Patient Care across Health Care Institutions: An Enterprise Modelling Approach

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Abstract. This paper presents a modelling exercise conducted in the health sector, to identify functional requirements for Electronic Patient Records. The model is based on a holistic modelling approach, Active Knowledge Modelling and is conducted by a multi-disciplinary team with domain and modelling experiences. The main aim of the paper is to share our experience and to highlight the advantages from a holistic approach to modelling. The paper describes the needs of the stakeholders that drove the modelling activity and the design decisions that influenced the model. The model supported a common understanding among the model creators and the data providers. In addition, it helped identify new requirements for Electronic Patient Records that will enable better continuity in care in the health sector.

Keywords: Enterprise Modelling, Active Knowledge Modelling, Model Design, Health Information Systems, Electronic Patient Records.

1 Introduction

Health Information Systems or Medical Informatics is one of the fastest growing areas of Information and Communication Technology (ICT). A number of IT systems are used in the health sector to support both patient care as well as administrative and financial services. One of the central applications of ICT is the Electronic Patient Journals or Electronic Patient Records (EPR), which is an electronic means of documenting and storing patient related information that can be shared among health care professionals. EPR are an essential step to providing an up-to-date and coherent view of a patient's medical history to health care providers.

Norway was among the first to start using EPR and there is much to suggest that Norway may have been the first with almost full coverage of EPR in both the GP services and specialist health care services [1]. However, smooth electronic collaboration and sharing of clinical information across health care institutions is still limited to a few services. The current versions of the commercially available EPR systems are designed to replicate the paper-based patient journals and thus lack the support for health care processes.

The EPR systems in use today are products that are developed by commercial vendors. Different health care institutions use different systems; thus, EPR share a

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similar interoperability problem as other IT systems in sharing and exchanging information. The lack of interoperability causes problems in the exchange of information across different health care institutions. Interoperability has been defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [2]. This definition of interoperability identifies interoperability at the technical as well as semantic levels. Often, interoperability problems are resolved at the technical level with little or no concern for the actual work processes that these systems support. The notion of information modelling is often used where the focus is on the actual data exchanged. Furthermore, when the work processes span over several enterprises, e.g. different health care institutions as in the case of patient care, there is a need to consider different aspects of the problem such as the processes where the information exchanges across the systems occur. The European Interoperability Framework takes the concept of interoperability further to the organizational level [3]. Similarly Gao and Krogstie also propose the organizational perspective in additional to the technical and operative contexts in modelling [4]. There is a need for EPR to be interoperable at the process and enterprise levels, in order to support health care processes to enable continuity of care across health care institutions.

The aim of this paper is to describe a modelling exercise that was conducted to identify functional requirements for EPR. The contents of the paper are focused towards modellers, particularly in the health informatics domain. The main contribution to the modelling community is the added benefits achieved by taking an enterprise modelling approach rather than an information modelling approach.

The main aim of the model that was developed is to support the identification of functional requirements for EPR that can support planning and implementation of continuity of care processes, in which patient-related information and biological material are exchanged across health care institutions. The request for investigations or laboratory tests is such a process and one that has been identified as needing interoperability among supporting IT systems [2].

The main aim of the modelling exercise is to go beyond information modelling to see the "context" of the information or the processes where the information exchanges occur. The context is particularly important in complex domains such as health care because there are several actors involved, a number of different resources are needed, the work affects people; it is not only information that is exchanged between processes and institutions, but also physical material and the quality and timeliness of the processes are important. This exercise aimed at understanding the flow of information within a process by analyzing the process and work flow in a holistic way. The modelling exercise and the model contributed to the understanding of the processes in order to identify areas of improvement. They also helped focus on the work processes and the patient rather than the information exchange itself.

