Modelling and Decision Support of Clinical Pathways

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Abstract. The German health care market is under a rapid rate of change, forcing especially hospitals to provide high-quality services at low costs. Appropriate measures for more effective and efficient service provision are process orientation and decision support by information technology of clinical pathway of a patient. The essential requirements are adequate modelling of clinical pathways as well as usage of adequate systems, which are capable of assisting the complete path of a patient within a hospital, and preferably also outside of it, in a digital way. To fulfil these specifications the authors present a suitable concept, which meets the challenges of well-structured clinical pathways as well as rather poorly structured diagnostic and therapeutic decisions, by interplay of process-oriented and knowledge-based hospital information systems.

1 Development of the Process-Oriented Perspective in German Hospitals to the "Clinical Pathways"

Since the mid 1990s process orientation is steadily gaining importance by popular buzzwords like Business Process (Re-)Engineering in enterprises and business managements, and it is nowadays essential basis for goods and services and service offering with the aim of improving the success affecting variables *time, cost* and *quality* [5]. Further important, and often with process orientation associated objectives, are transparency of business processes as well as quality-oriented requirements or certificates [1].

Contrary to the establishment of process orientation in most industry sectors, it could not gain importance in the field of German hospitals until the 2000s. The modelling, analysis and visualisation of workflows in hospitals in the areas of diagnosis, therapy and care proceeded with the goal of getting a detailed overview of the "hospital enterprise".

The initial goal was oftentimes the process acquisition, for example in accordance with the aspired ISO 9001-Certification.[1] During this procedure the business process of the complete enterprise was initially mapped, then in each department the process landscape with the main processes was compiled, and, in a third step, the precise process sequence was surveyed and modelled (cf. figure 1).[2]

[1] The obligation to adopt quality management in hospitals originates from §135a, subparagraph 2, sentence 1 of the German Social Security Code Book (*dt. Sozial Gesetzbuch, SGB*). The standards DIN EN ISO 9000ff. are one of the prevalent quality management methods and were developed for the service and production sector [1].

[2] cf. for the relationship between quality- and process-orientation in hospitals also [10], [1].

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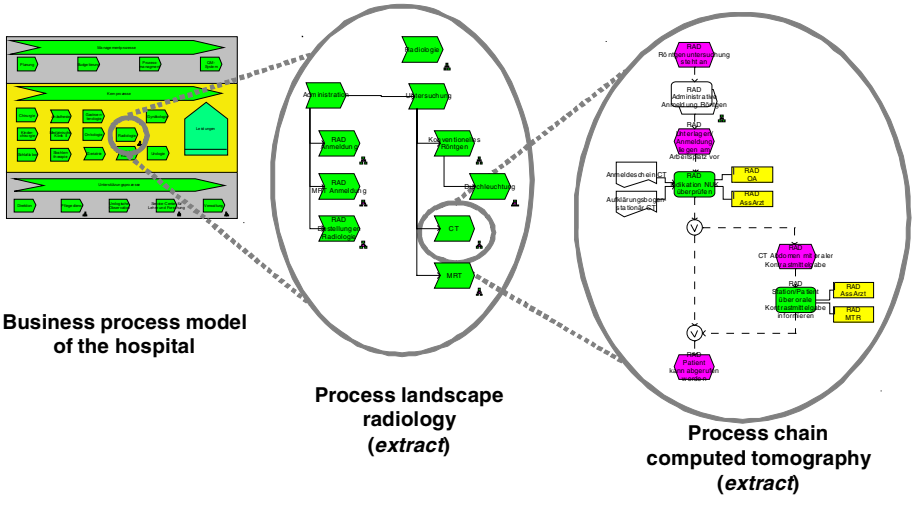

Fig. 1. Business process, process landscape and process chain

From an organizational point of view this form of modelling at least succeeded in picturing the detailed layout of the different functional areas (e.g. the clinic for radiology in figure 1), and its service offerings as well as the concrete process sequence of the service offerings, e.g. in the notation of an event-driven process chain (EPC).

