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DEVELOPMENT OF A METHODOLOGICAL APPROACH FOR REQUIREMENTS MANAGEMENT IN CROSS-COMPANY NETWORKS (ReMaiN)

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ABSTRACT

Large variety, global competition and reduced development time of complex products are forcing companies to face constantly increasing challenges.
In order to face these challenges and to ensure the market position, several companies are merging together to a corporate network. This leads to new problems regarding to the communication between the companies within their network as well as the holistic registration of requirements. However, specific knowledge about requirements and their importance in relation to the stakeholders are decisive for producing high quality products in the future. To counteract this particular problem a development of a new methodical approach for requirements management in cross-company networks is needed. This paper presents a first concept for an approach for requirements management in cross-company networks, which is built on a model-based concept of system engineering.

Keywords: requirements management, corporate network, model based systems engineering, complexity

INTRODUCTION

The relationships of cooperation with other companies in a corporate network provide through the flexible specialization many advantages for an individual company for example a solution-oriented approach and just in time reaction against the rapid development or increasing innovation pressure (Storper et al., 1987; Piore et al., 1984). As a part of a corporate network, an individual company has the opportunity to respond to fast market changes in order to reduce costs.

Although the trend of merging together to a corporate network is continually rising in the last years, research for this form of organisation has been neglected (Glückler et al., S.6.; Stadlbauer 2007, S. 13). Ncube et al. (Ncube et al. 2013), (Lewis et al. 2009), (Hallerstede 2012) and (Meyers 2006) see a need for further research, particularly concerning the traceability of requirements. They note that the current approaches of requirements management are insufficient to realise the traceability of the requirements and the managing of product and service complexity in corporate networks. A recent study shows that a fast response to the customer's requirements has a high significance and it is considered to be very important (98,6% percent of the surveyed companies) for the companies in the future (next five years).

Hereby, it is clear that the requirements and their fulfilment are very essential for a corporate network. However, a standardized approach to handle requirements in a corporate network does not currently exist (Ncube et al. 2013).

In this paper corporate network is defined as a socio-technical system that consists of three or more companies with common goals and relationships of cooperation. In order to accomplish that, resources and core competences of each company need to be combined in a goal-oriented manner and used to reach a required performance. This can be achieved by concentrating the core competencies of companies and through the addition of further needed competencies by choosing the proper network partners. In this way, core competencies of various companies from different disciplines are bundled in order to realize best performances in the manufacturing of mechatronic products. Certainly, the interaction of various disciplines could cause issues due to the fact that every discipline has their own individual, intern processes, technical jargon and models to handle complexity (Willing, 2015). Based on those divergences and the complex interactions of various companies in a corporate network, there are resulting issues concerning the requirements management of a corporate network. These are supposed to be discussed in this article:

- How can be ensured that these inconsistency requirements of the customers from different countries can be recorded and checked?
- How is it possible not only to collect data of the requirements in a corporate network, but also to realize it in a structured, validated and systemically way?

In this context, requirements are defined as the expectations and needs of stakeholder, which are in usually assumed or obligatory (Winzer 2012). In order to realize a sustainable and effective organisation of a corporate network requirements need to be defined specifically, collected systematically, structured and analysed. In case that a requirement has been incorrectly defined and incompletely implemented, the success of the products and services can no longer be guaranteed (Ponn 2011).

In a corporate network, as complex organisation, the incorrect definition of a requirement due to an insufficient allocation between service providers and customers can be a major problem. In addition, a loss of knowledge can result from the application of different and specific corporate languages. (Nicklas et al. 2012; Killich 2007). Which steps have to be taken to ensure that the requirements are clearly defined and implemented with a common language between the network companies? One possible solution for this problem is a methodical approach to handle requirements in a corporate network. This methodical approach, presented in the following paper, could be a solution to create a common language within corporate network in order to define correctly and implement requirements completely. The new approach is based on a comprehensive literature analysis of requirements management procedures, which points out the absence of a standardized procedure (Nicklas 2016). For this reason, systems engineering is used to control and overcome the previously mentioned complex problems. It needs to be ensured that the requirements of different stakeholder are collected, structured, weighted systemically and distributed to the right cooperation-partner. Furthermore, the tracking and updating of the requirements have to be realized. This can only be done by a controlled approach of system engineering that is able to describe the relationships between system elements and subsystems in order to show the complexity of an entire system transparently (Dohms 2001).

For this system approach, an interdisciplinary system model for corporate networks and their products has to be created. This system is supposed to interact iteratively with a general and standardized procedure to accomplish a requirements management. In this way, the constant updating of requirements and information flows in a corporate network can be recognized.

For this purpose, first the current approaches of requirements management from science and practice will be analysed in the next chapter (“Requirement management approaches”). Based

on the strengths and weaknesses of the approaches, a concept for the requirements management in company networks will be worked out and presented in the chapter "Development of an innovative methodical approach for requirements management in cross-company networks". This approach needs to comply the demands concerning the new methodical approach for requirements management in cross-company networks. After that, the applicability of the new approach in the field of public transport will be verified (see chapter "Practical application of the methodical approach for requirements management in cross-company networks"). In the last chapter the results and conclusions will be discussed.

