Personal Decision Support Through Mobile Computing

Reinhard Kronsteiner Wieland Schwinger
Department of Telecooperation, Johannes Kepler University Linz
{reinhard.kronsteiner | wieland.schwinger}@jku.ac.at

Abstract

Mobile computing technology offers the basis to leverage decision support beyond web-based decision support paving the way for next generation of personal decision support. As an instance of a personal decision support case a personal buying decision is analysed in detail. Prerequisite mobility criteria comprising temporal, spatial and media uncertainty and the requirements on information, communication and coordination are presented. After discussing the mobility potential for each of the buying decision process' phases the potential for being supported by mobile computing technology is discussed identifying future challenges in personal decision support.

1. Introduction

Decision support systems have already a very long tradition in management science stemming back to the late 1960s e.g. [10]. Constantly developing over the decades such systems are now designed to assist a decision maker from strategic to operational business decisions, from political group decisions to personal life decisions. Examples are Management Informations Systems (MIS) [29], Executive Information Systems (EIS) [27], Knowledge-based Systems [15], Online Analytical Processing (OLAP) [cf. 24, 1], Business Intelligence (BI) [cf. 20] just to mention a few. Whereas the first decision support systems have been monolithic the second generation was predominated by client server applications. With the rise of the Web most of the systems have been undergoing a sweeping transformation from traditional client server applications to *Web-based decision support systems* overcoming the obstacle of system boundaries and availability [cf. 26, 2].

The advent of mobile computing promises a revolution comparable dramatic as the one of the web. Mobile communication technology enables the decision maker to get support not limited to the office space but also directly at the location where the decision is up to be made. Thus forming the next, *mobile generation of decision support systems*.

Mobile decision support systems will shift in focus due to essential differences in available communication infrastructure and computational power. Computational and data intensive decision support systems like Data Mining [cf. 1] will not be a first hand application domain for mobile computing. In contrary to the work of Maes et. al. [18], which focuses on the role of agent support in the buying behaviour model, we concentrate on the mobility support of decision issues in the buying process. Thus, rather than porting traditional decision support applications to mobile computing technology we expect that mobile computing technology - not least since mobile devices are more and more acting as personal trusted devices [33] - will enable new personal decision support.

In this paper we investigate how personal decision as a buying decision can be supported by mobile computing technology. In Chapter 2 the general problem of personal buying decisions is discussed as a motivating scenario. Chapter 3 presents mobility analysis on basis of mobility criteria applied in a phase-wise analysis of the personal buying decision. Mobile computing support enabling personal decision support is discussed in Chapter 4. Chapter 5 concludes with an outlook pointing towards relevant challenges to address in future research.

2. Personal Buying Decision

The following scenario sketches the motivation behind our research and is discussing the potential for supporting the customer by mobile computing.

Consider Annie is strolling down the main shopping street passing a photo store. The shop window offers various digital photo camera models differing in the features and last but not least in price. Before being able to decide on a certain model it is important to learn what the offered features are and their importance for Annie. Comparing the models is difficult since the given information for the cameras do not match (different cameras offer different features). Assistance is offered by the sales assistant but she also wants to solicit suggestions sources she trusts. Given the fact that certain criteria are more important to her than others she elects a model which easily fits into her pocket rather than a larger model which would promise better picture quality and buys it. Not before extensive usage she discovers that better picture quality should have been more important in her decision which she wants to remember for the future.

The considered scenario describing the decision for buying a digital photo camera was chosen because it has a lot of peculiarities:

- spontaneous decision
- high buying risk (high price, quality differences between products)
- mid-term investment (you don't buy a camera every day)
- high price differences between different shops
- technical difficulty (many characteristics to consider)
- short innovation cycles

2.1. Personal Buying Decision Process

Although different phase models of the buying process exist, mostly they share similarities [16]. For our purpose we suppose a decision process comprising a 6 phases: problem perception, information seeking, information processing alternative evaluation, decision and buying act, and finally the decision evaluation phase.