This paper describes the case that was examined and the process of creating a model of a health care process. The process of gathering information for the model, the ideas and design decisions behind the model and the factors that affected the design of the model are discussed. The main focus of the paper is on the modelling exercise rather than the description of the contents of the model. In addition to supporting the identification of functional requirements for EPR, the model also helped identify additional roles that can be played by today's IT systems that are used

in the health sector and the desired functionality in existing systems. The experiences from the modelling exercise and the benefits of it and the model are discussed in detail.

The rest of this paper is organized as follows: Section 2 describes our modelling approach, Section 3 describes the case, Section 4 describes our methodology for creating the model and the design of the model, Section 5 provides an analysis of the model that was created, Section 6 describes the evaluation of the model and Section 7 provides a summary of the paper.

2 Background and Modelling Approach

The concept of Enterprise Modelling has been around for sometime; e.g. Vernadat presented the perspectives of production and manufacturing in [5] and a more IT perspective was presented by Fox and Gruninger in [6].

Modelling work is often conducted by IT people for developing IT support, using UML [7]. Thus, there has often been a tendency to reduce the problem and thus, the analysis and solutions to IT applications [8]. Business process modelling is often used to analyze a situation and to propose an improved process. Business process modelling languages such as BPMN [9] have influenced this work. However, even with the added value provided by process modelling methods and supporting technologies, the focus may often be on the implementation.

Enterprise Modelling calls for the analysis of a much larger scope of contents and a multi-dimensional analysis, taking into account the processes, products resources, information elements and possibly others [8]. The concept of Active Knowledge Models (AKM), introduced by Lillehagen, advocates the analysis of several dimensions or aspects of the model and the power of visualization of the model contents [10]. AKM also considers the analysis of several aspects and how they depend on or influence one another. In addition to some of the concepts considered in IT-focussed modelling such as goals (e.g. [11]) or process-oriented concepts such as actions and decisions (e.g. [12]), AKM considers the product (information-based or physical) as important as the process modelled. This calls for a greater analysis of the product.

Several studies conducted in the health care sector for the standardization of information focus on the information exchange and model the information, primarily using UML. Ideas of enterprise modelling have been used by Staccini et al., where they have applied IDEF0/SADT techniques to identify requirements for ICT, (e.g. [13],) and to map care processes to ICT-based services (e.g. [14]). In [15], Jun at al. reviewed different methods that are used for modelling health care processes and identified the strengths and weaknesses of the different methods. They also highlighted which methods are most applicable when. Some of the methods or diagrams presented by them include stakeholder diagrams, information diagrams, process diagrams, swimlane activity diagrams and state transition diagrams. One of their conclusions was that there was no one technique for capturing the essential elements in all the diagrams and combining them. However, the importance of considering a multitude of aspects was confirmed and emphasized and is aligned with the AKM thinking.

In addition to experience in Enterprise Modelling, the AKM methodology encourages an insight into the domain modelled; in fact experience shows that for a successful model, knowledge about the domain is essential. Thus, for our work the modelling team is composed of people with both the domain and modelling experience.

The design of the model discussed in this paper is based primarily on our experience in modelling and the aims of the model rather than the validation of a specific modelling approach or a theory. The main influence in the modelling approach is from the ideas in AKM [10], a holistic approach to modelling. The Business Process Visual Architect from Visual Paradigm [16], based on the BPMN [9], was used to create the model. Thus, the limitations of the functionality of the tool with respect to the AKM methodology hindered the explicit representation and visualization of some of the concepts considered in the model.

3 Case Description

The work described in this paper is a part of the ELINS-2 project, which is a project within a series of projects that are focused on electronic information in the health sector. The long term vision of these projects is to enable the health care systems to plan and implement continuity of care through more effective electronic communication and collaboration between the actors and better knowledge. ELINS-2 focuses on electronic information flow in and across health care institutions, in particular, when two or more institutions are involved, such as the General Practitioner (GP) and the hospital. One of the main aims of this project is to achieve EPR systems that also provide support to the health care processes.

