On the Validation of an Evaluation Framework: Assessment by Experts

by Tamara Högler[1] and Johan Versendaal[2,3]

Introduction

Högler et al. (2015) describe a framework that delivers insight into the tangible and intangible effects of a mobile (IT) system, before it is being implemented. The framework has been developed because of a lack of such insight (other frameworks merely focusing on monetary effects, neither taking into account singularities of mobile technologies). The framework consists of 3 pillars with 7 included activities. Figure 1 shows the framework, also identifying interdependencies between the activities and their inputs and outputs.

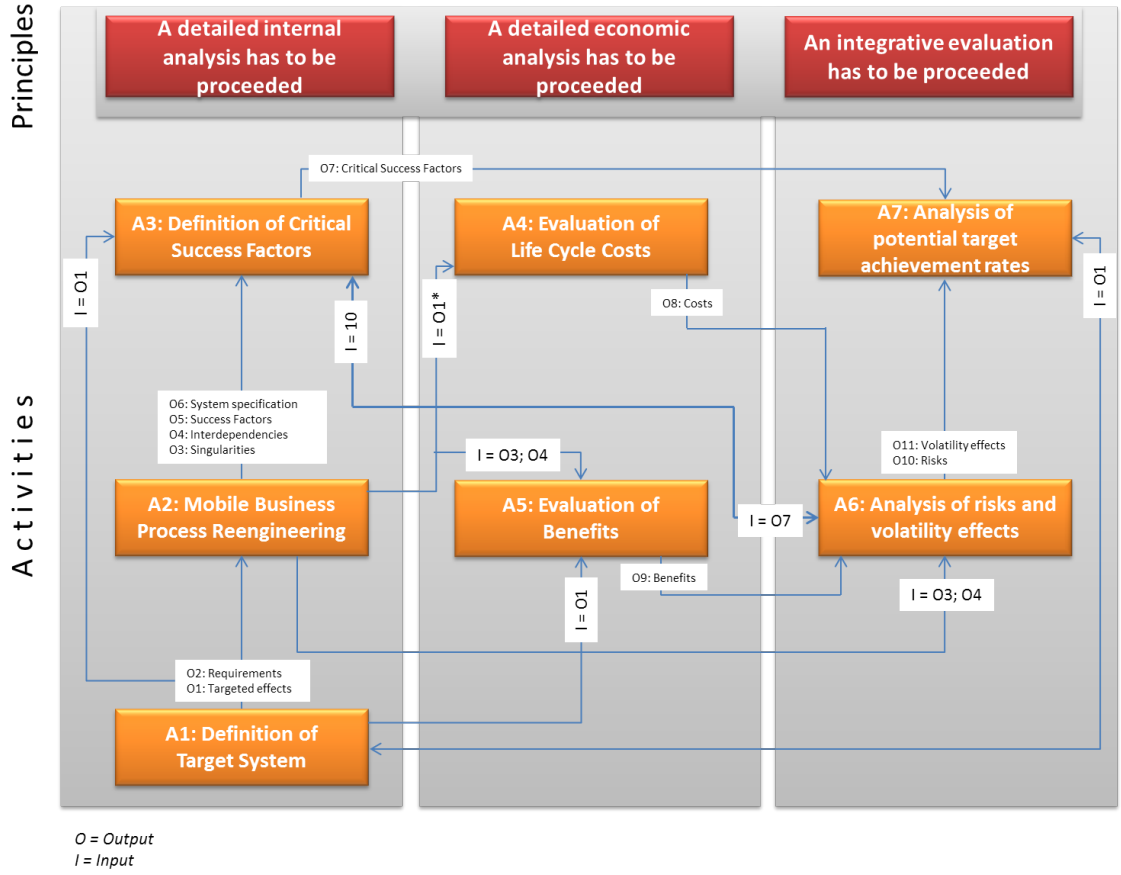

Figure 1: Integrative Framework for Mobile Systems (Högler et al., 2015)

A description of each of the activities from figure 1 is taken from Högler & Versendaal (2016), pp. 3-4:

[1] hoegler@cyberforum.de, CyberForum, Germany
[2] johan.versendaal@hu.nl, HU University of Applied Sciences, Utrecht
[3] johan.versendaal@ou.nl, Open University of the Netherlands

1. "Activity 1: Definition of the target system by following the multi-attribute decision making (Hwang & Yoon 1981); this activity outlines a procedure for defining the target system leveraging the Analytical Hierarchy Process (AHP) (Saaty 1996) which is extended by following activities (see figure 2), differing fundamentally from previous approaches:
   - interdependence analysis between individual objectives (Kirchmer 1999; Drews & Hillebrand 2010; Rückle & Behn 2007);
   - consideration of the effective strength of the objectives and the probability of occurrence of interdependencies (Klabon 2007; Charette 1991) and thus their respective value; and
   - weighting of objectives in the context of these latter two aspects.

[...]

2. Activity 2: Mobile Business Process Reengineering as proposed by the authors builds upon Mobile Process Landscaping (Gruhn & Wellen 2001; Köhler & Gruhn 2004).
3. Activity 3: Definition of critical success factors, their interdependencies, correlation analysis and weighting (Iqbal et al. 2015; Nysveen et al. 2015; Hway-Boon & Yu 2006).
4. Activity 4: Evaluation of life cycle costs (Wild & Herges 2000; Berghout et al. 2011), performed by identifying costs during the whole lifecycle of mobile systems including the preliminary phase, utilization phase and disposal phase.
5. Activity 5: The evaluation of benefits, based on the total benefit of ownership model (Gadatsch & Mayer 2004), involves the capture of cost savings and non-monetary benefits or qualitative and strategic variables which are not considered in the traditional approaches of economic evaluation.
6. Activity 6: Sensitivity analysis: As an uncertainty of the results achieved in the previous steps remains, a sensitivity analysis is conducted to check the stability of results. Particularly the variables success factors (Corsten 2000; Rockart 1979), risks (Kronsteiner & Thurnher 2009) and the accompanying volatility effects (Kulk & Verhoef 2008; Singh & Vyas 2012) are analysed.
7. Activity 7: Analysis of potential target achievement rates: Based on the results of the sensitivity analysis, the potential achievement rates can be determined. To do so, results of activity 1 (target system), activity 2 (current and target processes incl. key (performance) indicators) and activity 6 (volatility effects) are merged."

Although both papers (Högler et al., 2015; Högler & Versendaal 2016) provide an evaluation of this integrative framework for mobile systems to some extent, in both papers it is suggested that effort is needed in validating it more extensively. In this report we test the validity of the framework through an assessment by experts in terms of its completeness, correctness and its usefulness.

The study took place in the timeframe of February and April 2017 and involved 6 experts from research and practice. The selection criteria for choosing experts were:

1) a high familiarity with the topic IT project management and
2) a high familiarity with the evaluation of economic efficiency of IT systems and
3) a long-time experience in practice.

To identify the experts efficiently, we have chosen the following procedure: One of the authors checked her business contacts (LinkedIn, Xing and her own contact list) in order to identify potential candidates. To get a better understanding of their experience related to the integrative framework, we manually checked the Curriculum Vitae of each potential respondent and their company web page to gain as much understanding as possible on their experience.

In a second step, the authors agreed on a first group of 7 evaluators from Europe to be contacted within one week. These experts were addressed personally via email, explaining the purposes of the survey and asking them if they were interested in participating in the survey. If successfully acquired as evaluator, they have been provided a description of the framework and the related questionnaire.

The questionnaire was developed by one of the researchers following the general rules for a questionnaire (Kirchhoff, Kuhnt, Lipp, & Schlawin, 2008): a first part with focus on a general introduction into the topic and the scope of the interview; a second part that gathered general data about the interviewee, followed by a contextual third or – in our case – more main parts that focused on the validation of the research topic (see figure 1). In our case, the contextual parts that were focusing on the validation of the framework contained following main parts: Validation of the axioms of the framework, validation of the framework (overall approach of the framework) and separate validation of all seven activities of the framework.
The second researcher reviewed the questionnaire and provided improvement suggestions, that were bilaterally discussed between the researchers and agreed upon. Annex 1 contains the full questionnaire.

In the first stage of the survey, interviews with three experts (two from research, yet with profound knowledge of practice, and one from business) were conducted. The questionnaire (see Annex 1) as well as the description of the integrative framework (see Annex 2) were sent out to the experts prior to the interview. Two out of three interviews have been recorded with the mobile phone[4], notes were taken by one of the authors directly into the questionnaire. The duration of the interviews was approximately 1.5 hours. The comments and suggestions for improvement of the integrative framework were elaborated more in detail following the interview and sent to the interviewees for approval. No revisions of the elaborated questionnaires were needed.

Based on the feedback of these three interviewees the authors decided not to proceed on this particular interview strategy due to following reasons:

[4] One interview was not recorded due to technical problems with the mobile phone.

- It was very time consuming to get an appointment for an interview scheduled as the interviewees had high positions (mainly professors, CEOs and similar) and where thus extremely busy. In addition, re-scheduling of the interviews was necessary in 2 cases which caused additional delays.
- Most of the questions had discrete (yes/no) answers that did not provoke much discussions.
- Merely in the case that the answer was “no” or “partly”, an explanation was asked from the expert (interviewee).

Thus, we encouraged subsequent respondents to fill out the (unchanged) questionnaire and to return it to the authors using e-mail. This procedure was much easier to handle as the experts were able to fill in the questionnaire whenever they had time to do so and no scheduling and re-scheduling of appointments was necessary.

In case of any ambiguities in the provided feedback, or not agreeing (fully) with the parts of the framework, the experts were providing feedback through a call and/or personal meeting.

Detailed structure of the questionnaire

The questionnaire contained 11 sections: One introductory section that contained general information like scope of the interview and questions as regards to the general understanding of the procedure (questions 1-4 (Q1-4)). Section 2 gathered general information about the interviewee's personal data, experience in the topic of the integrative framework and confidentiality / usage of the gathered data. The third section of the questionnaire provided the most important axioms of the integrative framework for validation (Q5-7). Section 4 concentrated on the validation of the integrative framework as a whole (Q8-13) whereas sections 5-11 validated every single of the seven activities of the framework (Q14-32).
The questionnaire had mainly dropdown menus with pre-defined answers (yes / no / partly) and the possibility to enter free text for the case, if “no” or “partly” was chosen in the previous question as answer.

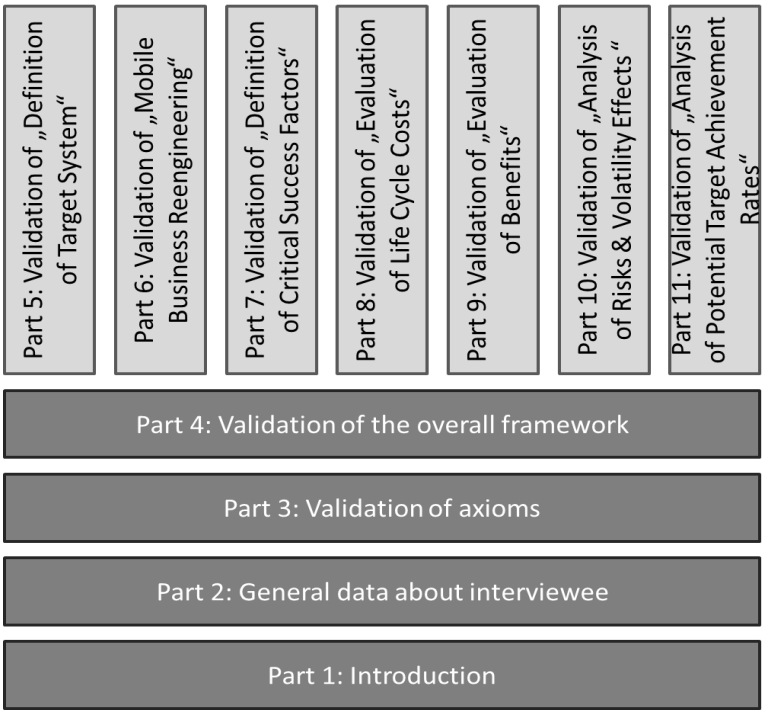

Figure 1: Structure of the questionnaire

Survey results

In terms of organization characteristics, the six interviewees came from SMEs and research institutions. They all had high positions like CEO or professor and several years of experience in the topic “IT project management”:

Name	Affiliation	Position	Familiarity	Practical experience since
Hans Mulder	Venture Informatisering Adviesgroep NV	Managing director	Very familiar	1995
Prof. Dr. Rainer Neumann	University for Applied Sciences, Karlsruhe	Professor	Very familiar	1995
Prof. Dr. Dieter Hertweck	HHZ Research Centre, Reutlingen University	Professor, Head of Research Group	Very familiar	1996
Dr. Asarnush Rashid	Zentrum für Telemedizin Bad Kissingen	Managing director	Familiar	2004
Daniel Stucky	Keller Informatik AG	Owner	Very familiar	1988
Rüdiger Bäcker	@TOLL GmbH	CEO	Very familiar	2004

Table 1: Participants of the study

All evaluators confirmed all questions in the first section of the questionnaire, i.e. that they received (Q1) and read (Q2) the questionnaire and that they understood the general description of the framework (Q3), as provided in Annex 2. They also confirmed that it was clear that the approach was meant for the decision making process / ex-ante evaluation of mobile systems (Q4).

	Yes	No	Partly	*Total no. of answers*
Q1: Did you receive the document describing the integrative framework?	6	0	0	*6*
Q2: Did you have time to read the document?	6	0	0	*6*
Q3: Did you understand the general procedure of the framework?	6	0	0	*6*
Q4: Was it clear for you that the approach is meant for supporting the decision process (i.e. ex ante evaluation)?	6	0	0	*6*

Table 2: Results of Part 1 of the Questionnaire

In the second section of the questionnaire, all evaluators provided their personal data and information about familiarity / experience with the topic and confirmed that data provided by them can be used by fully stating their names and affiliations. All experts were familiar or very familiar with the topic and have been working in the field of IT project management for at least 13 years. Table 3 shows the structure of the second part of the questionnaire:

Name:		Company:	
Surname:		Position:	
Familiarity with topic	*Very familiar / familiar / somehow familiar / not familiar at all*	City:	
Working in the topic since	*Insert year*	Country:	

Table 3: Structure of Part 2 of the Questionnaire

The third section of the questionnaire focused on validating the axioms of the integrative framework. Table 4 shows the general results:

	Yes	No	Partly	*Total no. of answers*
Q5:In our approach we derive requirements from objectives as defined in the target system. Do you agree that in this manner objectives and requirements are inherently related?	5	0	1	*6*
Q6: In our approach we derive the (technical) system specification from requirements (as defined in activity 1) during activity 2 (mobile Business Process Reengineering / mBPR). Do you agree that in this manner a system specification can be derived from (general) requirements during the mBPR??	4	0	2	*6*
Q7: In our approach we define risks as (critical) success factors that are not taken into account. Do you agree that in this manner risks and success factors are inherently related?	5	1	0	*6*

Table 4: Part 3 of the questionnaire: Validation of Axioms

We received following input for Q5:
Prof. Hertweck (partly agreeing) said that "[…] requirements (e.g. security, feasibility, personnel skills of workforce,…) are more or less a derived target system from business strategy that constitute itself a target system (bundle of requirements) for the Information System strategy, whereas mobile systems are only one possible solution for the predefined requirements".