REQUIREMENT MANAGEMENT APPROACHES

Table 1 shows the different methods of requirements engineering and management (c.f. table 1). Generally, requirements management and requirements engineering approaches can be categorised into the most well-known disciplines (e.g. software engineering or product development).

Table 1 - Selected phases of requirements management (Based on Nicklas 2016)

Literature	Proposed management of the phases					
General approaches						
(Hull 2005)	Coordination		Analyze and model	Deduce and qualify	Coordinate	
(Lewis 2009)	Definition of the system	Analyzation of the system	Analyzation of the interactions	Capability analysis	Analyzation of the gab	
(Schulze 2016)	Collect	Analyze	Validate	Allocation	Verification of the design	
(Lou 05)	Elicitation	Negotiation	Specification	Validation		
(Parviainen 2005)	Collect	Analyzation	Negotiation and prioritization	Documentation		
Software and electronics development						
(Broy 2007)	Acquire	Analyze	Filter	Classify	Modelling	
(Ebert 2014)	Acquire	Specification	Validate	Analyze	Stipulation	Manage
(Hood 2008)	Elicitation	Specification	Analyzation	Review		
(Partsch 2010)	Acquire	Describe	Analyze (Verify and validate)			
Product development						
(Jiao 2009)	Elicitation	Analyzation	Specification			
(Lindemann 2009)	Determine	Structure & weight	Documentation			
(Ponn/ Lindemann 2011)	Determine	Structure	Analyze and prioritization	Maintain and integration		
(Stadlbauer 2007)	Determine	Analyze	Documentation	Verify and validate		
(Lindemann; Ponn 2011, S.39)	Determine	Structure	Analyze and structure	Maintain and integration		
(Bender et all. 2016)	Elicitation	Analyze	Documentation	Release and communicate		

Most approaches begin with the elicitation-, acquire- or collect-phase of requirements, which are the basis for the next steps. In this phases, it is very important to know and to document the sources (stakeholder) of the requirements, so that information about service providers, customers or suppliers cannot be lost (Winzer 2012). In addition, the source of requirements can be tracked if necessary. This cannot be done when the sources are not assigned to the requirements. Basing on the first phase, the next phase (structuring, analyse and describing of

the requirements) follows. The final phase is defined as validate, maintenance or documentation. All approaches from table 1 concentrate on individual companies and not on a corporate network. None of the approaches captures and examines the inconsistency requirements of customers from different countries or collects data about the requirements in a corporate network. Moreover, none of the approaches ensure that the requirements in a corporate network will be implemented in a structured, validated and systemically way. Furthermore, none of the approaches realise the transparent traceability of the requirements. Hence, requirements cannot be assigned to their source (stakeholder) or to the person, which is responsible for implementing requirements. The results of the analysis show that there is a scientific and practical gap concerning an approach for requirements management in cross-company networks. In order to fill this gap a new, methodical approach has to be developed, which has to fulfil the following demands:

- Ensure that inconsistency requirements of the customers from different countries can be recorded and checked.
- Collect data of the requirements in a corporate network and realize it in a structured, validated and systemically way.
- Realise a transparent traceability of the requirements.

A possible solution to fulfil the demands above will be shown in the next chapter.

DEVELOPMENT OF AN INNOVATIVE METHODICAL APPROACH FOR REQUIREMENTS MANAGEMENT IN CROSS-COMPANY NETWORKS

For a systematically implementation of a requirements management in corporate networks a new methodical approach needs to be developed. In addition, it must be possible to understand and describe a corporate network by using this approach. For this purpose, a model-based concept of systems engineering (Model-based engineering) has been used to describe a corporate network as a system model. It shall show the implicit relationship between the companies in a corporate network transparently and offer a better management of the complexity of the whole system. Model-based engineering (MBE) “is an approach for engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of the capability of a system, and/or product throughout the acquisition life cycle” (Model-based Engineering Subcommittee, 2011). It includes an interdisciplinary procedure, which is combined with a system model for handling complexity (Sage, 2009; Weilkiens, 2006). This procedure starts with the definition of the system that is focused on. In the following, a problem solution in form of a procedural concept is worked out to solve the problem in a systematic and structured way.

In order to develop a system model in the first step, a system modeling method is required. In practice and science, there are numerous, different procedures for system modelling, such as the Axiomatic Design (Suh, 2001), Consens (Gausemeier et al. 2012) or the structural complexity management (Maurer 2007). Those procedures were created to describe a technical system in the product development phase. Nevertheless, none of these procedures are suitable for application in a corporate network. They only focus on the product. But the new approach also needs to consider the organisation structure of the companies as an integral part of the system. For that reason, a method, which is called eDeCoDe (enhanced Demand Compliant Design), developed by the Research Group Safety and Quality Engineering, was selected.

