan for devices nearby as part of their interaction concept). We did so to provide a more tangible experience of the possible technological support options as a means to frame the later discussions. We then presented empirically derived use cases (e.g. being co-located at the supermarket), engaged in discussions to evaluate their authenticity, and consequently modified and selected the realistic cases.

While the workshop helped us to validate and further specify the potentials for support, it became clear that users were influenced by the concepts of existing ridesharing applications introduced previously. In particular, this became obvious when we asked participants what features they would expect from an application based on co-presence. It turned out they pinpointed features for stating offers and requests and/or coordination features. This was of particular interest, as these steps were heavily criticized in existing applications.

Based on the insight from the previous steps we developed a rapid prototype that allowed users to enter information about their common locations. If a user happens to be at the same location, the devices detect each other's co-presence using Bluetooth. The application then proceeds with matching drivers and passengers based on shared locations that the user entered previously. In this way, the users only need to provide whereabouts once, and matching happens on a serendipitous basis, thereby resembling the current ridesharing practice.

In the second workshop we introduced the use cases that were elicited in the first workshop, as well as our prototype. Participants were free to explore the prototype initially and then were asked to perform certain tasks, such as entering a location, responding to a ride invitation, and chatting with the ride host. We chose a workshop as the setting for evaluating the concept, as "in-the-wild" studies would require a more sophisticated prototype, as well as substantial efforts to distribute the applications to create a critical mass of users.

In DCS 3 we adressed the potentials of more situated, opportunistic ridesharing. Our decision to focus on this concept was suggested by the findings of DCS 2. We discussed the potentials and prevalent challenges of (opportunistic) ridesharing approaches. Based on a literature review, we identified "suitability for daily use," "location privacy," and "meaningful data collection and enrichment" as key challenges for opportunistic ridesharing. We further discussed how these issues could be addressed by designing appropriate tracking and analysis features and validated our ideas by means of a prototype that was tested by 15 users. We showed that the insights derived from the collected data in consideration of technical and privacy-related restrictions can be of vital importance to establish ridesharing in situations in which the required effort must be reduced instead of being compensated for (e.g. since financial incentive systems fail).

In summary, the design approach we followed in DCSs 2 and 3 required the user to provide input mostly to validate our understanding of the problem space and to critique the solutions presented. During the design process in particular, we deliberately overruled the user to extend the design space.

9.3 Discussion of Approaches

As highlighted at the beginning of this thesis, we followed various approaches to user involvement. This section focuses on specific points that turned out to be positive and negative aspects of each design process.

9.3.1 Alternative Design Solution: Future Imagination vs. Retrospective Innovation

The design process in the *Sehr Mobil* case can be described as what we call "future imagination," since participants tried to envision a new practice that entailed the use of a tool that they co-designed based on their experiences with existing transportation tools. However, the knowledge of existing ridesharing aimed at supporting long-distance travels that we introduced previously limited their creativity and even prevented them from thinking about alternative solutions. While the *Sehr Mobil* prototype was appreciated, in particular with regard to public transportation and taxi services, its appropriation showed that the concept of ridesharing was not suitable for everyday mobility. It clearly resembled existing ridesharing tools (including their limitations), extended with functionalities that aimed at reducing coordination efforts. For instance, several women from our group wanted to have an option to show only rides offered by female drivers. Other participants wanted to exclude rides offered by pet owners due to allergies, had certain restrictions because of luggage they needed to transport, or wanted specific ways to state variable pick-up times. Thus, instead of questioning the concept as whole, the inherent limitations of the approach remained. Consequently, the ridesharing feature of the application was used only rarely. Participants complained about the necessity of planning and entering trips in advance to publish the request or the offer. Further, the necessity of reaching a critical mass in order to justify the efforts to enter a ride or a request resulted in a vicious circle of missing offers and requests: *"I seldom use the app. Sometimes I open it out of curiosity, but I've never needed it. I like the way it is designed and I can see the PT connections. But you only start using ridesharing when you are sure that someone will reply. It's a dead end right now" (Participant's comment, Evaluation Study).*