Problem Perception: Decisions start with the perception of the decision problem. The perception is initiated by a communicated need. The perception of the decision problem can be initiated internally or externally. Internally initiated decisions base on a personal need whereas an example of an externally initiated decision problem is the perception of an attractive offer. A part of the problem perception is the structuring and specification of the problem along with the attempt to formalize requirements on the decision in form of decision domain specific criteria. Result of this process phase is the (mostly incomplete) specification of the problem. In our scenario the problem perception is initiated externally by advertisement information perceived while walking through the city. The decision domain is “buying a digital camera”. Examples of criteria identified are price and the specification of an optical zoom which derives from the advertisement information.

Information Seeking: Information seeking starts from the problem specification but also effects the prior phase in that new decision problems may occur. The customer searches for relevant alternative solutions for her/his problem and tries to attribute solutions according to already identified evaluation criteria. The found information has implications on the criteria and also increases sensibility in problem perception. Also noted informal information like the haptic impression are important criteria. Not only product information are relevant but also the accompanying conditions like support quality. During this phase the customer in our scenario tries to find where in her surroundings she can find a digital camera that meets her very early requirements. Information is collected by scanning electronic and photo equipment stores looking for available products. Additionally, more information may be gained by reading specialised magazines, browsing dedicated web sites and calling some friends asking for advice.

Information Processing: The information collected in the previous phase needs to be organized in a homogeneous form to serve the ensuing evaluation phase. For this the decision criteria are related to each other and the information is categorized according to these criteria. The customer decides which of the attributes are most relevant, nice to have or unimportant. Formal as well as semantic checks allow to identify missing or false information. An example for a formal check is the validity of information (e.g. used metrics). In the scenario considering the information found, the decision problem is restructured. Knowing about available information on various models of digital cameras one can identify a basic set of criteria that influence the decision.

Alternative Evaluation: During this phase the alternatives are compared and valued according to the identified criteria. If more than one model fits his/her requirements the remaining alternatives are brought into an order by being rated and ranked according to the fulfillment of the identified criteria. Thus the result of the alternative evaluation process a list of suggested alternatives. In our scenario the comparison of available digital cameras is conducted along criteria selected in an ad-hoc manner which are enriched by visual and haptic impression.

Decision and Buying Act: Based on the evaluation of the alternatives the customer may decide to go for one of the alternatives. The buying act is initiated with negotiation about details (mostly the price). Usually this is also accompanied with detailed information about the product and a last attempt of the salesman to extend the business on other goods. The result of the buying act is a contract over a product and the initiation of financial transactions. In our scenario the camera is directly bought in the store.

Decision Evaluation. Decision evaluation is important to learn from past decisions and so be able to improve decision performance (faster decisions with higher consumer satisfaction) in the future. The evaluation may comprise on the one hand an evaluation of the decision's outcome (i.e. the product) and on the other hand on the decision process itself (i.e. the underlying criteria leading to a decision). This can result in a reconfiguration of decision criteria and therefore different decisions in the future. Experiences gained with the product may also be exchanged bilaterally. In the scenario envisioned important features and limitations which shall be considered next time are not discovered until practical use.

3. Mobility Analysis

Goal of the mobility analysis is the identification of mobility potential in a specific scenario. The analysis shall show to what extent each phase can be supported by mobile computing regarding our criteria.

3.1. Criteria

As a prerequisite for identifying the potential for mobile computing support like in [11] a set of criteria[1] are identified which are applied later on in the analysis of the mobility potential. We apply research on the categorisation of group-ware systems to mobile decision support. The chosen criteria fall into two groups: The first group focuses the dimension of *distribution and uncertainty of the process* comprising distribution in time, space and media relating to [7]. The second group focuses on *task specific requirements* for electronic decision support systems comprising *information, communication, and coordination* applying the ideas of [30].

Distribution and uncertainty of the decision process:

- *Time (T)* is an important aspect since decision processes may be spread over time or be conducted in parallel requiring *synchronization* at later points in time. *Spontaneous* user interaction also implies time constraints like for example maximum time until a task has to be completed. Spontaneous user interaction implies *temporal uncertainty* and thus flexibility within the decision process. Both time synchrony and temporal flexibility can be supported by mobile computing means since flexible process control and maintenance of task dependencies can be enforced.

