Universität Leipzig

Fakultät für Mathematik und Informatik

Institut für Informatik

Comparison of a Japanese and a German Hospital Information System on the Basis of 3LGM² models

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Jahn, Franziska

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Betreuender Hochschullehrer: Prof. Dr. Alfred Winter

Institut für Medizinische Informatik, Statistik und Epidemiologie (IMISE)

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Abstract

Whereas health informatics professionals know about the architectures of hospital information systems in their country, they often have no insight into hospital information systems of other countries or even other cultural areas. However, crossing cultural and country borders always offers the chance to gain new ideas and to learn from each other. Therefore this thesis compares the hospital information system of Chiba University Hospital (Japan) with the hospital information system of the University Hospital of Leipzig (Germany) in order to find similarities and differences which can be discussed against each other.

As a basis for the comparison 3LGM² models of hospital information systems were chosen. In addition, the Reference Model for the Domain Layer of hospital information systems provided a unique basis of concepts that made the hospitals comparable. Thus, a method for a comparison of hospital information systems based on 3LGM² models and the Reference Model for the Domain Layer was needed. Relevant criteria taken from recent literature on hospital information systems were examined with respect to their analyzability by means of 3LGM² models and integrated into a structured catalogue of criteria. A 3LGM² model of the hospital information system of the University Hospital was already available, hence only a 3LGM² model of the hospital information system of Chiba University had to be created from scratch.

The comparison by means of the identified criteria revealed several differences and similarities of the two hospital information systems. Both hospital information systems adopt clinical, administrative and strategic application systems. However, the hospital information system of Chiba University Hospital has a centralized, less fragmented architecture than the hospital information system of the University Hospital of Leipzig. That architecture leads to fewer functional redundancies, which is also supported by the Electronic Medical Record system that offers a wide range of functions for the hospital-wide medical and nursing documentation. In contrast, the University Hospital of Leipzig has a more decentralized and fragmented architecture with application systems from many different vendors. Although there is a hospital-wide clinical documentation system, too, many departmental subsystems cause more functional redundancies. The high heterogeneity of the hospital information system leads to a broad implementation of communication standards. With respect to the hardware architectures both hospitals use client-server architectures and typical techniques to limit unavailability.

Contents

1 Introduction 1

1.1 Subject and Motivation 1
1.1.1 Subject 1
1.1.2 Problem area 2
1.1.3 Motivation 2

1.2 Problem definition 3

1.3 Objectives 3

1.4 Posing of questions 3

2 Fundamentals 5

2.1 Overview 5
2.1.1 Definitions of hospital information systems 5
2.1.2 The architecture of hospital information systems 6

2.2 Information management in hospitals 7

2.3 Using Models to describe and compare hospital information systems 9
2.3.1 Definitions 9
2.3.2 3LGM² - A meta model for hospital information systems 10
2.3.3 A Reference Model for the Domain Layer of Hospital Information Systems 14
2.3.4 A procedure for modeling an enterprise information system 15

2.4 Classification criteria for the architecture of hospital information systems ... 18
2.4.1 Architectural styles of the logical tool layer 18
2.4.2 Architectural styles of the physical tool layer 19

2.5 Quality criteria for hospital information systems 20
2.5.1 Assessing quality of structures 21
2.5.2 Assessing outcome quality 25
2.5.3 A comprehensive collection of quality criteria for hospital information systems 26
2.5.4 Accreditation of hospital information systems 27

2.6 Comparison studies 27

3 Approach 31

4 A method for comparing HISs on the basis of 3LGM² models 32

4.1 The 3LGM² tool and the Reference Model for the Domain Layer in the context of the comparison 32

4.2 Identification of criteria 33

4.3 Defining a procedure for the comparison 36
4.3.1 Initiation of the comparison 36
4.3.2 A method for comparing HISs on the basis of 3LGM² models 38

4.4 The catalogue of criteria 46

4.5 Summary 48

5 Modeling the HISs to be compared 49

5.1 A Procedure Model for modeling the HIS at Chiba University Hospital 49

5.2 Practical Implementation of the Procedure Model 52
5.2.1 Week 1: Get to know and understand the hospital 52
5.2.2 Week 2 and 3: Data collection 52
5.2.3 Week 3 and 4: Modeling 54

5.3 A model of the UKL-KIS 58

5.4 Summary 59

6 Results of the comparison 62

6.1 Basic facts about the hospitals and information management 62
6.1.1 Short Characterization of the hospitals 62
6.1.1.1 Key figures 62
6.1.1.2 Organizational and Spatial Structure 63
6.1.1.3 Strategic goals 64
6.1.2 Information Management 64
6.1.2.1 Organizational Structures of Information Management 64
6.1.2.2 Characterization of Information Management 66

6.2 Functionality of computer-based subsystems 68
6.2.1 Adoption of clinical systems 68
6.2.2 Adoption of administrative systems 72
6.2.3 Adoption of strategic systems 74
6.2.4 Coverage of the functionality of the EMR system within the UKL-KIS 75

6.3 Architecture of the Logical tool layer ... 77
6.3.1 Architectural style of the logical tool layer ... 77
6.3.2 Use of communication standards ... 80
6.3.3 Fragmentation of the information system ... 82
6.3.4 Informational Redundancy and Data integration ... 83
6.3.5 Access Integration ... 84
6.3.6 FRR ... 86
6.3.7 Degree of computer support ... 87
6.3.8 Degree of Heterogeneity ... 87

6.4 Architecture of the Physical Tool Layer ... 88
6.4.1 Architectural style of the physical tool layer ... 88
6.4.2 Techniques to limit unavailability ... 89

7 Supplement: The HIS of Chiba University Hospital ... 91

8 Summary ... 93

9 Discussion and Outlook ... 97

Bibliography ... 99

Figures ... 103

Tables ... 104

Appendix ... 105

Appendix A – The hierarchy of functions of the Reference Model for the Domain Layer of HISs ... 105

List of abbreviations and terms

3LGM²	Three-layer graph-based metamodel
ADT	Admission, Discharge and Transfer
ARIS	Architecture of integrated Information Systems
DICOM	Digital Imaging and Communications in Medicine
EAP	Enterprise Architecture Planning
EMR	Electronic Medical Record
HIS	Hospital Information System
HL7	Health Level 7
HL7 CDA	HL7 Clinical Document Architecture
HL7-RIM	HL7 – Reference Information Model
IMISE	Institute for Medical Informatics, Statistics and Epidemiology
IRC	Information Resource Catalog
IS-H	Industry Solution Hospital
LIS	Laboratory Information System
M	See MUMPS
MUMPS	Massachusetts General Hospital Utility Multi-Programming System
PACS	Picture Archiving and Communication System
RAID	Redundant Array of Independent Disks
RIS	Radiology Information System
TOGAF	The Open Group Architecture Framework
TSMED	Toshiba Sumiden Medical Information Systems
UKL	University Hospital of Leipzig (German: Universitätsklinikum Leipzig AÖR)
UKL-KIS	Hospital Information System of the University Hospital of Leipzig
UML	Unified Modeling Language
XSL	Extensible Stylesheet Language
XSLT	XSL Transformations

1 Introduction

1.1 Subject and Motivation

1.1.1 Subject

Healthcare systems of industrial countries are facing new challenges due to the declining birthrates and the increasing life expectancy of their population. Population models for Germany predict that in the year 2050 up to 36% of the population will be over 65 years old compared to 19% in 2005 [STATISTISCHES BUNDESAMT (2006)]. In Japan, the country with the highest life expectancy in the world, the aged population will account for a similar ratio (35.7%) in 2050 [IPSS (2002)]. The phenomenon of ageing societies will have a lasting effect on organizational structures of healthcare and its information systems [HAUX R (2006)].

Hospital information systems (abbr.: HIS) – as an instance of health information systems – are characterized by a high heterogeneity and complexity of their infrastructure which, especially in the future, has to be carefully managed to meet the requirements of the healthcare market.

