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ENHANCING THE ACCENTUATED FACTOR FRAMEWORK: DEPENDENCIES BETWEEN FACTORS

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Abstract

Handheld computing and mobile information systems are continuously breaking new ground, with an increased importance for business. However, there is evidence that we still have lessons to learn concerning the design of handheld information systems. Handheld information system poses challenges to the designer in the unique properties of handheld technologies and the conditions of use of handheld technologies. Hence, this paper is based on the assumption that handheld information systems has unique properties, and dependencies between properties, that should to be considered in the design of such a system in order to design appropriate information systems for the mobile workforce. The purpose in this paper is to further enhance the usefulness of the Accentuated Factor Framework by describing dependencies between factors in the framework and by this enhance the efficacy in the design process. The theoretical foundation for the paper is the Accentuated Factor Framework, illustrating the unique properties of handheld information systems whereas the expected use settings are the mobile workforce. The empirical data collection was performed via interviews with experienced practitioners, case studies, workshops and studies of software. The Accentuated Factor Framework enhanced with explanatory dependencies between factors provides the opportunity to enhance the design process by reducing the risk of reengineering in design.

Keywords: Accentuated Factors Framework, handheld information systems, mobile information systems, design science

1 Introduction

The recent years of rapid development in handheld technologies create opportunities for new user-groups in the mobile workforce to take advantage of computerised information systems based on handheld technologies- - handheld information systems. However, in order to apprehend and utilise these opportunities it is crucial to fully understand the user group and the handheld technology (Zheng and Yuan, 2007).

There is evidence in the form of IS failure supporting the opinion that we still have lessons to learn on how to design and develop mobile IS for the mobile workforce. For example, a large corporate group in northern Europe within the heavy industry and haulage sector implemented a service order system for their 280 service technicians in Sweden, where the end user platform was handheld computers. Savings due to shorter lead-times from the ordered service to the invoice being sent was one of the main reasons for developing and implementing the system. From the management perspective the desired benefits were achieved when the time between order to invoice was cut from three weeks to three days. The service technicians, however, deemed the system a failure owing to the increase in administration on their part from 20 to 90 minutes per day, and the lack of support for the service technicians' vital information needs. Post-implementation evaluation showed that the production loss caused by the technicians spending more than one hour less per day actually performing services could have been avoided if the system had been designed accordingly to how the technician performed the service order administration in the field (Andersson, 2008).

Similar stories in the business press and academic literature indicate that the example above is not an isolated anecdote but a typical example of how mobile IS projects do not harness their potential due to a failure in understanding the usage situation and the nature of the handheld computing devices (See, for example, Allen and Wilson, 2005 , BlecharConstantiou and Damsgaard, 2005, Er and Kay, 2005, Fussell and Benimoff, 1995, Kay and Er, 2005, Luff and Heath, 1998, Norman and Allen, 2005, Steinert and Teufel, 2005). Hence, research informing designers regarding the usage situation and the nature of the handheld computing devices is valuable in order to design appropriate handheld information system and by this harness the potential of these systems.

However, there exist few frameworks supporting designers of handheld information system. When it comes to framework revolving the nature of handheld computing and handheld information systems, most frameworks are typically high level descriptions, such as Zheng and Yuan's (2007) description consisting of the entities mobile workers, mobile context, mobile tasks and mobile technologies describing the differences between the stationary and mobile context. Kakihara and Sörensen's (2002) discuss mobility and include temporal, spatial and contextual mobility within mobility as a phenomena. Focusing on the context of handheld computing, Tarasewich (2003) suggests that the context should be divided into three categories: activities, environment and participants. An extended view on the concepts of anywhere and anytime put forth by Perry et al (2001) broadens the view on mobility. These descriptions are important contributions to the field of computerised handheld information systems in describing what mobility is. However, these frameworks are not specifically developed to support the design of handheld information systems. One of the few illustrations of the characteristics of handheld information systems is the Accentuated Factors Framework by Andersson and Henningsson (2011) who put forward fifteen factors being specific to handheld information systems for the mobile workforce, from a designer perspective. Hence, the Accentuated Factors Framework will be of special interest in this paper.