The health care process studied in this paper is the situation in which a health care professional, such as a GP, requires a laboratory test conducted for a patient – a Request for Investigation. A request is made by the doctor and a laboratory form and biological samples are sent to a laboratory in another health care institution. The laboratory test results are sent back to the doctor or the institution that requested for the investigation. An electronic request for investigation, generated directly from the EPR is still in its early stages; in particular, when the receipt of the request and the results of the investigation have to be conveyed back to the origin of the request.

A simplified version of the request for investigation process can be considered as follows: a health care professional would like an investigation, e.g. a laboratory test, to be conducted. Once a request form is created, it is sent to the relevant health care institution for processing; i.e. for the actual samples to be collected from the patient and the analyses to be conducted at the laboratory. Once the results of the required tests are available, the results are conveyed back to the requestor of the investigation.

The process of requesting for an investigation is illustrated in Fig. 1. The person making the request decides upon the test that she wants to be conducted and decides who will conduct the tests before she writes the request form. After the data collection workshop (described in section 4.2), it became apparent that there are situations when the health care professional making the request has to search for specific information. For example, if the condition that the doctor would like investigated is a rare disease or if there are specific requirements or constraints that must be complied with in

conducting the test. In such situations, health care professionals sometimes searched on the internet or called around asking for information. Similarly, laboratory personnel also had the same problem in obtaining relevant information. This not only meant that they searched on the internet and various databases, but also numerous telephone conversations took place to share information among health care professionals.

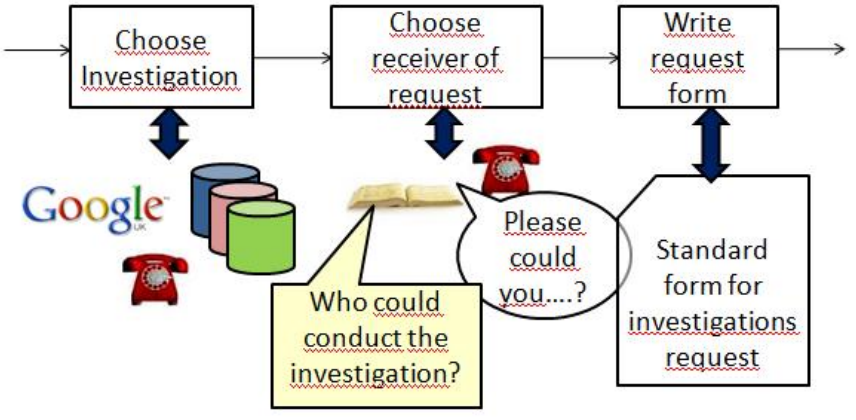

Fig. 1. Current situation when creating a request for an investigation

Currently, the forms used to request for an investigation are standardized and are intended to cover the common investigations that are conducted. If a doctor needs to request for an investigation that is not included in the standard laboratory form, there is no electronic means of including this as a part of the form.

4 Method

The project consisted of five participants, three of whom had a background in the health sector. The creation of the model was a collaborative process among three of the project participants. This was a multi-disciplinary group, where two were experienced health workers (a mid-wife and a bio-engineer) with IT and modeling experience and one with experience in Enterprise Modelling. The data for the model was collected at an interactive workshop with health care professionals. The following steps were followed in creating the model:

- Preparation for data collection and the workshop
- Conduct workshop
- Synthesize data from the workshop
- Create preliminary model and present in a follow-up workshop
- Refine model

4.1 Data Collection

A workshop was held to collect data for the model. Effort was made to include participants that represented all the stakeholders of the process and to represent health care professionals that were involved in all aspects of the request for investigation process. Similarly, effort was made to represent as many of the different hospitals and health care institutions across the country. The participants included a doctor, a nurse, a radiographer and laboratory personnel. Nine participants joined the workshop, which lasted four hours. The workshop consisted of plenary sessions at the beginning and at the end, and a session for interactive information gathering.