In the context of this study a hospital information system is seen as the "socio-technical subsystem of a hospital which comprises all information processing as well as the associated human or technical actors in their respective information processing roles" [WINTER A et al. (2001)]. Consequently, the management of a HIS implies not only the management of a set of computer-based application systems. It also deals with humans who process information by using application components both computer-based and paper-based and their underlying technologies.

Managing a HIS includes long- and short-term planning, monitoring and directing of the information system. To support information managers analyzing and planning the future of the information system adequate descriptions of information system architectures can be helpful. Therefore the three-layer graph-based metamodel (3LGM²) has been developed at the Institute of Medical Informatics, Statistics and Epidemiology (University of Leipzig). 3LGM² provides an ontological basis for modeling hospital information systems on three layers (cf. [WINTER A et al. (2003)]): The domain layer describes enterprise functions (e.g. patient admission or order entry) and the information that is updated by them. The logical tool layer focuses on application components which support enterprise functions. The physical basis for application components is represented by physical data processing components such as servers and PCs which are assigned to the physical tool layer within 3LGM².

For creating 3LGM²-conform graphical models of hospital information systems the 3LGM² tool was implemented. Besides the documentation of the information system the

3LGM² tool provides different features for analyses of the information system. During the past few years a couple of 3LGM² models have arisen which describe complex hospital information systems in the German-speaking world, e. g. the model of the University Hospital of Leipzig (UKL-KIS model).

Modeling hospital information systems can be facilitated by using reference models. One particular reference model for the domain layer of hospital information systems had been specified by [HUEBNER-BLODER G et al. (2005)] which has been modeled by means of 3LGM², too. Until now the reference model of the domain layer has only been applied to models of central-European hospitals like the UKL and the Tiroler Landeskrankenanstalten (TILAK) in Innsbruck, Austria.

1.1.2 Problem area

In general, European health informatics professionals do not exactly know how a Japanese HIS is organized just as the Japanese probably have only a vague idea of a German HIS. On the one hand it seems possible that a Japanese HIS might be similar to a German HIS in many respects. On the other hand the Japanese could have a different view on a hospital and its information system due to their completely different cultural background. For instance, if Japanese hospitals define for cultural reasons other strategic goals than German hospitals, then these different goals could lead to different information architectures although considering enterprises of the same business and a similar size (cf. [HEINRICH (2005), p. 52]). However, as Japan is regarded as a highly technologized country, it would be a plausible consequence if Japanese HISs were more sophisticated compared to HISs in European countries.

Before a comparison of hospital information systems can be done at all it is necessary to determine what aspects of the information systems shall be compared. Although there are some characteristics of information systems that seem more immediately appropriate than others for a comparison such as architecture patterns or architectural quality criteria, a comparison should preferably be comprehensive and meaningful. Furthermore, the means for a comparison of information systems have to be carefully chosen to cover a wide range of comparison criteria. The 3LGM² method and the reference model for the domain layer may be a foundation for a comparison but they have never been used for these purposes. Moreover, it can hardly be anticipated whether the application of a reference model which possibly does not reflect the domain layer of every hospital within Europe is suitable for an East-Asian HIS.

1.1.3 Motivation

The benefits of a comparison of a Japanese HIS and a German HIS are multifaceted. Firstly, German or European health informatics professionals gain insight into the Japanese way of managing and organizing a HIS. Likewise, the Japanese get an idea of the information system architecture and information management in a German hospital.

Analyzing the results of a comparison between a Japanese and a German HIS, which discusses amongst other things architecture styles and architectural quality criteria, strengths and deficiencies of both HIS can be identified. These findings provide a basis to learn from each other and initiate further collaboration of the two countries in the field of medical informatics. The motivation seems to be confirmed by [HAUX R (2006)], who regards international strategies for health information systems as a future aim for health informatics. Such strategies could be the result of international collaboration.

1.2 Problem definition

- Problem P1: There is no general idea about the similarities and differences of an East-Asian and a German HIS compared with each other.
- Problem P2: There currently exists no structured method for comparing hospital information systems by means of 3LGM² models and the Reference Model of the Domain Layer for Hospital Information Systems.
- Problem P3: A 3LGM² model of the HIS of Chiba University Hospital based on the Reference for the Domain Layer of Hospital Information Systems is needed.

1.3 Objectives

- Objective to solve problem P1:
    - Objective O1: It is an objective of this work to compare the HIS of Chiba University Hospital with the HIS of the University Hospital of Leipzig.
- Objective to solve problem P2:
    - Objective O2: It is an objective of this work to develop a method for a structured comparison of hospital information systems by means of 3LGM² and the Reference Model for the Domain Layer of Hospital Information Systems.
- Objective to solve problem P3:
    - Objective O3: It is an objective of this work to model the HIS of Chiba University Hospital by means of 3LGM² and the Reference Model for the Domain Layer of Hospital Information Systems.

1.4 Posing of questions

- Questions to be answered for achieving Objective O1:
    - Question Q1.1: What are differences and similarities of the two examined HISs?

  - Question Q1.2: What conclusions derive from different characteristics of both HISs?

- Questions to be answered for achieving Objective O2:
  - Question Q2.1: What are suitable criteria for a comparison of two HISs by 3LGM² models and the Reference Model for the Domain Layer?
  - Question Q2.2: To what extent are the identified criteria measurable by means of 3LGM²?

- Questions to be answered for achieving Objective 3:
  - Question Q3.1: Which procedures should be applied in order to model the HIS of Chiba University Hospital?
  - Question Q3.2: Is the Reference Model for the Domain Layer of Hospital Information Systems suitable for modeling the HIS of Chiba University Hospital?

2 Fundamentals

2.1 Overview

This chapter aims to establish the theoretical foundations for the comparison of the hospital information systems of Chiba University Hospital and the University Hospital of Leipzig. Thus, the following subjects are dealt with in this chapter:

- Initially, the domain of this study is introduced. Basic concepts like hospital information systems, information system architectures and information management are defined.
- As a second step, a way to conceive complex information systems is introduced. I.e. it is explained how hospital information systems can be described with the help of models, metamodels and reference models. For example, the three-layer graph-based metamodel (3LGM²) which helps to describe, evaluate and plan hospital information systems, is introduced.
- Finally, possible comparison criteria for hospital information systems are surveyed. Besides the description of criteria that help to categorize or assess hospital information systems, available studies that deal with comparisons of hospitals information systems are presented.

2.1.1 Definitions of hospital information systems

The term "hospital information system" is not used unambiguously in literature as well as in daily practice at hospitals. Within hospitals the computerized system used for administrative and clinical documentation is often regarded as "hospital information system." That perception is reflected in the following definition.

"Hospital information systems (HISs) are computerized information banks that deal with patient-related data, typically including demographics, medical information (such as history, diagnosis, laboratory findings) and financial information." [SATYA-MURTI (1993)]

However, in a broader sense, hospital information systems do not only consist of computers and software products, but also of people who use a variety of tools to document and process information. In order to follow that more comprehensive view on hospital information systems the term "hospital information system" will in this study throughout be used in the following sense.

"A hospital information system is that socio-technical subsystem of a hospital which comprises all information processing as well as the associated human or technical actors in their respective information processing roles." [WINTER A et al. (2001)].

The definition does not yet include concrete clues about what a HIS is composed of and what aspects of a HIS are suitable to be examined. Hence, a closer look at the inner composition, i.e. at the architecture of a HIS, is required.

2.1.2 The architecture of hospital information systems

The [IEEE 1471-2000] specification defines the architecture of a system as "*the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution*."

In the following the interpretation of that definition in the context of hospital information systems according to [HAUX R et al. (2004), p. 29 et seq.] is presented.

Enterprise functions, business processes, application components and physical data processing components are characteristic *components* of information system architectures. Enterprise functions are perpetual tasks of an enterprise which serve to achieve the goals of an enterprise. Therefore they have no fixed beginning or end. By an enterprise function it is expressed what is done in an enterprise, but not how it is done. Typical examples for enterprise functions in a hospital are “execution of diagnostic procedures”, “coding of diagnoses and procedures” and “financial accounting”. In contrast to enterprise functions business processes describe how activities are performed, i.e. in what chronological and logical order activities are initiated.