This was especially interesting, as ridesharing was a common practice amongst our participants during the project (e.g. when people joined a ride to visit our weekly meetings), yet users preferred to use the messengers that we had introduced during the pre-study to arrange the ride in these cases. While this tendency is in line with the results of the initial context studies (Meurer, Stein, Randall, et al., 2014), it highlights an interesting aspect of the participants' design choices: although their actual usage differed from the concept they actively co-designed during the PD sessions, they did not really question it or let go of the concept, but rather actively pushed the implementation of features they later criticized as being cumbersome or even problematic ("only women" and "no-pets" filters, etc.). Although users agreed to reduce the impact and prominence of these factors, they were still worried about removing these settings completely (in the end we disregarded these aspects when matching rides and informed users only about mismatches in preferences).

In contrast, the Opportunistic Ridesharing case can be described as what we would call "retrospective innovation," since the design process and the resulting design were based on the existing practices of the participants, and we as researchers introduced a design option to extend the design space. As the workshops had showed, it was very difficult for the participants to let go of existing concepts and fully grasp the potentials of proximity-based interactions, despite our best efforts to explain these. This limited their ability to envision alternative design solutions (Crabtree, 1998; Mogensen, 1994).

This observation is in line with Coleman et al. (2010), who argue for not introducing inexperienced users to existing technologies before conducting design activities. To push the project forward, we changed the approach of our workshops. While we still discussed design suggestions with the users, we focused on understanding the problem space that the users were describing as a rationale for their suggestions, but did not use their suggestions for the design. To re-involve the users, we then introduced a tangible example in form of a prototype. Somewhat to our surprise, the participants appreciated the results and recognized the similarities to their existing practices: *"It's pretty much like our WhatsApp group, or that other thing [Telegram]. Everyone gets the same message" (Female10, 63).* The participants even highlighted the reduced efforts compared to the *Sehr Mobil* prototype. *"When I use the other ridesharing app, I have to open the application to get the information. With this app it happens without even having to search for anything directly" (Male1, 81).* Overruling the users in this case resulted in a novel application that, in the end, turned out to be preferred by the users over the concept that we created in the *Sehr Mobil* case, which largely resembled existing tools (Crabtree, 1998; Mogensen, 1994).

It should be stressed that we did not take lightly this decision to counteract the users' preferences; this choice was a response to the experiences of the first DCS, where we had experienced a certain "tunnel vision" on the part of the participants. This issue has been pointed out before with regard to prototyping solutions (Crabtree, 1998; Sol, 1984):

"Prototyping's strength lies in its orientation to future practice and the construction and iterative development of potential applications in (varying degrees of) cooperation with end-users[...]. Prototyping's strength however, is also its weakness: in the iterative construction of potential applications lies the endemic problem of 'tunnel vision' – i.e. the danger of designing perfect technological solutions to wrong problems of work [...]." In the *Sehr Mobil* case, this had led to a situation in which we as designers and our participants iteratively added details and functionality to a prototype that nonetheless was flawed in its basic conceptualization. Only after testing the design in real life did we recognize the flaws in our basic concept. This risk has been pointed out by Mogensen (Mogensen, 1994): *"First of all, prototyping is directed towards the future (potential computer applications) ... Once the process of development of successive prototypes has started, the danger arises that one is led to elaborate the details of the current prototype instead of questioning its underlying premises."*

