On the Requirements Analysis Process for Domain-Specific Languages in the Realm of Multi-Perspective Hospital Modelling

Michael Heß, Ulrich Frank, Monika Kaczmarek
Information Systems and Enterprise Modelling
Institute for Computer Science and
Business Information Systems
Faculty of Economics and Business Administration
University of Duisburg-Essen
45141 Essen, Germany
m.hess@uni-due.de,
ulrich.frank@uni-due.de,
monika.kaczmarek@uni-due.de

Lars Podleska[1,2], Georg Täger[2]
[1]Department of Trauma Surgery
University Hospital of Essen
[2]Musculoskeletal Surgical Oncology
Sarcoma Centre at the West German Cancer Centre (WTZ)
University Hospital of Essen
45122 Essen, Germany
lars.podleska@uk-essen.de,
georg.taeger@uk-essen.de

***Abstract*—The analysis of requirements for Domain-Specific Modelling Languages (DSMLs) can be very challenging, since prospective users often do not have a clear idea of a DSML. This is especially the case if prospective users lack a technical background. This paper reports on the use of a dedicated method to support the analysis of requirements for DSMLs in hospitals. Apart from an elaborate process model, the method recommends developing a specific kind of use scenarios that serve as a medium to get users involved. The presented work was part of a larger project that is aimed at developing multi-perspective hospital models.**

I. Motivation

The German health care system, similarly to other health care systems in industrialised countries, has to face a number of challenges resulting out of demographic, epidemiological, and economic developments, as well as medical and technological advances. Medical and technological advances offer new possibilities for medical treatments [1, p. 11]. The ageing and increasingly multi-morbid population requires delivery of more complex medical care, which entails higher health care system expenses. However, while postulating higher quality of care, public health's stakeholders demand more transparency in the medical care provision process as well as a reduction of the overall public health expenditures. This forces the health care sector to address partly contradictory goals, namely [1, p. 11]: (1) to increase the quality of medical care, (2) to increase the transparency of medical care provision process and resulting costs, and (3) to increase its cost-effectiveness.

Achieving these goals can be facilitated through application of clinical pathways (CPs) that extend medical guidelines with institution-specific aspects and, as such, can foster the increase of quality and transparency in medical care. A clinical pathway "explicitly states the goals and key elements of care based on evidence based medical guidelines, best practice and patient expectations by facilitating the communication, coordinating roles and sequencing the activities of the multidisciplinary care team, patients and their relatives; by documenting, monitoring and evaluating variances; and by providing the necessary resources and outcomes" [2, p. 562]. In addition, by supporting a pathway-oriented accounting, clinical pathways can become an adequate instrument to increase cost-effectiveness [3].

The already conducted research shows that creating models of clinical pathways that include a graphical representation, can foster understandability and clarity of medical knowledge as well as of sequence of medical activities and clinical decisions to be taken [4]. However, currently no approach offers a full support for modelling and analysis of all clinical pathways' aspects (see [4] for evaluation of currently available solutions). Therefore, the development of a comprehensive modelling method is postulated. It should support not only modelling and analysis of a clinical pathway itself, which can be seen analogously to business process modelling and analysis, but also of other aspects from the hospitals' action system[1] and information system: medical resources' usage, hospital's and IT infrastructure, hospital's strategic goals, information on costs and revenues. In this way, the resulting models can serve as a foundation for model-based hospital management, as well as the (re-)design of supporting information systems and the hospitals' action system.

To support the efficient and convenient development and use of respective models, a modelling method should provide adequate concepts. On the one hand, in order to foster comprehensibility, they should correspond to the technical (professional) terminology used in the domain. On the other hand, they should reflect abstractions that are suited to foster professional

[1]"An action system is a system of interrelated actions that reflect the corresponding actors' intentions and abilities, organisational goals and guidelines, contextual threats and opportunities, as well as mutual expectations." [5, p. 42].

TABLE I
COMPARISON BETWEEN MANUFACTURING ORGANISATIONS AND HOSPITALS IN THE CONTEXT OF LEAN MANAGEMENT – SELECTED ASPECTS BASED ON [6, XVI–XIX]

Feature	Manufacturing organisation	Hospital
Human involvement	Automation plays a major role in order to reduce human involvement and the need for high skills and knowledge	Skills, knowledge and experience of professionals play major role
Performance measurement	Performance of workers is easy to measure	Performance of healthcare professionals is not easily measurable
Process effectiveness	Process outcome is predictable	It is hard to predict the degree of the success (the outcome) of healthcare service
Product uniformity	Machine produces identical products	It is difficult to perform a medical operation that will have exactly the same output. Each patient may require diff. service
Cycle time	Cycle time of the production could be precise and determined in advance	Healthcare service cycle time could vary and is difficult to determine prior to the service
Customer involvement	Customers are not involved in manufacturing the product	Customers are directly involved in producing the services
Consumption	Products are produced and consumed at a later stage	Products are produced and consumed simultaneously
Information flow	Mainly depends on the process flow	Healthcare activities are information-based activities
Quality	The primary quality problem in manufacturing settings is the quality of the final product	The primary problem in healthcare services is not the quality of the actual implementation of the process, but the quality of information that controls the process

analysis and decision making. To the best of our knowledge such a comprehensive approach allowing to include various perspectives and to model the hospital's action system, is not available. Against this background, the aim of our project is the development of a domain-specific modelling method (DSMM), which provides modelling concepts reconstructed from the medical terminology (for more details see [4]). In this paper, we report on the conducted requirements analysis process and discuss the lessons learned from the undertaken activities.

"A modelling method [...] consists of at least one modelling language and at least one corresponding process model, which guides the construction and analysis of models" [7, p. 5]. A domain-specific modelling language (DSML) extends concepts of general purpose modelling language (GPML) with domain-specific modelling concepts, which are reconstructed from the domain of discourse's professional terminology [5, p. 26-28]. Thus, a DSML is used to create conceptual models of the domain it is related to [5, pp. 26-28].

One of the most challenging aspects of DSML development is the identification of specific, domain-dependent requirements [8], [9], i.e., all of the conditions and capabilities needed by prospective users to address their problems and support their actions and/or that should be possessed by the constructed artefact [10], [11]. Performing a thorough requirements analysis process[2] is crucial for the subsequent modelling method's design in order to ensure the method's appropriateness and purposefulness. Furthermore, requirements can be used for the needs of evaluation of the resulting artefact.