At the beginning, the participants were asked to introduce one another as an initiative to facilitate interaction among them. A fictitious scenario of a patient and the request for investigation process was presented to set the scene for the workshop. Five topics, which are also the main processes in the request for investigation, that were identified during the preparations for the workshop were also presented:

1. Preparing the request
2. Taking samples
3. Sending the samples
4. Sending test results
5. Receiving test results

The "Evaluation Café" method was used during the workshop to drive the conversation as well as to ensure contributions from all participants [17]. The Evaluation Café method is a method for group facilitation that allows all participants to contribute their views and have an impact on the outcome of the work. It is a fast, result-driven means to collect information and points of view. It is also a means to initiate a collaborative dialogue and for sharing knowledge and experiences.

The workshop area was set up as a café' where the participants could move from one table to another and join the discussions. This is illustrated in Fig. 2. The tables were covered in paper tablecloths that the participants could write or draw on. These tablecloths also served as a means of gathering data and as a part of the documentation of the workshop contents. Each table had a facilitator and a topic for discussion. Each participant had 30 minutes at each table, where s/he met a different group every time to

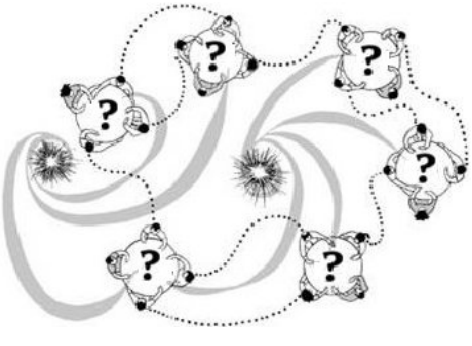

Fig. 2. Illustration of the Evaluation Café workshop method (taken from [17])

discuss one of the topics. The facilitator ensured that the conversation continued to be relevant to the topic under discussion and that each participant was able to contribute their views. The facilitators also made notes during the conversations, which they used in synthesizing the data gathered during the workshop.

At the end of the Evaluation Café session, the participants gathered in a plenary session where a summary of the workshop was presented.

4.2 Synthesize Data

After the workshop, the facilitators summarized the information gathered during the workshop and structured them as follows:

- Current situation – a description of how things were done today.
- Desired situation – ideas for how health care professionals would like things to happen in the future.
- Challenges or hindrances – some of the challenges faced by health care professionals with the current practice.

The information gathered during the workshop was used as the basis for designing and creating our model. Prior to creating the model, the project team discussed the contents and some of the ideas for the model.

4.3 Modelling Process

The model is a result of a collaborative process where the strengths of the three members of the group were used. The modeling process, once the data was gathered from the workshop, is illustrated in Fig. 3. The members with a background in health care started by modelling some of the specific sub-processes, while the member with the experience in Enterprise modeling focused on achieving a holistic model and on how the different topics discussed in the workshop could be combined in a single model, as a generic Request for Investigation process. The specific models were combined into a single model.

A follow-up workshop was conducted with the same participants as the first workshop. The main purpose of this workshop was to verify if we had understood the

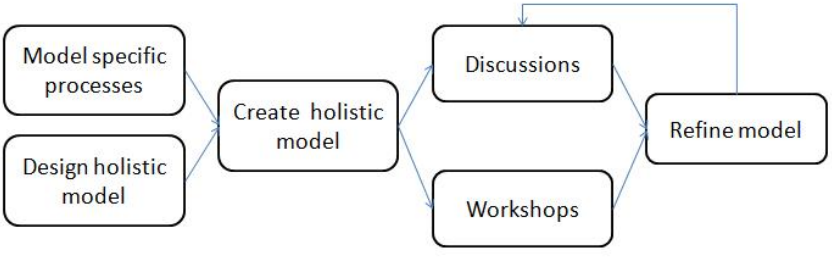

Fig. 3. Modelling Process

process correctly and that the process that we had modelled was not in conflict with the way things could be done. Note that since our task was to model a normative process, it did not reflect the current situation, rather the desired situation.

Based on the feedback from the workshop participants and further discussions among the group, the model was refined.