- *Spatial distribution* (S) refers to both the *physical distribution of artifacts* in the real world as well as the *virtual distribution of information* both required for the process. Physical distribution can be overcome by bringing the computational support to the actual location of the physical artefacts. Virtual distribution is relaxed by telecommunication support enabling electronic access to distributed information sources and services on basis of wireless communication technology.

- *Media break* (M) refers to the fact that underlying media changes (e.g. from paper material to electronic data) during the process, such changes between media, are very often the reasons of errors introduced into the process. Furthermore, changing the media requires additional resources due to unnecessary duplications. Eliminating media brakes with consequent use of electronic support increases quality and efficiency of the decision process.

Task specific requirements:

- *Information (I):* Two factors indicate a need for mobile computing support with respect to information: i) *quantity of information* and ii) *complexity of information*. As the amount of information, at the place where a decision occurs, increases it may become more and more difficult for humans to process and store this information without adequate mobile computing support offering already today huge amount of storage capability. The same holds as information gets more complex in structure as well as in manipulation. Mobile computing can assist the user through programs processing information on the user's behalf. The quantity of information demands capabilities for efficient information capturing, storing and processing. The complexity of information requires flexible structuring and derivation mechanisms of information.

- *Communication (Cm):* Interaction with partners in a process implies the need for communication to transfer and exchange information. Communication effort increases as the *number and type of communication partners* increases and the *communication means vary*. Mobile communication means as wireless communication and ad-hoc networking empower the user to conduct communication with multiple partners more efficiently by maintaining the required communication flexibility.

1 The letters in parenthesis after the criteria are the references used in the subsequent mobility potential analyses step.

- *Coordination (Cr):* Processes including more than one actor sharing resources or artefacts will require coordination. Coordination effort increases dramatically as the *number of participating actors* increases. Additionally, coordination effort increases dramatically as the *process flexibility* increases. Mobile computing empowers actors to efficiently coordinate with multiple partners while cooping with flexibility in terms of scheduling, resource management, and protocols.

3.2. Mobility Potential

In general *mobility potential* of a phase refers to the phase's potential of being supporting by mobile computing technology. A process phase's individual mobility potential is determined by the set of impacts of the mobility criteria, as outlined above, for that particular phase:

Problem perception: The customer is continuously confronted with commercial offers by various means like shopping windows, flyers, public displays drawing the customers' attention towards these offers (M). Consequently, problem perception (i.e. the occurrence of a buying decision) is not limited in terms of time (T) or place (S). A large variety of diversely structured information from various information sources makes sorting out appealing offers a complex task (I). The number of potential process-partners (i.e. potential customers looking for offers as well as salesmen trying to get into contact with many customers to increase sales) implies high communication effort (Cm). Although more than one process-partners are involved little coordination need occurs since they are not sharing resources or collaborating in this phase (Cr).

Information seeking: Given the high information demand of different information sources like: product catalogues, branch specific magazines, product review Web sites etc. but also informal and unstructured information like hands-on experience (M) will be consulted. Most of time information is required instantaneously (T) from physically and virtual sources that are spatially distributed (S). The information sought for comprises collection of alternative products as well as evaluation criteria which can both be given explicitly or need to be derived from other given information and may be incomplete (I). Communication for retrieving the information in an iterative process until the necessary level of detail is obtained, which is limited due to the customer's abilities of transferring information and communicates only to one information provider at a time (Cm). Coordination demand is solely relevant with respect to ensuring smooth communication if more partners are involved (Cr).

Information processing: Supposing that dealing with various media sources is resolved while collecting information, media distribution is no longer an issue (M). Also temporal (T) and spatial distribution (S) is not occurring. Homogenizing and formal as well as semantic checks can be conducted with mobile computing support automatically upon the information. Also the very complex process of bringing miscellaneous information in a comparable state requires electronic support (I). In contrary, no mobility potential can be identified since communication (Cm) and coordination (Cr) does not occur in this phase since this phase is solely a task of the customer.