The paper aims at presenting and discussing experiences gathered in the area of requirements analysis process while designing DSMLs incorporated in a DSMM for Multi-Perspective Hospital Modelling (MPHM). The design of modelling methods belongs to the field of design-oriented Information Systems research [12, p. 8 f.]. The research process should consist of the phases "Analysis", "Design", "Evaluation", and "Diffusion" and should address the research principles "Abstraction", "Originality", "Justification", and "Benefit" [12, p. 9]. The requirements analysis process is mainly part of the "Analysis" and "Design" phases, and is conducted on iterative basis in order to make sure that no vital requirement is omitted or misinterpreted [11]. Therefore, the requirements analysis process should be seen as a continuous process rather than a closed phase within a design project [11, p. 39. f.].

Designing a modelling method (or DSMLs) can be guided by an elaborate process model proposed by [8], [9]. According to this model, a structured approach should be followed in order to identify the domain- and application-specific requirements. In order to make sure that the domain-specific aspects are rightfully considered, the involvement of domain experts having a dedicated professional background and the joint development of use scenarios in the form of diagrams using domain-specific visualisations, is recommended. By using domain-specific diagrams to visualise resulting models, the characteristics of human processing is taken into account [13], [14], which can contribute to clarifying scope, purpose and potential benefits of the method's usage.

The paper is structured as follows. After this brief motivation, the main vision of the targeted modelling method is shortly presented. Then, we focus on the requirements analysis process in the context of targeted method. Next, we present the method followed, the process to derive specific requirements as well as lessons learned. The paper concludes with final remarks and an outlook on future work.

II. MULIT-PERSPECTIVE HOSPITAL MODELLING

Hospitals, analogously to traditional enterprises, have to be managed from an economic perspective. However, they incorporate a set of unique characteristics (see Table I) that

[2] We refrain from using the term *requirements engineering* Despite its widespread use, we regard it as being unfortunate. On the one hand, requirements are not engineered, but reflect actual needs of prospective users. On the other hand, the process of discovering and (re-)constructing requirements demands for getting users involved, i.e. is not restricted to mere engineering activities.

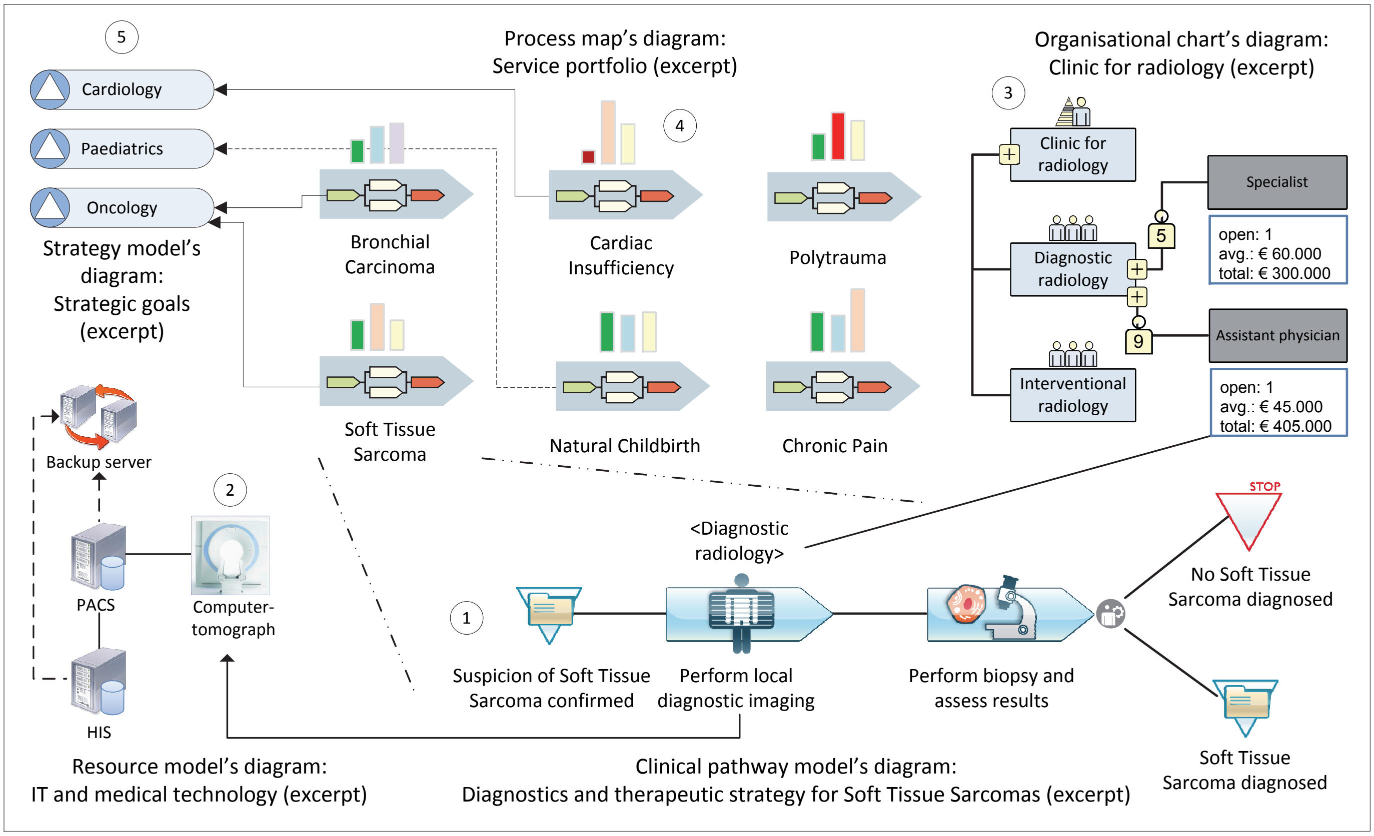

Fig. 1. Exemplary diagram of a Multi-Perspective Hospital Model [4, p. 371]

justify the development of a corresponding domain-specific modelling method [4].

A DSMM for hospitals, similarly to enterprise modelling, should allow to "comprise conceptual models of software systems, e.g., object or component models, that are integrated with conceptual models of the surrounding action systems, e.g., business process models or strategy models" [7, p. 2 f.]. The envisioned Multi-Perspective Hospital Modelling method aims at [4, p. 372 f.]:

1) increasing transparency of the hospital's relevant aspects by providing corresponding models using domain-specific abstractions in order to foster clarity and understandability for all involved stakeholders;
2) serving as an instrument to foster communication between different stakeholders by providing concepts corresponding with their particular (professional) perspective and terminology;
3) providing a basis for conducting purposeful analyses in order to answer stakeholders' questions on the hospital's current state, e.g., from the medical, economic or technical perspective;
4) building a foundation for (re-)designing the hospital's action system, as well as its information systems to increase efficiency and/or effectiveness.