5 Design of the Model

Our task was to design a "normative" process model; i.e. the aim was not to model the current situation (or as-is); rather to model a process that illustrates the desired process, yet one that can be realized in the near future.

The design of the model was influenced by the outcome of the workshop and the information that was gathered from the workshop. An interesting observation was that the practice in the different health institutions varied. This is perhaps natural as the different institutions had different kinds of patients and their practices were often influenced by the regional differences in terms of geography and availability and accessibility of resources. However, from the perspective of national standardization of practice such that a national health IT infrastructure could support it, this is not only interesting, but also a challenge.

The design was driven by the needs of the health care professionals expressed during the data gathering workshop. These needs may be summarized as follows:

- **Easy access to relevant information.** Health care professionals have a need for easy access to information that are relevant for their work, such as descriptions about specific laboratory tests, overview of where specific health services could be obtained and contact details for them or experiences of other health care professionals that could benefit others. There was also a need for information that was reliable in terms of its quality and source.
- **Status of the request for investigation.** There was a need, in particular from doctors who would be requesting for an investigation most of the time, for the possibility to obtain and follow-up the status of a request that they had made. There was a need to be able to know where in the process as well as the physical location of the request at any point in time and to know as fast as possible when the test results were available. Ideally, access to this information was desired from the EPR. In particular, in situations when the request does not proceed as smoothly as expected, often it was difficult to trace the request. For health care professional, the possibility to have the status of the requests was an indicator of the quality of the service.
- **Documentation of the patient care.** There was a need for better documentation of the patient care process, including processes such as the request for an investigation. Health care professionals would benefit if they were able to obtain an overview of all patient related information from the EPR. Thus, there was need to identify when and what information was either accessed and extracted from the EPR or updated in the EPR at any point in the process.

Based on the above needs, the following design decisions were made for the model:

- To explore the idea of accessing common information sources, wherever possible, rather than transferring information from point to point (or in addition to this, if necessary). For example, make available databases (or health registers as they are often referred to) that can be accessed and shared by a range of health care professionals.
- To explore the idea of a traceability log for the request for investigation, which could provide the status of the request and be accessible to all stakeholders in the process.
- To focus on the information that is required and used in the process, its roles, the type of information (e.g. static or dynamic), its format and where it is created, accessed from and stored.
- To focus on what flows between the sub-processes to identify the requirements from the sub-processes. This comes from the fact that physical material such as blood samples flow between processes and they have to be coordinated with their information counterparts.

6 Analysis of the Model

This section describes the model that was created and how the design decisions that were presented in the previous section influenced the model. The model that was created is fairly large and therefore, it is not possible to include a figure containing the complete model. However, we will attempt to describe important elements in the model, as a direct consequence of our design decisions, using illustrations.

6.1 Access to Common Information Sources

We have identified several points in the process where access to information is necessary for the work. For example, when the doctor prepares the request, she may access a source that provides information about different tests that could be conducted. Similarly, when the nurse or the laboratory staff take samples from the patient and conduct the tests, they may also require access to the same information. Rather than all the different parties searching on the internet or elsewhere for the relevant information, it is desirable that this is available in a (national) database that contains information that are correct, updated and reliable. In contrast to the scenario illustrated in Fig. 1**,** the idea of commonly accessible databases with reliable information not only ensures that all parties access correct information, but it also saves time, avoids duplication and redundancy of information and contributes towards an increase in the quality of the service provided. This idea is illustrated in Fig. 4, where the doctor making the request and the laboratory personnel conducting the tests are able to access the same “Analyses Database” containing information about laboratory analyses. Similarly, making the request form available through the EPR provides information about the test done for a patient for all care providers.