As regards to Q6, Prof. Mulder stated that "[…] not all specifications can be derived from requirements during activity 2[5]", whereas Prof. Neumann said that the "[…] derivation is correct on a coarse level – but having only the descriptive paper [in Annex 2] it is not clear if the technical specifications will be complete by applying this approach". So for both experts, an in-depth analysis of requirements is needed in the mBPR.

All experts – except for R. Bäcker – confirmed, that risks can be defined as (critical) success factors that are not taken into account and that thus risks and success factors are inherently related. R. Bäcker stated that "risk could be a critical success factor by itself", implying that vice-versa consideration is also needed.

The 4th section of the questionnaire focused on validating the overall approach of the framework with following six questions (Q8-Q13):

[5] Mobile Business Process Reengineering

	Yes	No	Partly	*Total no. of answers*
Q8: Do you agree with the set of 3 Principles, in terms of completeness and correctness?	4	0	2	*6*
Q9: Do you agree with the set of 7 activities of the framework, in terms of completeness and correctness, and their order?	4	0	2	*6*
Q10: Do you think that the framework is applicable for non-mobile environments as well?	5	0	1	*6*
Q11: Do you think that the framework is complete (as for the seven described activities)?	4	0	2	*6*
Q12: Do you think that the framework is correct (as for the seven described activities)?	6	0	0	*6*
Q13: Do you think that the framework is usable (as for the seven described activities)?	6	0	0	*6*

Table 5: Part 4 of the questionnaire - validation of the overall framework

Prof. Mulder confirmed that the 3 principles are correct (Q8), but that he is not sure if they are complete in terms of all aspects as, e.g., an analysis of culture could be needed in some cases. He also stated that the completeness of the approach can be achieved by amplifying the approach with additional methods. At the same time he pointed out that the completeness depends on the project scope. Also Prof. Neumann confirmed that the principles are correct. Nevertheless he emphasized that it is important to depict when the principles are "complete" or "good enough" for a reasonable result as the questionnaire did not provide any definition of "complete". As regards to the questionnaire, he suggested that it would be better to use the term "sufficient"[6] instead of the term "complete".

Question 9 tried to figure out if the set of 7 activities of the framework were acceptable for the experts, in terms of completeness and correctness, and their order. All experts confirmed their correctness and order, but similar to Q8, Prof. Mulder stated that the completeness depended on the level of details of the analysis, so that it could be necessary to extend the activities with more detailed specification if a very high level of details is needed. Prof. Neumann suggested to mention that this is an *iterative* approach which did not become clear in the provided description of the framework. Nevertheless, he stated that also without a change the set of 7 activities would keep its validity, but that in practice a waterfall model, even in an a priori evaluation context, would not lead to useful results. Dr. Rashid provided a quite similar input as he stated that he missed the possibility to reflect the definition of the target system in case that the former

[6] Additional note from Prof. Neumann: From a mathematical and engineering view the framework would not be valid if we are talking about "completeness". "Completeness" as it is meant in the questionnaire is more like the "time-boxing model" in Software Engineering ("what is feasible in a given timeframe" / "what is feasible with a given budget"), which confirms that it is better to apply the term "sufficient".

target system is not applicable or not defined well enough. Thus, he also suggested an iterative approach. Also R. Bäcker suggested an iterative approach by taking a redesign loop into account (see also Q11), as he did not see the seven activities as a straight forward process.

In Q10 the experts were asked to evaluate the applicability of the integrative framework for non-mobile environments. Stucki stated that Business Process Reengineering is even more important when dealing with mobile environments than with non-mobile environments. In fact, his remark confirms the importance of mBPR particularly for mobile environments and systems.

Section 5 of the questionnaire focused on validating the first activity of the integrative framework – the definition of the target system.

	Yes	No	Partly	*Total no. of answers*
Q14: Do you agree with the approach for defining a preference-neutral target system?	6	0	0	*6*
Q15: Do you know similar approaches?	3	3	0	*6*
Q16: Which alternatives do you propose for getting a valid target system that is based on effects / influences between targets?				*see text below*
Q17: Do you agree that the main outputs of this first activity are the Targeted Effects (i.e. benefits that should be achieved by the system) and the requirements?	6	0	0	*6*

Table 6: Part 5 of the questionnaire: Validation of Activity 1 - Definition of the Target System

All experts confirmed the validity of the approach of the preference-neutral target system (Q14). None of the experts knew another preference-neutral approach, although three experts knew similar approaches (Q15). Prof. Neumann and Dr. Rashid commented, that also in agile development approaches a pairwise comparison is applied which is deemed as useful as it makes comparison easier than other approaches. Prof. Neumann proposed these approaches as an alternative for identifying targets (Q16). In the suggested case, the pairwise comparison is not applied for defining objectives, but for comparing two tasks as regards to the effort needed for their implementation and their expected business value. Similar to the preference-neutral approach, the result of agile methodologies is a matrix. All experts agreed that the main outputs of this first activity are the Targeted Effects (i.e. benefits that should be achieved by the system) and the requirements (see Q17).

The sixth section of the questionnaire was dedicated to the validation of activity 2 – Mobile Business Process Reengineering (mBPR). It contained following questions:

	Yes	No	Partly	*Total no. of answers*
Q18: Do you agree that analyzing the current processes is important in order to figure out how they could be supported by mobile systems?	6	0	0	*6*
Q19: Do you agree that the main outputs of the mBPR are the identification of Singularities of mobile systems, of Interdependencies (between the single system components, i.e. people, technologies, processes) and of Success Factors?	4	0	2	*6*

Table 7: Part 6 of the questionnaire: Validation of Activity 2 - Mobile Business Process Reengineering

All experts confirmed that analyzing the processes is important in order to figure out how they could be supported or improved by mobile systems (Q18), though Prof. Mulder added to this the importance to also include a culture analysis. In Q19 the experts were asked if they agree that the main outputs of the mBPR are the identification of Singularities of mobile systems, of Interdependencies (between the single system components, i.e. people, technologies, processes) and of Success Factors. Four out of six experts confirmed this. Prof. Neumann explicitly acknowledged that it is highly important that interdependencies between the single system components are taken into account, as risks can only be identified if singularities and their interdependencies are considered. The approach of Agile Methodologies, where Personas, Stories and Context and thus interdependencies play an important role, confirm the chosen approach. D. Stucki said, that Mobile Business Process Reengineering should also show the (economical) potential resulting from such process optimization[7]. For R. Bäcker, a singularity is not an outcome, but a condition[8].

Section 7 focused on the validation of activity 3 – Definition of Critical Success Factors.

	Yes	No	Partly	*Total no. of answers*
Q20: Do you agree with the proposed procedure for defining Critical Success Factors?	6	0	0	*6*

Table 8: Part 7 of the questionnaire: Validation of activity 3 - Definition of Critical Success Factors

All experts confirmed the proposed procedure for defining Critical Success Factors (Q20). Prof. Neumann suggested to define CFS in the description of the framework in a clearer way, so that it becomes clearer at which point success

[7] This is in fact done in activity 4, "Analysis of life-cycle costs"

[8] The reason for this answer is probably the formulation of the question Q19. Singularities are not "created", but identified. Thus we assume that the term "outcome" is here slightly misunderstood.

factors become critical. To do so, he recommended to apply e.g. a Venn diagram for visualization.

In the eighth section, the validity of activity 4 – Evaluation of Life Cycle Costs was examined:

	Yes	No	Partly	*Total no. of answers*
Q21: Do you agree that it is important to take into account all life cycle costs IF this is appropriate for the project?	6	0	0	*6*

Table 9: Part 8 of the Questionnaire: Validation of Activity 4: Analysis of Life Cycle Costs

All experts confirmed that it is important to take into account all life cycle costs for the case that this is appropriate for the project (Q21). Prof. Neumann pointed out that particularly for software and the development of software it is very difficult to evaluate life-cycle costs as the innovation cycles are very short.

Section nine validated activity 5 – Evaluation of Benefits. Table 10 shows the related questions:

	Yes	No	Partly	*Total no. of answers*
Q22: Do you agree that it is important evaluate the POTENTIAL benefits of the implementation of a mobile system?	6	0	0	*6*
Q23: Do you agree that when evaluating potential benefits also the objectives (as defined in activity 1) have to be taken into account?	6	0	0	*6*
Q24: Do you agree that when evaluating potential benefits also the singularities of a mobile system (as identified in activity 2) have to be taken into account?	6	0	0	*6*
Q25: Do you agree that when evaluating potential benefits also the interdependencies between the single system components (as defined in activity 2) have to be taken into account?	6	0	0	*6*

Table 10: Part 8 of the Questionnaire: Validation of Activity 5 - Analysis of Benefits

Again, all experts confirmed that it is important evaluate the POTENTIAL benefits of the implementation of a mobile system (Q22), and that also objectives (as defined in activity 1) (Q23) and the singularities of a mobile system (as identified in activity 2) (Q24) as well as interdependencies between the single system components (Q25) have to be taken into account when evaluating potential benefits. Prof. Neumann underlined that without taking singularities into account the framework would not keep its validity and that also in this case

Agile Methodologies with their Personas, Stories and Context (i.e. singularities) confirm the chosen approach. In addition, he emphasized the importance of change management after implementation of a mobile system.

The validation of activity 6 – analysis of risks and volatility effects took place in section 10:

	Yes	No	Partly	*Total no. of answers*
Q26: Do you agree that it is important to analyze the risks and (related) volatility effects when evaluating the implementation of a mobile system?	5	0	1	*6*
Q27: Do you agree that when analyzing risks and volatility effects also the singularities of a mobile system (as defined in activity 2) have to be taken into account?	6	0	0	*6*
Q28: Do you agree that when analyzing risks and volatility effects also the critical success factors (as defined in activity 3) have to be taken into account?	6	0	0	*6*
Q29: Do you agree that when analyzing risks and volatility effects also the costs (as evaluated in activity 4) have to be taken into account?	6	0	0	*6*

Table 11: Part 10 of the Questionnaire: Validation of Activity 6 - Analysis of risks and volatility effects

The experts were asked if they agreed that it is important to analyze the risks and (related) volatility effects when evaluating the implementation of a mobile system (Q26). All experts confirmed the importance; nevertheless, prof. Neumann stated that he would have expected the analysis of risks and volatility effects in an earlier activity as this step if highly important. He added that also criteria for the evaluation of risks should be defined.

As regards to the analysis of risks and volatility effects, all experts confirmed that singularities of a mobile system (as defined in activity 2) (Q27), critical success factors (as defined in activity 3) (28) and costs (as evaluated in activity 4) (Q29) have to be taken into account.

The last section of the questionnaire was dedicated to the validation of the last activity – analysis of the potential target achievement rates (see Table 12). All experts confirmed that it is important to analyze the potential target achievement rates (Q30) and that these can be estimated by taking into account critical success factors, risks and volatility effects (Q31). They also confirmed that potential target achievement rates should take the formerly defined target system into account (Q32).

	Yes	No	Partly	*Total no. of answers*
Q30: Do you agree that it is important to analyze the potential target achievement rates?	6	0	0	*6*
Q31: Do you agree that potential target achievement rates can be estimated by taking into account critical success factors, risks and volatility effects?	6	0	0	*6*
Q32: Do you agree that potential target achievement rates should take the formerly defined target system into account?	6	0	0	*6*

Table 12: Part 11 of the Questionnaire: Validation of Activity 7 - Analysis of the Potential Target Achievement Rates

Analysis of results and suggestions for improvement of the integrative framework

Analyzing the above shown comments and suggestions by the experts following becomes clear:

1. The set of three principles and the set of the proposed seven activities and thus the framework as a whole were confirmed as correct by all experts. Also the usability and usefulness of the framework were confirmed.
   As regards to the completeness of the three principles, the seven activities and thus of the framework as a whole, the experts commented that the completeness depends on the scope and probably specific techniques are useful. Due to the fact that the integrative framework delivers a guideline for evaluating (mobile) ICS which can be applied in different contexts and within different sizes of projects, it does not provide a standardized procedure that can be applied with the same quality of results for all kinds of projects. The framework can definitely be 'situationally' applied, and the following statement makes sense: the bigger and more complex a project is, the more detailed and extensive the evaluation has to be. This in turn means, that additional techniques within an activity can become necessary, which are currently not made explicit in the integrative framework (e.g. a culture analysis as proposed by Prof. Mulder, which can be part of a.o. mBPR).
2. Several times the interviewees mentioned an iteration of the seven activities. The framework can indeed be improved by explicitly stating that iterations between activities are possible. Note that readdressing activities within the framework is already possible, but it mainly focuses on activity 7 (analysis of the potential target achievement rates) including activity 1 (definition of the target system) – by figuring out which targets can finally be achieved with the given project framework (e.g. budget, timeframe).
3. As regards to the axioms, the level of detail for activity 2 (mBPR) needs to be described more precisely for a better understanding. Otherwise it is

difficult to judge, if all requirements (based on activity 1) and system specifications can be derived from mBPR[9].

4. The framework, especially activity 2 - mBPR, seems also useful for specifying non-mobile IT components. It is confirmed that stationary IT can and also probably will, at least partly, be part of the solution that fulfills the target system. As one of the interviewees stated that "mobile systems are only one possible solution for the predefined requirements".
5. Earlier consideration (and collection) of risks and volatility effects is suggested and can e.g. be part of the activity related to the definition of critical success factors.
6. The definition of the target system and its proposed preference-neutral prioritization contributes to the uniqueness of the framework.
7. Interesting in general, but expected, is the approach of the experts towards the integrative framework: Each expert bases its comments on his current research and / or business topic, so that we gained a good insight into potential improvements from different perspectives.

Conclusions

In this report, the integrative framework as presented by Högler et al. (2015) is shortly presented. This framework delivers insight into the tangible and intangible effects of a mobile (IT) system, before it is being implemented and thus represents an ex-ante evaluation approach. It consists of three pillars with seven included activities which are evaluated in this case by experts that are familiar or very familiar with the topic of the framework. The results of this validation are shown in detail in this report.
The experts confirmed the validity of the framework to large extend and gave several suggestions for improvements, notably in the consideration of specific techniques to ensure quality of results of the activities of the framework.