Enterprise functions and business processes describe hospital information systems from a functional point of view. The functional description of hospital information system has a *relationship* to the application architecture. More precisely, enterprise functions are supported by application components which can either be computer-based or paper-based. Computer-based application components are controlled by application programs which are customized software products. The following table lists typical computer-based application components that can be found in a hospital [HAUX R et al. (2004), p. 89-100]:

Application component	**Function**
Clinical information system	comprises the functions of a medical documentation system, a nursing documentation system, an order entry system and a ward management system
Knowledge servers	provide medical knowledge for healthcare professionals
Laboratory Information System (LIS)	system used in the laboratory unit to manage the execution of orders and to analyze the specimens
Medical Documentation Systems	supports healthcare professionals with documenting patient-related data like patient history, diagnoses, reports and care plans
Nursing Documentation	a special medical documentation system supporting the

System	workflow of nurses
Operation Documentation System	supports the documentation during operations
Operation Management System	for operation planning and the documentation during an operation
Operation Planning System	planning dates and times for operations
Order Entry System	for ordering services and receiving results of diagnostic or therapeutic departments
Patient Data Management System (PDMS)	documentation of vital parameters in intensive care units
Patient Management System (PMS)	management of administrative patient data needed for admission, discharge and transfer (ADT) of patients
Picture Archiving and Communication System (PACS)	system that is responsible for storing radiological pictures and communicating radiological pictures to the workstations where they are needed
Radiology Information System (RIS)	supports the procedures in a radiology department
Ward Management System	supports the bed management on a ward

Table 1. Typical application components within a hospital

The use of paper-based application components like forms for the documentation of a patient's anamnesis follows written or generally approved working plans.

Application components in turn are related to physical data processing components. Computer systems like servers and PCs as well as paper-based tools like hardcopy archives and human actors processing information are usually regarded as "physical data processing components".

The introduced architecture concepts "enterprise function", "application component" and "physical data processing component" and their relationships form the basis for the three-layer graph based metamodel (3LGM²) which is explained in chapter 2.3.2.

Since the implementation of an information system architecture strongly depends on *the principles governing its design and evolution* according to the IEEE definition given above, the origin of such information management principles should be considered. That is why the next chapter introduces concepts of information management.

2.2 Information management in hospitals

In [WINTER A et al. (2001)] a three-dimensional framework for information management tasks is proposed. Thus, planning, directing and monitoring tasks have to consider certain objects of the hospital information system within different scopes (Figure 1). Objects of interest for information management activites are the information itself, application components and physical data processing components. The scope of information management embraces strategic, tactical and operational tasks.

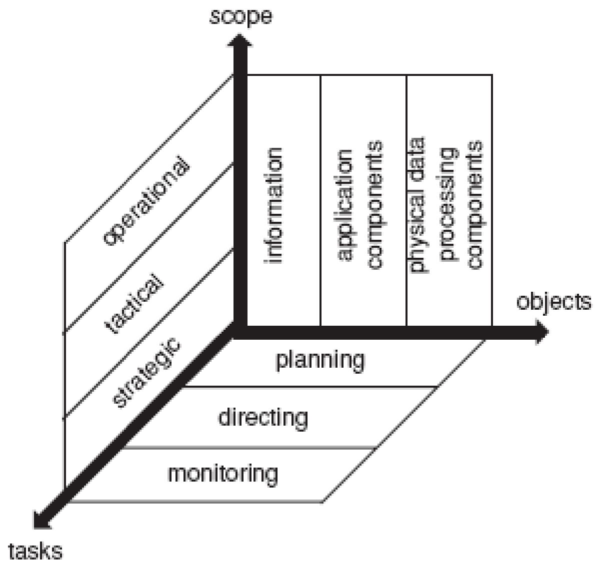

Figure 1. Three-dimensional classification of information management activities [WINTER A et al. (2001)]

Below the activities of strategic, tactical and operational information management are described.

- *Strategic Information Management* tasks focus on the whole hospital information system and its further development. In concordance with the hospital's strategic goals the future goals concerning the hospital information system are defined. An important result of strategic information management activities is the strategic information management plan which includes the direction of information management and stipulates the further development of the HIS architecture. Strategic Information Management initiates tactical projects following from the strategic information management plan and monitors the adherence to the information management goals.

- *Tactical Information Management* preeminently deals with the planning, execution and monitoring of projects which aim, for example, at the introduction or modification of application components. The enterprise information system is the final result of tactical projects.

- *Operational Information Management* plans, directs and monitors the proper operation of the HIS components. The maintenance tasks of operational information management include for example the planning of resources like facilities, staff and finances and providing procedures for the management of operating faults like system failures.

The information management approach introduced here focuses on tasks which can be assigned to the three planning horizons “strategic”, “tactical” and “operational”. According to [KRCMAR (2005), p. 34] task-oriented views on information management are especially found in German-speaking countries. Furthermore, [KRCMAR (2005), p. 45] distinguishes between problem-oriented, process-oriented, layer-oriented and architecture-oriented concepts of information management. These concepts arise from different perspectives on information management.

For instance, problem-oriented approaches are prevalent in the United States. Thus, an information manager has to focus on the topics *Strategic Impact* of IT, *Changing Technologies*, *Organizational Learning*, the *Sourcing Policy* (“make or buy”) and the *Applications Life Cycle.* There should be a *Power Balance* between the IT department, the users of IT in the competent departments and the business management. A standard reference for this problem-oriented concept is [APPLEGATE et al. (2001)].

Likewise, [VOGEL LH and PERREAULT LE (2006)] focus on problems of information management in hospitals that have to be solved against the background of changing healthcare environments. Thus, information management in a hospital has to deal with and react on *Changing Technology*, *Changing Culture*, *Changing Process* as well as *Management and Governance*.

It becomes apparent that there are different basic approaches to information management which can be assigned to certain linguistic areas and therefore might result from different cultural backgrounds.

2.3 Using Models to describe and compare hospital information systems

Understanding the complexity and heterogeneity of a HIS can be facilitated by using models. Regarding the comparison of HIS the use of models might additionally support a structured analysis by means of comparison criteria.

In this chapter concepts related to modeling, i.e. models, metamodels and reference models, are defined. Furthermore, an example for a metamodel and an example for a reference model of a HIS are given which will later serve as a basis for the comparison of two HISs.

2.3.1 Definitions

“A model is a description of what the modeler thinks to be relevant to a system.” [HAUX et al. (2004), p. 26]

According to this definition a model is the result of a modeler’s activity. The modeler looks at some aspect of a system and prepares a model of it. The use of ‘relevant’ information about the system for the model refers to the abstracting nature of the modeling process. Hence, the modeler has the responsibility to find the suitable type and granularity of information in order to answer questions relating to aspects captured by the model. To support such modeling decisions the use of metamodels is helpful.

"*A metamodel usually describes the modeling framework which consists of*

- *modeling syntax and semantics […]*
- *the representation of the objects […]*
- *and (sometimes) the modeling rules[…].*"

[HAUX et al. (2004), p. 63]

Thus, metamodels provide a description language for a set of models. In the domain of enterprise architectures, for example, metamodels like ARIS (Architecture of integrated Information Systems, [SCHEER (1998)]) or TOGAF (The Open Group Architecture Framework) are available.

Even if there is a framework which supports the modeler, modeling complex information systems from scratch is a time and cost-intensive task. To accelerate the modeling process reference models may help.

Reference models present a kind of model pattern for a certain class of aspects. On the one hand, these model patterns can help to derive more specific models through modifications, limitations or add-ons (generic reference models). On the other hand, these model patterns can be used to directly compare models concerning their completeness (nongeneric reference models). [HAUX et al. (2004), p. 73]

As a consequence, the use of reference models facilitates modeling and takes over otherwise time-consuming modeling decisions. In addition, reference models can serve as a starting point for the comparison of models.