2 Objectives

The paper is based on the proposition that mobile and handheld IS has distinctive characteristics compared to more traditional information system use in the form of stationary information system (Andersson and Henningsson, 2010, Fällman, 2003, Lyytinen and Yoo, 2002, Zheng and Yuan, 2007),

which ought to be managed properly in design and development in order to harness the possibilities of handheld information systems.

The theoretical framing is the Accentuated Factors Framework put forth by Andersson and Henningsson (2011), a framework illustrating, from a developers perspective, the distinctive characteristics of handheld information systems. The framework comprises fifteen factors worthwhile to consider during design of handheld information systems for the mobile workforce. However these fifteen factors are not interconnected, that is the relations between factors are not explained, or in other terms, the framework can be categorised as a theory for analysis using Gregor's (Gregor, 2006) taxonomy; 'Say what is. The theory does not extend beyond analysis and description. No causal relationships among phenomena are specified and no predictions are made' (Gregor, 2006, p. 620). Hence, the Accentuated Factors Framework is chiefly contribution as a checklist improving the effectiveness of design, that is, improve the likeness that an appropriate system is designed, although from a specific stakeholders perspective.

The purpose in this paper is to further enhance the usefulness of the Accentuated Factor Framework by describing dependencies between factors in the framework and by this enhance the efficacy in the design phase. That is, if the most important factors are known in the early steps of design, these factors should be the first to consider in design in order to reduce reengineering in later phases of the design. This enhancement further develop the Accentuated Factors Framework in to an explaining and predicting theory according to Gregor's taxonomy; 'Says what is, how, why, when, where, and what will be. It provides predictions and has both testable propositions and causal explanations' (Gregor, 2006, p. 620).

A specification of the core topic is warranted here. The paper principally discusses handheld information systems, although in the majority of research the term mobile information system has more or less been equated with handheld information systems. The framework is only applicable to handheld devices in which the small form factor (Fällman, 2003) is applicable.

3 Accentuated factors of handheld information system

The Accentuated Factors Framework put forth by Andersson and Henningsson (2011) illustrates a set of important aspects from a designers' perspective. That is, they are considered as factors manageable in development and thereby important in design. An important aspect of this framework is that experienced practitioners have evaluated it and considered it to be comprehensive and detailed, or in Gregor's (2006) terms, complete, distinct and simple. Another important aspect is that the context for the framework is the mobile workforce; an effect of this is the treatment of mandatory versus voluntary use. The assumption is that in the workforce setting use is most often mandatory, an assumption that influence design.

Andersson and Henningsson (2011) stress that *accentuated* should be interpreted as a factor that already exists but that has gained greater importance, has changed its properties when the factors are managed from a handheld information system perspective *or* that it is a new factor. The term *factor* should be interpreted as a feature or circumstance contributing to or affecting the design and developmental efforts (adapted from the New Oxford Dictionary, i.e. 'a circumstance, fact, or influence that contributes to a result or outcome'). For example, the small form factor is an example of a factor in handheld computing and can be described by their properties such as a small screen or reduced keyboard. The Accentuated Factors Framework is composed of the following 15 factors (Andersson and Henningsson, 2011):

Field-use condition: This factor regards the physical surroundings as being quiet or noisy environments, with sunlight, darkness, heat or low temperature all influencing the field-use in their own way.

Industry dynamics: Illustrates the fast changing environment, with competing vendors, manufacturers and content providers, and it is argued that this factor is fiercer and withstanding compared to stationary computing.

Information system dependencies: It regards the mobile workforce's high reliance on their information system. If an implemented application is the only application the user may access, and this application is crucial for the user to conduct the work, the reliance on this application is higher than the equivalent desktop environment.

Interaction patterns: Illustrates that the mobile user benefits from short interaction sequences, short time periods of use, aversion to long boot sequences and that active behaviour is patterned to manage this. The main reason is that the mobile workforce is often occupied with tasks other than working with their computer.

Location awareness: Handheld devices are mobile and therefore able to appear in different places and can by different means use the information of its physical location. This location awareness can be achieved by GPS, triangulation, accessing nodes or other techniques.

Multimodal interfaces: Refers to new I/O possibilities such as motion control or LDR sensors. This factor is closely related to the small form factor, however a separation of concern is argued. Multimodal interfaces are an extension rather than the reduction that the small form factor is often considered.