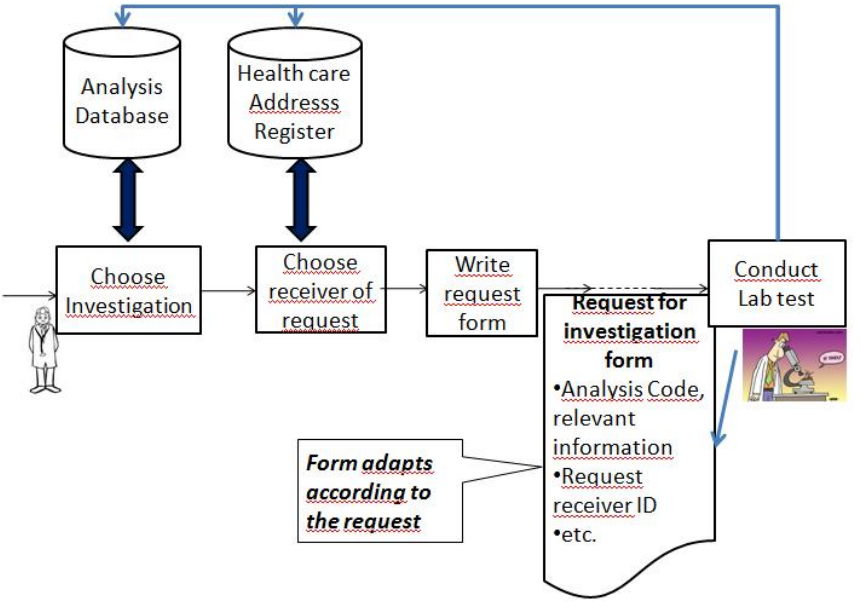

Fig. 4. Desired situation when requesting for an investigation

6.2 Traceability Log

The idea of a traceability log is introduced to keep track of the status of the request for investigation. The main idea here is that all requests for information are registered in a system (either regional or national), where each request has a unique ID, allowing it to be traceable for health care professionals. This will enable all parties involved to access the form as well as obtain the status of a particular request at any point in time. The access to this information is desired from the EPR. A part of the model that was created is shown in Fig. 5, where the main processes for creating a request form and taking samples are shown. This is to highlight that the traceability log and the request or the laboratory form are accessed at several points in the process. The data or information elements are modelled on the top of the model or between two main processes, placed above one another for. The dotted lines linking the processes and the data elements represent access to these elements. The access is not only to obtain status information, but also to access some content from the data element or to add to the contents of the element, e.g. to and from the EPR. It can be seen that the EPR, the laboratory form and the traceability log are accessed at several point in the process.

While the traceability log allows tracking a request and obtaining a status, it also means that several actors along the process have a responsibility to update the log. Based on this need, we are able to identify several functional requirements to the traceability log in order to support successful use of the concept for health care professionals and to support continuity in care for the patients.