2.3.2 3LGM^2 - A meta model for hospital information systems

The three-layer graph-based meta model (3LGM^2) provides a terminology for modeling hospital information systems [WINTER et al. (2003)]. By means of 3LGM^2 the interacting components of hospital information systems can be described on three layers – namely the domain layer, the logical tool layer and the physical tool layer. The elements of the three layers and their relationships are specified with the help of Unified Modeling Language (UML) diagrams which are presented below together with short descriptions.

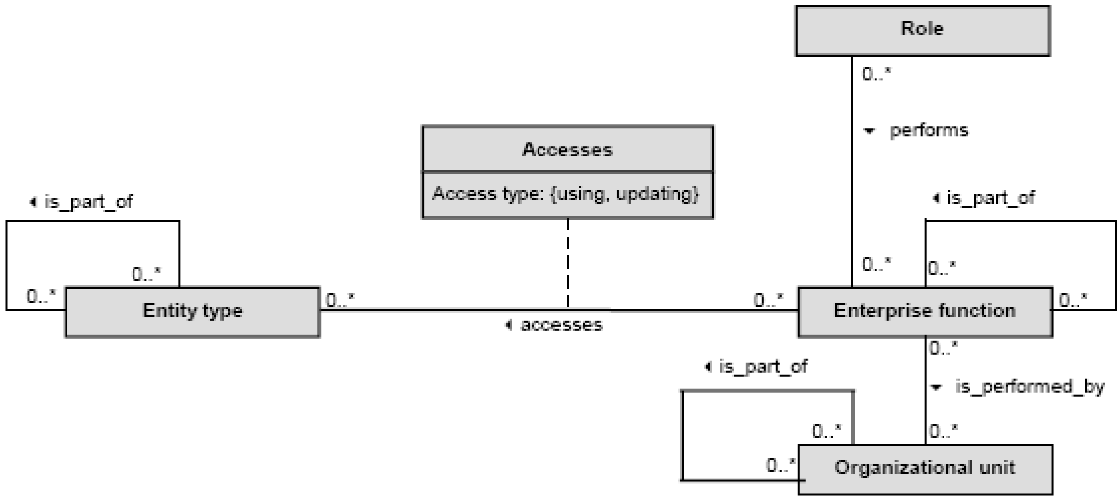

Figure 2. UML diagram of the domain layer within 3LGM² (taken from www.3LGM.de)

Domain Layer:

On the domain layer a hospital information system is described by enterprise functions and entity types. Enterprise functions use or update certain information on virtual or physical objects which are represented by entity types. Additionally, every enterprise function can be assigned to organizational units of the hospital. Enterprise functions and entity types can be refined by sub-elements. The functional description on the domain layer abstracts from software or hardware implementations within a hospital information system.

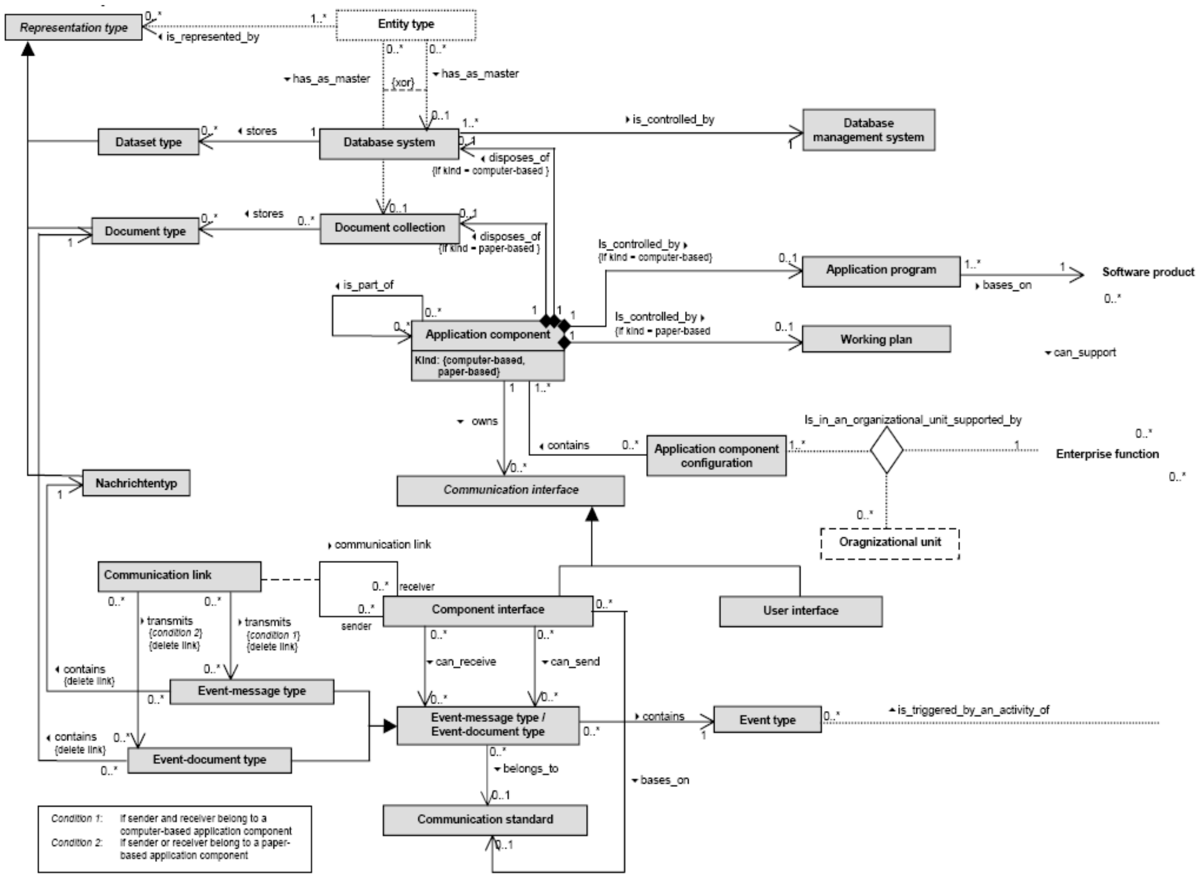

Figure 3. UML Diagram of the Logical Tool Layer within 3LGM² (taken from www.3lgm.de)

Logical Tool Layer:

The central elements of the logical tool layer are application components. Within 3LGM² application components can either be computer-based or paper-based. Computer-based application components are controlled by application programs which are adapted software products. Paper-based application components can be controlled by working plans. Whereas paper-based application components can store document collections, computer-based application components can have a database for storing information. The exchange of messages between application components is directed over communication interfaces which might use a communication standard. Interfaces have the ability to send and receive event type-message type-combinations or event type-document type combinations.

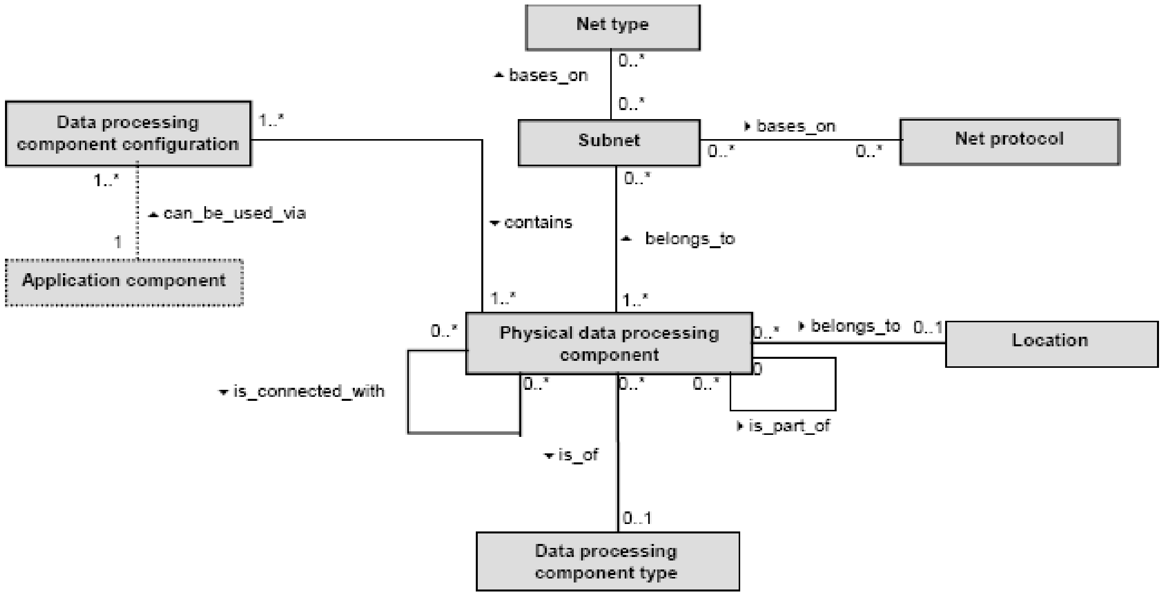

Figure 4. UML diagram of the Physical Tool Layer within 3LGM² (taken from www.3lgm.de)