Place critical: Anywhere is almost a trademark of handheld computing, which represents freedom of place, however in a work situation the interpretation of freedom of place can be questioned. The authors argue that for a mobile workforce and mandatory use the user is most likely not allowed to choose the place, on the contrary, the place may be specific – or critical.

Platform variation: The mobile industry is characterised by a large and heterogeneous set of actors and stakeholders. This creates a complex ecosystem with competing technologies and standards that in turn affect the designers trying to design systems functional on different platforms.

Security issues: In wireless communication, security issues are present due to the risk of interception. Another security issue is the small form factor and its omnipresence. The handheld device's small size means that it will be carried around to a greater extent than, for example, a laptop computer. Hence, increases the risk of it being stolen or lost than a desktop computer.

Small form factor hardware: Due to the miniaturisation of hardware, hardware capacity is limited compared to desktop computers. For example, the limited power supply is highly relevant for mobile devices, since in practice they require to be battery powered and independent of fixed power networks.

Small form factor interface: This factor concerns the small form factor with a small screen and limited keyboard. The keyboard may not be present or a keyboard offered which has a limited set of keys compared to an ordinary keyboard.

Support issues: This factor illustrates issues related to providing support to geographically distributed users. The fact that a considerable number of the mobile workforce is working by themselves in the field renders them with a lack of colleagues to gain support from, furthermore, the sheer physical distance can cause problems in offering support.

Supporting technologies: Compared to the office worker, the mobile workforce's accessibility to supporting technologies is often limited. Important documents may not be easily accessed and displayed through a handheld device. File management, servers, fax machines, written manuals, written ledgers or other support systems may not be available to the same extent as in an office environment.

Time critical: One trademark of handheld computing is "anytime", usually describing the fact that the user can access certain information, services or an application when the user wants, providing freedom in time. In contrast with the concept of freedom in time, when members of the mobile workforce

actually do need information it is often relatively time-critical information making “just in time” a more accurate term.

Varying connectivity: This factor illustrates the unpredictability in the quality of service, both in transmission rate and connectivity. With wireless networks, disconnection is a factor that needs to be managed.

Whereas the Accentuated Factors Framework is aiming on a comprehensive approach on the specific characteristics of handheld information system for the mobile workforce it does not convey information on how different factors relate or influence each other. It can be considered as a checklist of important factors that should be considered in the specific design project at hand. The outcome would be lesser mistakes due to factors not accounted for in a design. In other words, the Accentuated Factors Framework is an aid towards an appropriate product, however, the support to the design process are not explicit.

4 Research Approach

In the search for dependencies between factors in the Accentuated Factors Framework, a multitude of methods were applied, as suggested by Hevner and Chatterjee (Hevner and Chatterjee, 2010). The empirical data was gathered by semi-structured face-to-face interviews with experienced practitioners, three case studies involving developers and end users, studies of computer software and workshops. The mixture of data sources was a deliberate choice in order to capture different perspectives, and to acquire a richer description of the studied phenomena.

Sixteen experienced practitioners with an average working experience of nine years related to design, requirements engineering and mobile information system architecture were interviewed with semi-structured interviews. The interviews revolved around what the experienced practitioners considered as being significant in the design and development of mobile information systems, differences between stationary versus desktop development, their experience from real cases, about the importance of the factors derived from literature and the applicability of an overall framework. The average duration of the interviews was 1 hour and 30 minutes, and the interviews were audio-recorded. The data from the interviews were transcribed and analysed and the analysis were aided by the software HyperResearch (Researchware, 2012).

Data from three case studies were used, the 21st Century Mobile-case, the ASPEA Mobile-case and the ACME-case. The 21st Century Mobile-case, a longitudinal case study, was carried out from February 2005 to May 2007 by attending weekly meetings with a design/developer team (3–6 developers) concerning the development of a backbone system bridging data between a carrier network and computer network, data recorded by field notes and document studies. In the ASPEA Mobile-case, seven interviews investigating the designers’ and developers’ experiences in the development of the WinHast-logistic system administrating taxi transports, data recorded by field notes and document studies. In the ACME-case, nine interviews with users concerning the use of a service order system for ambulatory service technicians and studies of the implemented software were conducted, data recorded by field notes and photos. With these three case studies a chain of data were gathered, from a server system backbone to end users. Furthermore, the case studies improved the analysis by providing real case implementations where design efforts could be evaluated and compared to the information from the semi-structured interviews with the experienced practitioners.