Sitte/Winzer developed this method originally and it is based on the principle of systems engineering (Sitte 2011). The method contributes creating a standardized model by using a basis of data, information and knowledge. This system model realizes the interlinking of four standardized views (requirements, functions, processes and components) to depict a standardized system model. Furthermore, the interaction of the system elements within the whole system will be considered (Winzer, 2013). Certainly, a fifth view (social) is needed to realize a standardized view of a network as a socio-technical system. Therefore, the fifth view "persons" was integrated by Nicklas in his doctoral thesis. With the help of this fifth view a standardized depiction of collaborative networks in context of requirements management is possible. The linking of the system elements (requirements, functions, processes, components and persons) has been realized with a matrix, which is also called eDeCoDe - main matrix (cf. figure 1).

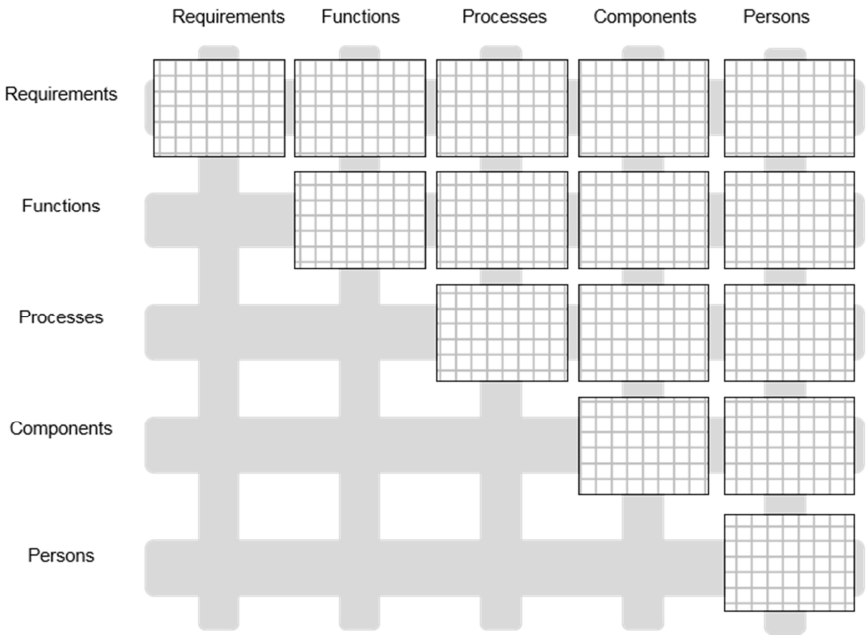

Fig. 1 - eDeCoDe- main matrix as tool for the implementation of DeCoDe (Sitte, 2011; Nicklas 2016)

The five views, which stand opposite to each other, are connected systematically and purposefully. Each matrix represents the dependence, interdependency and interaction of the system elements. The eDeCoDe-based system model uses requirements that are described as the expectations of the stakeholders. These requirements are translated into neutral functions. Functions are realized by processes, which are using components. Processes are interlinked with functions in a logical order to realize desired actions. Persons use and realize components as well as processes and generate input. In consequence, they realize functions, which correspond to the requirements (Winzer, 2013; Nicklas, 2016). All five element-classes are set in relation to each other with matrices to describe the (socio-) technical system. For example, the matrix "requirements-person" (top right in the figure 1) can contribute facilitating traceability of requirements. In this way, requirements can be assigned to the source (stakeholder) or to a person, which is responsible for the implementation of the requirement.

Another benefit of the eDeCoDe method is that it can be combined with other methods or approaches, e.g. methods for requirements elicitation, structuring, weighting and validation. Thus, it can be used for modelling a network and its requirements.

The next problem that has to be solved is the development of a standardized procedure that is based on eDeCoDe and can be used to realize the requirements management. On the basis of the analysis of requirements management and engineering approaches, Nicklas pointed out the following possible standardized procedure (c.f. Nicklas, 2016). For the adaptation, the phase "system definition" was implemented in the new approach. In addition, the steps "structure" and "analyze" were compiled. Each of the four phases interact with the uniform network model. The points of time (t) represents the versions of the system model respectively the uniform network model (c.f. figure 2).