Furthermore, the created organization and process model provides the starting basis for process costing as an economic tool for corporate management. To obtain an integrated overall model suitable tools are used. Prerequisite for a successful adoption is the adjustment of the process model to the requirements of process costing, for example by adequate process selection matrices and addition of adequate time and cost parameters. The creation of different process scenarios permitted comparison of process chains from an economic point of view. During process costing the problem-oriented consolidation of available information to key performance indicators and output of result reports takes place, e.g. to spreadsheets or web-reports. Particularly with the adoption of the lump sum compensation settlement or the German Diagnosis Related Group (G-DRG)-System the actual process of creation of value in hospitals takes centre stage. This process is called the *Treatment Path of the Patient, Clinical Path, Treatment Path or Clinical Pathway.*

A Clinical Pathway is an evidence-based treatment flow, crossover professions, considering costs, quality, policy and risk.

The reason for focussing on the clinical path comes from the altered revenue situation. Usually after admittance of patients in hospitals a specific diagnosis is made. Consequentially the assignment to a respective DRG takes place. With it the revenues of this patient are clearly defined.

The expenditures however result from the course of treatment that the patient takes through the different functional areas, and are only very insufficiently recorded. Therefore, to analyse the costs a particular patient or a “case” generates, it is necessary to closely examine the clinical path a patient takes from his admittance to his release.

Respectively, the clinical path acts as a central control for the complete medical course of treatment that ranges over patient care in hospitals as well as integrated concepts (e.g. nursing services or home care concepts). It specifies not only the inherent logic of the process sequence, but also further economic and medical aspects which are explained below.

2 Modelling of Clinical Paths

Fundamental prerequisite for the successful modelling and implementation of clinical paths is the use of a modelling syntax and notation that meets the requirements of clinical paths. Therefore, the first step in a business process modelling project consists on the development of the modelling conventions, their specification and the training of involved persons. Furthermore a critical success factor is the selection of an appropriate modelling tool.[3]

During the specification of the modelling conventions the utilised model types, the layer structure of modelling, the objects and their attributes have to be specified. In the specification of the model types focussing especially on the days of treatment is of great importance. Usually the first day is the day of admittance and the last day the day of release, whereas the administrative tasks on both days are less dependent on the respective path. Also the time differences of medical diagnosis are rather small. Oftentimes, on the next day after the day of admittance the operation takes place, which consists of the preparation, the procedure and post-processing of the operation. The other days are lay days, which are under minor variation. In accordance to this structuring the design pattern of a process chain with a column layout with rough presentation of the activities is suitable for the super ordinate level (main process sequence of the clinical path). Additionally the columns are structured according to the days of stay or to the activities that are performed on those days. The first day is the admittance of the patient; the treatments are on days 2 to 8, followed by the release. The activities on days 2 to 8 differ in whether the patient is to be treated in standard or intensive care unit. Accordingly, the function "standard care unit" contains the process chain, which is processed each day of treatment on each patient. Structurally, it is located on the second hierarchical modelling level. The patient receives different therapies on each day, like inhalation or breathing exercises. The detailed process description, which contains activities like the procedure of inhalation, is not displayed on this level. Rather the displayed level shows the composition or configuration of the individual "treatment modules" of the clinical path, which are specific to the path. The activities that have to be performed during the treatment are displayed as an event-driven process chain on the third and thus most detailed level. The following figure 2 visualises the described modelling example.

The explained structure shows the advantages of the concept. Because of the modular structure the range of services of a clinic or department of the hospital can be uniquely illustrated and is integrated into the respective clinical path. Therefore, during the development of policies that represent a clinical path, the acquisition and illustration of the

[3] For example the ARIS Toolset by IDS Scheer AG is suitable as a professional modelling tool because of different characteristics, like the widespread use, the widespread recognition as a virtual standard, the client-server architecture and the close connection methods.