Yet, from our experience, the issue of questioning the underlying premises is not just an internal "tunnel vision," but is rooted in earlier decisions in the design process and is subject to higher-level aspects, such as economic and political considerations. In our project, for example, switching from the design solution of the first DCS to the solution of the second DCS would have required the project's industry partners to rebuild most of the application, rendering it financially unpromising. Further, although the opportunistic solution was deemed more appropriate by the users, the issue of the solution's scalability rendered it inappropriate from the point of view of funding agencies. The problem of "improving solutions for the worse" instead of starting from scratch (Mogensen, 1994) has been known for decades, but it is of increasing importance considering the advancements in technology, such as advances in machine learning, the introduction of faster and increasingly pervasive ICT infrastructures, and the IoT vision of an ubiquitous network of devices. Hence, the decisions in our first case were also affected by the difficulty of introducing novel technologies that were alien to their prior experiences, such as the possibility of enabling opportunistic cases by proximity detection. This use case, despite its relative simplicity, turned out to be too far away from the lives and experiences of our users to fully grasp, calling for a more targeted investigation in the form of the Opportunistic Ridesharing study.

9.3.2 Shifting and Extending the Problem Space

While the previous section provides an example of how we, as designers, extended the participants' understanding of the design space, there were also several situations in which consideration of the design solutions and existing practices helped us gain a better understanding of what is important for the design. While one can argue that this is the very reason to engage in PD, we found that the interest of the users was mainly limited to working on the problem definition and instead provided feedback on existing design and functionality.

[Researcher 1 sums up a discussion during one of the weekly meetings about how the users want to participate in the design process. We agreed that new solutions should be developed by the project team and discussed with the users]

Researcher 1: […] so you would like to give feedback on the new ideas and steer the development?

Participant 1: …and you would then be able to ask for clarification immediately [as opposed to sending around ideas and mockups via messenger and discussing the design before the weekly meeting]. Or the others in the group. If someone wrote an 'app' [read "message sent via WhatsApp"], and I don't get the idea or you don't get what I sent around. There would be 20 apps [messages] going around. So I would think… I'd prefer the way it is now.

Participant 2: The feedback should be given here! On the other hand I would like to have the chance to look at the new things one or two days in advance [all others agree]. So you can have a look at it, think about it and contribute those thoughts to the discussion. If you just see the new things here for the first time, you need to give yourself some time to think about it. But not every small change has to be presented.

This discussion happened about 18 months into the three-year project. It illustrates how the participants wanted to be involved in the process. They preferred to just critique suggestions ("But not every small change has to be presented"), yet demanded transparency in the design process. They requested information about new things in advance to be able to relate to these changes and potentially drop them and readjust the focus of development. Due to this demand for control, the future imagination approach turned out to be very difficult and closely coupled to a design space that was shaped by existing, and in many ways inefficient, solutions. The retrospective approach turned out to be more fruitful, yet also more limited in terms of the involvement and creativity of the users. They were free to criticize the proposed solutions and designs, but we often overruled users in our attempts to open the design space and push for solutions that were too abstract and complex for our users to grasp easily.

In the second case, our attempts to empower participants took a different approach, focusing on enabling meaningful critique of technical capabilities, which also required an imagination of futures, but with a narrow problem space. Our goal was to broaden the design space by confronting the participants with new ideas. While the approach allowed us to explore and extend the design space with new concepts for the given problem, this approach clearly prevented the users from reframing or extending the actual problem. The *Sehr Mobil* process, in this sense, presented the opposite situation. The design space was narrowed down to knowledge about existing solutions. In this case, the users provided more input regarding the problem definition, introducing more details to be considered. For example, during the process of understanding how users decide when they want to use ridesharing, the discussion extended to the question of what triggers them to look for transportation options in the first place. It turned out that transportation is not only a logistical act, but is bound to an event or an activity. Focusing on support for the activity that necessitates the travel helped us broaden our view regarding the information we need to provide within the design solution to perform an activity such as running errands. In the *Sehr Mobil* prototype, this understanding resulted (among other things (Stein et al., 2017)) in the integration of a public event calendar, which turned out to be one of the most prominent features of the platform, as it provided incentives to look for alternative transportation opportunities, including shared rides.