As hospitals are highly complex socio-technical systems with a high number of different professions as well as professional disciplines, it is recommended initially not to aim at designing a method that covers the entire hospital's action system, but to instead at first focus on a selected part of the domain only. On the one hand this focussed research may serve as a feasibility study and on the other hand allow for eliciting requirements that can be reused while extending the MPHM method towards other fields of the domain.

The World Cancer Report reveals that "cancer is a major cause of morbidity and mortality, with approximately 14 million new cases and 8 million cancer-related deaths in 2012" [15, p. 16] and prognoses a rise in new cases of cancer of about 75 % over the next two decades [16, p. IX]. Therefore, taking into account the medical and societal relevance, the medical field of oncology has been selected as a current focus of the designed method.

An exemplary diagram of the targeted method – a Multi-Perspective Hospital Model – is presented in Fig. 1. The initial method design and evaluation is a joint project of Research Group Information Systems and Enterprise Modelling, University of Duisburg-Essen (UDE) and the West German Sarcoma Centre, which is part of West German Cancer Centre and is responsible for the treatment of bone and soft tissue tumours. The West German Cancer Centre (WTZ) is one of 12 comprehensive cancer centres (CCC) in Germany, certified by German Cancer Aid. It runs 14 different treatment programmes with more than 80 different clinical pathways. WTZ has more than 370 physicians in more than 20 clinics and 16 institutes, treating more than 70.000 outpatient and 20.000 inpatients per year.[3] The number of clinical pathways and cancer related care organisations in particular, as well as the number of about 2.000 German hospitals as prospective organisations to apply the envisioned method in general, shows the potential of reusing the proposed method.

The presented diagram (Fig. 1) visualises, using the extracted domain concepts, excerpts of soft tissue sarcoma clinical pathway diagram (①), a resource model's diagram (②), an organisational chart (③), a hospital's service portfolio (④) and its strategy model's diagram (⑤). By focussing on selected aspects, the diagram supports the perspective-specific presentation of relevant information to avoid the information overload and therefore, supports reducing the risk of cognitively overloading the user's mind [14, p. 767]. This requires a corresponding modelling environment to allow for flexible, perspective-specific visualisation of the model's information in corresponding diagrams.

The proposed Multi-Perspective Hospital Modelling method will be able to support hospitals in fulfilling the defined aims, only if it takes into account and is tailored to hospitals' specific characteristics, as presented above. This is to be ensured by the conducted requirements analysis process, which is described in the next section.

III. Requirements Analysis Process in the Realm of Multi-Perspective Hospital Modelling

Requirements analysis in the context of software development is a process of "identifying a user's needs and determining what to build in a system" [17, p. 95]. Pohl defines three main activities in the requirements analysis process: requirements documentation, elicitation and and negotiation [11, p. 48–50]. Within the requirements identification phase, a process of requirements elicitation takes place in which "tacit information about what to build is obtained from the user and his environment" [17, p. 95]. Requirements can be differentiated into goals, scenarios, and solution-oriented requirements [11, p. 53–55].

"Scenarios are arguably the starting point for all modelling and design" [18, p. 322]. They may be compared to "stories that illustrate how a perceived system will satisfy a user's needs" [17, p. 96] and which are "an important mean for creating social meaning and a shared sense of participation" [17, p. 96]. Scenarios are "related to model by a process of abstraction and to prototypes by a process of design" [18, p. 320]. In case of software development a scenario is "an idealized, but detailed description of a specific instance of a human-computer interaction" [19, p. 291]. A good scenario ought to be "an instantiation of a fledgling phenomenon" [19, p. 293]. It means that "the effect ought to hold over a wider range of circumstances, not to be dependent on the exact conditions of a particular setting" [19, p. 293].

[3] More details can be found at http://www.wtz-essen.de/.

The understandability of conceptual models by all involved stakeholders is of critical importance in the context of information systems development [13, p. 130]. If the conceptual models are not readily comprehensible and understandable by prospective users, then the users will not be able to verify whether the models are meeting or reflecting their requirements [13, p. 130]. Thus, it is essential that the means to present or derive requirements would take into account the characteristics of human processing and the problem situation, i.e. domain-specific features [13],[14]. That is why out of the available means, scenarios that can be represented using various forms, e.g., text, pictures or visual diagrams [17, p. 96],[20], and have proven to be an effective mean of communication between users and designers [21, p. 1072], are more and more often applied also in the area of conceptual modelling, in order to facilitate the requirements analysis process.

The method that we use to derive requirements for DSML is also based on scenarios [8], [9]. It suggests a specific kind of scenario that is based on the construction of prototypical diagrams, which are refined together with prospective users. Furthermore, it includes a macro process model that is decomposed in several micro process models and a corresponding role model. The method has already been successfully used in different projects (e.g., [22], [23]).

A. Design Method of MPHM – Requirements Identification

Figure 2 shows the macro process for designing DSML, as described in [8, p. 140], consisting out of 7 steps – starting from clarification of scope and purpose, through analysis of requirements, specification of language (abstract syntax), provision of graphical notation (concrete syntax) and optional development of modelling tool. The process ends with the evaluation and iterative refinement of developed artefacts. In this paper, we focus on the requirements analysis process, i.e., first three steps in the macro process.

The first step of the presented macro process, "Clarification of Scope and Purpose", allows to identify high-level requirements (HLR) and "outline a convincing motivation and rationale for designing a DSML" [9, p. 32].

The second step – "Analysis of Generic Requirements" – addresses requirements towards DSML in general. Thus, the generic requirements are not specific to a dedicated DSML. They may be roughly divided into formal requirements (e.g. "The specification of a modelling language should include a precise and complete specification of its syntax (...)" [9, p. 12]), user-oriented requirements (e.g., "The concepts of a modelling language should correspond to concepts prospective users are familiar with (...)" [9, p. 13]) and application-oriented requirements (e.g. "A modelling language should provide domain specific concepts as long as their semantics is invariant within the scope of the language's application" [9, p. 14]). The generic requirements apply to every DSML, however, with different weights. Therefore, they are not presented here, but instead the reader is referred to [8, p. 142] and [9, p. 32] for more details.