Alternative Evaluation: Since alternative evaluation has no external interfaces no temporal, spatial, or media distribution occurs (T,S,M). Most of the time the evaluation will be conducted on basis of detailed information about the products properties. Additional complexity is added by regarding the interdependent evaluation criteria (I). Because the evaluation is done by the customer there is no need for communication (Cm) and coordination (Cr). Mobile computing can facilitate the user to handle the large amount of information at the moment anywhere a decision occurs.

Decision and buying act: Deciding for a specific alternative again is not distributed in contrary the buying act directly following the decision includes temporal, spatial and media distribution (T, S, M) within the transactions with process partners. The information complexity can be high in terms of

transaction accompanying sub contracts (I). The coordination and communication demand is high to ensure the success of the transaction in conjunction with the participating process partners like bank, clearing institution, credit card firm (Cr, Cm). Mobile computing can help to overcome the process distribution by supporting communication and automating transactions.

Decision evaluation: The evaluation of a decision needs to be conducted whenever experience occurs thus recognizing the decisions effects. Especially for capturing experience and populate them into the set of criteria for future decisions needs to be facilitated anywhere (S) and any time (T). Those insights are not least due to the diverse usage situation memorized in various forms (M) or in the worst case abandoned since no appropriate mnemonic means is available at all. Furthermore, not only product features need to be evaluated but also the criteria underlying the decision increasing information complexity (I). The communication effort will increase when the evaluation result needs to be shared with others (e.g. review forum) and so making them available for other customers in comparable decision situation (Cm). The sub-process of decision evaluation includes no external process partners which avoids coordination effort (Cr). The capturing of evaluation experiences can be supported due to the anytime, anywhere availability of supporting technology enabling to record evaluation in pre-structured from for future decision directly.

Mobility Criteria / Phase	Distribution and uncertainty			Task Specific		
	Time	Space	Media	Information	Communication	Coordination
Problem perception	✓	✓	✓	✓	✓	✗
Information seeking	✓	✓	✓	✓	✓	✓
Information processing	✗	✗	✗	✓	✗	✗
Alternative evaluation	✗	✗	✗	✓	✗	✗
Decision and buying act	✓	✓	✓	✓	✓	✓
Decision evaluation	✗	✗	✗	✓	✓	✗

Table 1: Mobility potential analysis summary

Table 1 summarises the mobility potential analysis showing that all phases offer mobility support potential. All phases can be supported by mobile computing with respect to information. Additionally a strong need for mobility support is identifiable due to distribution and uncertainness in time, space and media. Although individual steps show less mobility potential we argue that to guarantee a seamless support of the decision process also their mobility potential shall be regarded in the subsequent step.

4. Mobile Computing Support for Personal Buying Decisions

Given the mobility potential identified in the previous section the support of mobile computing for the personal buy decision is discussed in the following:

Problem Perception. Mobile computing offers the customer to utilize a *new electronic distribution channel* and thus to receive offers electronically from surrounding shops while walking around. Although it is questionable whether the electronic form will fully replace the traditional advertisement forms it nevertheless a very powerful distribution media since it facilitates the mobile device to act as central nexus bridging formally distributed media (M). The issue of spatial and temporal distribution is also relaxed by combining ad-hoc connection (with short time connection to surrounding networks) with infrastructure-based connection facilities (allowing always on connectivity) (T, S). Given the scenario above identifying shops in the near surrounding is important. It can be provided by current positioning technology like Global Positioning System (GPS) [5] which is commercially available on the consumer market, accurate and subject to standardized usage ([22]) but indoor tracking falls behind. Although prototypical realizations exists [32, 28] they lack of availability and standardization.