This broadening of the problem space, on the other hand, might well have contributed to the initially unsuitable design of the ridesharing support in the prototype. Subsequently, due to this blurry problem definition, the second DCS started by clearly framing the problem space. One could argue that taking the users out of the loop regarding design activities and instead having them critique design alternatives, as suggested e.g. by (Vines et al., 2012), conflicts with certain premises of PD (e.g. users altering the design (Muller, 1991)). However, we would argue that the effects are rather the effect of a changed process of mutual learning resulting from the increasing complexity of both the problem space and the design space, and therefore calling for new methods and a potential re-conceptualization of what PD approaches intend. The experiences we gained are thus related to the ramifications of this increasing complexity resulting from deeper penetration of technology into everyday life.

9.4 Methodological Implications

Ultimately, the issues outlined above highlight how the problem space and design space cannot be separated and strongly interact with each other. The complexity of technologies that makes design spaces harder to oversee stems from, and at same time fosters, the blurring of borders in various spheres of life. For example, within the project our interest was to establish ridesharing as a new option in addition to currently used means of transportation. Based on this understanding, our participants reflected on and discussed the issues of ridesharing in various situations, and the social dynamics when riding with strangers, revealing information about sensitive destinations as well as issues of reciprocity and exploitation (Meurer, Stein, Randall, et al., 2014). Not only do these questions have implications in very different spheres of life, but they must be settled in different arenas (Gärtner & Wagner, 1996). While one could resolve issues of privacy and sharing of control through technology, by leaving it to the users themselves, questions such as sanctioning "freeloaders" (e.g. by introducing payment, ratings, or similar features) must be resolved by the community or the society, as underlined by the very diverse participant opinions regarding this topic. As a researcher and PD practitioner one must be sensitive about the arenas in which PD projects operate and in which PD methods are to be applied (i.e. the need to engage with ethical issues of design (Liegl et al., 2016)).

In line with Bødker et al. (S. Bødker & Iversen, 2002), we therefore argue for a staged, professionalized PD process. Particularly with regard the basis for empowering the intended users, the process of mutual learning (Béguin, 2003; Bjerknes & Bratteteig, 1995; S. Bødker et al., 1988; S. Bødker & Grønbæk, 1991; Greenbaum & Kyng, 1991; Kyng et al., 1987; Muller, 2003; Robertson et al., 2014) that is often considered a means to engage users in design activities in order to conceptualize future technologies and/or practices (Greenbaum & Kyng, 1991; Simonsen & Robertson, 2012) must be reconsidered as a central source of innovation (Robertson et al., 2014). Thus, while a third space (Muller, 2003), a space of shared understanding (Gregory, 2003) in which users and designers operate as equal partners in the design process, is vital to the creation of the design, the steps to create mutual understanding and reveal the "asymmetry of knowledge" (Fischer, 2000; Fowles, 2000) represent the key sources of innovation. The disturbance of both the designer representing the design space and the user representing the problem space, thus, is part of this staged process and must be systematized. We therefore see the evolution of PD very much in line with "*the turn to practice"* in HCI (Kuutti & Bannon, 2014), whose uptake we understand as acknowledgment of this complexity. In keeping with these arguments PD then is aiming at the design of practices which *"are contingent, mediated and cannot be understood without reference to the particular place, time and concrete historical context where they occur, they can only be studied 'close-up.' This is in a sharp contrast with many social science approaches that take isolated features of human behavior and study them at a distance, through modeling and generalization*" (Kuutti & Bannon, 2014). PD, in this sense, is a long-term commitment and, like practice-based research, is a "*labor-intense, risky, and long-term research approach […] one needs to build trustful cooperation with practitioners and their management. A considerable part of the research efforts are dedicated to satisfy the practitioners' problems which are not always academically interesting*" (Wulf et al., 2011). PD may also be understood as in line with the initial design goals stemming from the interests of the different stakeholders (Dachtera et al., 2014; Gärtner & Wagner, 1996).