Physical Tool Layer:

The physical tool layer mainly focuses on physical data processing components. Physical data processing components do not only comprise computer-based hardware components like servers and PCs, but also systems consisting of persons and conventional tools like hard-copy archives. A hardware component belongs to a location and can be part of a subnet which uses a network protocol.

Inter-Layer-Relationships:

In Figure 3 and Figure 4 inter-layer relationships between the domain layer and the logical tool layer and the logical tool layer and the physical tool layer can be identified. Enterprise functions assigned to an organizational unit are linked to application components through application component configurations. I.e. an enterprise function can be supported by one or more application components. Another relationship between the domain layer and the logical tool layer is that of entity types and their logical representation forms. Entity types can be represented by document types, dataset types and message types. Furthermore, a database system on the logical tool layer can be the master for entity types. Between the logical tool layer and the physical tool layer there is one type of relationship. Application components are linked to their physical basis via data processing component configurations. Data processing component configurations consist of all data processing components needed so that an application component on the logical tool layer can work.

The previously introduced concepts provide a standardized terminology for the description of hospital information systems. The theoretical basis provided by the 3LGM² builds the fundament for the corresponding 3LGM² tool [WENDT T et al. (2004)].

The 3LGM² Tool:

To create 3LGM² conform models the 3LGM² tool was developed at the Institute of Medical Informatics, Statistics and Epidemiology at the University of Leipzig. The 3LGM² tool can be used for documenting and planning a HIS and it also provides certain analysis functions for information systems. The following features of the 3LGM² tool can support information management by analyzing information system models in several respects [WENDT T et al. (2004), BRIGL B et al. (2005)]:

- The graphical representation of an information system over three layers can help to understand the structure of a respective HIS.
- A model consists of one or more submodels. A submodel can, for example, concentrate on a subsystem of a HIS or present an aspect of an information system in more detail.
- Graphical analyses focus on a certain model element and its relationships to other elements. For example, it can be graphically highlighted which application systems support a certain enterprise function or what interfaces and communication links use a certain communication standard (e.g. HL7).
- Exports via XSLT extract information out of a model by creating structured tables in HTML format. These HTML reports apply questions like “Which enterprise function updates or uses which entity type?” or “Which organizational units use which application components?” to the whole model or certain submodels.
- Furthermore, the 3LGM² tool provides analysis options to calculate the functional redundancy of enterprise functions and the data redundancy of entity types as introduced in 2.5. .

2.3.3 A Reference Model for the Domain Layer of Hospital Information Systems

The domain layer of a HIS can be described by enterprise functions and entity types (cf. 2.1.2 and 2.3.2). As the identification and modeling of adequate enterprise functions and entity types for a hospital is rather time- and consequently cost-intensive, [HUEBNER-BLODER G et al. (2005)] developed a functional reference model for the domain layer of hospital information systems. It consists of hierarchically structured sets of hospital functions and entity types. The designated enterprise functions base on the Heidelberg requirements index for information processing in hospitals [AMMENWERTH E et al. (2002)], thus the main enterprise function of a hospital is patient treatment, together with maintenance functions like supply management, scheduling and resource allocation, hospital administration, hospital management and research and teaching. The mentioned enterprise functions are in turn refined by sub-functions. Moreover, the enterprise functions bear a relation to each other by entity types which they can update or use. For defining entity types within the reference model of the domain layer the Health Level 7 Reference Information Model (HL7-RIM) was used.

The Reference Model for the Domain Layer of Hospital Information Systems is available as a 3LGM² model and can for this reason be immediately used for modeling hospital information systems. Following the definition of reference models in 2.3.1 the Reference Model of the Domain Layer can be used as a model pattern for the domain layer of hospital information systems and, additionally, can help to compare hospital information systems by means of a uniform terminology used for the domain layer. I.e. it is possible to see how the same enterprise functions are supported by application components in different information systems.

2.3.4 A procedure for modeling an enterprise information system

Within the context of Enterprise Architecture Planning (EAP) [SPEWAK SH and HILL SC (1992)] suggest an order for collecting data about the information system of an enterprise. The whole process of defining and planning a new enterprise information system consists of four layers [SPEWAK SH and HILL SC (1992), p. 13 et seq.]:

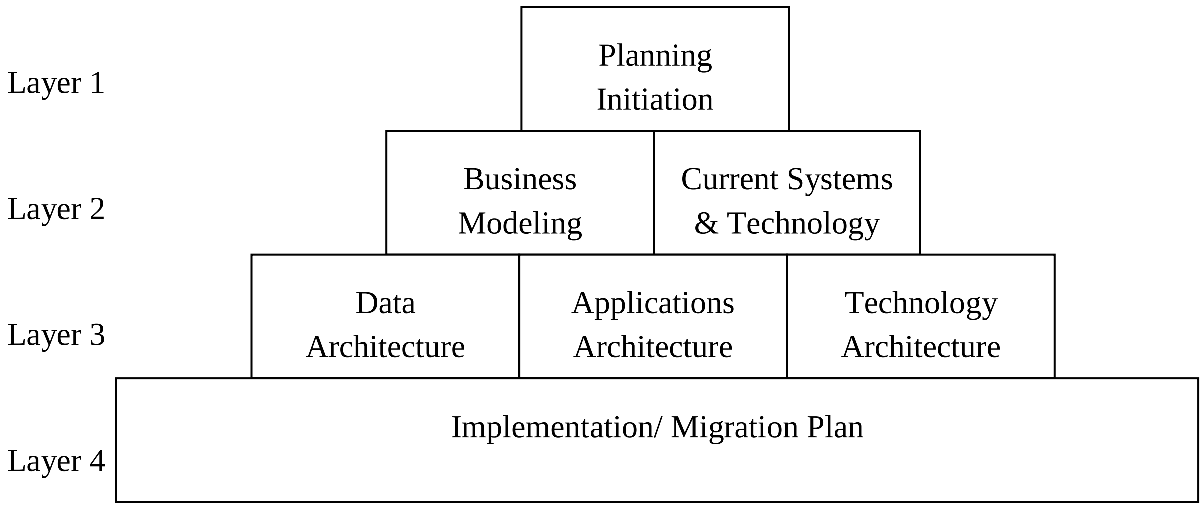

Figure 5. Components of Enterprise Architecture Planning according to [SPEWAK SH and HILL CH (1992)]

For modeling the current state of an information system only the steps on Layer 1 and Layer 2 are relevant. For this reason the following explanations focus on Planning Initiation, Business Modeling and Current Systems & Technology.

The two important results of the **Planning Initiation** on Layer 1 are a workplan that includes the phases and steps of the project and the acceptance and the commitment to support the project by the management of the enterprise. To reach this goal, [SPEWAK SH and HILL SC (1992), p.38 ff] identify the following steps.

L1.1 Determine scope and objectives for EAP.
A formal definition of the scopes and objectives of the project is useful for all project participants.

L1.2 Create a vision (initial meetings with management).
Together with the management a vision of how the information system looks like in the future is created.