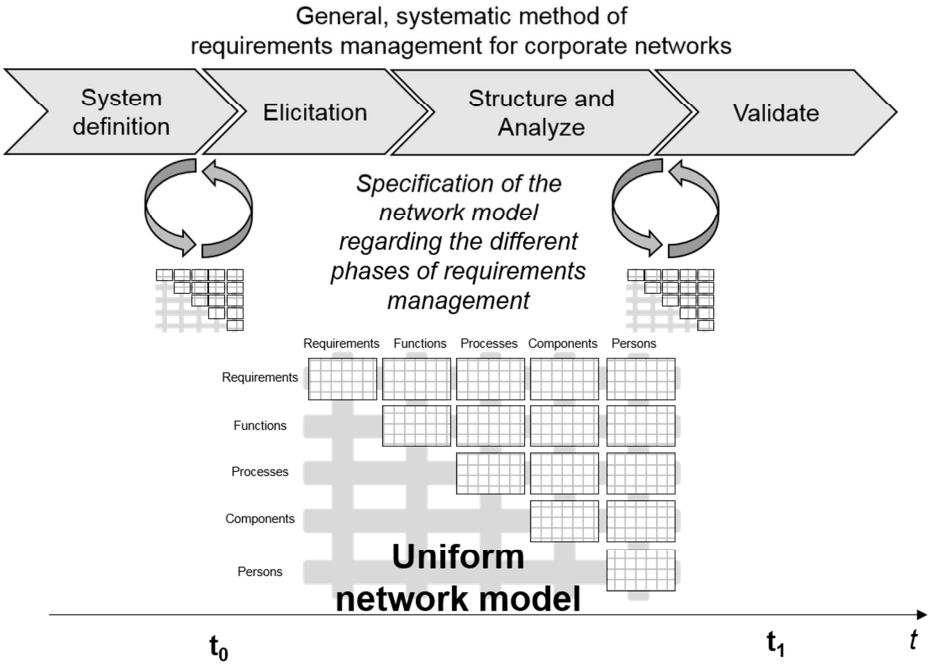

Fig. 2 - Methodical approach for requirements management in cross-company networks.

In the next section, the new approach shall be examined in more detail. In addition, the usability of the approach for corporate networks, which are focused on public transport, is discussed. In the chapter "results and conclusion" those findings are examined critically and derived if the defined demands of the new approach have been fulfilled.

PRACTICAL APPLICATION OF THE METHODICAL APPROACH FOR REQUIREMENTS MANAGEMENT IN CROSS-COMPANY NETWORKS

The application of the methodical approach was implemented within the project aim4it, which has been completed by the Research Group Safety and Quality Engineering.

The project „Accessible and inclusive mobility for all with individual travel assistance" (aim4it) concentrates on a public transport system, which is suitable for all groups of the society. The unrestricted use of a fully integrated cross-modal-public-transportation along the complete mobility chain allows handicapped persons to use the public transport without any barriers (e.g. no elevator for wheel-chair users in a station building). Every mobility chain is conducted by an information chain. Especially passengers with special mobility demands have to be informed early about their departure or transfer time at the station. This information should be current and also understandable. Relevant information need to be presented in an optical, acoustical, tactile way to the passengers or as a combination of two perception modes.

The project aim4it faces this challenge and combines the expertise of a multidisciplinary project team to develop a new, individual travel assistance. This holistic approach includes the representation of information which is explicitly tailored to the specific requirements of passengers with special needs. In order to consider the requirements of passengers (user groups) from planning to implementation, the methodical approach for requirements management in company networks from figure 2 of the last section was used. The following four steps were defined as:

- System definition
- Elicitation
- Structuring and analysis and
- Validation

1) System definition

In the first step the system itself and the stakeholders have to be defined. Due to the fact that aim4it focuses on a barrier-free public-transportation-system, special needs of passengers with disabilities, besides to normal passengers, are concentrated on:

- Deaf passengers,
- Wheelchair users and
- Blind passengers.

The next step is to involve the passengers, operators, legislator and developer into the progress of requirements development. According to systems engineering, the black-box approach from figure 3 helps to isolate the system from its environment, which influences the system (Haberfellner et al., 2012; Winzer, 2013). In addition, the inputs and outputs of the system are determined.

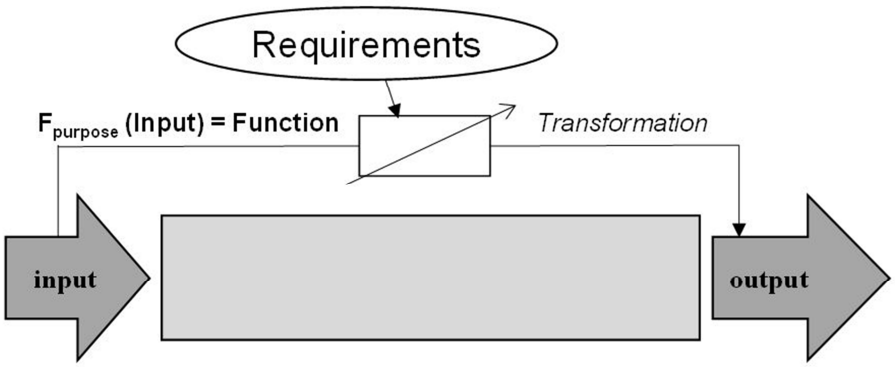

Fig. 3 - Black-box approach

Thus, the system focus can be realized in a more detailed and precise way. Generally, the system is defined as a set of related elements with mutual interactions and interdependences (Patzak, 1982). After clarifying the system's black box, the system itself has to be examined. The limitation of complex technical systems can be realized by decomposing the system into a set of subsystems by using the black-box approach from figure 3 (Visser, 2007; Ashby,

1957). Due to the variety of stakeholders of the aim4it system, the most important stakeholders have to be identified. First of all, passengers of the public transport are considered. Those who form the most important stakeholder-group of the new travel assistance system, their requirements have to be gathered and documented in a systematic way (c.f. next step 2 Elicitation).