To sum up, a total of 32 interviews were conducted; sixteen interviews with experienced practitioners, seven interviews with developers and nine interviews with the end users of a service order system. 71 weekly workshops concerning the development of a mobile IS messaging system were attended during the longitudinal case study at 21st.

Regarding internal dependencies between factors, the data were analysed in relation to the Accentuated Factors Framework, a work aided by the QDA software HyperResearch. Data were grouped into categories and relevant categories were associated to factors in the framework. If one of

the factors in the framework influenced of affected another factor, a dependency was noted. In this analysis no further considerations regarding the strength or nature of dependencies were made, that is whether it was a reinforcing or disruptive dependency. Below are two examples where dependencies were identified and one example where no dependencies were identified.

From the ASPEA-case a dependency between *field-use conditions* and *small form factor interface* were identified. The developers realised via field tests that using the touchscreen was a poor strategy due to the fact that the users (taxi and bus drivers) used the device/application during driving (notwithstanding the fact that the driver shouldn't be using a handheld device manually whilst driving). When driving, the car or bus jerks and jumps enough to make input on a touchscreen error prone. As a result, the developers disabled the input via the touchscreen and instead used the two buttons available on the device (MIO 710). The input using only these two buttons forced the developers to design the input workflow as a binary tree. This dependency reformulated; field-use conditions may limit the options available on a small form factor device, and the table was updated with *field-use conditions* ➔ *small form factor interface*.

At another interview the designer explained that in a specific system they could not use a handheld device due to the small form factor. The system was a logistic system and the end users were truck drivers transporting equipment and material to construction sites. The drivers had to read the information on the display in varying light and whilst driving and the small screens were considered impossible to use, and instead a tablet computer was selected as the target platform. The drivers were very satisfied with this device, and one reason given was that they could place the tablet in the passenger seat and not clutter the field of vision when driving. A second instance of dependency between *field-use conditions* ➔ *small form factor interface* was identified and inserted into the table.

In one interview a system for land surveyors were discussed. The land surveyor works out on the field regardless of weather and a sturdy device (shock and waterproof) was under consideration. However at that time such sturdy devices were very costly and the client decided to carry out a test; they selected ordinary off the shelf devices and the argument was that these are so inexpensive, only 20% compared to the sturdy device, that they could replace the device at least 5 times and still keep the hardware costs down. After three years of field use only a few handhelds had broken down due to rain or similar circumstance. In this case no dependency was recorded. The results were arranged in a table showing the depending and dependent factors and the number of influences (Table 1).

5 Dependencies between factors

The study on dependencies confirmed the existence of dependencies, although the informant's perceptions on dependencies varied. However, conformity between the informants' perceptions were not expected, inasmuch as developmental factors are most often wicked problems or dilemmas without one right answer (Rittel and Webber, 1973), however some consensus was discernable. That is, some dependencies are more frequent in the data as will be shown in the subsequent table.

It is important that dependencies may be positive or negative, and that in this paper no further consideration is made regarding this, the key point is to identify factors that do influence other factors, this based on empirical data from 32 interviews and 71 workshops. Regardless whether a dependency is positive or negative, a dependency does exist and therefore should be considered or discussed in the design or development. Furthermore, a dependency may be negative in one case and positive in another case and if that is the situation two dependencies are accounted for. Hence, the do not rule out each other.

Judging by the numbers of outgoing relations, two factors stands out as being the most influential factors: *varying connectivity* (a total of 20 occasions of influencing other factors) and *field-use conditions* (a total of 18 occasions of influencing other factors). Less powerful factors are Security Issues (0 occasions of influencing other factors) and Support Situation (0 occasions of influencing other factors).