L1.3 Adapt a planning methodology.
Purpose, deliverables, source documents, procedures, guidelines, roles, responsibilities and an effort estimate of the project steps should be specified.

L1.4 Arrange for computer resources.
A toolset that supports the project is determined.

L1.5 Assemble the planning team.
Project leaders and team members are named.

L1.6 Prepare EAP workplan.
The workplan serves as a schedule for the timely completion of the project.

L1.7 Obtain/confirm commitment and funding.
The management should approve the workplan and also be kept informed during the project by means of presentations.

Business Modeling on Layer 2 comprises the preparation of a Preliminary Business Model (L2.1.1 – L2.1.3), which contains business functions and organizational units, and the execution of an Enterprise Survey (L2.1.4-2.1.8) to collect details about every business function (cf. [SPEWAK SH and HILL SC (1992), p. 85 et seq.]).

L2.1.1 Document the organizational structure.
Organizational units, positions and titles and business goals are documented and entered into the toolset.

L2.1.2 Identify and define the business functions.
Business functions are described, decomposed and assigned to organizational units.

L2.1.3 Document the preliminary business model, and distribute and present it back to the business community for comments. The correct definition of enterprise functions and their relationships is verified.

L2.1.4 Schedule the interviews.
Interviews with employees performing certain business functions are scheduled. The main objective of the interviews is to identify the information needed for performing functions.

L2.1.5 Prepare for the interviews.
Interview forms and formats are prepared and the team members are trained.

L2.1.6 Perform the interviews.
A smooth execution of the interview according to the plan is managed.

L2.1.7 Enter data into a toolset.
The information obtained from the interview forms is entered into the toolset.

L2.1.8 Distribute the complete business model.
The management of the enterprise has to verify the business model.

For documenting **Current Systems and Technology** on Layer 2 an Information Resource Catalog (IRC) is prepared, containing all systems and technology platforms used in the enterprise [SPEWAK SH and HILL SC (1992), p. 141ff].

L2.2.1 Determine the scope, objectives, and IRC workplan.
For example, the applications to be included in the IRC are identified and the toolset is chosen.

L2.2.2 Prepare for data collection.
The respective forms are prepared and technology platforms are identified.

L2.2.3 Collecting the IRC data.
Forms are completed and the relationships between applications and business functions as well as applications and technology platforms are identified.

L2.2.4 Data entry.
The collected data is entered into the toolset.

L2.2.5 Validate IRC information and produce a draft of the IRC.
Those who contributed to the IRC should validate its correctness.

L2.2.6 Draw schematics.
The schematics should show all the systems' inputs, outputs and files.

L2.2.7 Distribute the IRC.
The completed IRC is distributed throughout the enterprise.

L2.2.8 Administering and maintaining the IRC.
Procedures for holding the IRC up-to-date are determined.

Additional levels are not introduced in this thesis; please refer to [SPEWAK SH and HILL CH (1992)].

2.4 Classification criteria for the architecture of hospital information systems

To describe a hospital information system it helps to categorize the architecture by assigning it to architectural styles. [HAUX R et al. (2004)] propose architectural styles for the logical tool layer and the physical tool layer (cf. 2.3.2) which are supposed to support descriptions, comparisons and assessments of hospital information systems. The subsequently characterized architectural styles focus on the computerized part of an information system.

2.4.1 Architectural styles of the logical tool layer

[HAUX R et al. (2004), p.112 et seq.] classify architectural styles of the logical tool layer of an information system according to the number of database systems within the HIS. The DB^1 architectural style is identified by only one application component having a database. Either the information system consists only of that one application component or there are also other application components that use the data stored in the central database.

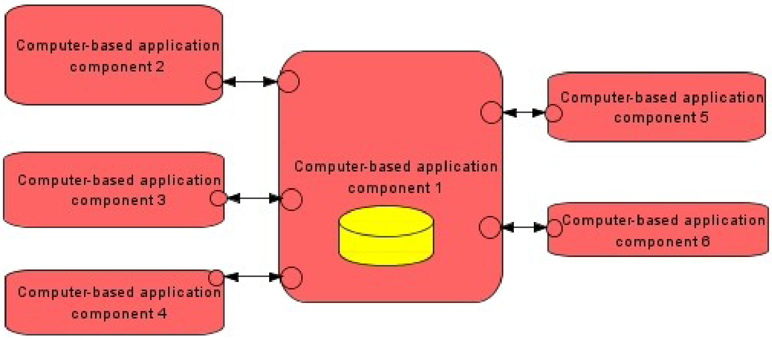

Figure 6. The DB^1 architecture style

On the contrary, different application components all having an own database denote the DB^n architectural style. In a HIS the DB^n style usually indicates redundant storage of patient-related data. For that reason strategies for keeping data of different databases up-to-date and consistent have to be put in place. A common method to exchange data within a DB^n architecture is the use of a central component (e.g. a communication server) which directs the communication between different application components. That leads to the so-called star architectural style. If there is no communication server within a DB^n architecture the application components are linked by many bidirectional communication links between each other (so-called “spaghetti style” according to [HAUX R et al. (2004)]).

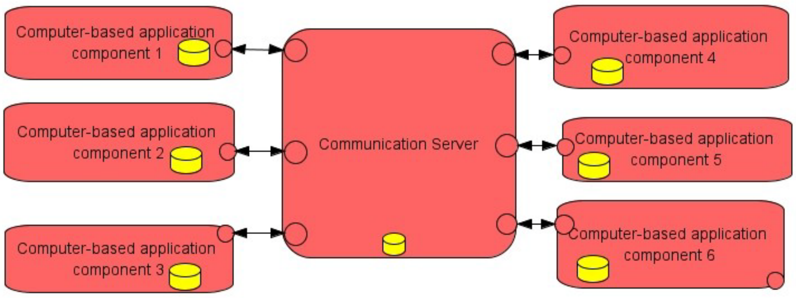

Figure 7. DB^n architectural style with communication server

Especially within a DB^n architecture style the exchange of data between different application components is eased by using standardized syntax and semantics for the exchanged messages. The HL7 standard for the exchange of patient-related data and the DICOM standard for the communication of medical images play an important role within health information systems (cf. [HAUX R et al. (2004)]).

2.4.2 Architectural styles of the physical tool layer

On the physical tool layer, i.e. concerning the physical data processing components of a hospital information system, [HAUX R et al. (2004), p.118 et seq.] distinguish between mainframe-based architectures and client-server-architectures. Several terminals connected to one central mainframe denote mainframe-based architectures. On the mainframe applications are installed which can be accessed by terminals. Terminals only possess input and output capabilities.

The nowadays prevailing client-server-architectures consist of servers and clients interconnected by a network. Servers provide services which are used by the clients. Examples for such services are the storage of data – done by database servers – or the provision of applications by so-called application servers. If the client is an ordinary PC which is in a large part responsible for the execution of the application and the server takes the role of a combined application and database server the architecture is called 2-tier architecture (cf. [WINTER A et al. (2005)]). In contrast, within a 3-tier architecture the application is not only stored but also executed on the application server. Therefore the database is stored on an additional database server. With the decentral style [WINTER A et al. (2005)] introduces a further architectural style of the physical tool layer of hospital information systems that refers to the hospital's organizational structure. Different departments of a hospital can have their own servers and corresponding 2- or 3-tier architectures which are decentrally spread over the hospital.

A further type of client-server-architectures is the so-called "thin client"-architecture. Thin clients do not store or process data, they access the applications running on a terminal server. That recent concept functionally corresponds to mainframe-based architectures which are considered to be legacy systems.

2.5 Quality criteria for hospital information systems

The international standard ISO 9000:2000 [ISO (2000)] defines quality as "the degree to which a set of inherent characteristics fulfills requirements". Relating this definition to hospital information systems the quality of a HIS depends on the HIS's ability to meet the needs of the systems' stakeholders. [HAUX R et al. (2004), p. 152 et seq.] described quality requirements of a HIS with respect to the tripartite division of quality into quality of structures, quality of processes and outcome quality. Thus, quality of structures means that all resources both technical and human necessary for information processing are at disposal.