Summarizing we conclude that the framework's applicability can be improved by

- Providing some additional definitions and explanations as regards to the used terms
- Allowing iterations explicitly
- Providing more details on how the single activities shall be implemented (description of related techniques)

References

Berghout, E., Nijland, M. and Powell, P. (2011): Management of lifecycle costs and benefits: Lessons from information systems practice. Computers in Industry. 62 (7), pp. 755-764.

Charette, R. N. (1991). The Risks with Risk Analysis. Communications of the ACM. 34(6), p. 106.

Corsten, H. (2000). Lexikon der Betriebswirtschaftslehre. München: Oldenbourg.

[9] System specifications are derived from requirements (which are outputs of activity 1), and based on outcomes of activity 2.

Drews, G. and Hillebrand, N. (2010). Lexikon der Projektmanagement-Methoden. Freiburg: Haufe.

Gadatsch, A. and Mayer, E. (2004). Grundkurs IT-Controlling: Grundlagen - Strategischer Stellenwert - Kosten- und Leistungsrechnung in der Praxis. Wiesbaden: Vieweg.

Gruhn, V. and Wellen, U. (2001). Process Landscaping: Modelling Distributed Processes and Proving Properties of Distributed Process Models. In: Unifying Petri Nets: Advances in Petri Nets. Ed. by Ehrig et al. Lecture Notes in Computer Science 2128. Berlin: Springer.

Högler, T., Versendaal, J. and Batenburg, R. (2015). Evaluation of Mobile Systems – An Integrative Framework. Proceedings of the 21rst Americas Conference on Information Systems in Puerto Rico (AMCIS 2015).

Högler, T. And Versendaal, J. (2016). Determining the Target System for Mobile Systems as Part of an Integrative Approach for the Economic Impact of ICS: Validation at an SME. Proceedings of the 29th Bled eConference"Digital Economy", June 19 - 22, 2016; Bled, Slovenia.

Hwang, C. and Yoon, K. (1981). Multi Attribute Decision Making: Methods and Applications – A State of the Art Survey. Berlin: Springer.

Hway‐Boon, O. and Yu, C.M. (2003). Success factors in e‐channels: the Malaysian banking scenario. International Journal of Bank Marketing. 21 (6/7), pp. 369-377.

Iqbal, N., Nadeem, W. and Zahee, A. (2015). Impact of BPR critical success factors on inter-organizational functions: an empirical study. The Business & Management Review. 6 (1), pp. 152-165.

Kirchhoff, S.; Kuhnt, S.; Lipp, P. and Schlawin, S. (2008). Der Fragebogen – Datenbasis, Konstruktion und Auswertung. 4th ed. Wiesbaden: VS Verlag für Sozialwissenschaften.

Kirchmer, M. (1999). Market- and Product-Oriented Design of Business Processes. In: Business Process Engineering – Advancing the State of the Art. Ed. by Elzinga, D.J., Gulledge, T. R. and C.-Y. Lee. New York: Springer, pp. 131-144.

Klabon, M.L. (2007). An Investigation of the Quantification of the Probability of Occurrence of Software Engineering Project Risks with Bayesian Probability. http://calhoun.nps.edu/bitstream/handle/10945/3121/07Dec_Klabon.pdf?sequence=1&isAllowed=y (visited 11/22/2015).

Köhler, A. and Gruhn, V. (2004). Mobile Process Landscaping am Beispiel von Vertriebsprozessen in der Assekuranz. In: Mobile Economy: Transaktionen, Prozesse, Anwendungen und Dienste. Proceedings of the 4. Workshop Mobile Commerce. Ed. by Pousttchi, K., Turowski, K. Bonn: Köllen, pp. 12-24.

Kronsteiner, R. and Thurnher, B. (2009). Opportunities and Risks for Mobile Decision Support. In: Handbook of Research on Mobile Multimedia. Ed-. by I. K. Ibrahim Hershey: IGI Global, pp. 93-104.

Kulk, G.P. and Verhoef, C. (2008). Quantifying requirements volatility effects. Science of Computer Programming. 72 (3), pp. 136-175.

Nysveen, H., Pedersen, P.E. and Skard, S.E.R. (2015). A review of mobile services research: Research gaps and suggestions for future research on mobile apps. SNF Working Paper No 01/15. http://brage.bibsys.no/xmlui/bitstream/handle/11250/279041/A01_15.pdf?sequence=1&isAllowed=y (visited 22.11.2015).

Rockart, J.F. (1979). Chief Executives Define Their Own Data Needs. Harvard Business Review. 57 (2), pp. 81-93.

Rückle, H. and Behn, M. (2007). Unternehmenserfolg mit Zielen. Renningen: Expert.

Saaty, T. L. (1996). Multicriteria Decision Making: The Analytic Hierarchy Process. RWS Publications, Pittsburgh.

Sing, M.P. and Vyas, R. (2012). Requirements Volatility in Software Development Process. International Journal of Soft Computing and Engineering. 2 (4), pp. 259-264.

Wild, M, and Herges, S. (2000). Total Cost of Ownership (TCO) – Ein Überblick. In: Arbeitspapiere WI, Nr. 1/2000. http://geb.uni-giessen.de/geb/volltexte/2004/1577/pdf/Apap_WI_2000_01.pdf (visited 11/22/2015).

Annex 1: Questionnaire

Part 1. Introduction: Scope of the interview and general understanding

The scope of this interview is to validate the integrative framework as regards to its usefulness, correctness and applicability in practice.

Question 1. Did you receive the document describing the integrative framework?

Wählen Sie ein Element aus.

Question 2. Did you have time to read the document?

Wählen Sie ein Element aus.

Question 3. Did you understand the general procedure of the framework?

Wählen Sie ein Element aus.

If "partly" or "no" in answer 3: Could you please explain.

_____

Question 4. Was it clear for you that the approach is meant for supporting the decision process (i.e. ex ante evaluation)?

(Remark: Decision making process regarding whether to implement a mobile system at all and / or to be able to choose the most appropriate alternative / system)
Wählen Sie ein Element aus.

If "no" or "partly" in answer 4: How can I make it clearer / more comprehensible?

_____

Part 2. General data about interviewee

Name:		Company:	
Surname:		Position:	
Familiarity with topic	Wählen Sie ein Element aus.	City:	
Working in the topic since	INSERT YEAR	Country:	

Herewith I agree that the content of my interview can be used for a publication related to this thesis.
Wählen Sie ein Element aus.

___ Anonymously
___ By mentioning my full name and affiliation

_____

Part 3. Validation of Axioms

Question 5. In our approach we derive requirements from objectives as defined in the target system. Do you agree that in this manner objectives and requirements are inherently related?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 6. In our approach we derive the (technical) system specification from requirements (as defined in activity 1) during activity 2 (mobile Business Process Reengineering / mBPR). Do you agree that in this manner a system specification can be derived from (general) requirements during the mBPR?

Wählen Sie ein Element aus.

_____

If "no" or "partly": Could you please explain?

_____

Question 7. In our approach we define risks as (critical) success factors that are not taken into account. Do you agree that in this manner risks and success factors are inherently related?

Wählen Sie ein Element aus.

_____

If "no" or "partly": Could you please explain?

_____

Part 4. Validation of the framework (overall approach of the framework)

Question 8. Do you agree with the set of 3 Principles, in terms of completeness and correctness:

1. Principle 1: A detailed internal analysis has to be proceeded
2. Principle 2: A detailed economic analysis has to be proceeded
3. Principle 3: An integrative evaluation has to be proceeded

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Why is this change necessary?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 9. Do you agree with the set of 7 activities of the framework, in terms of completeness and correctness, and their order?

1. Definition of target system
2. Mobile Business Process Reengineering
3. Definition of Critical Success Factors
4. Evaluation of Life cycle costs
5. Evaluation of benefits
6. Analysis of risks and volatility effects
7. Analysis of potential target achievement rates

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Why is this change necessary?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Question 10. Do you think that the framework is applicable for non-mobile environments as well?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Which changes would be necessary in order to make it applicable for non-mobile environments?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Question 11. Do you think that the framework is complete (as for the seven described activities)?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Which changes would be necessary in order to make it complete?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Question 12. Do you think that the framework is correct (as for the seven described activities)?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Which changes would be necessary in order to make it correct?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Question 13. Do you think that the framework is usable (as for the seven described activities)?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Which changes would be necessary in order to make it usable?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Part 5. Validation of activity 1: Preference-neutral target definition

Question 14. Do you agree with the approach for defining a preference-neutral target system?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Why is this change necessary?

_____

Would the framework keep its validity also if the **proposed changes would be made?**
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 15. Do you know similar approaches?

Wählen Sie ein Element aus.

If yes, which ones?

_____

Question 16. Which alternatives do you propose for getting a valid target system that is based on effects / influences between targets?

_____

Question 17. Do you agree that the main outputs of this first activity are the Targeted Effects (i.e. benefits that should be achieved by the system) and the requirements?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

From your point of view: What are the main outputs of activity 1?

_____

Part 6. Validation of activity 2: Mobile Business Process Reengineering" (mBPR)

Question 18. Do you agree that analyzing the current processes is important in order to figure out how they could be supported by mobile systems?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 19. Do you agree that the main outputs of the mBPR are the identification of Singularities of mobile systems, of Interdependencies (between the single system components, i.e. people, technologies, processes) and of Success Factors?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

What are the main outputs in your opinion?

_____

Part 7. Validation of the activity 3: Definition of Critical Success Factors

Question 20. Do you agree with the proposed procedure for defining Critical Success Factors?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Why is this change necessary?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Part 8. Validation of activity 4: Evaluation of Life Cycle Costs

Question 21. Do you agree that it is important to take into account all life cycle costs IF this is appropriate for the project?

(Remark: Appropriate = cost-benefit-ratio of investment in this in-depth-analysis is reasonable)

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Which alternative do you propose?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Part 9. Validation of the activity 5: Evaluation of Benefits

Question 22. Do you agree that it is important evaluate the POTENTIAL benefits of the implementation of a mobile system?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Which alternative do you propose?

_____

Would the framework keep its validity also if the proposed changes would be made?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 23. Do you agree that when evaluating potential benefits also the objectives (as defined in activity 1) have to be taken into account?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

If objectives would NOT be taken into account, would the framework still keep its validity?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 24. Do you agree that when evaluating potential benefits also the singularities of a mobile system (as identified in activity 2) have to be taken into account?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

If singularities would NOT be taken into account, would the framework still keep its validity?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 25. **Do you agree that when evaluating potential benefits also the interdependencies between the single system components (as defined in activity 2) have to be taken into account?**

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

If interdependencies would NOT be taken into account, would the framework still keep its validity?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Part 10. Validation of activity 6: Analysis of risks and volatility effects

Question 26. **Do you agree that it is important to analyze the risks and (related) volatility effects when evaluating the implementation of a mobile system?**

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Which alternative do you propose?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

_____

Question 27. **Do you agree that when analyzing risks and volatility effects also the singularities of a mobile system (as defined in activity 2) have to be taken into account?**

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

If interdependencies would NOT be taken into account, would the framework still keep its validity?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 28. Do you agree that when analyzing risks and volatility effects also the critical success factors (as defined in activity 3) have to be taken into account?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

If critical success factors would NOT be taken into account, would the framework still keep its validity?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Question 29. Do you agree that when analyzing risks and volatility effects also the costs (as evaluated in activity 4) have to be taken into account?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

If costs would NOT be taken into account, would the framework still keep its validity?
Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Part 11. Validation of the activity 7: Analysis of the potential target achievement rates

Question 30. Do you agree that it is important to analyze the potential target achievement rates?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Which alternative do you propose?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

_____

Question 31. Do you agree that potential target achievement rates can be estimated by taking into account critical success factors, risks and volatility effects?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Which alternative do you propose?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

_____

Question 32. Do you agree that potential target achievement rates should take the formerly defined target system into account?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Which alternative do you propose?

_____

Would the framework keep its validity also if the proposed changes would be made?

Wählen Sie ein Element aus.

If "no" or "partly": Could you please explain?

_____

Would the framework keep its validity also if the proposed changes would NOT be made?

Wählen Sie ein Element aus.

If “no“ or ”partly“: Could you please explain?

_____

Annex 2: Description of the Framework

(as sent to experts)

Evaluation of Mobile Systems – An Integrative Framework

Content

1 Introduction

Since the eighties, the debate about cost-effectiveness of Information Technologies (IT) – as parts of Enterprise Systems (ES) – is consistently resurrected. Many scholars have recognized the contradictory effects of IT. E.g., Solow (1987) stated that the computer age could be seen everywhere except in productivity statistics and Loveman had no doubt that "IT capital had little, if any, marginal impact on output or labour productivity, whereas all the other inputs into production – including non-IT capital – had significant positive impact on output and labour productivity" (Loveman 1994, p. 85).
By the current state of scientific knowledge it is recognized that the implementation of ES represents not only a major technical challenge, but requires new ways of thinking about business processes and organizational changes, system alignment, and enterprise architecture. Thus, IT investments should be accompanied by complementary investments, like improved business processes (Brynjolfsson and Hitt 1998, pp. 50,51; Brynjolfsson and Hitt 1995; Brynjolfsson and Hitt 2000; Brynjolfsson 1993; Robey and Boudreau 1999; Hong and Kim 2002; Al-Mashari et al. 2003), organizational changes (Markus & Tanis 2000) and focused training of employees (Amoako-Gyampah 2004; Amoako-Gyampah & Salam 2004).
Still, success factors for optimal enterprise architecting and maximized effect of IT implementation and thus organizational success need to be investigated more explicitly (cf. Niehaves et al. 2014). This also holds for mobile systems, sets of mobile technology and human (system) components which are inherently related (a definition for mobile systems is given in section 2.4). The aim of mobile systems is to integrate mobile processes and workstations into internal, mostly stationary corporate and enterprise-wide process chains and thus to overcome their spatial separation and accompanying information losses. Up until now, there is little development towards an integrative framework for performance measurement of mobile systems that takes into account principles of aligning IT with associated investments like process improvement.
This work presents an integrative framework for the **ex ante (i.e. decision making support focused)** evaluation of enterprise systems. As mobile technologies are reshaping the global economic landscape, enhancing speed and comfort of communication and information exchange and as they have a bundle of specific singularities that should be considered for evaluation, **mobile systems** have been taken **as example** for testing the integrative framework. The resulting framework consists of the following three main principles: a detailed organization-internal evaluation, a detailed economic evaluation and an integrative evaluation for a mobile system at hand. Thus, the integrative framework takes a strong socio-technical system perspective.
The following sections shortly describe the theoretical background of the integrative framework (section 2), the integrative framework itself (section 4; which is in detail described in Högler et al. (2015)) and how this framework can be applied in practice, by presenting several of the framework´s activities on real case studies (section 5).