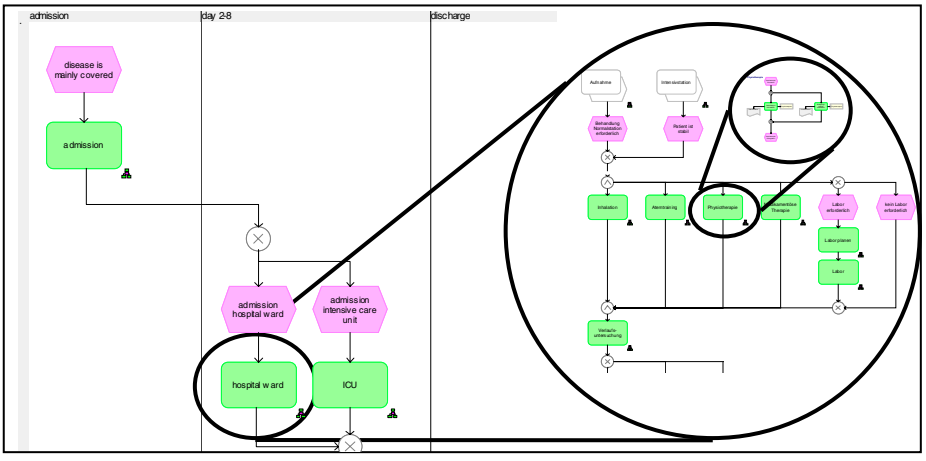

Fig. 2. Clinical Path Pneumonia

respective treatment modules come first. These modules in turn are referenced or integrated into the respective paths. With this the model of the clinical path meets the requirement of being a reticular and comprehensive course of treatment. Besides the dynamic illustration of the treatment paths, naturally also the static illustration of the organizational structure of the hospital and the departments and clinics are made.

With the goal of creating a homogeneous and consistent overall model, it is necessary to define the number of necessary objects for modelling appropriately. Therefore, the stocktaking of the resources has to be carried out initially to determine appropriate objects based on functional and technical modelling criteria. The following Table 1 provides an exemplary overview.

Table 1. Overview of Modelling Objects (selection)

Tag symbol	Object type	Usage
event	Event	Triggers function or is result of triggered function
function	Function	Activity that processes data or material and needs time or ressources for that
performance index	Performance figure	Is used in the attribute “Description/Definition” to indicate descriptions and notes on expenses
risk	Risk	Describes the risk of the activity including risk assessment and control measures

In the presented selection of objects the total number of objects provided for modelling was kept as small as possible, with the aim of creating well structured and comprehensible models. Especially in very extensive projects with involvement of employees from the functional areas this approach is suitable. Besides the visualisation of the path traversal in the form of a process model, the extension of the objects of the model with additional attributes is necessary. The attributes can for example contain additional descriptive information for the future users of the model (e.g. physicians or nurses). In addition, special attributes can also be used for further analysis or simulations, such as process costing. Respectively, while specifying the modelling conventions an overview of each object has to be created that shows, which attributes (optional or mandatory) have to be maintained and with which values or contents these have to be filled.

When using powerful and extensive modelling tools such as the ARIS Toolset, it is sensible to create suitable and problem-oriented model templates based on the method-handbook to assist the consistent implementation of the modelling conventions. Furthermore, it should not be possible for the modeler in the department to create new objects. Rather every possible object is to be collected in an as-is-analysis and created one-time to work with the instance of this object during modelling. This approach additionally aids the consistency of the models and prevents rank growth or also redundancy of objects.

3 Architectural Concept of a Knowledge-Base Process-Oriented Hospital Information System

Besides the modelling and adoption or implementation of clinical paths the support by information systems of the path traversal presents a major challenge for the clinic. In fact existing hospital information systems support only particular function-oriented stations of the complete path and offer no support for the overall process. When using a process-oriented HIS the holistic support of the clinical path of the patient and hence all diagnosis, therapy and nursing processes of a patient take centre stage and hence the necessity for information-technological support of all tasks and activities during the mentioned clinical processes.

The challenge of designing, implementing and using of process-oriented HIS is the detailed depiction of processes as well as the integration of information-oriented and functional application and information systems in the hospital. In addition to the usage of the existing path and process models in hospitals as well as their itemization and customization the integration of existing applications is necessary for the technological implementation. Besides the process-oriented electronic support of the clinical treatment path and the integration of data- and information-oriented applications other challenges exist in the configuration of the control layer as well as the creation of a suitable user- and role-model.

3.1 Limits of Process-Oriented Hospital Information Systems

An extension of the described architectural concept is necessary to allow active support for the processes. From the process-oriented perspective the focus is