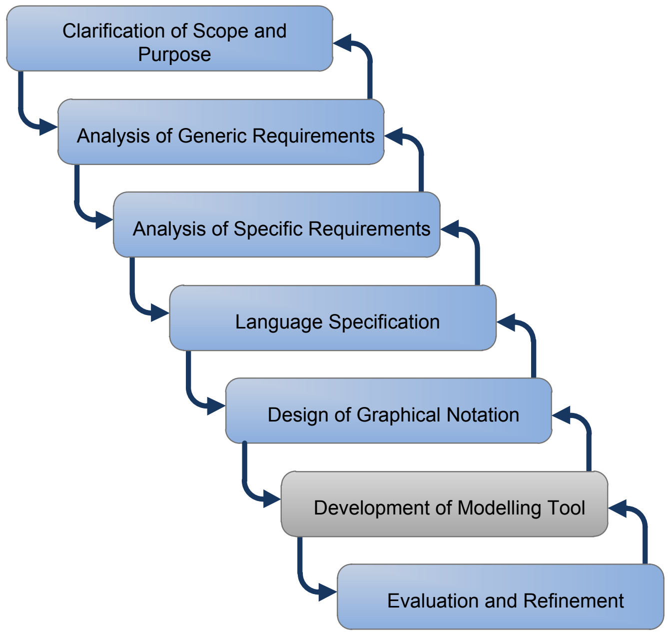

Fig. 2. Macro process for DSML design [8, p. 140]

In the third step, specific requirements towards the method's DSMLs are identified. Within this phase, based on the use scenarios, a list of specific requirements is formulated, providing understanding what a DSML should encompass in order to provide support to prospective users and solutions to identified challenges.

B. *Clarification of Scope and Purpose*

As already mentioned, the first step allows to identify high-level requirements and "outline a convincing motivation and rationale for designing a DSML" [9, p. 32]. The motivation and rationale were shortly presented in Sect. I and II.

Identification of high-level requirements requires both knowledge on Information Systems/Enterprise Modelling as well as on domain-specific aspects i.e., hospitals and medical care provision process peculiarities. Therefore, a group of actors with different professional background needs to be involved in the requirements analysis process (see the Role Model [9, p. 26 f.]).

During the MPHM method's design, the collaboration with the domain experts and prospective users was possible due to the already mentioned research project conducted by UDE and WTZ. Table II gives an overview on the actors and their roles within the macro process' first step.

Taking into account the selected medical field, it was crucial to involve a number of experienced senior physicians and medical specialists working in different fields of oncology, such as surgical oncology, medical oncology, radio oncology, and pathology. All of them were interviewed regarding their expectations towards the modelling approach to be applied in the hospital domain and towards potential initiatives aiming at the (re-)design of hospital's action system and of information systems. The knowledge gained during one-to-one and group interviews has been extended based on observations of different physicians during their daily working routines in different departments. In addition, additional insights have been gained by observing multidisciplinary case conferences: here physicians from various medical disciplines jointly plan and control each patient's CP-based individual treatment.

TABLE II
ACTORS AND THEIR ROLES IN THE REQUIREMENTS ANALYSIS PROCESS FOR HIGH-LEVEL REQUIREMENTS

Role	Actors
Domain Expert	Attending physicians from different WTZ departments working in the team of West German Sarcoma Centre
User	Attending physicians and medical specialists from different departments of WTZ working in the team of West German Sarcoma Centre
Business Analyst	Not involved in the initial phase of the project
Language Designer	Members of UDE
Tool Expert	Members of UDE
Graphic Artist	Members of UDE Professional graphics designer
Manager	Not involved in the initial phase of the project

Multiple interactions with and between these actors provided a basis for identification of high-level requirements (see [4]). Exemplary high-level requirements comprise a need to design a DSML for modelling clinical pathways, which should include the possibility to model medical decision scenarios, as well as medical goals, both on a type and instance level [4, p. 375]. Furthermore, the possibility to model roles and responsibilities, as well as to conduct medical and economic analyses on different levels of detail should be provided [4, p. 376 f.]. The list of high-level requirements is presented in Table III. The rationale and explanation may be found in [4].

Once the high-level requirements have been identified, the specific requirements, being in the focus of this paper, can be identified, as shown in the next section.

C. *Analysis of Specific Requirements*

The applied method to design DSMLs postulates following a defined structure in order to identify the specific requirements as shown in Fig. 3 and outlined subsequently.

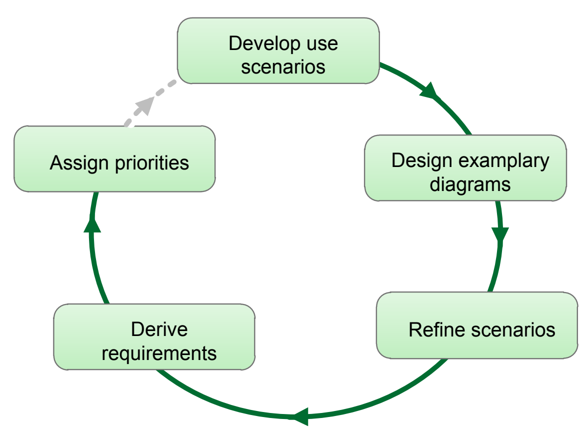

Fig. 3. Micro process on specific requirements analysis [8, p. 143]

TABLE III
IDENTIFIED HIGH-LEVEL REQUIREMENTS TOWARDS MPHM BASED ON [4]

No.	High-Level Requirement
1	DSMM for MPHM should provide a domain-specific modelling language for modelling clinical pathways.
2	DSML for CP modelling should provide concepts supporting comprehensive modelling of medical decision scenarios including decision alternatives, decision criteria, and corresponding potential values of the decision criteria.
3	DSML for CP modelling should allow for specifying one or more goals for each medical activity based on both, (evidence based) medical knowledge and patient-specific preferences.
4	DSMM for MPHM should support modelling domain-specific medical resources that correspond to the medical domain's professional terminology.
5	DSMM for MPHM should allow to add information on the underlying level of evidence to each medical activity modelled in CPs derived from the evidence-based medical knowledge.
6	DSMM for MPHM should allow for assigning at least one coordinating role to each CP.
7	DSMM for MPHM should allow for assigning responsibilities to each CP's medical activity, differentiated into those for performing the medical activity, as well as those responsible for its outcome.
8	DSMM for MPHM should allow for hospital model wide cost-based analyses. For CPs it should allow for it, both on the type and the instance level, as well as the comparison of their resulting costs with correspondingly realised DRG revenues.
9	DSMM for MPHM should allow for modelling potential risks for each medical activity, as well as for the overall CP including the risk occurrence likelihood and factors influencing its increase and decrease.
10	DSMM for MPHM should allow for supporting patient-specific medical documentation and deviation analysis based on the defined (type level) and instantiated patient-specific clinical pathway by combining corresponding type and instance level information.
11	DSMM for MPHM should allow for providing an aggregated view on all CP types defined within the hospital in a medical service portfolio. This portfolio should support the visualisation of key performance indicators for each CP type in order to allow for a high-level controlling perspective.
12	DSMM for MPHM should support the analysis of the alignment of hospital's strategy and medical services.
13	DSMM for MPHM should allow for modelling relevant IT components used in the context of provision of medical care including data exchange protocols and SLAs.
14	DSMM for MPHM should support modelling relevant data structures and data flows to allow for performing analyses regarding the flow and usage of data within medical activities and supporting IS, as well as the degree of integration of IS.
15	DSMM for MPHM should provide a graphical representation of the modelling concepts, which illustrates the intended semantics in an easily accessible and understandable way for prospective users.
16	A comprehensive method for MPHM should support the creation of corresponding diagrams tailored to the stakeholder's perspective-specific information needs.