Regarding mobile technology the customer is empowered to no longer act just as plain passive information receiver being sent advertisements of surrounding shops but to act actively. Advertisements received on the mobile device the customer can be *filtered* accepting only information which are in the wider scope of the customer's interest. By preconfiguring the device with a watch-list for particular decision problems (products) this capability can be even extended towards actively seeking for offers within the customer's interest (I). Many traditional advertisement channels like posters, shopping windows etc. allow - although limited in range - the seller to communicate with more than one customer. In contrary customers are limited in the number of information to take up. Mobile technology relaxes this limitation as it allows to establish communication between sellers and numerous customers but most important to empower the customer to communicate with many sellers simultaneously in terms of mass sendings or mass queries respectively (Cm).

Information Seeking. Likewise the previous phase mobile computing also offers a new channel for seeking information. Most of the time information seeking requires information instantaneously (T). Information seeking benefits most from mobile computing support since it enables to utilize virtually as well as physically spatially distributed sources (S) like the rich sources of the world wide web. Since also many information sources are electronically available [cf. 31] or can be provided electronically through e-commerce standards like [8] mobile computing can overcome the media break (M) at the place the decision occurs. Although standards for electronic business and information exchange exist, they are mainly dedicated to business to business scenarios [3]. Most importantly they are not trimmed towards the restricted communication and computation capabilities of mobile devices. Specialized m-commerce business and information exchange standards need to take these restriction into account and be adopted by the industry. Although information like haptic impressions can hardly be captured electronically it can be regarded by manual input facilities. Information seeking is assisted by mobile computing since it allows to collect large amount of detailed information in as systematic way (I). Complexity can be handled by mobile computing involving product ontologies [21, 34]. Mobile computing hosting personal agents [cf. 9, 12] allow to automate the communication with multiple information sources simultaneously and to speed-up information retrieval, relaxing the user from the tedious task of manually seeking for information (Cm). This can be provided together with additional product information and customer experience reports by trusted instances e.g. in form of Web-services. Given the coverage of global network infrastructure, communication with other customers is already enabled via various messaging capabilities like email, IRC, ICQ, BBS, etc. Nevertheless it is necessary to provide direct interfacing with the decision support system to seamlessly integrate the collected information into the decision process. Coordination as far as necessary can be addressed at a technical level by corresponding communication protocols (Cr).

Information processing. The main support task for mobile computing in this phase lies in assisting the filtering, clustering and homogenizing the information at the time and place needed (T, S). Various web data extraction tools [17] can assist the customer to (semi-)automatically extract relevant information [23]. Additional advanced filtering mechanisms can furthermore reduce the information insomuch that the amount of information is both suitable for the customers' decision as well as compliant with the limitations of mobile computing devices. Based on ontologies information can be clustered and related to each other and to transform them into decision relevant criteria. Furthermore this enables to conduct certain formal and semantic checks automatically. Also the very complex process of bringing miscellaneous information in a comparable state, e.g. common denominator, can be supported by mobile computing through value transformation (I) although this might require manual intervention by the customer.

Alternative Evaluation. Mobile computing can increase decision making quality, allowing to perform evaluation not feasible in the scenario due to limited human capabilities. First of all automated ranking of alternatives based on the given criteria tree can be proposed to the customer. The customer gets information about the rational criteria underlying a certain alternative ranking visualized graphically. She is endowed to analyse the evaluation by digging into evaluation details. Furthermore, customers can easily perform what-if analysis for example by re-weighting evaluation criteria to understand even better the underlying influence of criteria. Although not all information can be evaluated automatically it will provide the customer with a solid decision base (I). A pre-requisite are standardized or pre-configured domain dependent decision criteria-tree to increase the acceptance for personal decision support systems by reducing the customer's configuration effort.

Decision and Buying Act. The alternative selection shall not be automated leaving the customer in control. Mobile computing support lies primarily in the support of enabling the customer to take the decision whenever ready to and the connection to other phases of the decision process. In contrary the buying act itself that includes temporal, spatial and media distribution (T,S,M). This transaction with process partners can be supported by existing e-commerce services whereas the challenge lies in the integration in a consistent interaction model [14] (I,Cm). Mobile computing support can trigger financial transactions in terms of existing mobile banking services like [25]. Agents can be utilized on behalf of the customer to automatically perform (plan based) transactions between customer and salesman. This includes automatic negotiating mechanisms and proactive acting in buying situations (Cr).