primarily on the flow of the system. While the process chains described by the clinical path are well structured and suitable to be supported by a workflow management system, problems arise on the interfaces between the clinical paths (for instance entering a path or change of path) because of the rather poor structuring. A multitude of information (e.g. laboratory findings and vital signs) coincides at this point, which are of high importance for further treatment. Because of the multitude of alternatives, rules and decisions to be processed a workflow system is rather unsuitable in this case. In fact it is sensible to use a system because of its strength, which possesses its own knowledge, can process incoming information and conclude new decisions. The implementation of such a knowledge-based system onto the described interfaces would contribute further digital support to the treatment path of the patient. For instance, after admittance of a patient different examinations (e.g. radiological diagnostics and examining/measuring of vital- and blood values) are performed. These examinations constitute amongst others the starting point for diagnosis making. After performing the examinations the (partly) automated evaluation of the results or the assistance of the physician in evaluating the results takes place. After the evaluation of the partial results the diagnosis is completed, so that the therapy process can begin. With the described knowledge (for example in form of decision-making rules) one or more therapy processes or also the use of other diagnostic procedures are recommended, at which the level of information is supplemented with the rating of the alternatives and their respective probabilities and explanatory notes. These pieces of information serve or support the physician in his task to chose a suitable clinical process for the further treatment of the patient. Besides the usage and the additional support for the clinical process it should be possible for the decision maker to modify the existing decision-making rules or their weight, and therewith to contribute to the improvement of the system and expand its knowledge base.

3.2 Architectural Concept of a Knowledge-Based Hospital Workflow-System

From the described requirements for the architecture of a process- and decision-oriented HIS follow the necessity for the integration of a suitable system component that has the ability to use knowledge (e.g. in form of rules) on incoming data or information, come to a conclusion and describe the path to that conclusion as well as extend the existing knowledge based on the processed information. To meet these requirements the use of *knowledge-based systems (KBS)* is especially adequate. Its usage in the field of medicine so far has been especially successful in diagnostics in different fields of applications [6], [7]. For the implementation of the herein described requirements a much more open and universal system is necessary, which is equipped with the necessary components in terms of a common and ideal-typical architecture of a KBS [2].

The result of combining a knowledge based system with a process oriented system is an active knowledge- and process-oriented healthcare information system, visualized in the following figure 3.

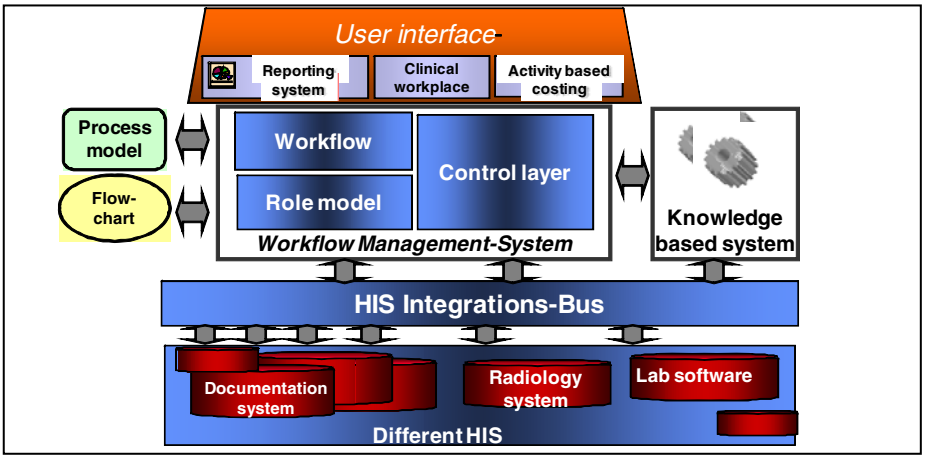

Fig. 3. Design model of an active knowledge- and process-oriented healthcare information system

From the illustrated architecture and alignment of the components follows the dominating role of the workflow management system for the complete concept. For instance, from the user's point of view the physician accesses the process-oriented system and receives the presentation of the results. The knowledge-based system provides beyond that no additional user environment; it rather takes over the role of the subsystem within the complete architecture. The same applies for the access to the knowledge-based system in the process sequence: the process-oriented system is the trigger and incorporates the KBS into the process within the process sequence. Thus, the KBS acts as a supporting subsystem that is triggered by the process-oriented system, then it incorporates further information and finally returns a result to the process-oriented system.

4 Synopsis and Future Prospects

The competition on the German hospital market is in full swing, and the progress on the health care market in Germany will lead to only efficiently and economically working enterprises prevailing.

Contrary to the predominant technology penetration in hospitals the idea of process orientation and especially the adoption of process-oriented hospital information systems have not yet been realized. For the coming years support by process-oriented and knowledge-based information- and communications technology will prove to be a critical factor for success.

On the other hand suitable approaches of the market leaders in this segment are still under development. With the described concept the authors provide a substantiated approach in practice to overcome the problems associated with process orientation in hospitals, and to present an efficient and suitable architecture as a solution for the problem.

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