2 Theoretical Background

We aim to develop an integrative framework for the **ex ante evaluation of mobile systems** by taking different theoretical perspectives as a starting point. While the basis for the work is a behavioral science research approach (section 2.1), we take

1) business/IT-alignment theory (section 2.2),
2) systems theory (section 2.3) and
3) identified singularities of mobile systems (section 2.4)

as starting points for the elaboration of the framework.

2.1 Behavioral Science

We apply behavioral science as it has been described in the context of design science research for information systems (Hevner et al. 2004). Behavioral science (in this context) is defined as follows: "*The behavioural science paradigm seeks to develop and verify theories that explain or predict human or organizational behaviour [...]. [It] seeks to develop and justify theories (principles and laws) that explain or predict organizational and human phenomena surrounding the analysis, design implementation, management and use of information systems*." (Hevner et al. 2004; March and Smith 1995). "*Such theories ultimately inform researchers and practitioners of the* ***interactions among people, technology, and organizations that must be managed if an information system is to achieve its stated purpose, namely improving the effectiveness and efficiency of an organization***." (Hevner et al. 2004).

2.2 Business/IT-alignment

The aim of theories and studies focusing on "alignment" or "fit" is to reveal "*conditions that facilitate a positively interactive relationship among two or more entities.*" (Hester 2014, p. 51). Henderson and Venkatraman (1993) developed the Strategic Alignment Model which is one of the first models that "*provided levers for organizations in introducing new IT technologies using business/IT-alignment concepts*" (Batenburg and Versendaal 2008, p. 3). Since then, many scholars have investigated the connection between alignment and organizational performance (e.g. Cragg et al. 2002 and Peppard & Ward 1999), but yet the model of business/IT-alignment that has been hardly applied to the domain of mobile IT and its business value so far.
Another example perspective for alignment is the Task-Technology-Fit (TTF) model (see also section **Error! Reference source not found.**), which is a valuation model that allows statements on the suitability of technologies to address particular tasks. The TTF model was developed by Goodhue and Thompson (1995) for the assessment on an individual level and adapted by Zigurs and Buckland (1998) for the usage on group level. Gebauer et al. (2005) defined the TTF in a mobile context as *"a three-way match between the profiles of managerial tasks (operationalized by difficulty, interdependence and time-criticality), mobile information systems (operationalized by functionality as notification, communication, information access, and data processing, form factors, and location-awareness), and individual use context (operationalized by*

distraction, movement, quality of network connection, and previous experience).” (Gebauer et al. 2005, p. 1). Following Goodhue and Thompson (1995), Gebauer et al. consider following elements when evaluating the TTF: Tasks of corporate governance, mobile technology to be used and individual context of users.

2.3 Systems Theory

As business/IT-alignment reveals “*conditions that facilitate a positively interactive relationship among two or more entities*” (Hester 2014, p. 51), we also leverage systems theory. Systems theory is an important perspective to achieve integration of concepts and methods. From this approach, system parameters are variables, whose values characterize the behavior of a system with a given structure (see also DIN 1995). The analysis of structures, reactions and functions allows certain **predictions about the expected system behavior**, whereas it does not focus on a separate consideration of each element (Bertalanffy 1976). Since the behavior of a system and therefore its performance are influenced by interaction or controlling of **system parameters**, they play an important role in matters of the integrative framework for evaluating mobile systems. System parameters with the highest influence on a system are characterized as “**critical success factors**” (CSF). CSFs are a limited number of system properties that particularly contribute to achieving objectives set by the company (Rockart 1979, p. 85). Relating to mobile systems, the current work defines CSFs as technical as well as social system parameters that have a significant impact on the performance of a mobile system.

2.4 Information and communication systems, enterprise systems and mobile systems

We apply insight from the field of Information and Communication Systems (ICS) as parts of enterprise systems. ICS comprehends, besides technological components, system components of human (social) nature, their relationships (represented by processes) and their properties (Högler 2012). We define enterprise systems as the overall combination of ICS that a business uses to organize and run its operations. This definition can also be applied to mobile enterprise systems as a special type of enterprise systems, aiming at integrating mobile processes and devices into internal, mostly stationary corporate and enterprise-wide process chains and hence overcoming their spatial separation and accompanying information losses – information becomes available any time at any place (Schiller 2000; Isaac and Leclercq 2006). The focus of this work are mobile enterprise systems – in short: mobile systems. It can be noted that our framework can be applied to enterprise systems in general as well; yet mobile systems have some specific characteristics, i.e. their singularities, as explained in the next section, which are explicitly anticipated upon.
Mobile systems exist in different forms and have a multiplicity of characteristics, which make them specific as compared to stationary ICS. This specific setting implies certain singularities to be taken into account on evaluation. Comparing mobile devices and stationary computers, the following main differences become apparent: First, mobile devices are much smaller than desktop computers and second, they are portable (in the meaning of that they can be used when being

carried around which in turn implies that a screen is integrated). The singularities of mobile devices are thus a result of the size of devices and the fact that the devices are portable. At the same time, the user is not bound anymore to a stationary working place – s/he becomes mobile by using portable devices. Table 13 shows the relationship between the three main distinguishing features and flashlights resulting singularities of mobile systems:

Distin-guishing feature	Resulting Singularity (examples)
Size	• "One-piece-system" (often no keyboard, no external (big) screen, no mouse) • Screen size • Battery size -> low capacity • …
Portability	• Due to environmental issues (sunlight, dust, rain, …): Ruggedized, sunlight-readable display… • Security problems (often stolen / forgotten, …) • Connection to wireless networks • Battery as only energy supply • New kinds of human-device-interaction • …
Mobility	• Distances to be bridged (by walking, driving, …) • Adaption to new environments • Distraction (noise, weather, visual impressions, …) • Media discontinuity • …

Table 13: Examples of derived singularities for mobile systems

The singularities of mobile systems have been discussed in detail by Högler and Versendaal (2014).

3 Integrative Framework for the Evaluation of Mobile Systems

The outcomes of the previous sections lead to define **three principles** that are, in our view, essential to develop an integrative framework for the assessment of mobile systems:

1. For an integrative evaluation of mobile systems a detailed **internal (intra-company) analysis** has to take place, including business process reengineering.
2. A detailed **economic analysis** is necessary to perform an integrative evaluation of mobile systems. It considers all life-cycle costs as well as quantitative, qualitative and integrative benefits of mobile systems.
3. For an **integrative evaluation** of a mobile system as a whole, potential target achievement rates and risks of implementing such a system have to be analyzed.

Regarding mobile systems as systems of technical as well as social components, that have relationships and that influence each other, system theory implies that singularities and success factors should be taken into account as well as risks that can occur if success factors are neglected. Systems theory enables the

development of an integrative framework for the evaluation of mobile systems by further specifying our three principles into several activities that are connected and depicted in Figure 2:

- Principle 1 (Ward and Peppard 2002): To adhere to this principle, following activities are considered necessary: Definition of a target system (activity 1), defining monetary and qualitative effects to be achieved by the implementation of a mobile system (output 1 / O1) as well as requirements (O2). These outputs are inputs for the Mobile Business Process Reengineering (mBPR, activity 2). Singularities (O3), interdependencies (O4) as well as success factors (O5) of the mobile system are derived from activity 2 and flow as inputs into activity 3, the definition of Critical Success Factors of mobile systems. During the mBPR requirements are refined.
- Principle 2: In order to achieve integrative results, following activities are considered necessary: Evaluation of life cycle costs of the planned mobile system (activity 4, Unhelkar 2009), based on outputs from activity 1 (intended effects (O1)) and activity 2 (potential effects (O1*)). Singularities (O3), interdependencies (O4) and intended effects (O1) are used as inputs for the evaluation of benefits (activity 5, Högler and Versendaal 2014) that follows activity 4. The outputs of these activities (expected life-cycle costs (O7) and potential benefits (O8)) are used as inputs for principle 3.
- Principle 3: The analysis of risks and volatility effects (activity 6, Kronsteiner and Thurnher 2009) is considered an explicit activity. The final assembly of these outputs (risks (O9) and volatility effects (O10)) leads to the assessment of potential target achievement rates (activity 7), which is – in addition to the constellation of all other activities within the three pillars – one of the scientific contributions of this work.

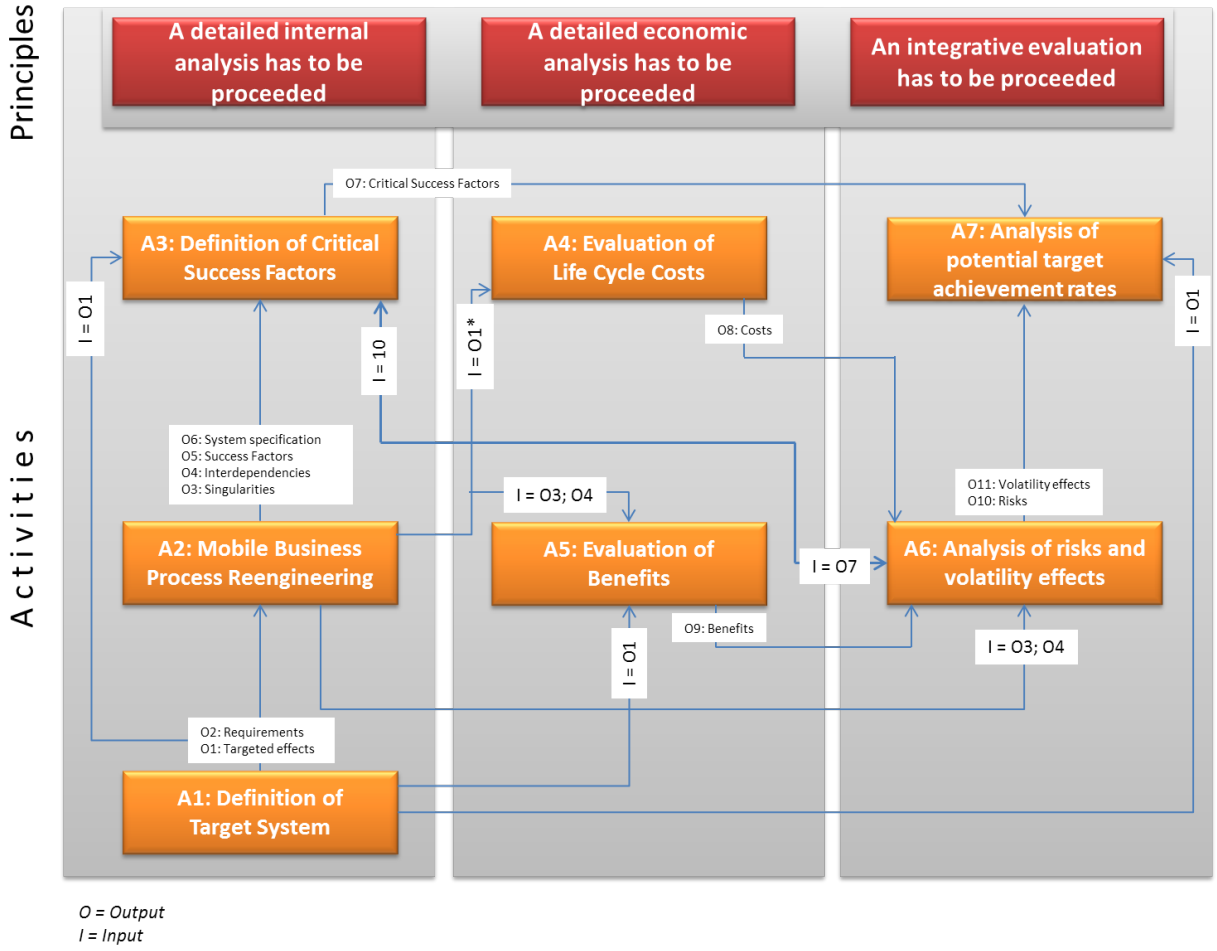

Figure 2: The Integrative Framework

The integrative framework provides activities and principles for proper ex ante evaluation of mobile systems, leaving room for particular instantiation.

4 Applying the Integrative Approach in Practice

In the following sections different case studies, implemented in the timeframe 2006-2016, are used to showcase the application of the integrative framework in practice. The headings of the sections lead to the case studies as described in the original papers and as published within international research conferences. More detailed information about the case studies can be sent on request.

4.1 Activity 1: Definition of the target system (Högler & Versendaal 2016)

We propose to define the target system by following the multi-attribute decision making (Hwang & Yoon 1981). Figure 3 outlines our proposed procedure which leverages the Analytical Hierarchy Process (AHP) (Saaty 1996). The main contribution is that the AHP is extended and applied in the context of an integrative approach for ex ante evaluating the economic efficiency of mobile systems in order to determine objectives for such a system. Figure 3 shows the differences between the AHP by Saaty and the extended AHP as it is applied within the integrative framework:

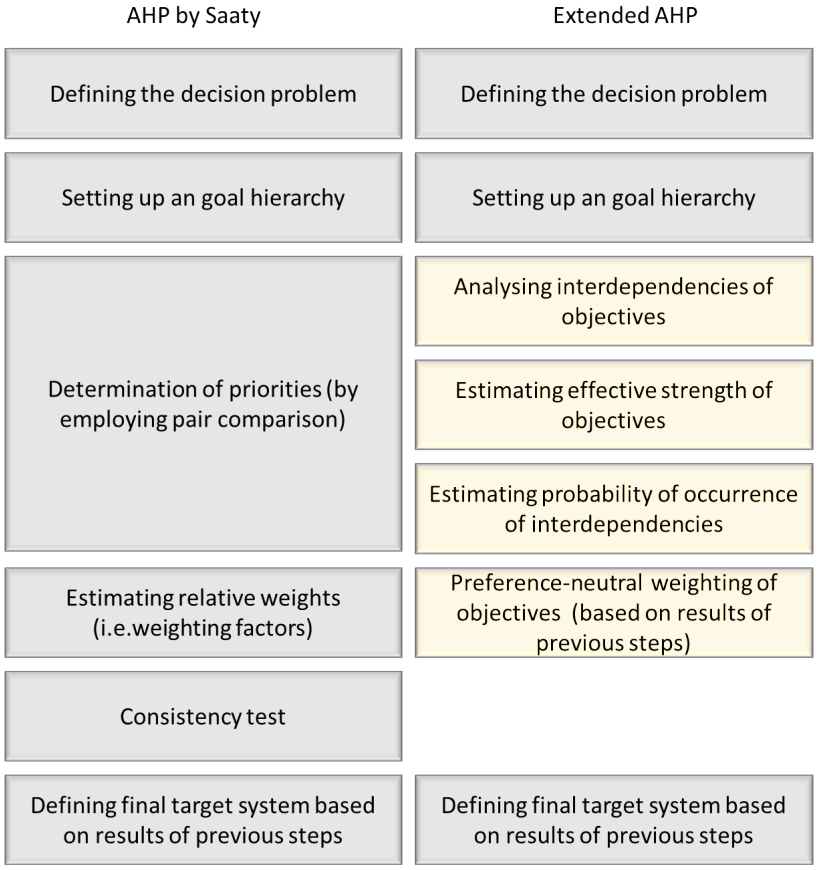

Figure 3: Comparison of original and our extended AHP

The uniqueness of the extended AHP is that the determination of priorities is not based on subjective assessment, but on the following steps (see Figure 3), differing from previous approaches:

- **Interdependence analysis** between individual objectives (Kirchmer 1999; Drews & Hillebrand 2010; Rückle & Behn 2007);
- **Consideration of the effective strength** of objectives and the **probability of occurrence** of interdependencies (Klabon 2007; Charette 1991) and thus their respective **value**; and
- **Preference-neutral weighting** of objectives in the context of these latter two aspects[10].