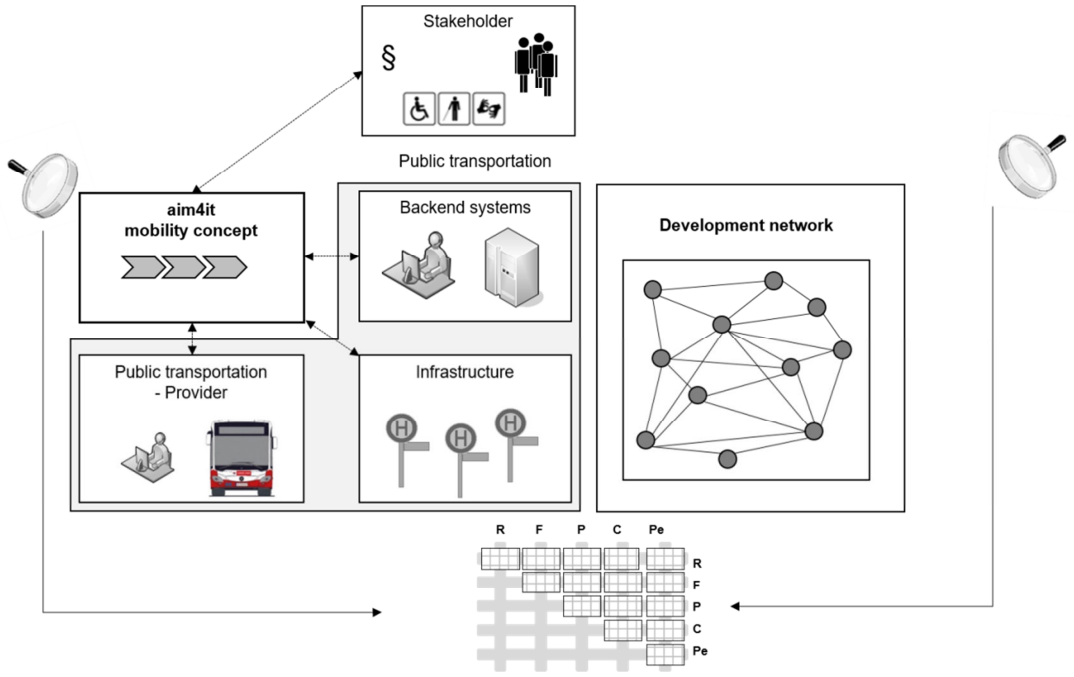

Fig. 4 - System limitation (cf. Nicklas, 2016)

Figure 4 shows the aim4it mobility concept with its connected parts (infrastructure, public transportation - provider, backend system) and the stakeholders (source of requirements). On the right side, the network, which develops and uses the aim4it application is depicted. To get a first overview of the aim4it system as a uniform network model, the mentioned system elements have to be integrated into the system model.

2) Elicitation

In the elicitation phase, the product system model is focused initially. Therefore, the elicitation of requirements, which regard to the product system has to be carried out. Generally the elicitation is the main challenge especially in collaborative networks (Marchlewitz et al., 2013; Meyers et al., 2006, Nicklas, 2013; Savio et al., 2011). This can be explained by:

- The variety of stakeholders.
- Stakeholders who cannot articulate their requirements regarding to too complex systems.
- The dynamic behavior of the system and its environment.
- Different partners, products, customers in network structures.
- Ambiguous structures, contact points and responsibilities.

There is a large diversity of methods for elicitation in literature, e.g. questionnaires, monitoring, different interview types (single interviews or focus groups), workshops, market studies, use-cases etc. (c.f. Ehrlenspiel/Meerkamm, 2013; Ponn/Lindemann, 2011; Yu et al., 2011).

A general approach for requirements elicitation is described by Hickey/Davis (c.f. figure 5). Requirements, which are already known can be elicited and formalized in a systematic way based on the problem- and solution domain (c.f. figure 5).