Thus, as a first step to systematize the process, Figure 31 attempts to visualize the strategies of "future imagination" and "retrospective innovation" mapped onto the dimensions of the complexity of the problem and the design space. It shows the different directions that our two approaches took and highlights their strengths and weaknesses: future imagination, in our experience, is more helpful when exploring the problem space (in our case extending ridesharing to new situations). Retrospective innovation, on the other hand, in our case was a means to explore the design space for a narrow problem (easing ridesharing within the existing practice).

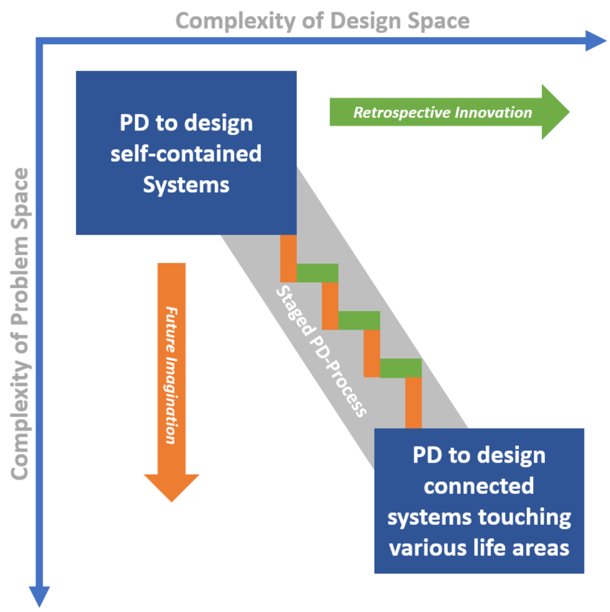

Figure 31: Retrospective Innovation and Future Imagination as different strategies in PD

While the retrospective innovation approach turned out to be more successful in our case when working with elderly people, we do not claim that it is generally the more successful strategy. One must carefully consider the preconditions of the process, such as users' expertise with the design space and the researcher's interests (understanding the problem and/or finding suitable designs), and this may lead to different decisions when defining the role of the users. However, with technology becoming increasingly ubiquitous, more complex, context-spanning and potentially disruptive, the skills and knowledge that are required for participating in PD projects are increasing for participants and researchers alike. Thus, the degree of technological complexity that we bring into the lives of users is one aspect that requires staging. The vision of the IoT, combined with approaches from ubiquitous and pervasive computing, leads to a situation where we are no longer dealing with systems as much as we are thinking about designing of, for, and with systems of systems (Liegl et al., 2016).

To fully achieve this, it will be necessary to overcome the inherent limitations of approaches such as those we followed in our project, and think about the possibilities for meaningfully engaging users in very complex problem and design spaces. From this point of view, using critique as a design resource (Vines et al., 2012) could be understood as one way to initiate a staged exploration of the design space. With regard to the problem space, a fruitful tool that has recently become popular is the use of design fictions, which make it possible to span arenas easily, focusing on higher-level and long-term aspects of new technologies instead of technical features in the short term. At the same time, they make it easy to reduce the technical overhead, helping shift the focus from the development to the contextualization of technologies (Blythe, 2014; Linehan et al., 2014). As we experienced, this is becoming more and more important. Perhaps the recent proliferation of design fictions is a result of the same challenges that we faced in our projects. We believe they can help a great deal in providing perspective and lowering barriers for users to become involved in PD activities and thereby help systematize the PD process.

10 Conclusion

Recent years have changed how we think about mobility. As we saw in the Introduction, many factors have contributed to a shift in the number of trips people take and the length of these trips (Handke & Jonuschat, 2012). Thus, we see that resource constraints influence our ability to create transport infrastructures that are financially, environmentally, and socially sustainable. Usage of non-individual transportation systems depends on the availability of information. Advances in ICTs have the potential to change access to information, enabling systems to provide more and better information related to transportation infrastructures.