The first step is the identification and description of relevant modelling scenarios (development of use scenarios). Each scenario is related to a certain diagram type, which should be clearly described regarding its purpose and key concepts. After the clarification of the purpose of the scenario, and preparation of a rudimentary graphical representation, a list of questions that relate to the diagram should be developed.

The formulated questions should be answered based on the diagram's final version, thus, they are implicitly defining the information that the diagram should provide to the prospective users. Taking into account the consecutive development of a modelling tool (fifth phase of the macro process), for each identified question one of three categories should be assigned indicating, whether it can be answered by a machine, by a human or in a partially automated manner. Then, based on the example diagram and the prepared list of questions, all involved participants (i.e., both domain experts as well as a method designer) are supposed to commonly develop specific requirements and identify substantial challenges for the next phase – specifying the DSML's abstract syntax. Finally, priorities need to be assigned to the derived requirements or to their realisation during the method's design phase.

TABLE IV
ACTORS AND THEIR ROLES IN THE REQUIREMENTS ANALYSIS PROCESS FOR SPECIFIC REQUIREMENTS – RELEVANT FOR A SELECTED GROUP OF USE SCENARIOS

Role	Actors
Domain Expert	Attending physicians - different WTZ departments Nursing staff from different WTZ departments Medical management staff from University Hospital of Essen (UHE) Medical documentation staff from UHE Information systems specialists from UHE General management staff from UHE
User	Medical and non-medical UHE personnel
Business Analyst	Medical staff with management responsibility from UHE Medical and general management staff from UHE Members of UDE
Language Designer	Members of UDE
Tool Expert	Members of UDE
Graphic Artist	Members of UDE Professional graphics designer
Manager	Medical staff with management responsibility from UHE Medical and general management staff from UHE

Due to the number of different use scenarios identified, the number of actors with different professional background involved in the specific requirements analysis process needed to be further increased (see Table IV) in comparison to the previous step. Apart from already mentioned physicians also nursing staff, medical and general management staff, as well as hospital IT specialists needed to be involved.

Figure 4 shows an exemplary diagram excerpt of a clinical pathway model (i.e., a graphical representation of an exemplary scenario). It shows performing a cat scan, on the type level, documentation of the radiation applied, storage of the images taken in the picture archiving and communication system (PACS), as well as the results being documented and evaluated in the hospital information system (HIS). It uses a domain-specific graphical visualisation of process and resource types.

The diagram addresses the use scenario "Documentation of clinical pathways on the type level". Envisioning a possible (re-)design of the hospital's action system and information system allows for identifying additional use scenarios. They result out of the domain experts' envisioned HIS support of clinical documentation, in the context of model-driven software engineering. They are as follows:

1) Support of the pathway oriented clinical documentation on the instance level.
2) Support of the clinical cancer registration based on the clinical documentation.
3) Support of the epidemiological cancer registration based on the clinical cancer registration.
4) Support of the semi-automated letter of discharge generation.

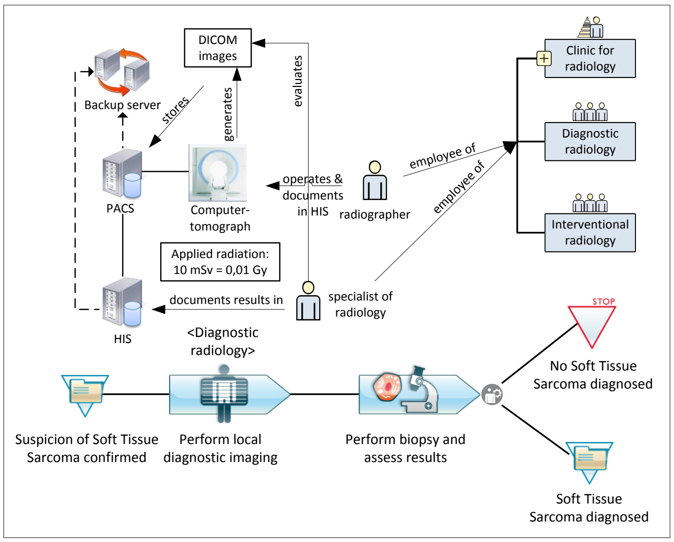

Fig. 4. Exemplary diagram draft for use scenario

Table V shows specific requirements based on the use scenario visualised in Fig. 4. The specific requirement's (SR) leading number allows for identifying the high-level requirement (HLR) that it details, e.g., 1.1 indicates the first specific requirement resulting out of high-level requirement 1.

The priorities have been assigned to the specific requirements based on the sequence of HLR they belong to: Priority 1 to HLR 1, 2 to HLR 4, 3 to HLR 7, 4 to HLR 13.

As stated in [19], use scenarios represent concrete parts of more general use cases. Therefore, they usually do not provide a comprehensive set of specific requirements and corresponding specific sub-requirements (SSR), which then need to be derived based on additional use cases, or added based on the domain analysis. Taking into account the page limit, two specific requirements, namely SR 1.1 and SR 4.1, were selected, for which exemplary further sub-requirements are presented in Tab. VI and Tab. VII, respectively.

Table VI concretises SR 1.1 into 9 SSRs, which need to be fulfilled by MPHM method, in order to allow for modelling different types of diagnostic imaging processes with respect to different diagnostic imaging procedures. Analogously, SR 4.1 is concretised into 9 SSRs (4.1.1 to 4.1.9, see Tab. VII), which need to be fulfilled by MPHM method, in order to allow for modelling different diagnostic imaging resource types used in diagnostic imaging processes.