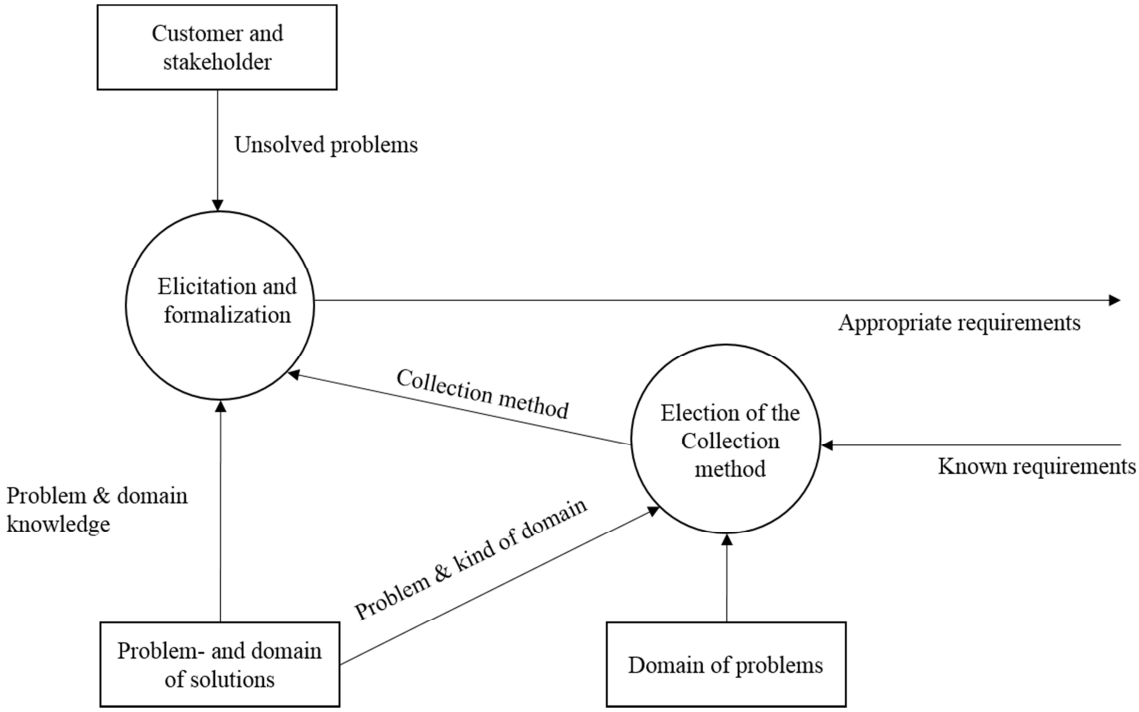

Fig. 5 - Approach for requirements elicitation (Hickey et al., 2004)

The example of aim4it shows the need for a precise requirements elicitation. Especially in case of different stakeholders or groups of user e.g. deaf persons who need special assistances for requirements elicitation are demanded. Therefore, a combination of requirements elicitation methods has to be used: questionnaires, workshops and single interviews. By using this combination, every requirement from stakeholders can be documented and used for system development. First, requirements from passengers of the public transport form the most important group.

Their requirements can be explained by adequate (correct, precise, timely and understandable) information in any case of disruptions of the regular service. Even more requirements become obvious regarding to people with disabilities e.g. relevant information about defects of station elevators in sign language. The requirements are gathered and formalized by use-cases (Nicklas et al., 2015). Certainly technical requirements of developers, quality engineers and public operators also have to be considered in a systematic view. A dictated system model of the product is helpful to realize a mutual understanding for stakeholder groups. Figure 6

shows the combination between procedures for requirements elicitation with the system model. Input data from the first version of the system model was used from the use-case participants and responsible persons. Use case activity diagram and customer survey provide input data for a more detailed system model (c.f. figure 6).

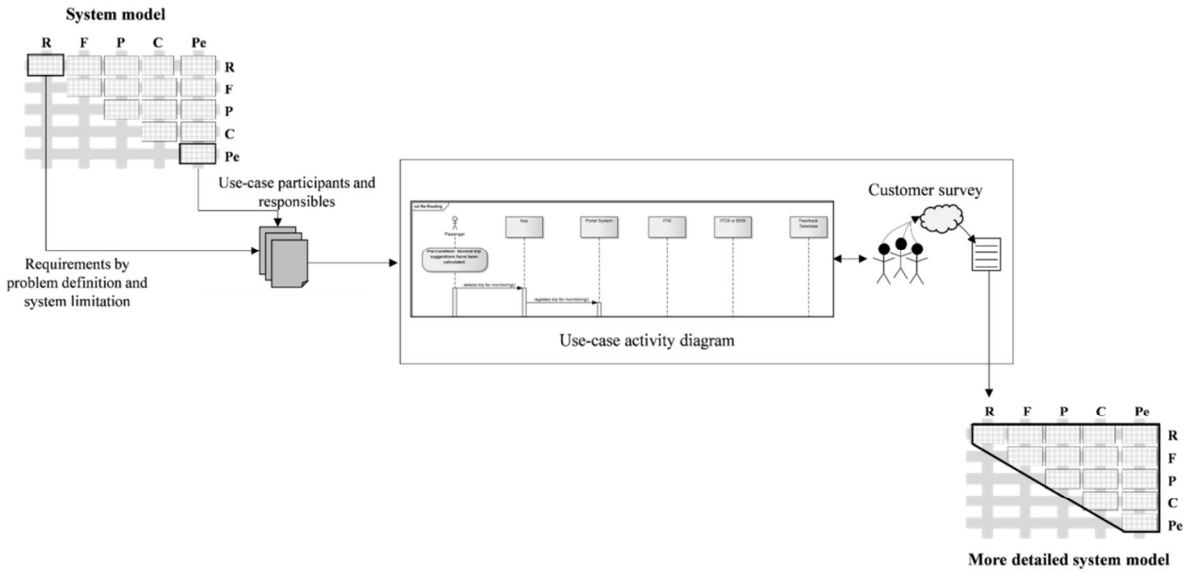

Fig. 6 - Combined procedure for requirements elicitation with the help of the system model (cf. Nicklas, 2016)

The use-cases are SysML and UML-based (system modeling language, unified modeling language), which are combined with a storyline that integrates the users. In addition to that, a consistent combination of the technical requirements (UML-flowcharts) and the user requirements (requirements lists, storylines) are realized to develop the system model with more details.