By following such a preference-neutral weighting and prioritization of objectives, a consistency test becomes unnecessary and is thus omitted in the proposed procedure.
Figure 4 depicts our proposed steps for the definition of the target system:

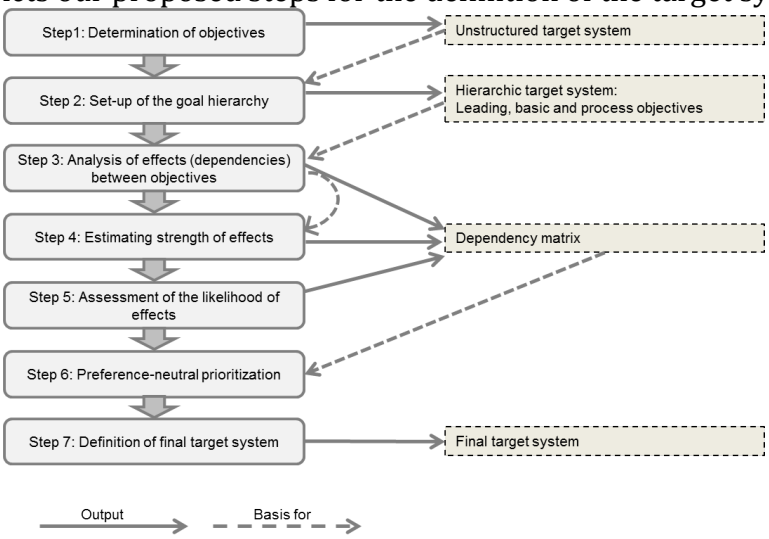

Figure 4: Steps in the definition of the target system

What follows is a detailed description of each of the steps. Note that for each step we suggest particular approaches where alternatives may well be suitable as well, as long as the outcomes are reliable in the given context of the determination of the target system.

Step 1: Determination of objectives

First, objectives are determined e.g. by task observation, in a workshop or from interviews with the help of a questionnaire. The output of this step is an unstructured target system (i.e. a non-structured list with objectives) that contains all gathered objectives.

Step 2: Set-up of the goal hierarchy

In step 2, the identified objectives are brought in a hierarchical relationship (goal hierarchy; what we define in levels 'key objectives', 'basic objectives' and 'process objectives'). A goal hierarchy is only complete if *"each element of a hierarchy level has a direct relationship to the next higher element [...]"* (Ahlert 2003, p. 37) (figure 4).

[10] With the constraint to leave this step out in simple projects.

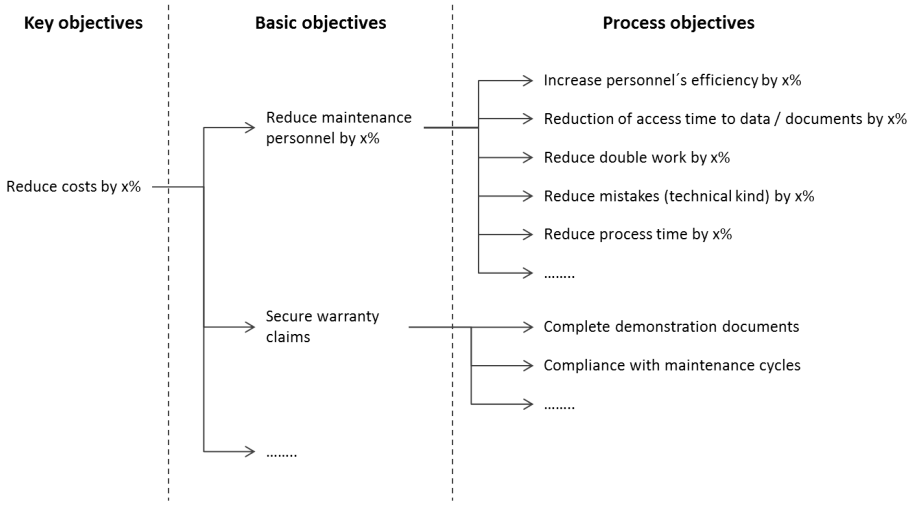

Figure 5: Example for a goal hierarchy

Key objectives are the benefits / business value that should be achieved with the implementation of a mobile system, whereas basic objectives present the "actions" how the key objectives can be achieved. Process objectives describe HOW basic objectives can be achieved on process level.

Step 3: Analysis of effects / interdependencies between objectives

In the 3rd step, the identified process objectives are evaluated in a paired comparison concerning their mutual, direct interdependencies. The aim of this comparison is to identify particularly competing objectives, as setting priorities among them reduces inconsistencies in the target system. Table 14 shows an example. In simple target systems with only a very limited number of objectives this step can be omitted. But particularly for complex target systems with many objectives it is quite useful to keep an eye on the different types of effects as by doing so mistakes can be easily detected (e.g. using wrong values when estimating the strength, e.g. a positive value instead of a negative one for negative effects): Red fields can ONLY receive negative values (see explanation in step 4).

Remark:

It is necessary that the interviewees agree internally on the nature of the effects (positive, neutral, negative) – but not necessarily on their effective strength and likelihood – since without such an agreement, the target-relation-matrix cannot be installed. The individual effects between objectives should not be regarded as absolute and as in all circumstances occurring, but rather they indicate general trends which may be reinforced, mitigated or neutralized under certain circumstances, or by the use of respective (appropriate or inappropriate) systems.

Objective	Increase personnel´s efficiency by x%	Reduction of access time to data / docs by x%	Reduce double work by x%	Reduce mistakes by x%	Reduce process time by x%
Increase personnel´s efficiency by x%					
Reduction of access time to data / docs by x%					
Reduce double work by x%					
Reduce mistakes by x%					
Reduce process time by x%					

Table 14: Example for a Target-relation-matrix. Reading direction: from left to right.

Explanation:

(green)	Complementary objectives: Pursuing objective X has a positive effect on achievement of objective Y
(white)	Indifferent objectives: Pursuing objective X has no effect on achievement of objective Y
(red)	Competing objectives: Pursuing objective X has a negative effect on achievement of objective Y
	Same objective -> not analyzed

Step 4: Estimating strength of effects

The strength of interdependencies is estimated in step 4, which is largely subjective and based on experience of the involved interviewees. The scale for the estimation is arbitrary, but it should not be too fine-grained, since this would cause pseudo-accuracies (Meixner & Haas 2012). To avoid pseudo-accuracy due to excessive fine granularity, scores were classified into a three-point scale.
The authors propose following three-level scale:

- low (positive / negative) effects (values +1 / -1)
- medium (positive / negative) effects (values +2 / -2)
- strong (positive / negative) effects (values +3 / -3)

The individual effects between objectives should not be regarded as absolute and as in all circumstances occurring, but rather they indicate general trends which may be reinforced, mitigated or neutralized under certain circumstances, or by the use of respective (appropriate or inappropriate) systems. Table 15 shows an example.

Objective	Increase personnel´s efficiency by x%	Reduction of access time to data / docs by x%	Reduce double work by x%	Reduce mistakes by x%	Reduce process time by x%
Increase personnel´s efficiency by x%				-2	3
Reduction of access time to data / docs by x%	3				3
Reduce double work by x%	3			2	3
Reduce mistakes by x%	3		3		2
Reduce process time by x%	2			-3	

Table 15: Example for the effective strength of the dependencies between objectives.

Step 5: Assessment of the likelihood of effects

Next, the estimation of the likelihood (probability) of effects is needed (step 5). It is methodologically based on risk management (e.g. NIST 2012; Stoneburner, Goguen and Feringa, 2002) and in practice on the experience of the involved individuals. Again a three-level scale is proposed to estimate the likelihood of effects: effect is possible, but improbable (value 1); effect is probable (value 2); effect will occur with the utmost probability (value 3). Table 16 shows an example.

Objective	Increase personnel´s efficiency by x%	Reduction of access time to data / docs by x%	Reduce double work by x%	Reduce mistakes by x%	Reduce process time by x%
Increase personnel´s efficiency by x%				2	3
Reduction of access time to data / docs by x%	3				2
Reduce double work by x%	3			2	3
Reduce mistakes by x%	3		2		2
Reduce process time by x%	1			3	

Table 16: Example for the likelihood of effects.

Step 6: Preference-neutral prioritization

To ensure that mainly high priority objectives are pursued, which have the greatest benefit, competing relations between objectives must be detected. This is done in the 6th step, where the objective priorities are determined.
Based on the prospect theory by Kahneman & Tversky (1979), a preference-neutral prioritization assumes that the priority of an objective can be determined by its active and passive value. To receive these values, for each objective its strength of effects (values in Table 15) is multiplied with the likelihood of its occurrence (values in Table 16). The resulting (mathematical) products are subsequently summed up for each objective in both the horizontal (so-called "active value") as well as in the vertical ("passive value") axis of the table. This procedure is legitimate insofar as the value of an effect can be defined as the product of strength of effects and their likelihood of occurrence (Kahneman & Tversky 1979)(Table 17).
The objective with the highest active value influences many other objectives in a positive way and the objective with the highest passive value will be reached anyway by achieving other objectives. This implies, that objectives with high active values should have a very high preference because it can be expected that by their achievement many other objectives will be reached automatically. In contrast, the achievement of objectives with a very low or even negative passive value is not supported by other objectives. If these objectives are important for the company, they need specific attention.
The greater the positive effects on other objectives and the higher the likelihood of occurrence, the higher the value and thus priority of an objective. Conversely, the more negative an effect is and the higher the likelihood of his occurrence is, the more important is that appropriate risk management measures are taken or respective requirements for the new system are defined in order to reach a defined objective.

Objective	Increase personnel´s efficiency by x% (O1)	Reduction of access time to data / docs by x% (O2)	Reduce double work by x% (O3)	Reduce mistakes by x% (O4)	Reduce process time by x% (O5)	*Active value*
Increase personnel´s efficiency by x% (O1)				-4	9	***5***
Reduction of access time to data / docs by x% (O2)	9				6	***15***
Reduce double work by x% (O3)	9			4	9	***22***
Reduce mistakes by x% (O4)	9		6		4	***19***
Reduce process time by x% (O5)	2			-9		***-7***
Passive value	**29**	**0**	**6**	**-9**	**28**	

Table 17: Values of effects, resulting in active and passive values of objectives

Objectives are proposed to be divided into 4 priorities:

- Priority A: Most important objectives ("must have objectives") (as they have many positive effects on other objectives). *Remark*: If these objectives are not achieved, the project will probably fail.
- Priority B: Important objectives ("should have objectives") (as they have positive effects on other objectives, but are also positively influenced by other objectives).
- Priority C: Objectives that have neither many positive effects on other goals nor that are much positively influenced by other objectives ("could have objectives"). If these objectives are important for the company (e.g. due to strategic reasons), they should receive specific attention.
- Priority D: Objectives that are influenced very positively by other objectives so that it can be assumed that they will be reached anyway ("not important objectives") – even if not explicitly followed.

In order to get the preference-neutral prioritisation, all objectives are inserted into a coordinate system. The active values are taken as values for the x-axis of a coordinate system, whereas passive values are taken as values for the y-axis. Figure 6 shows the five objectives of table 5 in a coordinate system:

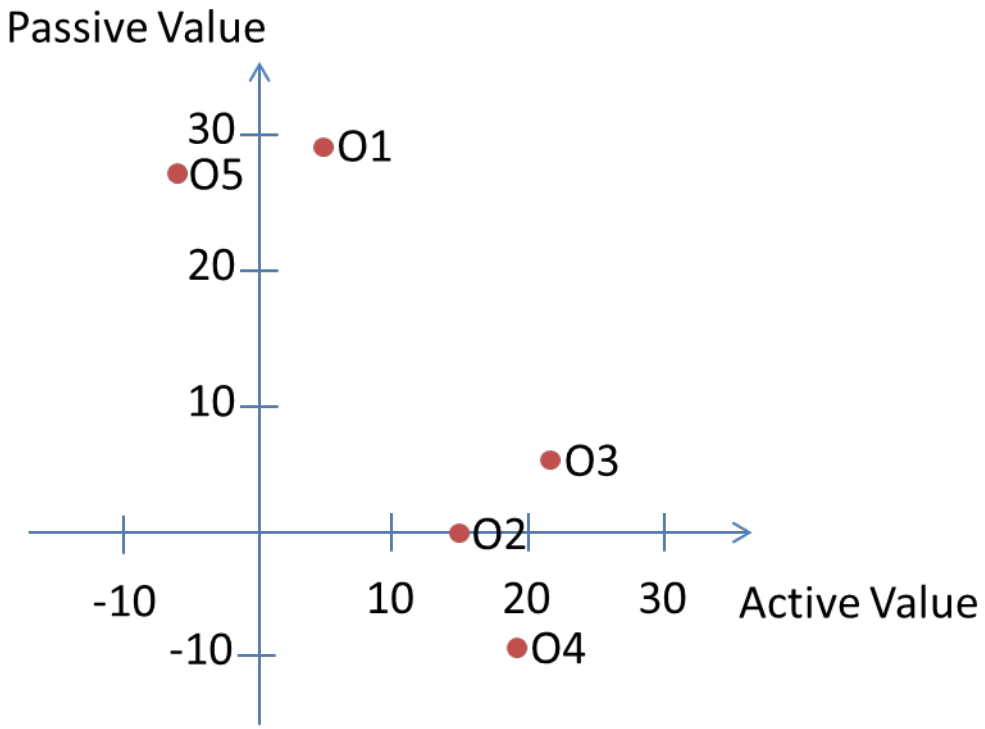

Figure 6: Objectives as scatter plots in a coordinate system

In Figure 6 it can be seen, that objectives O2, O3 and O4 have quite positive effects on other objectives and support their achievement (i.e. they have a high active value), but that they themselves are not positively affected by other objectives (low passive value). In contrast, objectives O1 and O5 have a very high passive value, which indicates that they will be achieved anyway, even if not focusing on them during the project. In this (simple) case the objectives O2, O3 and O4 would advocate for priority A and the objectives O1 and O5 for priority D. As the example is very simple with a very limited number of objectives, there are no priority B and C objectives.