Decision evaluation. Decision evaluation can be supported during practical usage in that certain features are re-evaluated during practical usage at any place and time. Mobile computing allows to revisit the decision process and thus to easily cope with both the product features and underlying criteria (I). This experiences captured electronically can be utilized in a subsequent decision since kept in the personal electronic memory (M). Communication of decision evaluation results can be facilitated by distributed experiences to multiple external sources automatically like e.g. in a customer forum of a specific manufacturer (Cm).

mobility criteria / *Phase*	Distribution and uncertainty			Task specific		
	Time	*Space*	*Media*	*Information*	*Communication*	*Coordination*
Problem perception	ad-hoc connection	location awareness	central nexus	filtering	mass sending mass queries	✗
Information seeking	instant information	global resources	ecommerce standards	systematic capturing, ontologies, trusted instances	autonomous agents, alobal infrastructure	seamless DSS integration
Information processing	permanent filtering clustering homogenizing	mobile filtering clustering homogenizing	✗	learning filters, Web data extraction, semantic checks, value transformation	✗	✗
Alternative evaluation	✗	✗	✗	visualization, what-if analysis, ad-hoc ranking	✗	✗
Decision and buying act	ad-hoc decision	mobile decision	consistent interaction mode	ecommerce standards	ecommerce standards	plan based transactions
Decision evaluation	✗	✗	electronic experience capturing	revisit decision process	experience sharing	✗

Table 2: Technology support summary

Table 2 summarises the technology support offered by mobile computing for the various phases of the personal buy decision process.

5. Conclusion and Future Challenges

Mobile computing promises a new generation of personal decision support systems. In this study the potential of a buy decision process is analysed on basis of a set of mobility criteria. These criteria comprise on the one hand the distribution and uncertainty of the decision process in terms of time, space and media. On the other hand information, communication and coordination requirements are considered. For the analysis of the mobility potential the phases of the buy decision process spanning form problem perception, information seeking, information processing, alternative evaluation,

decision and buy act and finally decision evaluation are considered. The analysis shows the mobile potential is mostly given because of the information processed and the distribution and uncertainty of the decision process. As a consequence this paper discusses how the personal buy decision can be supported technically by mobile computing technology.

It can be identified, that the challenges to support personal buying decision comprises beside technical issues also organisational ones, that are critical for the success of personal decision support systems:

- **Location awareness** needs to be extended beyond existing positioning techniques to allow fine grained location-based services also in in-door scenarios, supporting identification of physical closeness, navigation, and coordination.
- **Usability** of mobile technology and applications is of paramount importance to increase acceptance by reducing interaction effort [13]. Currently mobile computing devices still falls short in as not delivering enough freedom in interaction e.g. multi-modality and better integration with the user's every day behaviour. Disappearing device initiatives [6] connected permanently with ubiquitous computing environment and multi-modal interface research efforts [19] promise improvement.
- **Domain dependent decision criteria-trees** based on ontologies are lacking to increase the acceptance for personal decision support systems by reducing the customer's configuration effort. These could be provided together with additional product information and customer experience reports by trusted instances e.g. in form of Web-services.
- **Information retrieval mechanisms** must be optimized for mobile devices, to process the large amount of ingoing information, as shown in our scenario.
- **Critical mass of participants** are needed to guarantee the availability of sufficient spectrum and amount of offers and participating shops. Not given the critical mass of participants customer's will not utilize the new possibilities offered by mobile computing technology.
- **M-commerce protocols** are needed which are agreed by a large community of participants.
- **Privacy and security mechanisms** are needed to protect the customer [4]. Trusted instances can take into account the security and privacy needs of customers and protect the customers against spamming and misinformation.

Although technology developments have paved they way for next generation personal decision support the the successfulness of it will be determined by interplay of technology and organisational basis in real world application scenarios we are going to investigate in the future.

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