3) Structuring and Analysis

For a systematic system development the requirements have to be structured and clustered. To insert structural input into the system model, a use case cluster was used (c. f. figure 7). The structure of the hierarchy is built in a logical way and starts with the goal, which is divided into different use-cases. Requirements of the application were derived from individual use-cases and further classified into detailed requirements. In addition, they could be described by using attributes like stakeholders (source of the requirements). After that, the requirements can be prioritized with methods of group decision making.

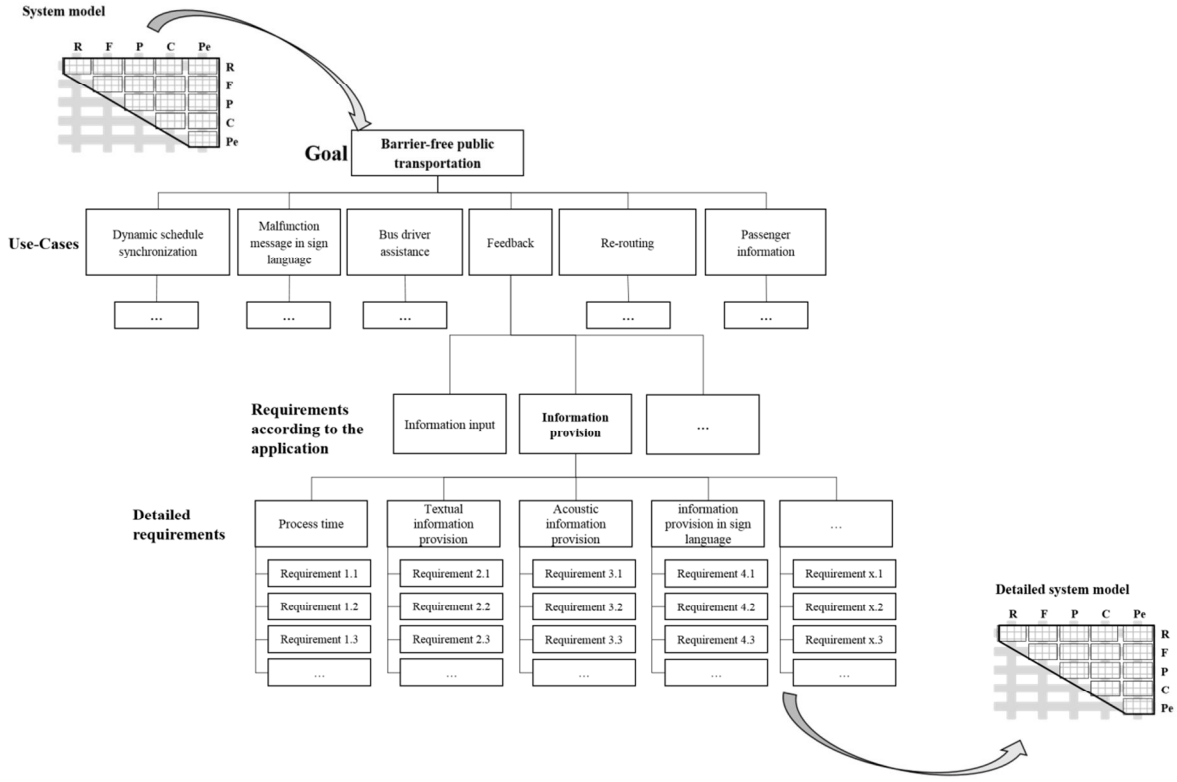

Fig. 7 - Requirements structuring and analysis

There are many different methods (pairwise comparisons, ranking-methods etc.), which can be used for the prioritization of the requirements (Nicklas, 2016). The working group has chosen the analytical hierarchy process (AHP), because the experience has shown that this is the most suitable method to prioritize the requirements systematically (Nicklas, 2016).

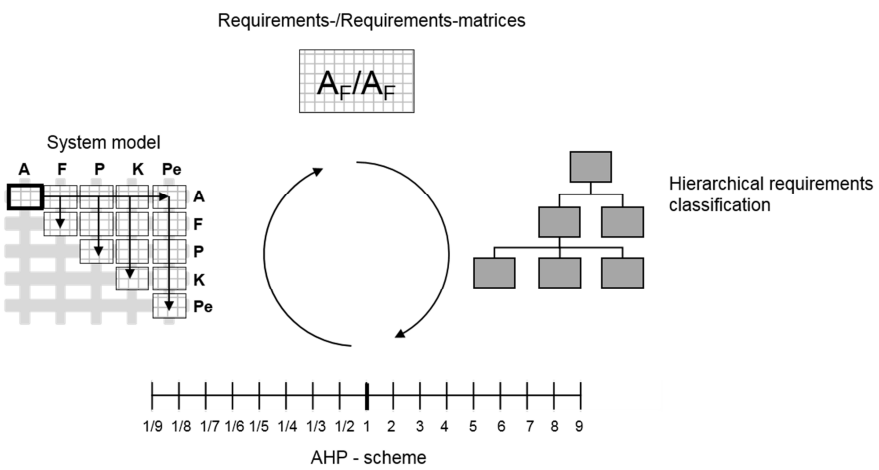

Fig. 8 - Requirements analysis by the usage of the AHP

The use and update of the system model by utilizing the AHP is an important step for a systematic and consistent system development.