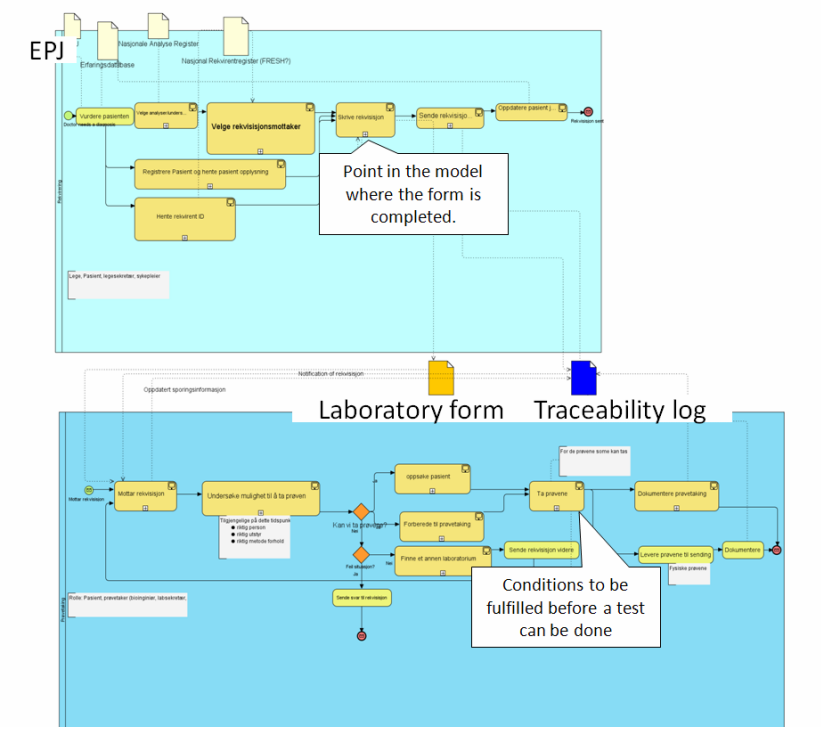

Fig. 5. Overview of a part of the model, highlighting the traceability log (*Note that due to the large model, the text is unreadable. Hence, additional text elements are inserted to highlight the important elements in the model.*)

6.3 Role of Information

One of the main roles of ICT is to support the flow of information. However, by focusing on the role of information in processes provides additional insight into the needs for supporting information flow and documentation of patient related information. For example, being able to distinguish between clinical information about a patient and the administrative information helped us identify when the EPR played a role and what role it played in the process.

An understanding of the information aspects of the model helped us identify when specific information is required or generated. For example, in the top part of the process model shown in Fig. 5, several sub-processes are shown before a request form is completed. These sub-processes describe how a request for investigation form is put together by several bits of information such as the address of the recipient, clinical and administrative information related to the patient, information about the tests to be done. These sub-processes are linked to data elements where these information could be obtained from. Similarly, some of the links indicate points where information is added to the data element, most important of which is the documentation of the patient history in he EPR that continues throughout the process.

By focussing on the information itself enabled us to identify information that is static (at least from the perspective of the request process), e.g. address, dynamic, e.g. patient history or the status of request. Taking this further, we were able to identify that some dynamic information such as the status of the request have a lifetime where it is dynamic and the interest is mostly the log, whereas the clinical information about a patient is constantly updated with a variety of information. The lifetime of this is intended to last as long as the patient lives. The nature of these two types of information and the purpose they serve in the process sets requirements on them and the ICT support that is required. In addition to the status, static and dynamic information, we were also able to identify points where awareness information could be used to let the relevant actors know about certain things, in particular when their attention is required as soon as possible. For example, when a possible laboratory cannot be done, the doctor needs a notification as soon as possible to take remedial action, so that the best possible care is extended to the patient.

Most importantly, by examining the nature of the information through an entire process allowed us to identify the evolution of the EPR that is desirable and the flexibility that is required.

6.4 What Flows between Sub-processes?

It is sometimes important to identify what flows between two sub-process, e.g. information (paper or digital) or material (physical). This is particularly important in the request for investigation process, where the flow of the laboratory form and the physical samples have to be coordinated across health care institutions. This is illustrated in Fig. 6, where a request for investigation is sent along with blood samples from one health institution to another.