In more complex target systems a threshold should be defined which allows the classification of objectives in different priorities. As there is no standardized procedure for defining such a threshold, we propose to choose a threshold with the participants involved in the earlier steps of this activity 1. We suggest to divide the objective in four priorities as follows:

1. Choose two objectives that are nearby the centre of all objectives
2. Put a horizontal line between them (example in figure 5: you can put a horizontal line between objectives O2 and O3)
3. Compare these two objectives by answering following question: Is objective x (the lower one) as important as objective y or is it more important?
4. If it is as important as the above objective, shift the line between objective y and the next upper one (e.g. objective z).
5. Repeat the procedure until you get the answer “objective m is as important as objective n”

6. Proceed in the same way with a vertical line. Compare these two objectives by answering following question: Is objective x (the right one) as important as objective y (the left one) or is it more important?
7. Repeat the procedure until you get the answer "objective m is as important as objective n"

Figure 7 shows the result of the preference-neutral prioritization of objectives in a coordinate system.

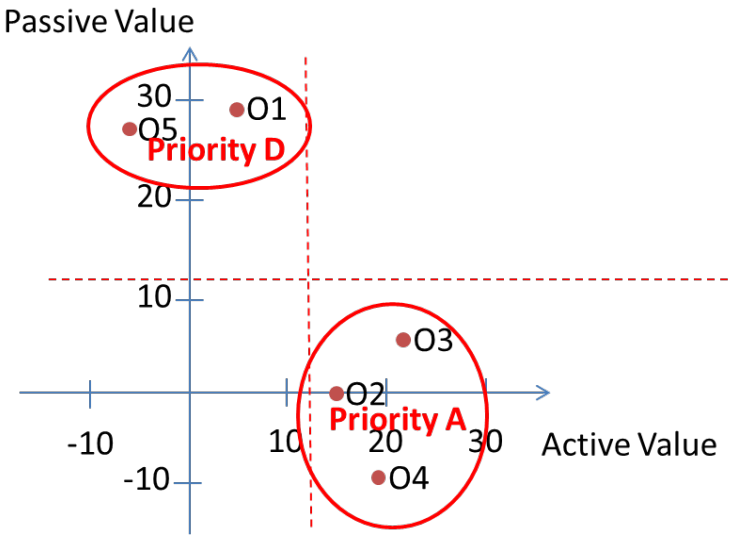

Figure 7: Objectives and their preference-neutral priorities

Step 7: Defining the final target system

In the last step (7) the final target system is defined by consolidating the earlier steps and assigning final priorities to objectives. Some objectives can receive a higher priority than the one proposed by the preference-neutral prioritization due to strategic issues. And in some complex projects resources (time, budget, staff…) can be that limited that even for high priority objectives a weighting is necessary so that within the project only a few objectives will be followed.
Based on the final target system, first – initial – requirements for the system to be implemented can be defined. Taking the objectives O2, O3 and O4 as basis, following requirements can be derived in cooperation with the focus organization, as shown in Table 18 (example):

Objective	Related requirement
O2: Reduction of access time to data / docs by x%	**Data /documents available everywhere -> data / documents available in digital form Mobile devices that allow access to data everywhere Network (wireless / wired) that allows access to data …..**
O3: Reduce double work by x%	**Regarding documentation: System has to allow direct data entry / no paper-based entries; …. Regarding maintenance work: System has to be able to check e.g. the correctness of the machine to be repaired -> RFID-/ barcode reader or manual entry of machine ID; System has to be able to check if task was already done by someone else; ….**
O4: Reduce mistakes by x%	**Regarding documentation: System has to allow direct data entry / no paper-based entries; System has to be able to check meaningfulness of data entry Regarding maintenance work: System has to be able to check e.g. the correctness of the machine to be repaired -> RFID-/ barcode reader or manual entry of machine ID; System has to be able to check if task was already done by someone else; ….**

Table 18: Example for requirements derived by objectives

4.2 Activity 2: Mobile Business Process Reengineering

Business Process Reengineering (BPR) is aimed at analyzing and documenting existing processes. The resulting process models can include – besides a detailed description how operations are conducted – information regarding the employed data, IT resources, and other artifacts like KPIs and responsibilities (cf. Scheer 2000; Recker et al. 2009). The aim of the analysis and documentation of business processes is the (value-neutral) recording of process-descriptive data. It is the basis for reengineering and optimization as well as performance measurement. As standardized procedures exist, we refer to standard literature like Hammer and Champy (1994).

The *mobile* Business Process Reengineering (mBPR), as it is defined in this work, corresponds in many parts to the term as defined by Hammer & Champy (1994). However, it focuses, as the name implies, on mobile processes. The mBPR is not aiming – as called for in the early days of BPR – on a fundamental rethinking of the company and its business processes, but rather at optimizing of existing (mobile) business processes using mobile technologies. It is defined for this reason as follows: mobile Business Process Reengineering involves significant improvement and restructuring of mobile business processes using mobile technologies.

For the analysis of mobile the business processes we propose to apply the Mobile Process Landscaping for mBPR by Köhler & Gruhn (2004)(cf. Gruhn et al. 2007). Surely there are more ways in operationalizing mBPR application; we particularly mention methods:

- Service-Blueprinting by Ritz & Stender (2003),
- Opportunity Discovery Framework for mobile processes by Valiente & van der Heijden (2002)

Yet, these seem less appropriate[11].

After analyzing and modeling existing processes, the as-is state of processes affected by the planned transformation, particularly the often occurring and continuous process types, are identified and assessed; the mobile parts of the processes are identified, too, and (graphically) depicted. Also the information needs are determined (Gruhn & Wellen 2001, p. 105). The primary goal of the information needs analysis is therefore to determine information-related requirements for ICS. For this purpose:

(1) the subjective (the 'perceived information needs of the user'), as well as
(2) the objective (really required information and data in order to proceed a task) information needs

have to be analyzed and defined user-specifically. For the analysis of the as-is state of information flows we propose a so-called deductive approach (Koreimann 2000, S. 58 ff.; Schütt 2006, p. 70ff;) that focuses on the determination of information needs of the focused user groups, and an inductive approach that analyses the existing offer of information. For the deductive approach, the task analysis is an appropriate tool. For the inductive approach, a

[11] Service Blueprinting is better suited for the analysis of mobile services than for the analysis of mobile systems and associated processes. The Opportunity Discovery Framework is quite similar to the Mobile Process Landscaping; however, it is less comprehensive. In addition, the Opportunity Discovery Framework focuses on activities of "decision-making", "control" and "co-ordination", while mBPR as applied in the present work has no such focus.

document analysis as well as employee interviews are common methodologies for deriving knowledge about required information (ibidem).
On the basis of the analyzed processes and identified information needs, mobile Business Process Reengineering is processed in accordance with the target system:

1. In a first step, the processes are redesigned in accordance to the set objectives. By doing so, the expected interdependencies between the single system components can be identified (e.g. how do mobile devices influence the technicians´ routines / work / processes? Are they seen as a technical support or a burden? Does the identified necessary information fit in its currently available form to the planned type mobile devices (e.g. readability of needed documents on a device) etc.) – the singularities of the mobile system become clear.
2. In a second step, functional as well as non-functional requirements as defined in activity 1 (definition of the target system) are refined on basis of the findings of the previous step (particularly the singularities) and supplemented (result = technical system specification[12]; see Table 19)
3. Based on the findings of step 1 and 2, general success factors are determined. They form the basis for activity 3 of the integrative framework.

[12] "[…..] requirements represent the application from the perspective of the user, or the business as a whole. The specification represents the application from the perspective of the technical team. Specifications and requirements roughly communicate the same information, but to two completely different audiences." Or levels (requirements state what has to be achieved – and the (technical) specification shows HOW this will be reached from technical perspective." Source: http://softwareengineering.stackexchange.com/questions/121289/what-is-the-difference-between-requirements-and-specifications.

Objective	Related requirement	Refined and supplemented requirements (= technical system specification)
O2: Reduction of access time to data / docs by x%	Data /documents available everywhere -> data / documents available in digital form Mobile devices that allow access to data everywhere Network (wireless / wired) that allows access to data …..	**WiFi / at least 3G connectivity** **Hardware EX certified** **90% coverage with WIFI / 3G** **Network available 24/7, availability rate 99,8%** **Different types of mobile devices needed: SmartPhones and tablets with following specification: sun-readable displays, ruggedized (1,5m drop, dust, splash water,…) ,….** **All documents available in xyz format** **Offline access must be granted on tablets as in some cases no WIFI / 3G but access to xyz needed.** **Ease of use of device and programs (usability, usefulness)** **…….**
O3: Reduce double work by x%	Regarding documentation: System has to allow direct data entry / no paper-based entries; …. Regarding maintenance work: System has to be able to check e.g. the correctness of the machine to be repaired -> RFID-/ barcode reader or manual entry of machine ID; System has to be able to check if task was already done by someone else; ….	**Devices with readers (RFID / barcode); start-stop function for tasks at app.** **All machines need an ID** **Automatic synchronization between devices and backend-system** **…..**
O4: Reduce mistakes by x%	Regarding documentation: System has to allow direct data entry / no paper-based entries; System has to be able to check plausibility of data entry Regarding maintenance work: System has to be able to check e.g. the correctness of the machine to be repaired -> RFID-/ barcode reader or manual entry of machine ID; System has to be able to check if task was already done by someone else; …. …..	**Documents available online must be editable** **Plausibility: e.g. via ranges, pre-defined data types (e.g. only numbers, no characters)** **Devices with readers (RFID / barcode)** **All machines need an ID** **System has to be able to check if task was already done by someone else: Immediate data exchange between tasks on mobile device and backend system** **…..**

Table 19: Example for requirements refined on the basis of the mBPR

4.3 Activity 3: Definition of critical success factors

Preface: Definition of" success", "success factors" and "critical success factors"

The terms success and success factors are not clearly defined in literature. Rather, depending on the interests and research fields of the respective authors, these terms are defined in some cases very differently. In order to fit the thematic topic of this work, these terms are examined from the economic perspective that attempts to identify the factors that are responsible for the long-term success of a system as regards to business value ([Blec99]).

Success

Schneck defines success as a positive result of entrepreneurial activity which is

measured in qualitative or quantitative terms (Schneck 2005, p. 320). Thus, success and business value are closely linked to each other.

Success factor

The term success factor is used in the literature to characterize the cause of success. Corsten defines success factors as "*factors that have a significant impact on the potential success of a strategic business area*" (Corsten 2000, p. 231ff.).

Critical success factors

Rockart defines critical success factors as follows: „Critical success factors thus are, for any business, the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation." (Rockart 1979, p. 85). Critical success factors are a limited number of properties that contribute in particular to achieving the objectives set (by the company). Referring to a mobile system, the present work defines critical success factors as technical as well as human system parameters that have a significant impact on the business value of the mobile system. System parameters are quantities, whose values characterize the behaviour of the system with a given structure (DIN 1995; Tröster 2011). Thus, critical success factors are requirements that are indispensable.

In our case success factors are derived from requirements identified in the first activity (definition of the target system) and singularities of mobile systems as identified in the second activity (mBPR) of the integrative framework. Figure 8 shows the proposed method for identifying *critical* success factors, which includes the specific user context of the running system into account.

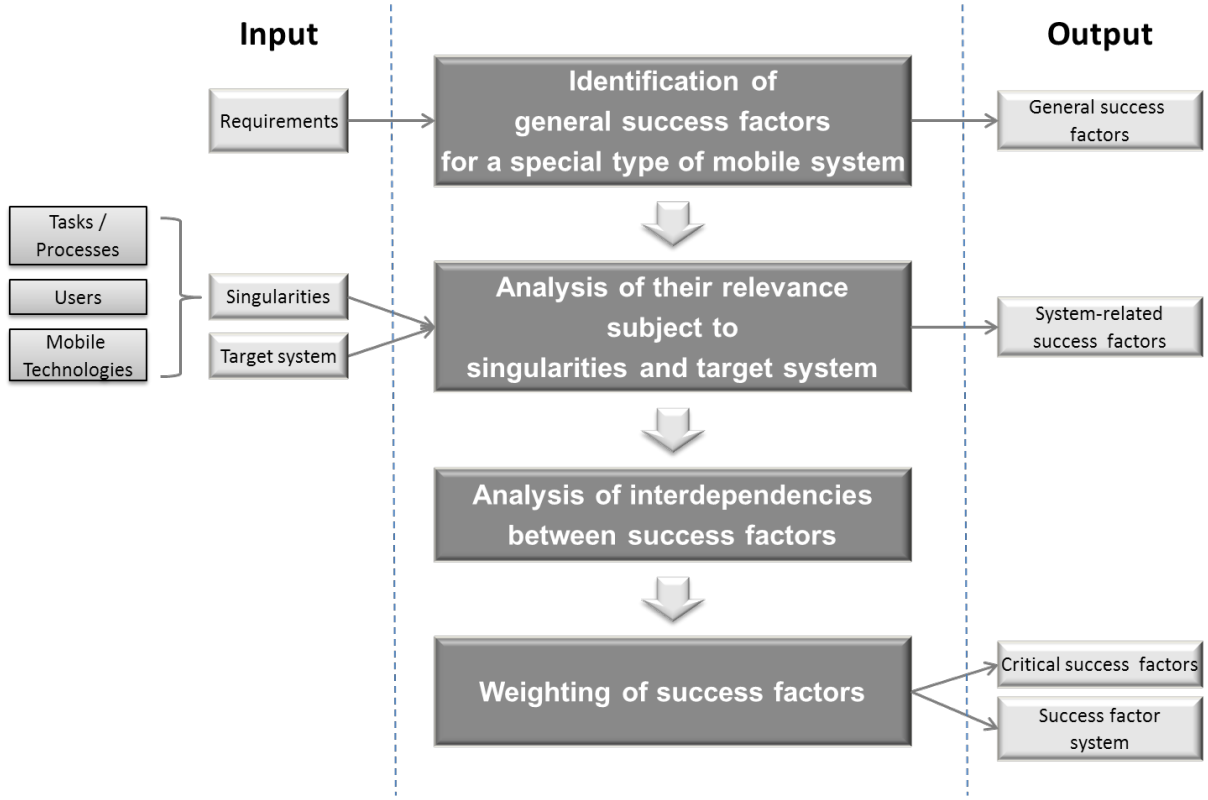

Figure 8: Proposed method for identifying success factors

Based on the requirements of the planned mobile system, general success factors for a special type of mobile system (e.g. a mobile maintenance management

system) can be derived. The relevance of these success factors is analyzed subject to the singularities of a specific mobile system (i.e. users and tasks / processes related to these tasks, combination of mobile technologies) and the objectives determined in activity 1 (target system). As a result we receive system-related success factors. These system-related success factors are valid for a specific mobile system (i.e. a specific combination of technical as well as non-technical system components). In order to identify critical success factors, we analyze the interdependencies between success factors in the same way as described in step 3 of activity 1 of the integrative framework. Depending on the complexity of the overall project, we can divide success factors into different groups of different relevance (high value = high relevance / critical; low value = low relevance / not critical). In complex systems with many success factors a weighting of the success factors can be necessary in order to identify critical success factors and to define the success factor system.