Depending factor	Dependent factor	Sum	Aggr
Varying Connectivity (VarC)	Industry Dynamics (IndD)	1	20
Varying Connectivity (VarC)	Small Form Factor Hardware (SmfH)	6	
Varying Connectivity (VarC)	IS Dependencies (IsdP)	6	
Varying Connectivity (VarC)	Supporting Situation (SupS)	1	
Varying Connectivity (VarC)	Interaction Patterns (IntP)	3	
Varying Connectivity (VarC)	Security Issues (SecI)	3	
Field Use Conditions (FieU)	Small Form Factor Interface (SmfI)	3	18
Field Use Conditions (FieU)	IS Dependencies (IsdP)	1	
Field Use Conditions (FieU)	Security Issues (SecI)	2	
Field Use Conditions (FieU)	Interaction Patterns (IntP)	6	
Field Use Conditions (FieU)	Small Form Factor Hardware (SmfH)	6	
Small Form Factor Hardware (SmfH)	Field Use Conditions (FieU)	1	13
Small Form Factor Hardware (SmfH)	Location Awareness (LocA)	1	
Small Form Factor Hardware (SmfH)	Platform Variation (PlaV)	2	
Small Form Factor Hardware (SmfH)	Varying Connectivity (VarC)	2	
Small Form Factor Hardware (SmfH)	Security Issues (SecI)	2	
Small Form Factor Hardware (SmfH)	Small Form Factor Interface (SmfI)	5	
Platform Variation (PlaV)	Industry Dynamics (IndD)	1	9
Platform Variation (PlaV)	Small Form Factor Hardware (SmfH)	2	
Platform Variation (PlaV)	Small Form Factor Interface (SmfI)	3	
Platform Variation (PlaV)	Supporting Situation (SupS)	1	
Platform Variation (PlaV)	Interaction Patterns (IntP)	2	
Small Form Factor Interface (SmfI)	Interaction Patterns (IntP)	6	7
Small Form Factor Interface (SmfI)	Platform Variation (PlaV)	1	
Multimodal Interfaces (MutI)	Supporting Situation (SupS)	1	6
Multimodal Interfaces (MutI)	Interaction Patterns (IntP)	2	
Multimodal Interfaces (MutI)	Small Form Factor Interface (SmfI)	1	
Multimodal Interfaces (MutI)	Location Awareness (LocA)	1	
Multimodal Interfaces (MutI)	Supporting Technologies (SupT)	1	
Industry Dynamics (IndD)	Interaction Patterns (IntP)	1	5
Industry Dynamics (IndD)	Small Form Factor Hardware (SmfH)	2	
Industry Dynamics (IndD)	Supporting Situation (SupS)	1	
Industry Dynamics (IndD)	Platform Variation (PlaV)	1	
IS Dependencies (IsdP)	Supporting Situation (SupS)	1	5
IS Dependencies (IsdP)	Varying Connectivity (VarC)	4	
Place Critical (PlaC)	Varying Connectivity (VarC)	1	4
Place Critical (PlaC)	Small Form Factor Hardware (SmfH)	1	
Place Critical (PlaC)	IS Dependencies (IsdP)	1	
Place Critical (PlaC)	Time Critical (TimC)	1	
Time Critical (TimC)	Place Critical (PlaC)	2	4
Time Critical (TimC)	Small Form Factor Hardware (SmfH)	1	
Time Critical (TimC)	IS Dependencies (IsdP)	1	
Interaction Patterns (IntP)	Supporting Situation (SupS)	4	4
Location Awareness (LocA)	Interaction Patterns (IntP)	1	1
Supporting Technologies (SupT)	Field Use Conditions (FieU)	1	1
Security Issues (SecI)	-	0	0
Supporting Situation (SupS)	-	0	0

Table 1. Number of dependencies for each factor-to-factor are displayed in column "sum" and the aggregated number of dependencies from one dependent factor distributed out to several other factors in column "Aggr" – indicating the power of its influence on other factors.

6 Reflections on dependencies between factors

When managing aspects in design and development, such as the factors in the Accentuated Factors Framework, it is often worthwhile first managing the most influential factors or circumstances.

For example, with knowledge from the ASPEA-case (see section 4) a designer should first start by investigating *field-use conditions* and make design considerations related to *field-use conditions* before embarking on design considerations related to *small form factor interface*. If this order were applied, the use of a touchscreen would most likely not be considered at all. Doing the opposite, if starting with *small form factor interface*, the likelihood is that effort made in optimising *small form factor interface* will be disrupted when the dependent factor *field-use conditions* are considered and optimised. That is, designing an application focusing on benefits of the touchscreen would not be a surprise due to the opportunities the touchscreen seems to offer. However, invested efforts in touch screen design would be a waist of resources due to reengineering later on.