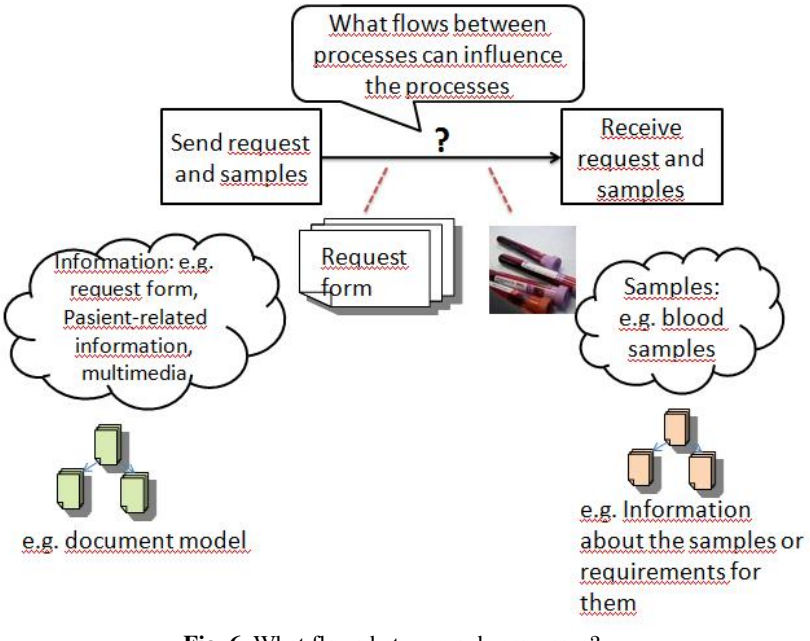

Fig. 6. What flows between sub-processes?

This poses challenges not only in the coordination and tracking of the request, but it may also influence the sub-processes themselves. For example, if the blood samples have to be handled in a special way (information that may be available from the Analyses Database), then it may affect the procedures followed by the laboratory staff and the resource planning they have to do. It may also have requirements and/or constraints on the procedures, competences and facilities for conducting the test. See the point marked "conditions to be fulfilled before a test can be done", in Fig. 5. Thus, taking a holistic approach to the model, it allowed us to identify points where the design of the sub-processes in the model may be affected and how they may be affected.

7 Evaluation

The aim of the model was to support the identification of functional requirements for EPR that provide support for health care processes. Thus, the evaluation of the model was done in two ways: (i) by examining if the model fulfilled its aim and (ii) from the feedback from the follow-up workshop.

We believe that the model does fulfill its aim as it has facilitated us to identify several functional requirements for EPR. Some of the requirements identified are related to the structuring of the information in the EPR as well as role-based access to its contents. The model not only facilitated the identification of new requirements for EPR, but also for other health information systems that currently exist or are desired by health care professional. An example of such a new system would be the traceability log.

None of the workshop participants were used to Enterprise or Process models and thus found the model very complicated to understand or relate to. However, when the rationale behind the model was explained and an overview of the contents was presented, positive feedback was received. The participants were in favour of the ideas adopted for tracing of the request and liked the fact that this would enable all actors at any point in time to obtain the status of the request. They also like the fact that such information was seen as essential information that should be included in an EPR. There was unanimous support that this was a possible way to increase the quality of the care provided for patients.

The main reason why the participants could not understand the model was the fact that the model was presented using the modelling tool, BPVA, assuming familiarity with the notation and large process models. This is perhaps a mistake made by modellers in many occasions. This highlighted the importance of visualization of models and the need for functionality for different means of visualizing models.

8 Summary

One of the main contributions of the modelling exercise was the support for a better understanding of the request for investigation process and a holistic view of the complete process from the beginning to the end. This assisted understanding the actors, the resources, in particular, the information resources and the communication

that took place in the process. The model also facilitated a common understanding among the model creators and acted as a basis for discussion of the normative process and the role of the information elements and the role of EPR and ICT in the process. The model also acted as a means of conveying our understanding of the process to the participants of the workshop which facilitated a deeper understanding of the process among everyone. Describing the process at a sufficient level of detail facilitated the refinement of the model.

The model also facilitated the thinking process, specially with respect to detail and allowed us to identify issues and grey areas. For example, a number of legal issues were identified with respect to the privacy of personal data and responsibility. In addition to this, ambiguities in the routines at the health institutions were identified.

By applying a holistic approach to modelling and using ideas from AKM, the model enabled us to identify several functional requirements for future versions of EPR, which will not only serve the purpose of documentation, but will support the work processes of health care professionals and enable better collaboration and coordination in health care. The approach used enabled us to go beyond the scope of the model initially envisaged to obtain a better understanding of not only the request for investigation process, but also other similar processes where information and the patient may move across health care institutions. Our next modelling exercise will be to examine the referral process, where one doctor or an institution refers a patient to another doctor. We plan to use the same design ideas for the model and we feel that the experience has prepared us well for the work ahead.

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