Example: During activity 1 it becomes clear that mobile devices and a WIFI network are required (i.e. requirements). But usually it is not clear which kind of devices is needed and which kind of technical specification they should have (technical system specification). It is also not fully clear, which kind of IT background the users of the devices and of the applications running on the devices have and which kind of information they need for accomplishing their tasks (e.g. only task descriptions or also other informative documents like circuit plans). During activity 2 (mBPR) affected processes are analyzed in depth and by doing so, also the singularities of the mobile system become clear, including the interactions of all components of the mobile system.
To identify the system-related success factors e.g. following questions can be helpful:

- For determining technical success factors:
    - What is the environment like during work (e.g. sunlight, dust, wearing gloves, carrying around many tools, distraction, ….)
    - What kind of information / data is needed? Should the data be only inserted or also processed? Is there a need for bigger figures like circuit diagrams?
    - How often per day can the devices be charged? What is the power consumption of the applications / devices like?
    - …
- For determining non-technical success factors:
    - Who are the users? What kind of IT experience do they have / how familiar are they with mobile devices? How smart are they in using small devices? Do they have disabilities?... (Resulting in non-technical success factors)
    - ….

As a result a “bunch” of success factors for a special type of system is identified as shown in Table 20.

Technical success factors
Devices: Minimum possible size & weight of device Usability Ruggedized device Explosion prevention and protection class II No "pen" needed (usable only with fingers) Speed of processing data High resolution / big display (for specific tasks) Existence of a well-usable keyboard ....
Programs (applications): Usability High security / privacy Speed of processing data ....
Network: Always-on connectivity Coverage of x% ....
....
Non-technical success factors (valid for all systems)
Personnel: Personnel skilled for usage of mobile maintenance management systems (trainings) Acceptance of specific system User involvement from beginning ...

Table 20: Examples for success factors for a Mobile Maintenance Management System (MMMS)

4.4 Activity 4: Evaluation of life-cycle costs

Taking the above mentioned intended and potential effects into account, we are able to propose several combinations of technical components (mobile devices, appropriate maintenance applications and wireless networks) and to calculate the expected costs for the equipment by applying the life-cycle oriented Total Cost of Ownership approach (Ferrin & Plank 2002, Gartner 1997, Grob 1993). This approach takes all costs into account that occur during the lifetime of a mobile system, including costs that occur in other departments that are directly or indirectly affected by the implementation of a mobile system.

4.5 Activity 5: Evaluation of benefits

Taking the results of the mBPR, the identified potential effects and the respective KPIs into account, a first evaluation and estimation of the potential benefits (e.g. cost savings, quality improvement) of each alternative is possible. For this purpose, for each system alternative (or combination of system components) the following question is proposed to be answered:

- How does the process change / improve *as much as possible* by using mobile technologies (identification of potential qualitative effects like quality of the documentation of every task; potential quantitative effects like duration of tasks)?

In order to answer this question, the Mobile Process Landscaping (Köhler & Gruhn 2004) model is to be examined, potential benefits are to be identified and the best possible processes and combinations of components (systems) are to be taken as basis for further consideration[13].

[13] For more detailed examples on evaluating benefits of mobile systems see also Gruhn et al.2005, Heijden & Valiente 2002, vom Brocke et al. 2010.

4.6 Activity 6: Analysis of risks and volatility effects

Preface

Decision making theory defines risk as *"reflecting variation in the distribution of possible outcomes, their likelihoods, and their subjective values"* (March et al. 1987). The potential risk is the product of the measure of damages and the associated probability of occurrence.

The aim of a risk analysis is to ensure that the (mobile) system is beneficial to the company and that it is not becoming uneconomical due to the occurrence of unforeseen costs or the loss of prognosticated benefits (Gruhner & Homburg 1986).

In the context of this work, we analyze risks in the framework of success factors due to following considerations (see Figure 9):

1. In our context (i.e. mobile systems) targeted effects (i.e. objectives and the resulting value for a company) shall be achieved by enhancing processes by applying mobile technologies. Thus, there is a close relationship between the identified objectives and affected business processes. As a result, we take a process-oriented perspective.
2. Success factors in turn are tightly related to business processes as they are identified during mBPR (see section 4.3) and strongly affect the targeted process optimization; in addition, they are related to the singularities of mobile systems which are an output of activity 2 (mBPR).
3. The combination of the first two considerations shows that the achievement of objectives is closely linked to success factors.

Based on these considerations, risks related to the mobile system are derived from critical success factors. We propose to analyze risks in two steps:

a) (Critical) success factor based risk assessment as described in the following sections.

b) General risk assessment as described in standard references like the Project Risk Management Practice Standard by the Project Management Institute[14], that also considers organizational or management risks like improperly defined objectives and system requirements (Sumner 2000), financial risks (Kliem 2000), human risks like drop out of skilled personnel (e.g. due to illness, strikes), or environmental risks (Peltier 2004). As these risks are not system related, we refer to standard references and will not focus in this work on the evaluation of such general risks.

The introduction of new (mobile) technologies is always associated with risks, system-related risks or general risks that are more or less same for all systems (see preface). System-related risks may be exacerbated by disregarding critical success factors and are thus in the main focus of this work. This is due to the fact that critical success factors contribute to achieving the full benefits of a mobile system (see activity 3) and thus also contribute to the overall business value of a mobile system. In contrast, their disregard can intensify or even cause risks, so

[14] www.pmi.org

that the benefit appears to a much lesser extent or later than expected – both leading to a reduced business value and thus in most cases a reduced economy of the system. For this reason, the integrative framework demands not only the investigation of volatility effects[15] that could occur caused by risks (by applying a sensitivity analysis), but it demands in particular the analysis of those critical success factors that influence the volatility effects significantly (risk analysis). The sensitivity analysis takes into account uncertainties by monitoring the stability of results and by determining critical values which strongly influence the targeted results.

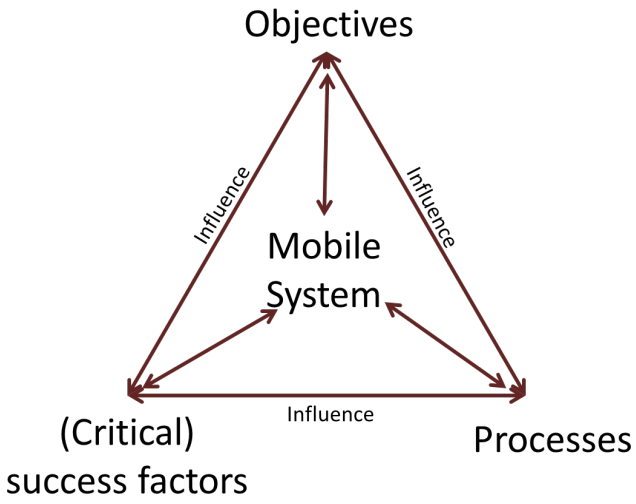

Figure 9: Relationship between objectives, processes and (critical) success factors

In order to analyze risks related to success factors and to analyze volatility effects, following questions are suggested to be answered for every single combination of mobile technologies or system, respectively:

- Question 1: How do (critical) success factors, derived from the singularities of a specific mobile system, and interdependencies between its system components affect the planned processes?
- Question 2: What happens, if critical success factors are not considered?
- Question 3: How does this affect the processes in terms of expected costs and potential benefits and thus the overall targeted business value?

In our approach, we apply the general procedure for assessing risks (see also step 6 of activity 1). First we analyze the strength of the effect[16] and then the probability of occurrence[17]. The values are multiplied in each cell. The criticality of a risk is the overall (horizontal) sum of the calculated values.
In contrast to activity 3 of the integrative framework (definition of critical success factors), we do not only know if the success factor is critical or not, but we also have an indication now on how much it affects processes. The higher the criticality of a risk, the worse the negative effects on the processes will be in case of occurrence.
In order to verify the results, we propose a countercheck by analyzing the effects of processes on objectives. Again, we propose to estimate the effect of each

[15] We define volatility effects as deviation from an average target achievement rate.
[16] Values 0-3 (no effect, weak / medium / strong negative effect)
[17] Values 1-3 (effect is possible, but improbable / effect is probable / effect will occur with the utmost probability)

process[18] on each objective that has to be achieved by implementing the project and to sum up horizontally the values. In most cases, only objectives with high priority are analyzed. This procedure allows a prediction concerning the volatility effects of the potential benefit achievement caused by the risks as we receive best case and worst case scenarios.

4.7 Activity 7: Analysis of the potential target achievement rates

The last activity is the analysis of the potential target achievement rates, for which results of the previous activities are taken into account. Operations Research (OR) encompasses different problem-solving techniques and mathematical methodologies for improved decision making. Which of these methodologies can be applied for the analysis of potential target achievement rates depends on many factors like complexity of the project.
We suggest the following procedure that follows the Integer Linear Programming Problem – to find the optimal solution (maximum benefit against minimal cost). For each alternative (i.e. combination of mobile system components) following have to be answered (see also :

- How do the single alternatives consider system-related requirements and system specifications? (see activity 1 & 2)
- How do the single alternatives support the affected processes? (see activity 2)
- How do the single alternatives consider critical success factors? (see activity 3)
- How do the single alternatives contribute to reach the benefits? (see activity 5)
- How do the single alternatives cope with risks? (see activity 6)

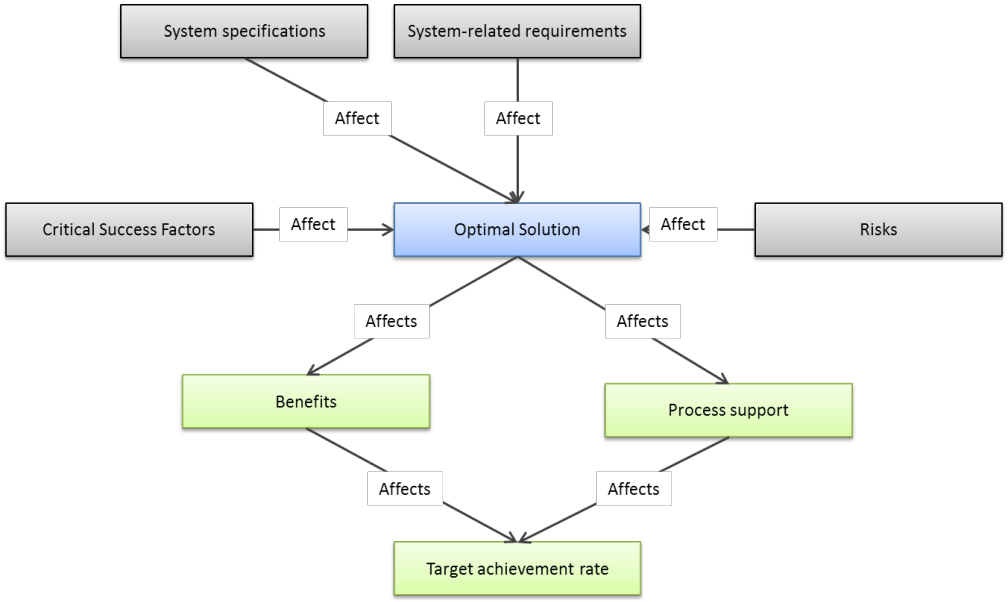

Figure 10: Influences of different factors on optimal solution and the target achievement rate

[18] values 0 -3 (no effect, weak / medium / strong positive effect

The alternative that has received the highest overall rating is seen as the optimal solution for the defined problem. On this basis a profound decision making is possible.

REFERENCES

Ahlert, M. 2003. Einsatz des Analytic Hierarchy Process im Relationship Marketing. PhD thesis. Wiesbaden: Gabler.

Al-Mashari, M., Al-Mudimigh, A. and Zairi, M. 2003. "Enterprise resource planning: A taxonomy of critical factors," *European Journal of Operational Research* (146:2), pp. 352–364.

Amoako Gyampah, K. 2004. ERP implementation factors: A comparison of managerial and end user perspectives. Business Process Management Journal, 10 (2), pp.171 – 183.

Amoako-Gyampah, K. and Salam, A.F. 2003. An extension of the technology acceptance model in an ERP implementation environment. Information & Management, 41 (6), pp. 731-745. http://dx.doi.org/10.1016/j.im.2003.08.010.

Applin, S.A., Fischer, M.D. 2011. "Pervasive Computing in Time and Space: The Culture and Context of 'Place' Integration," in *Proceedings of the 7th International Conference on Intelligent Environments*, pp.285-293. URL: http://kar.kent.ac.uk/28367/1/Applin_Fischer_PervasiveComputingInTimeAndSpace.pdf (visited 2014/11/12).

Batenburg, R. and Versendaal, J. 2008. Maturity Matters: Performance Determinants of the Procurement Business Function. In: Proceedings of the ECIS. pp. 563-574.

Bertalanffy, L. 1976. "*General System Theory*." New York: George Braziller Inc.

Blecker, T. 1998. Unternehmung ohne Grenzen: Konzepte, Strategien und Gestaltungsempfehlungen für das strategische Management. PhD thesis. Wiesbaden: Dt. Universitäts-Verlag.

Bostrom, R.P. and Heinen, J.S. 1977. "MIS problems and failures: a socio-technical perspective; part I: the causes," *MIS Quarterly* (1:3), pp. 17-32.