Quality of structures refers to

- quality of data,
- quality of information processing components and
- quality of component integration.

The quality of information processes performed to meet the expectations of users is summarized under the term "quality of processes". Quality of processes means

- that the right information is presented at the right time at the right place to the right people in the right form (*efficiency of information logistics*)
- a task should be supported by as few information processing tools as possible (*leanness of information processing tools*)
- data should only be recorded once but used in every application component where it is needed (*single recording, multiple usability of data*)
- transcribing data from one media to another should be avoided (*controlled transcription of data, no media cracks*)
- information processing should not concentrate on a single institution but on the patient (*patient-centered information processing*)

[HAUX R et. al (2004)].

Outcome quality within a hospital information system centers on the results of information processing. I.e. the hospital information systems should contribute to the goals of information management or rather support the hospital reaching its goals. According to [HAUX R et al. (2004)] outcome quality comprises

- fulfillment of the hospital's goals
- fulfillment of information management laws
- fulfillment of the expectations of different stakeholders.

Below recent literature dealing with the assessment of hospital information systems with respect to three different quality dimensions is reviewed.

2.5.1 Assessing quality of structures

Architectural Quality Criteria

[BRIGL et al. (2005)] introduced a couple of quantitative architectural quality criteria which are a first step to formally assess the quality of structures within hospital information systems. As basic concepts for the definition of ratios, the 3LGM² terminology (namely enterprise functions, application components, application component configurations, database systems, entity types and software products) was used (cf. 2.3.2.). To understand the ratios listed in Table 2 the following abbreviations are necessary.

is … a $3LGM^2$ conform HIS model

$\underline{EF}$ … the set of enterprise functions

$\underline{ACC}$ … the set of application component configurations

$\underline{DBS}$ … the set of database systems

$\underline{ET}$ … the set of entity types

$\underline{SWP}$ … the set of software products

xyz_no … number of elements xyz, e.g.

$cbacc\_no$ … number of computer-based application component configurations

$pbacc\_no$ … number of paper-based application component configurations

Architectural Quality Criteria	Equation/Condition	Interpretation
(1) Functional Redundancy	$FRED_{IS}(is) := \frac{\sum_{ef \in EF_{US}} FSUP_{EF}(ef)}{\max\left(1, \left\|\underline{EF_{RED}}\right\|\right)}$ with $FSUP_{EF}(ef) := acc\_no(ef) - 1$ and $EF \neq \emptyset$	If $FRED_{IS}(is) > 0$ the information system is functionally redundant, i.e. enterprise functions are supported by more than one application component on average.
(2) Functional Undersaturation	$FUS_{IS}(is) := \frac{\sum_{ef \in EF_{US}} FSUP_{EF}(ef)}{\left\|\underline{EF}\right\|}$	$FUS_{IS}(is) < 0$ indicates undersaturation of the information system is, otherwise it is functionally saturated. Functional undersaturation means that at least one enterprise function is not supported by any application component.
(3) Functional Correspondence	Functional correspondence • of an enterprise function is given iff $FSUP_{EF}(ef) = 0$ • of an information system is given iff $FRED_{IS}(is) = 0 \ and \ FUS_{IS}(is) = 0$	If an enterprise function is only supported by exactly one application component configuration functional correspondence is indicated. The principle can analogously be applied to the whole information system.
(4) Data Redundancy	$IRED_{IS}(is) := \frac{\sum_{et \in ET_{RED}} ISI_{ET}(et)}{\max\left(1, \left\|\underline{ET_{RED}}\right\|\right)}$ with $ISI_{ET}(et) := dbs\_no(et) - 1$ (Informational Storage Indicator of an entity type)	IRED calculates for entity types mean numbers of databases where they are redundantly stored. $IRED_{IS}(is) = 0$ indicates informational leanness. Values >0 stand for informational redundancy.

(5) Informational Correspondence	Informational correspondence • of an entity type is given iff $ISI_{ET}(et) = 0$ • of an information system is given iff $IRED_{IS}(is) = 0 \; and \; IUS_{IS}(is) = 0$ IUS_{IS} is an analogon to FUS_{IS}.	Informational correspondence means that one entity type is only stored in one database or all the entity types of an information system are each stored in only one database, respectively.
(6) Degree of Computer Support	$DCS(is) := \frac{\sum_{ef \in \underline{EF}} cbacc\_no(ef)}{\sum_{ef \in \underline{EF}} (pbacc\_no(ef) + cbacc\_no(ef))}$	$DCS(is)$ relates the number of all computer-based application component configurations to the total number of application component configurations.
(7) Degree of Heterogeneity	$HG(is) := \lvert \underline{SWP} \rvert - 1$	A HIS is homogeneous if $HG(is) = 0$, i.e. there is only one software product within the HIS.

Table 2 Architectural Quality Criteria according to [BRIGL B et al. 2004]

The functional redundancy measure calculated by FRED (1) determines whether the information system is functionally redundant or not. Comparing the FRED value of two information systems a statement about lower or higher functional redundancy is possible, too. However, there is no interpretation for the concrete value >0. Therefore [WINTER A et al. (2007b)] defined an algorithm for calculating FRR – the functional redundancy rate of an information system. FRR relates to the set of application systems supporting the set of enterprise functions within an information system. FRR indicates how many percent of the application systems used in an information system could be omitted at most without losing the support of any enterprise function.

For calculating the FRR, the support of enterprise functions $\underline{EF}:=\{ef_1,\ldots,ef_P\}$ by application components $\underline{AS}:=\{as_1,\ldots,as_N\}$ is represented by a matrix $SUP := (\mathrm{sup}_{p,n})_{p=1\ldots P, n=1\ldots N}$ with $sup_{p,n} \in \{0,1\}$.

$$sup_{p,n} := \begin{cases} 1 & \text{if the function } ef_p \text{ is supported by the application system } as_n \\ 0 & \text{else} \end{cases}$$

See Figure 8 for an example of a SUP matrix.

		application systems					
		as_1	as_2	as_3	as_4	as_5	as_6
Enterprise functions	ef_1	1	0	0	0	0	1
	ef_2	0	0	1	1	0	0
	ef_3	0	1	0	1	0	1
	ef_4	1	0	1	0	1	0

Figure 8. Example of a matrix SUP

[WINTER A et al. (2007b)] developed an algorithm to find all “minimal functionally non-redundant sets of application systems” $\underline{AS_{min}}$. (In the example in Figure 8 {as_1, as_4} and {a_3,a_6} are $\underline{AS_{min}}$.) The algorithm for that NP-hard problem is based on decision trees.

The cardinality M of the sets $\underline{AS_{min}}$ is adopted in the measure for the FRR:

$$FRR = \frac{N - M}{N}$$

N is the total number of all application systems.

The architectural quality measures introduced mainly focus on quality of structures. They may help to quantitatively assess HIS architectures, reveal weaknesses and can help to compare hospital information systems.

From Fragmentation to Integration

According to [HASSELBRING (2000), WENDT T (2006)], vertical fragmentation of an information system means that different persons in different organizational units use different application systems to fulfill different or even equal enterprise functions. I.e. every organizational unit has its own business architecture, application architecture and technology architecture. Vertical fragmentation should be resolved by horizontal integration in order to support business processes independently from organizational units [HASSELBRING W (2000)].

Generally, “integration is a union of parts making a whole, which as opposed to its parts, displays a new quality“ [HAUX R et al. (2004), p. 127]. In the context of information systems there are different types of integration, e.g. [WENDT T (2006)] divides between physical integration, data integration, functional integration, semantic integration, contextual integration, presentation integration and access integration, which are defined in the following ways.

- Physical integration is provided, if the necessary physical infrastructure for any data exchange is available [WENDT T (2006)].