In order to ensure the required quality of models resulting out of applying the targeted Multi-Perspective Hospital

TABLE V
SELECTED SPECIFIC REQUIREMENTS BASED ON USE SCENARIO IN FIG. 4

No. of HLR	No. of SR	Specific Requirements derived out of HLRs
1	1.1	A DSML for modelling CP should provide a concept for modelling diagnostic imaging processes and allow to distinguish between diagnostic imaging processes applying radiation and not applying radiation.
4	4.1	A DSML for modelling medical resources should provide concepts for modelling diagnostic imaging resources and allow to distinguish between resources applying radiation and not applying radiation.
4	4.1.1	A DSML for modelling diagnostic imaging resources should provide a concept to model computer tomographs.
4	4.2	A DSML for modelling medical resources should provide concepts for allocating diagnostic imaging resources to corresponding diagnostic imaging processes.
4	4.3	A DSML for modelling medical resources should provide concepts for modelling medical staff with their specific qualifications.
7	7.1	A DSML for modelling hospitals' organisational structure should provide concepts for modelling positions of physicians and assistive personnel.[4]
13	13.1	A DSML for modelling information technology landscapes should provide concepts for modelling healthcare-specific information technology artefacts.

Modelling method, the corresponding language specification needs to limit the possibility to create semantically incorrect models. Therefore, it is important to take into account that for each diagnostic imaging process type a specific diagnostic imaging resource type has to be used. Table VIII provides the mapping of process and resource types constituting a basis for conceptualising corresponding associations, respectively constraints, in the resulting language specification. Thereby, it contributes to addressing the aforementioned challenge of fostering semantic correctness of resulting models already in the phase of language specification.

Based on the specific requirements and documented corresponding rationale, the specification of the DSMLs' abstract and concrete syntax, i.e., specification of meta-models and corresponding constraints, as well as graphical notation are developed.

IV. Experiences and Lessons Learned

In the following we summarise the main lessons learned.

A. Bridging the Gap Between Different Domains

The derivation of requirements towards an artefact to be developed is never an easy task, as the person(s) deriving the requirements need(s) to be able to bridge the gap between the application domain and information systems domain [11]. This is even more challenging in the conducted project, as the hospital domain differs significantly from a typical business domain as described earlier. Furthermore, it is characterised by a number of different stakeholder groups having different profession-specific goals and using partly different professional terminologies, such as medical, medical and general management, information technology terminology, etc.

TABLE VI
COMPLEMENTARY SPECIFIC REQUIREMENTS WITH RESPECT TO SR 1.1

No. of SR	No. of SSR	Complementary Specific Sub-Requirements with respect to SR 1.1
1.1	–	A DSML for modelling CP should provide a concept for modelling diagnostic imaging processes and allow to distinguish between diagnostic imaging processes applying radiation and not applying radiation.
1.1	1.1.1	A DSML for modelling diagnostic imaging processes should provide a concept to model computer tomography process.
1.1	1.1.2	A DSML for modelling diagnostic imaging processes should provide a concept to model magnetic resonance imaging process.
1.1	1.1.3	A DSML for modelling diagnostic imaging processes should provide a concept to model positron emission tomography process.
1.1	1.1.4	A DSML for modelling diagnostic imaging processes should provide a concept to model combined positron emission and computer tomography process.
1.1	1.1.5	A DSML for modelling diagnostic imaging processes should provide a concept to model combined positron emission tomograph and magnetic resonance imaging process.
1.1	1.1.6	A DSML for modelling diagnostic imaging processes should provide a concept to model (digital subtraction) angiography process.
1.1	1.1.7	A DSML for modelling diagnostic imaging processes should provide a concept to model sonography process.
1.1	1.1.8	A DSML for modelling diagnostic imaging processes should provide a concept to model scintigraphy process.
1.1	1.1.9	A DSML for modelling diagnostic imaging processes should provide a concept to model x-ray process.

TABLE VII
COMPLEMENTARY SPECIFIC REQUIREMENTS WITH RESPECT TO SR 4.1

No. of SR	No. of SSR	Complementary Specific Sub-Requirements with respect to SR 4.1
4.1	–	A DSML for modelling medical resources should provide concepts for modelling diagnostic imaging resources and allow to distinguish between resources applying radiation and not applying radiation.
4.1	4.1.1	A DSML for modelling diagnostic imaging resources should provide a concept to model computer tomograph.
4.1	4.1.2	A DSML for modelling diagnostic imaging resources should provide a concept to model magnetic resonance scanner.
4.1	4.1.3	A DSML for modelling diagnostic imaging resources should provide a concept to model positron emission tomograph.
4.1	4.1.4	A DSML for modelling diagnostic imaging resources should provide a concept to model combined positron emission tomograph and computer tomograph.
4.1	4.1.5	A DSML for modelling diagnostic imaging resources should provide a concept to model combined positron emission tomograph and magnetic resonance scanner.
4.1	4.1.6	A DSML for modelling diagnostic imaging resources should provide a concept to model angiography system.
4.1	4.1.7	A DSML for modelling diagnostic imaging resources should provide a concept to model ultrasound device.
4.1	4.1.8	A DSML for modelling diagnostic imaging resources should provide a concept to model gamma camera.
4.1	4.1.9	A DSML for modelling diagnostic imaging resources should provide a concept to model x-ray apparatus.

TABLE VIII
MAPPING OF DIAGNOSTIC IMAGING PROCEDURES AND DIAGNOSTIC IMAGING RESOURCES

Diagnostic Imaging Procedure	Diagnostic Imaging Resource
Computer Tomography	Computer Tomograph
Magnetic Resonance Imaging	Magnetic Resonance Scanner
Positron Emission Tomography	Positron Emission Tomograph
Positron Emission Tomography combined with Computer Tomography	Combined Positron Emission Tomograph and Computer Tomograph
Positron Emission Tomography combined with Magnetic Resonance Imaging	Combined Positron Emission Tomograph and Magnetic Resonance Imaging
(Digital Subtraction) Angiography	Angiography System
Sonography	Ultrasound Device
Scintigraphy	Gamma Camera
X-Ray	X-Ray Apparatus

A profound understanding and usage of different professional terminologies is a key factor for successfully bridging the gap between different stakeholder groups and becoming an accepted partner for activities aiming at the hospital's action system and information system (re-)design. Thus, the combination of profound knowledge in the Economics and Information Systems discipline as well as basic knowledge about the medical domain with the special focus on hospitals and the field of oncology, as well as hospital and/or medical management seems to be a key success factor for this specific project. This applies to persons acting as business analysts and language designers. They need to be able to understand and, to some extent, use the domain-specific terminology.