Brandt, T. 2006. *Prozeßorientiertes Controllingkonzept für Maßnahmen des Total Quality Managements,* PhD thesis. University Hamburg. Hamburg: Diplomica.

Brynjolfsson, E. 1993. "The Productivity Paradox of Information Technology," *Communications of the ACM* (35:12), pp. 66-77.

Brynjolfsson, E. and Hitt, L. M. 1995. "Paradox lost? Firm-Level Evidence on the Returns to Information Systems Spending," *Management Science* (42:2), pp. 541–558.

Brynjolfsson, E. and Hitt, L.M. 1998. "Beyond The Productivity Paradox," *Communications of the ACM*, (41:8).

Brynjolfsson, E. and Hitt, L. M. 2000. "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," *The Journal of Economic Perspectives* (14:4), pp. 23–48.

Charette, R.N. 1990. Applications Strategies for Risk Management. New York: McGraw-Hill.

Charette, R.N. 1991. The risks with risk analysis. Communications of the ACM, 34 (6), pp. 106-107.

Corsten, H. 2000. Lexikon der Betriebswirtschaftslehre. 4th ed. München, Wien: Oldenbourg.

Cragg, P., King, M. and Hussin, H. 2002. "IT alignment and firm performance in small manufacturing firms," *Journal of Strategic Information Systems* (11:2), p. 109-132.

Davis, F. 1985. A technology acceptance model for empirically testing new end-user information systems – theory and results. PhD thesis. Massachusetts Inst. of Technology.

Davis, F., Bagozzi, P. and Warshaw, P. 1989. "User acceptance of computer technology – a comparison of two theoretical models," *Management Science* (35:8), pp. 982–1003.

DIN 1995. OENORM DIN 19226-1:1995-07-01: Leittechnik – Regelungstechnik und Steuerungstechnik – Allgemeine Grundbegriffe, Berlin: Beuth.

Drews, G. and Hillebrand, N. 2002. Lexikon der Projektmanagement-Methoden. Haufe-Lexware.

Ferrin, B.G. and Plank, R.E. 2002. "Total cost of ownership models: an exploratory study", Journal of Supply Chain Management, Vol. 38 No. 3, pp. 18 29.

Gartner Group. 1997. *"TCO analyst. A white paper on Gartner Group's next generation total cost of ownership methodology"*, available at: www.netvoyager.co.uk/pdf/TCO_analyst.pdf (last visited 02.02.2017).

Gebauer, J.; Shaw, M. J.; Gribbins, M. L. 2005: Towards a Specific Theory of Task-Technology Fit for Mobile Information Systems, URL: http://www.business.uiuc.edu/Working_Papers/papers/05-0101.pdf visited 17.02.2014).

Giddens, A. 1989. "A reply to my critics," in *Social Theory of Modern Societies: Anthony Giddens and His Critics*. D. Held and J.B. Thompson (eds.), Cambridge: Cambridge University Press, pp. 249-301.

Goodhue, D.L.; Thompson, R.L. 1995. “Task-Technology Fit and Individual Performance,” *MIS Quarterly* (19:2), p. 213-236.

Goos, G. and Zimmermann, W. 2005. *Vorlesungen über Informatik, Band 1: Grundlagen und funktionales Programmieren,* Berlin: Springer 4. Ed.

Grob, H.L. 1993. Capital Budgeting with Financial Plans: An Introduction. Wiesbaden: Gabler.

Gruhn V., Köhler A., Klawes R. 2005. Modeling and Analysis of Mobile Service Processes by Example of the Housing Industry. In: van der Aalst W.M.P., Benatallah B., Casati F., Curbera F. (eds) Business Process Management. BPM 2005. Lecture Notes in Computer Science, vol 3649. Berlin, Heidelberg: Springer.

Gruhn, V.; Koehler, A. and R. Klawes. 2007. "Modeling and analysis of mobile business processes", Journal of Enterprise Information Management, vol.20, no.6, pp. 657-676.

Gruhn V., Wellen U. 2001. Process Landscaping: Modelling Distributed Processes and Proving Properties of Distributed Process Models. In: Ehrig H., Padberg J., Juhás G., Rozenberg G. (eds): Unifying Petri Nets. Lecture Notes in Computer Science, vol 2128. Berlin, Heidelberg: Springer.

Gruhner, K.; Homburg, C. 1986. Innovationserfolg durch Kundenbindung. In: *Albach, Horst; Wildemann, Horst (Hrsg.)*: Strategische Investitionsplanung. Wiesbaden: ZfB Ergänzungsheft 1/86, p. 1-48.

Hammer, M. and Champy, J. 1994. *Reengineering the corporation: a manifesto for business revolution*, New York: Harper Business.

Heijden, H. van der, Valiente, P. 2002. Mobile Business Processes: Cases from Sweden and the Netherlands. SSE/EFI Working Paper Series in Business Administration, Stockholm School of Economics. https://pdfs.semanticscholar.org/3ecc/0fbff512d1c5ba15e9a9e40460ce16e46913.pdf.

Henderson, J.C. and Venkatraman, N. 1993. “Strategic alignment: Leveraging information technology for transforming organizations,” *IBM Systems Journal* (32:1), pp. 4-16.

Hester, A. J. 2014. “Socio-technical systems theory as a diagnostic tool for examining underutilization of wiki technology,” *The Learning Organisation* (21:1), pp. 48-68.

Hevner A.R., March S.T., Park J., Ram S. 2004. “Design science in information systems research,” *MIS Quarterly* (28:1), 75-105. http://www.brian-fitzgerald.com/wp-content/uploads/2014/05/Hevner-et-al-2004-misq-des-sci.pdf (visited on 10/30/2014).

Hitt, L. M. and Brynjolfsson, E. 2002. “IT, Organisational Transformation, and Business Performance,” in *Productivity, Inequality and the Digital Economy: A Transatlantic Perspective*, N. Greenan, Y. L´Horty, Y. and J. Mairesse (eds.), Massachussets: MIT Press, pp. 55-92.

Högler, T. 2012. “Framework for a Holistic Evaluation of ICT,” in *Proceedings of the 25th Bled eConference,* URL: https://domino.fov.uni-mb.si/proceedings.nsf/Proceedings/A0F9C70C2698908FC1257B6E003B0E2B/$File/03_hoegler.pdf (visited 2012/08/28).

Högler, T. and Versendaal, J. 2014. „Identification of Success Factors for Mobile Systems Deployment: A Method,” in *Proceedings of the Bled eConference 2014, AIS Electronic Library*. URL: http://aisel.aisnet.org/bled2014/9 (2014/06/20).

Högler, T., Versendaal, J. and R. Batenburg. 2015. Evaluation of Mobile Systems - An Integrative Framework. In: Proceedings of 21st Americas Conference on Information Systems, AMCIS 2015, Puerto Rico.

Hong, K.-K. and Kim, Y.-G. 2002. “The critical success factors for ERP implementation: An organization fit perspective,” *Information & Management* (40:1), pp. 25–40.

Horvath, P. 1988. „Wirtschaftlichkeit neuer Produktions- und Informationstechnologien,“ in *Proceedings of the Stuttgarter Controller-Forum*, 14.-15. September 1988. Stuttgart: C.E. Poeschel.

Hwang, C.-L. and Yoon, K. 1981. Methods for multiple attribute decision making. In: Multiple attribute decision making. Berlin, Heidelberg: Springer, pp. 58-191.

Isaac, H. and Leclercq, A. 2006. “Give me a mobile phone, and I will work harder! Assessing the value of mobile technologies in organizations: an exploratory research,” in *Proceedings of the International Conference on Mobile Business ICMB*.

Kahneman, D. and Tversky, A. 1979. “Prospect theory: An analysis of decision under risk,” *Econometrica* (47:2), p. 263-291.

Kahneman, D. 2011. *Thinking, fast and slow,* New York: Farrar, Straus and Giroux, pp. 278-288.

Kirchmer, M. 1999. Market-and Product-Oriented Design of Business Processes. In: Business Process Engineering. Springer, pp. 131-143.
Klabon, M.L. 2007. An investigation of the quantification of the probability of occurrence of software engineering project risks with Bayesian probability. PhD Thesis. Monterey, California: Naval Postgraduate School.
Köhler, A. and Gruhn, V. 2004. „Lösungsansätze für verteilte mobile Geschäftsprozesse," in *Proceedings of the Konferenz Elektronische Geschäftsprozesse*, pp. 243-255.
Koreimann, Dieter. S. 2000. Grundlagen der Software-Entwicklung. 3. ed., München: Oldenbourg.
Kronsteiner, R. and Thurnher, B. 2009. "Opportunities and Risks for Mobile Decision Support," in *Handbook of Research on Mobile Multimedia*, I. K. Ibrahim (ed.), Hershey: IGI Global, pp. 93-104.
Loveman, G. 1994. "An Assessment of Productivity Impact of Information Technologies," in *Information Technology and the Corporation of the 1990's*. T. Allen and M.S. Morton (eds.), New York: Oxford, pp. 84-110.
March, S.T. and Smith, G.F. 1995. "Design and natural science research on information technology," *Decision Support Systems* (15:4), pp. 251–266.
Markus, M. L. and Tanis, C. 2000. The Enterprise System Experience — From Adoption to Success. In: Zmud, R. W. (ed.): Framing the Domains of IT Research: Glimpsing the Future Through the Past. Cincinnati: Pinnaflex Educational Resources, pp. 173-207.
Meixner, O. and Haas, R. 2012. Wissensmanagement und Entscheidungstheorie: Theorien, Methoden, Anwendungen und Fallbeispiele. facultas. wuv/maudrich.
Ney, M. 2005. *Wirtschaftlichkeit von Interaktionsplattformen: Effizienz und Effektivität an der Schnittstelle zum Kunden*, PhD thesis, Technical University of Munich.
Niehaves, B., Poeppelbuss, J., Plattfaut, R., Becker, J., 2014. "BPM capability management – a matter of contingencies," *Business Process Management Journal* (20:1), pp. 90-110.
NIST 2012. Special Publication 800-30 Revision 1: Guide for Conducting Risk Assessments. http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-30r1.pdf
Orlikowski, W. 2000. "Using technology and constituting structures: a practice lens for studying technology in organizations," *Organization Science* (11:4), pp. 404-428.
Peppard, J. and Ward, J. 1999. "'Mind the Gap': diagnosing the relationship between the IT organisation and the rest of the business," *Journal of Strategic Information Systems* (8:1), p. 29-60.
Picot, A., Reichwald, R. and Wigand, R. T. 2003: *Die grenzenlose Unternehmung – Information, Organisation und Management*, Wiesbaden: Gabler.
Pietsch, T. 1999. *Bewertung von Informations- und Kommunikationssystemen – Ein Vergleich betriebswirtschaftlicher Verfahren,* Berlin: Erich Schmidt.
Recker, J., Rosemann, M., Indulska, M. and Green, P. 2009. "Business process modeling: a comparative analysis", Journal of the Association for Information Systems, Vol. 10 No. 4, pp. 333□63.
Renkema, T.J.W. and Berghout, E.W. 1997. "Methodologies for information system investment evaluation at the proposal stage: a comparative view," *Information and Software Technology* (39:1), pp 1-13.
Ritz, T. and Stender, M. 2003. Modellierung von Business-to-Business Geschäftsprozessen im Mobile Commerce. In: Workshop Mobile Commerce, pp. 27-41.
Robey, D. and Boudraeu, M.-C. 1999. "Accounting for the Contradictory Organizational Consequences of Information Technology: Theoretical Directions and Methodological Implications," *Information Systems Research* (10:2), pp. 167–185.
Rockart, J.F. 1979. "Chief Executives Define Their Own Data Needs," *Harvard Business Review* (57:2), p. 81-93.
Rückle, H. and Behn, M. 2007. Unternehmenserfolg mit Zielen: mit Checklisten, Leitfäden und Übungen. expert verlag.
Saaty, T.L.. 1996. Multicriteria Decision Making: The Analytic Hierarchy Process. Pittsburgh: RWS Publications.
Scheer, A.-W. .2000. ARIS - Business Process Modeling, 3rd edition, Berlin, Heidelberg: Springer.
Schiller, J. 2000. Mobilkommunikation. Techniken für das allgegenwärtige Internet. München: Addison-Wesley.
Solow, R. 1987. "We'd Better WatchOut," *New York Times Book Review* 1987-07-12.
Schiller, J. 2000. *Mobilkommunikation. Techniken für das allgegenwärtige Internet*, Munich: Addison-Wesley.

Schneck, O. 2005. Lexikon der Betriebswirtschaftslehre. 6th ed. München: Deutscher Taschenbuch Verlag.

Schütt, M. 2006. Informationsmanagement auf elektronischen B2B-Marktplätzen: Unterstützung der elektronischen Beschaffung durch integrierte Informationsprozesse. Wiesbaden: Deutscher Universitätsverlag.

Stoneburner, G.; Goguen, A.Y. and Feringa, A. 2002. Sp 800-30. risk management guide for information technology systems.

Tröster, F. 2011. Steuerungs-und Regelungstechnik für Ingenieure. Oldenbourg Verlag.

Unhelkar, B. 2009. *Handbook of Research in Mobile Business, Second Edition: Technical, Methodological and Social Perspectives*. Hershey: Information Science Reference.

Valiente, P.; van der Heijden, H. 2002. A method to identify opportunities for mobile business processes. http://swoba.hhs.se/hastba/papers/hastba2002_010.pdf, visited on 11.08.2005.

Venkatesh, V., Morris, M., Davis, F. and Davis, M. 2003. "User acceptance of information technology – toward a unified view," *MIS Quarterly* (27:3), pp. 425–478.

Versendaal, J., Akker, M. van den, Xing, X., Bevere, B. de 2013. „Procurement maturity and IT-alignment models: overview and a case study," *Electron Markets* 23, pp. 295-306.

vom Brocke, J.; Recker, J. and J. Mendling. 2010. "Value□oriented process modeling: integrating financial perspectives into business process re□design", Business Process Management Journal, Vol. 16 Iss: 2, pp.333 – 356.

Ward, J. and Peppard, J. 2002. *Strategic Planning in Information Systems*. Chichester: John Wiley & Sons.

Zahn, E., Schmid, U. and Dillerup, R. 1999. Investitionsentscheidungen in flexible Fertigungssysteme. In: *Innovation und Investition*, Albach, H. (ed), Wiesbaden: Gabler, pp. 43-67.

Zigurs, I.; Buckland, B. K. 1998. „A Theory of Task-Technology Fit and Group Support Systems Effectiveness," *MIS Quarterly* 22 (3) p. 313-334.