For specific user groups such as the elderly, these changes pose both challenges and opportunities. Elderly people are often in a state of transition in terms of changing needs and capabilities. Particularly with regard to technological advancements, it is necessary to take into account the specific requirements of this growing target group. By 2025, the number of older Americans will have more than doubled, so that nearly every fourth person will be over the age of 65. In Europe, China, and Japan this effect will be even more dramatic, because migration is not as high as in the US. All but the most fortunate senior citizens will be confronted with an array of medical and other constraints on their mobility, even as they continue to seek an active community life (Mollenkopf et al., 2005). Many older adults drive but still face mobility barriers or suffer from physical and medical problems (Rosenbloom, 2004). Furthermore, a large number of elderly people live in regions that are underserved by public transportation infrastructure (Mollenkopf et al., 2005), although this serves as a substitute for the private car in many cases (Fobker & Grotz, 2006). Even if mobility services are well established, access to information on where and when to use them can be made difficult by a lack of experience with ICT-based tools that often represent the only means of access to certain services. Regarding this issue, debates on providing mobility for the elderly in gerontology, transport studies, health research, and urban studies do not always capture the complexity of the situation.

10.1 Summary

In this work, we propose a practice-oriented approach to address this complexity from the elderly's point of view. We presented three different design case studies, each of which builds upon the results of a context study of participatory co-design of ICT-based tools to support mobility. These tools were evaluated by studying their appropriation (in case of DCSs 1 and 2) and validating their technological concept (DCS 3).

DCS 1 presents the most extensive study, especially in terms of the empirical efforts. The context study emphasized a focus on the user's intended activity (which, in many cases, constituted the performance of everyday life practices) instead of purely logistical, mode-related information provision. We developed a multimodal transportation information system that integrated further non-logistical information such as information on public events or POIs and allowed users to adjust the system to individual, partly age-related needs (stating that one needs help, e.g. to enter a car due to a walker). However, the design generally followed wellbeing-oriented approaches, providing support to stay independent and preserve decisional autonomy. By studying the appropriation of the prototype, we were able to identify the importance of context-specific, personally relevant information that users employ to assess the suitability of transportation opportunities and information that provide incentives to explore alternative, potentially helpful modes of transportation in the case of specific practices. In particular, it turned out that the use of different means of transportation is highly routinized in the context of the framing practice. Disturbing these routines necessitates an understanding of the situations in which each different transport mode provides a suitable alternative.

DCS 2 built upon the results of DCS 1 and focused on the challenge of integrating ridesharing, and specifically on existing ridesharing situations, in order to understand the specific circumstances that facilitate ridesharing. By revisiting and extending the interview data, we identified (current or regular) physical proximity and co-presence as important conditions that facilitate engagement in ridesharing. The study thus revealed the supplementary nature of ridesharing in the everyday life of our participants, a fact neglected by existing ridesharing tools. By providing technological means to create awareness about nearby ridesharing opportunities, thereby making others addressable, the prototype we developed help to overcome civil inattention in public spaces and allowed the participants to leverage existing procedures and tools to deal with subtle social issues of trust, reciprocity etc., which have been highlighted as challenges in the related work on ridesharing support.

DCS 3 included the technological exploration and validation of an opportunistic ridesharing concept based on continuous location monitoring. Based on a literature review and consideration of the findings from DCSs 1 and 2, we identified unresolved technological challenges. We presented a prototype based on passive location monitoring and local data analysis that resolved the issues of "practical feasibility of continuous location monitoring," "location privacy," and "meaning data collection and enrichment" in the case of ridesharing. The concept we addressed supported the subtle social negotiations that are necessary for successful ridesharing arrangements, allowed it to be integrated with existing daily routines, and hampered the commercial exploitation of tools building on voluntarism.