B. Clear Communication

The conducted studies revealed that the expectations of hospital stakeholders regarding the usefulness of the IT innovations/information systems are usually based on their prior beliefs, rather than on rational and objective evaluation of the considered IT artefact [24]. It influences highly the outcome (success or failure) of the implementation [24]. Therefore, from the early beginning of the project, meetings with the involved stakeholders were initiated, in order to clearly communicate the aims, role and potential further usage of MPHM method, as well as to avoid misunderstandings and not-fulfilled expectations. In addition, it turned out to be indispensable to find within the domain experts at least one person who understands the idea and, by speaking the language of the targeted group, is able to explain the role and benefits of the postulated method and moderate the requirements analysis process.

C. Stakeholders' Involvement

The major challenges in requirements elicitation are in understanding actual stakeholders' needs in order to reflect them properly in the further design and implementation [11]. Therefore, specialists from all relevant medical fields should be involved in the requirements analysis process, as they can contribute field-specific insights, knowledge, and requirements. Furthermore, the requirements of stakeholders from administrative and supportive professions should be also identified and reflected.

As highlighted by [25], each stakeholder group has a different point of view, e.g., "clinicians will be more motivated by issues of clinical effectiveness, administrators will be interested in financial issues and the management of other resources that have an impact on the quality of care, governmental agencies will focus on efficiency, and patients will be concerned with quality and safety" [25, p. 106]. Therefore, as already discussed and indicated, e.g., in Tab. IV, our aim was to involve as many different internal stakeholders, as possible, in order to ensure that the requirements of all prospective users are addressed by the proposed method.

Our aim was to organise common meetings for all involved stakeholders. However, this turned out to be challenging due to two aspects:

- during common meetings, due to differences in the terminology used by different stakeholders groups, reaching a common understanding required additional effort and explanations,
- due to the higher number of stakeholder groups affected and therefore being involved, it has been difficult to identify time slots for common meetings, esp. for the group of medical specialists from different medical fields, e.g., because of different duties and department-dependent schedules.

Nevertheless, identifying use scenarios and resulting requirements from various different perspectives, contributes to raising the artefact's acceptance of prospective users. Therefore, it is important to ensure a constructive working environment for the requirements analysis process and to openly address potential disbeliefs, fears of adverse consequences resulting out of the DSMM's application and resistances against the method's design project (see Sect. IV-B).

D. Observations of Working Routines

Taking into account the scarcity of the time resource of almost all involved stakeholders, a strong disinclination for interviews and various questionnaires, as well as group meetings quickly became apparent.

The preferable approach therefore, turned out to be the observations of the working routines of the involved stakeholders. Especially the medical personnel found the observations far less intrusive and taking less of their time.

Therefore, the following actions were undertaken during the requirements analysis process (for each of the identified scenarios and each stakeholder group):

- getting familiar with the clinical pathways documentation (if available) and the available literature on the given topic,
- observations of the working routines of the involved stakeholders,
- preparations of the initial sketches – use scenarios' diagrams,
- short consultations and meetings with the involved stakeholders, repeated on a regular basis, aiming at introducing corrections to the diagrams and common derivation of the requirements.

The followed approach had a few advantages in comparison to the interview-based approach:

- the UDE team members (so the business analysts/language designers) were able to obtain a better understanding of the given topic encompassing also expectations and needs of the involved stakeholders,
- the risk that the given stakeholder forgets to mention something or not mention something deliberately considering it to be not important, was minimised.

E. Defining the Method's Scope

With respect to the (re-)design of hospitals' action system and information systems, it is important not only to consider use scenarios related to modelling hospitals, but also to model-based (re-)design of hospitals' action system and information systems. In general, it is recommended not only to think about requirements towards the most-obvious solution, but also about completely new, innovative use scenarios and alternatively designed action systems and information systems [26].

F. Domain-Specific Graphical Representation of Models

We have also learned that the exemplary diagrams indeed fulfil a very important function by providing domain experts, usually not familiar with the modelling concepts, with an illustration of what they might expect from the developed method. Graphical representations of models using a domain-specific concrete syntax are probably the best way to improve the communication between medical, administrative, and information system teams and clearly define, for all involved stakeholders, the targeted scope of the method.

In this case, the usage of illustrative domain-specific graphical representation (as shown in Fig. 4) was a key success factor, as it allowed especially medical personnel to quickly grasp the idea and allowed to avoid a long learning process. Due to the scarce time resources, especially of medical personnel, this is crucial for later adoption of the targeted method.

V. CONCLUSIONS AND OUTLOOK

Beyond any doubt the requirements analysis phase is one of the most challenging and crucial in software development projects. The same applies to the design of any general or domain-specific modelling method.

In case of the medical application domain the task is even more challenging due to the domain's specific characteristics: various stakeholders with different professional terminologies and partly contradictory goals, highly complex organisations, knowledge-intensive processes, etc.

In this paper, we have shown how the process of requirements analysis could be organised and which groups of actors should be involved. We have also shown how the process can be facilitated by the usage of a structured approach to define use scenarios, preparation of preliminary diagrams and in consequence, derivation of requirements, and assigning priorities with respect to the subsequent phases of DSML design. In addition, we have shown that the approach proposed by [8], [9] involving the usage of graphical preliminary diagrams illustrating the targeted method's application, contributes to facilitating the process of requirements derivations, fostering the understanding of the targeted method itself, as well as fostering the multi-professional and multidisciplinary communication.

Next research activities encompass the further development of Multi-Perspective Hospital Modelling method, its prototypical application and evaluation, as well as its iterative refinement according to the design-oriented Information Systems research paradigm.

References

[1] P. Hensen, N. Roeder, and D. Franz, "Das deutsche Gesundheitssystem im Wandel," in *Gesundheitsökonomie, Gesundheitssystem und öffentliche Gesundheitspflege. Ein praxisorientiertes Kurzlehrbuch*, N. Roeder, P. Hensen, and D. Franz, Eds. Köln: Deutscher Ärzte-Verlag, 2014, pp. 1–18.