4) Validation

In order to verify the degree of implementation, requirements have to be added and validated. To validate the system, users were tested based on the prototypical phone use-case. After that, measurements have been made to determine the satisfaction of the users. The purpose of those measurements was to compare the user's or customer's satisfaction data with the requirements, which have been defined in the second phase (Elicitation).

The results of the satisfaction measurements (customer data) are integrated and interlinked as new requirements in the system model. Figure 10 shows the principle usage of the defined requirements (system model t_n) and the comparison to the customer data (t_{n+1}).

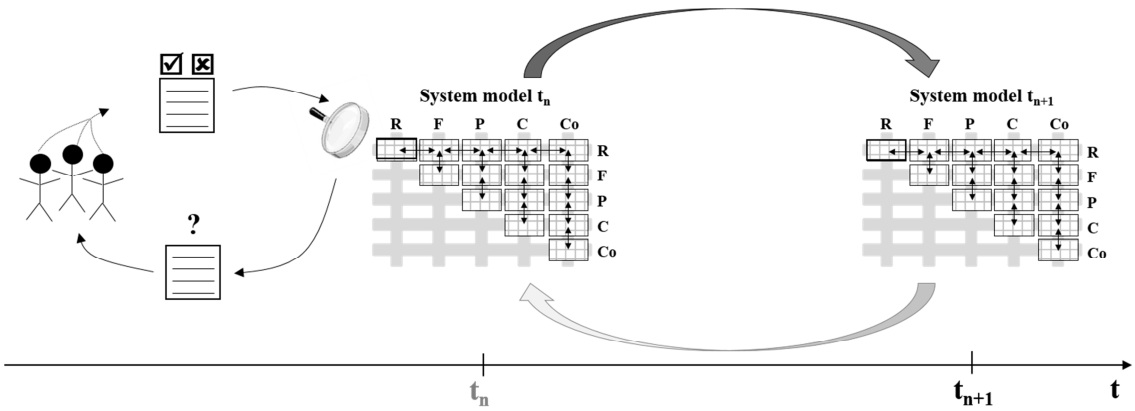

Fig. 9 - Requirements validation

The system model can also be used at a later point of time, e.g. for integration of new customer satisfaction data or new use-cases and systems to realize a consistent system model (over time). However, potential new partners of the collaborative network can use the existing network model for an easier integration into the network.

RESULTS AND CONCLUSION

In summary, this paper describes a new methodical approach which shows how to ensure that requirements of the customers can be recorded, checked, structured and validated in a systematical way. Furthermore, through the application of the new approach it should be possible to realize a transparent traceability of the requirements to their sources (stakeholder) or to the person, which is responsible for implementing the requirements. Approaches from science and practice have been analysed and demands for the new approach have been deduced. The new approach is a combination of adapted steps of requirements management and a uniform network model, which is based on eDeCoDe, a standardized procedure from the model-based engineering sector. Each of the four steps interact with the uniform network model in order to generate and update the system. The usability of the new methodical approach has been tested by a corporate network in the field of public transport. In the following will be discussed and examined, if the defined demands of the new approach have been fulfilled:

- Ensure, that inconsistency requirements of the customers from different countries can be recorded and checked.

Within the scope of project aim4it requirements of users, respectively customers from three different countries (Austria, Germany and Poland) have been recorded. By comparison between system model t_n and system model t_{n+1} in the phase of validation, it can be possible to check and identify inconsistency requirement of the customers (c.f. figure 9, subchapter validation). Therefore, in order to check, if the new approach could also be suitable for an application at companies from different countries, further research has to be carried out.

- Collect data of the requirements in a corporate network and realize it in a structured, validated and systemically way.

Based on the black-box approach, the limitation of complex systems can be realized and a system model can be created. For the collection of data and consistent description of requirements use cases were used. The input for those use cases were the defined requirements from the system model (c.f. subchapters system definition and elicitation). By using the analytical hierarchy process (AHP) the requirements of the aim4it system was classified and structured in a systemically way (c.f. subchapter structuring and analysis). Furthermore, a prioritization helps to identify the use cases, which are mostly frequented and important. Based on this knowledge, the requirements of the product systems can be prioritized.

- Realise a transparent traceability of the requirements.

With the help of the eDeCoDe main matrix tool a transparent traceability of requirements could be realised. However, a traceability of requirements is very dependent on data, information and knowledge, which are available in the system model. It could be interesting to model the traceability of the requirements not only represented in matrices, but also graphically. For further research, the presented approach has to be evaluated in more scenarios and with more examples.

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