These three DCS helped us to answer the research question presented in the beginning of this work:

What informational needs need to be considered to support everyday mobility of older adults that can be addressed by information and communication technology especially focusing on the adoption of unfamiliar mobility options?

Understanding the research involved in all three DCSs as a coherent process, we showed how the practice orientation and the selected paradigmatic and theoretical assumptions provide helpful means to illuminate specific aspects of our empirical data, which in turn reframed the design problem of support for mobility. At the beginning of this process we identified the breadth and complexity of everyday mobility.

Regarding the first part of the research question, we found that the informational needs for everyday transportation are highly dependent on the current activity, the transportation option at hand and individual to the person and his/ her experiences. The first DCS showed that there is especially a need to integrate logistical and non-logistical information to facilitate the adoption of unfamiliar transportation opportunities. As an exemplary case, we looked more closely at ridesharing to answer the second part of the question how ICT can help to adopt ridesharing on a daily basis. By narrowing the problem and we were able provide to conceptualize and validate a new concept for ridesharing that addresses shortcomings of current solutions. While we consequently oriented our research and design approach towards participatory design, we also followed different approaches of user involvement in DCS 1 as opposed to DCSs 2 and 3. We discussed "future imagination" approaches and "retrospective design" approaches with regard to their potentials for understanding and framing the problem space and exploring the design space.

10.2 Relevance of Findings, Transferability, and Future Work

The results of this work, in the first instance, present a comprehensive study of older adults' mobility routines in (semi-) rural areas in Germany. However, since several of our arguments are in line with related work in gerontology, transportation, and mobility research, as well as in HCI, we believe that they present a promising first step and potentially hold true for other user groups, regions, and transport modes. Specifically with regard to other commercial developments that happened during or after our studies, our empirical insights allow us to "ground" (Rohde et al., 2016) design advancements in tools such as Google Services and Foursquare. These services introduced background monitoring of locations to provide users with nearby opportunities (Foursquare) or, by learning from past behavior, provided subtle, automatically retrieved information, e.g. about traffic (Google Maps/Google Now). Further, a stronger orientation towards certain activities within tools such as Google Maps (see Figure 32) can be grounded in the activity orientation that we found to be crucial within the everyday day lives of participants.

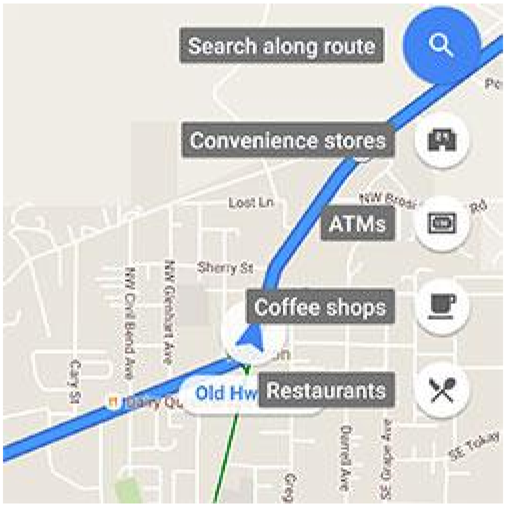

Figure 32: Example of recently introduced Google Maps feature of "Searching along routes"

Nevertheless, the aim of this work was not to prove a hypothesis or concepts on a general level, but rather to explore alternative transportation support concepts for the elderly that can inform the design of ICT-based tools. While we believe that in future work it might be fruitful to explore other user groups and regions to validate our findings for different contexts, we especially want to emphasize that the designed prototypes can be understood as a means to transfer design concepts to other areas (Zimmerman et al., 2007). In particular, if these IT-artifacts are appropriated in unconsidered contexts and for unintended tasks, the results of this study might transfer to areas and applications that have yet to be anticipated. The appropriation of such tools in different contexts allows researchers to address “wicked problems” (H. W. Rittel & Webber, 1973) and, by comparing these different cases, develop a more profound understanding of the phenomena at hand.

11 References

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