Although in the example above one isolated dependency is discussed, the principle of beginning with the most influential factors should be appropriate. Even though dependencies are not stable across different specific cases, some different factors particularly stand out as having many influencing ties to other factors. With the ambition to illustrate the dependencies a network diagram is constructed. The visualisation software Graphviz (Ellson et al., 2003), along with the Neato-scheme (GansnerKoren and North, 2005) was used to draw the diagram (see figure 1).

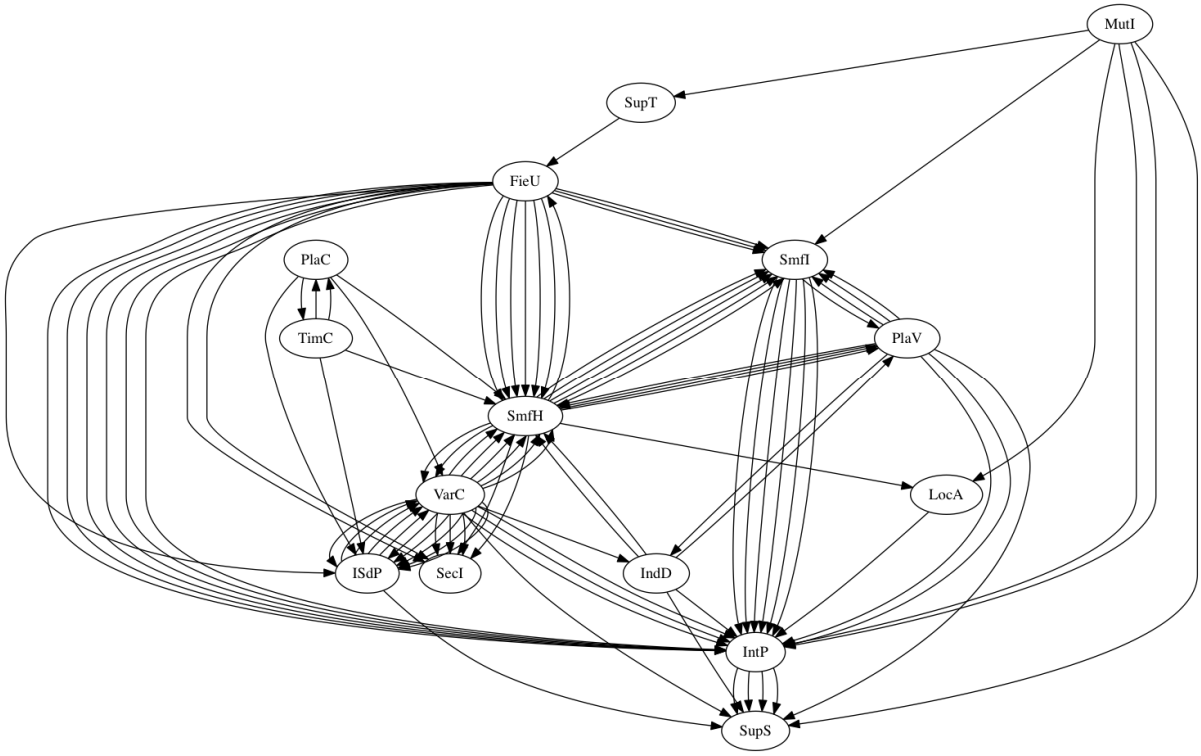

Figure 1. The complete set of factors and their internal dependencies. The dependencies are illustrated with arrows between factors and the arrowhead indicates the direction of dependencies. The factors are labelled with abbreviations in order to keep the ovals at the same size and avoiding misinterpretations if there were of different size. See table 1 for the conversion of abbreviations.

Although comprehensive, the illustration in figure 1 may be complex to interpret. With the ambition to focusing on the most influential factors the data were filtered using SCCMAP (North and Gansner, 2001). From this a diagram is constructed where the neighbours with low influence are reduced and removed from the diagram. The arrows in the diagram display the direction of influence (see figure 2).

Due to this reduction the number of dependencies in table 1 and figure 2 are not equivalent. However, a note of precaution whereas the dependencies are not casual laws, instead they should be considered as likely outcomes and aspects to investigate between the designers and customers. The reduced diagram illustrates the seven most influential factors.