[2] L. de Bleser, R. Depreitere, K. d. Waele, K. Vanhaecht, J. Vlayen, and W. Sermeus, "Defining pathways," *Journal of Nursing Management*, vol. 14, no. 7, pp. 553–563, 2006. [Online]. Available: http://dx.doi.org/10.1111/j.1365-2934.2006.00702.x

[3] T. Rotter, L. Kinsman, E. James, A. Machotta, H. Gothe, J. Willis, P. Snow, and J. Kugler, "Clinical pathways: effects on professional practice, patient outcomes, length of stay and hospital costs (review)," *Cochrane Database of Systematic Reviews*, vol. 7, no. 3, 2010. [Online]. Available: http://apps.who.int/rhl/reviews/CD006632.pdf

[4] M. Heß, "Towards a domain-specific method for multi-perspective hospital modelling – motivation and requirements," in *Design Science at the Intersection of Physical and Virtual Design. 8th International Conference, DESRIST 2013 Helsinki, Finland, June 11-12, 2013. Proceedings*, ser. LNCS, J. vom Brocke, R. Hekkala, S. Ram, and M. Rossi, Eds., no. 7939. Heidelberg: Springer, 2013, pp. 369–385.

[5] U. Frank, "Multi-perspective enterprise modelling: Background and terminological foundation," University of Duisburg-Essen, Institute for Computer Science and Business Information Systems (ICB), ICB-Research Report 46, 2011.

[6] N. Wickramasinghe, L. Al-Hakim, C. Gonzalez, and J. Tan, Eds., *Lean Thinking for Healthcare*, ser. Healthcare Delivery in the Information Age. New York: Springer, 2014. [Online]. Available: http://dx.doi.org/10.1007/978-1-4614-8036-5

[7] U. Frank, "Multi-Perspective Enterprise Modeling: Foundational Concepts, Prospects and Future Research Challenges," *Journal of Software and Systems Modelling*, vol. 13, pp. 941–962, 2013.

[8] ——, "Domain-Specific Modeling Languages: Requirements Analysis and Design Guidelines," in *Domain Engineering*, I. Reinhartz-Berger, A. Sturm, T. Clark, S. Cohen, and J. Bettin, Eds. Berlin: Springer, 2013, pp. 133–157.

[9] ——, "Outline of a Method for Designing Domain-Specific Modelling Languages," Institute for Computer Science and Business Information Systems, University of Duisburg-Essen, Essen, ICB Research Report 42, 2010.

[10] IEEE, *IEEE Standard Glossary of Software Engineering Terminology*, IEEE Std., 1990.

[11] K. Pohl, *Requirements Engineering: Fundamentals, Principles, and Techniques*. Heidelberg: Springer, 2010.

[12] H. Österle, J. Becker, U. Frank, T. Hess, D. Karagiannis, H. Krcmar, P. Loos, P. Mertens, A. Oberweis, and E. J. Sinz, "Memorandum on design-oriented information systems research," *European Journal on Informafion Systems*, vol. 20, pp. 7–10, 2011. [Online]. Available: http://memo.iwi.unisg.ch/fileadmin/docs/ejis201055a.pdf

[13] D. L. Moody, "Cognitive load effects on end user understanding of conceptual models: An experimental analysis," in *Advances in Databases and Information Systems*, ser. Lecture Notes in Computer Science, A. Benczr, J. Demetrovics, and G. Gottlob, Eds. Springer Berlin Heidelberg, 2004, vol. 3255, pp. 129–143.

[14] ——, "The physics of notations: Toward a scientific basis for constructing visual notations in software engineering," *IEEE Transactions on Software Engineering*, vol. 35, no. 6, pp. 756–779, 2009.

[15] D. Forman and J. Ferlay, "The global and regional burden of cancer," in *World Cancer Report 2014*, B. W. Stewart and C. P. Wild, Eds. Lyon: International Agency for Research on Cancer, 2014, pp. 16–53.

[16] B. W. Stewart and C. P. Wild, Eds., *World Cancer Report 2014*. Lyon: International Agency for Research on Cancer, 2014.

[17] H. Holbrook, III, "A scenario-based methodology for conducting requirements elicitation," *SIGSOFT Softw. Eng. Notes*, vol. 15, no. 1, pp. 95–104, Jan. 1990. [Online]. Available: http://doi.acm.org/10.1145/382294.382725

[18] A. Sutcliffe, "Scenario-based requirements engineering," in *Proceedings of the 11th IEEE International Conference on Requirements Engineering*, ser. RE '03. Washington, DC, USA: IEEE Computer Society, 2003, pp. 320–. [Online]. Available: http://dl.acm.org/citation.cfm?id=942807.943884

[19] R. M. Young and P. Barnard, "The use of scenarios in human-computer interaction research: Turbocharging the tortoise of cumulative science," *SIGCHI Bull.*, vol. 18, no. 4, pp. 291–296, May 1986. [Online]. Available: http://doi.acm.org/10.1145/1165387.275645

[20] N. Maiden and I. Alexander, *Scenarios, stories, use cases : through the systems development life-cycle*. J. Wiley and sons, 2004.

[21] A. Sutcliffe, N. A. M. Maiden, S. Minocha, and D. Manuel, "Supporting scenario-based requirements engineering," *Software Engineering, IEEE Transactions on*, vol. 24, no. 12, pp. 1072–1088, Dec 1998.

[22] S. Strecker, U. Frank, D. Heise, and H. Kattenstroth, "MetricM: A modeling method in support of the reflective design and use of performance measurement systems," *Information Systems and e-Business Management*, vol. 10, no. 2, pp. 241–276, 2012. [Online]. Available: http://www.springerlink.com/content/e73g3t2405w59471/

[23] D. Heise, *Unternehmensmodell-basiertes IT-Kostenmanagement als Bestandteil eines integrativen IT-Controllings*. Berlin: Logos, 2013, PhD Dissertation at University of Duisburg-Essen.

[24] A. Vishwanath, S. R. Singh, and P. Winkelstein, "The impact of electronic medical record systems on outpatient workflows: A longitudinal evaluation of its workflow effects," *International Journal of Medical Informatics*, vol. 79, no. 11, pp. 778 – 791, 2010. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S138650561000167X

[25] L. Lapointe, M. Mignerat, and I. Vedel, "The IT productivity paradox in health: A stakeholder's perspective," *International Journal of Medical Informatics*, vol. 80, no. 2, pp. 102 – 115, 2011, special Issue: Security in Health Information Systems. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1386505610002248

[26] U. Frank, "Die Konstruktion möglicher Welten als Chance und Herausforderung der Wirtschaftsinformatik," in *Wissenschaftstheorie und gestaltungsorientierte Wirtschaftsinformatik*, J. Becker, H. Krcmar, and B. Niehaves, Eds. Heidelberg: Physica, 2009, pp. 167–180.