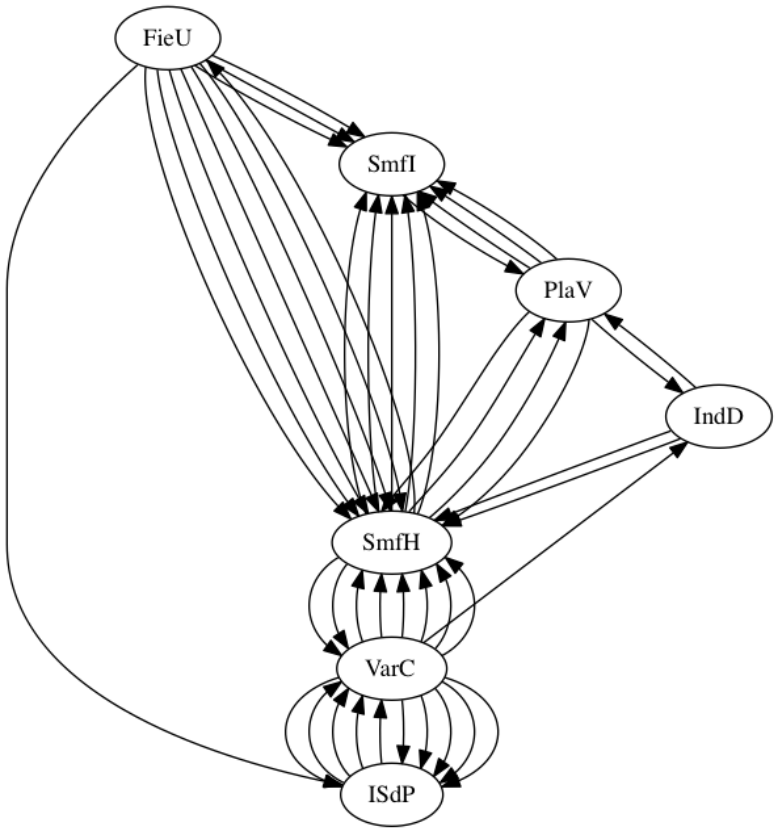

Figure 2. Dependencies between factors in the Accentuated Factors Framework. In this diagram the less influencing factors, that is, the distant neighbours are removed and only the core factors from data in table 1 is visible. Abbreviations are used in the figure, see table 1 for the conversion.

7 Conclusion

This paper rests on the assumption that handheld information system has specific properties compared to stationary or desktop computing, which ought to be managed properly in design and development in order to harness the possibilities of handheld information system.

Whereas the original Accentuated Factors Framework and the individual factors can be considered as a tool to improve the product (the designed system) the dependencies and their impact on design can be considered as a tool to improve the design process.

It is concluded that dependencies exist between factors in the Accentuated Factors Framework, with varying importance, which affect the outcome of a certain design effort. Implications for theory is the development of an analytical framework to an explaining and predicting framework useful for scholars in analyses of design and evaluation of handheld information systems. Implication for practice is that in the design phase of mobile IS the initial focus should be on the most influential factors in order to reduce the risk of extensive revision to the design later on in the project. That is, starting the

optimisation process by managing low important factor is most likely a waste of resources because addressing more important factor later on may ruin any previous optimisations made.

A limitation is that the illustrated dependencies are only between factors, that is, only the internal dependencies. The individual factors or a set of factors may depend or influence external factors, however this is recognisable in an actual design project. Another aspect mentioned during the interviews is the dramatic change in the mobile/handheld landscape due to the entrance of players such as Apple and Google. However, the changes caused were not considered affecting the Accentuated Factors Framework. The framework and the factors were considered as independent of realising technologies, although in the future some aspects such as the approachability to stable and fast wireless connections may be managed by carriers or Wi-Fi operators instead of designers and developers, however the factor will still be important.

Two avenues for future work have been identified. First, further work on building an empirical basis on the dependencies with more in-depth analysis and identifying the mechanisms behind the dependencies. Second, improve the applicability of the framework with dependencies by develop a tool or a method that fits the work context of handheld information systems design activities. One suggestion from the informants were to align a future method with SCRUM technologies such as Scrum Cards and Scrum Walls (Berczuk, 2007, Sharp and Robinson, 2010).

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