- Data integration is provided if certain data, e.g. hospital case data must only be recorded once even if the respective information is needed for the work with other application systems [WENDT T (2006)].
- Functional integration is provided if functions which are needed in different application systems are implemented only once and can then be invoked from the application systems, e.g. the presentation of findings on a screen or the coding of diagnoses and procedures [WENDT T (2006)].
- Semantic integration is provided if different application systems use the same concepts, i.e. data is interpreted the same way [WENDT T (2006)].
- Context integration is provided if during the interaction with different application systems a certain context, e.g. the context of signing on or the context of a patient, must only be established once but is then adjusted automatically between the application systems. [WENDT T (2006)].
- Presentation integration is given if input elements and presentation elements for the same data are equal or similar in different application systems and need not be learned newly [WENDT T (2006)].
- Access integration is realized if application components needed for a certain task are available where they are needed [HAUX R et. al (2004)].

[WENDT T (2006)] uses the $3LGM^2$ terminology introduced in 2.3.2 as a basis for defining methods to assess data integration, functional integration, semantic integration and context integration. Furthermore, [WENDT T (2006)] extends the metamodel $3LGM^2$ to $3LGM^2_A$ to improve the assessment of integration within $3LGM^2$ models of information systems.

2.5.2 Assessing outcome quality

With the so-called "HIS-monitor" [AMMENWERTH E et al. (2007)] introduced an instrument to assess outcome quality criteria of hospital information systems. The HIS-Monitor assesses to what extent the expectations of different stakeholders are fulfilled, regarding the support of patient care activities by information processing tools. For that purpose questionnaires for nurses, physicians and administrative staff are prepared. The questions refer to a set of defined process steps of patient care, e.g. patient admission that is subdivided into appointment scheduling, administrative admission and clinical admission. The answers are given on a 4-point Likert scale ranging from "bad" to "good", from "not adequate" to "adequate" or from "seldom" to "frequently". The results of the questionnaire can therefore be analyzed by statistical methods. A pilot test of the HIS-Monitor showed that the instrument can help to assess the quality of a hospital information system. The authors suggest that the HIS-Monitor could be used for assessing the quality of the HIS at a particular moment, for monitoring the quality of a HIS and, finally, for comparing different organizational units and hospitals.

2.5.3 A comprehensive collection of quality criteria for hospital information systems

To provide IT departments with a catalogue of 'best practices' for the implementation of hospital information systems, [VAN DEN BOSCH B et al. (2002)] composed a collection of recommendations and quality criteria for HIS. From a practical point of view the authors give concrete advice on what principles should be realized within a HIS. Thus, they focus on quality of structures and quality of processes. The following issues are discussed on different levels of detail within their paper.

- **Architecture and integration of the HIS**: types of architectures (connected vs. integrated systems), splitting the HIS by user groups or departments, technical options for data exchange (syntax for data exchange, operational reliability, performance), component integration
- **Content-Related Structure**: data organization (patient numbers, codings, structuring), functionality provided by the HIS
- **Availability of the Computer System**: techniques to limit unavailability (e.g. backup, hardware redundancy, clusters), redundancy criteria for a HIS
- **Archiving**: physical problems (choice of media) and logical problems (choice of file formats)
- **Security**: access control, authentication, authorization, management of users, automatic blocking of a session in the case of inactivity, auditing, encryption and digital signature, viruses, worms and Trojans, physical access to computer systems, theft of laptops, access for hardware support, internet access, virtual private networks, access control at application level
- **Key Issues in Project Management**: purchasing negotiations, composition of decision-making bodies, make-or-buy decisions, user training, emergency procedures
- **PACS – 'Picture Archiving and Communication Systems'**: individual aspects of a PACS, integration of PACS into the whole IT infrastructure
- **Telematics**: security in telematics, technology for tele-interaction between persons, telelinking of and telelinking to medical files

2.5.4 Accreditation of hospital information systems

Accreditation organizations certify institutions that meet predefined quality standards [HAUX R et al. (2004)]. There are a lot of healthcare accreditation organizations in different countries, e.g.

- JCHCQ (Japan Council for Healthcare Quality), Japan
- The Joint Commission (formerly known as JCAHO – "Joint Commission on Accreditation of Healthcare Organizations"), USA
- KTQ (Cooperation for Transparency and Quality in Healthcare), Germany

Organizations like these usually base their accreditation programs on the ISO 9000 norm and assess the overall quality management within a hospital [HAUX R et al. (2004)]. Thus, the quality of information management or some aspects of the information system are also inherent to the quality standards. For example, the German KTQ audits as one of six major issues the "flow of information" within a hospital and therefore assesses the following claims [KTQ (2007)]:

- Handling of patient data: There exists a coordinated procedure in the hospital that assures the acquisition, documentation and availability of patient data.
- Transmission of information: There exists a coordinated procedure in the hospital that assures the adequate transmission of information.
- Usage of information technology: Within the scope of supplying patients, information technology is used to improve effectiveness and efficiency.

The claims are formulated very generally and do not dictate best practices.

2.6 Comparison studies

There are few comparisons of HISs available and they often analyze the adoption and the current use of IT for different tasks within a hospital. Three of these comparison studies, especially the applied methods, are presented in this chapter.

"Status and Perspective of Hospital Information Systems in Japan" [HARUKI Y et al. (1999)]

[HARUKI Y et al. (1999)] evaluated the status and the future plans for hospital information systems in Japan. They quantitatively analyzed the use of computer-based application systems and their benefits in hospitals belonging to the Japanese Hospital Association. For this purpose hospital managers were asked to answer questionnaires about the use of four categories of subsystems, namely (a) Dedicated Management Systems (supporting e.g. patient billing, the management of medical records, diagnostic and therapeutic procedures etc.) (b) Order Entry Systems for Outpatients, (c) Order-Entry Systems for Inpatients and (d) Reference Systems and Other Applications (e.g. references to patient information, medication history, test results etc.). The authors collected information about

- the hospital profiles and the persons responding to the questionnaire,
- the current use of subsystems belonging to the groups (a), (b), (c) and (d),
- the expected and the real impact of introduced subsystems,
- the causes which impeded the introduction of certain subsystems,
- planned future improvements of the HIS and
- user attitudes towards planned subsystems.

The exact questions asked are not available, it is therefore not clear how, for example, the effects of the introduced subsystems were measured. From the analysis results it can be inferred that most of the questions could be answered with yes or no. Some of the results are described below.

[HARUKI Y et al. (1999)] found that at the time of the questionnaire at least 95% of the hospitals used one dedicated management system and approximately half of the hospitals had certain reference systems. Order entry systems were not yet widely used. According to the users' expectations, dedicated management systems could efficiently decrease office work. Besides facilitating office work, order entry systems and reference systems helped to shorten the waiting time of patients. Nevertheless, the introduced computer-based subsystems could not increase incomes or reduce expenditures of the hospitals. The missing benefits and high costs for the introduction of new subsystems were the main reasons for hospitals having not yet introduced certain systems.

"Exploring Hospitals' Adoption of Information Technology" [BURKE DE et al. (2002)]

Besides the use of IT in hospitals [BURKE DE et al. (2002)], examine the coherence between IT adoption, organizational factors and market factors. The so-called Dorenfest database which stores IT data of over 4000 hospitals is the data source for the study. The IT profile of the hospitals is determined by calculating four scores for the adoption of administrative IT, clinical IT and strategic IT as well as the overall adoption of IT. Administrative IT comprises, for instance, billing systems and human resources systems. Clinical IT covers all systems that support patient care. Systems that support managerial decision-making tasks like cost accounting are treated under the term 'strategic IT'. The factors are calculated by dividing the hospitals' IT adoption for the different functions by a measure for the respective available IT. The latter was established using the Dorenfest database. Furthermore, organizational measures like the numbers of beds and market factors like the proportion of available beds in the market area are captured. T-tests are performed to measure the influence of organizational factors and market factors on IT.

[BURKE DE et al. (2002)] discovered a correlation between high overall IT adoption and the adoption of strategic IT. They give the reason that only hospitals well equipped with administrative and clinical IT have necessary electronic data for strategic systems. On the other hand, a low IT adoption often concurs with the adoption of administrative systems. Furthermore, hospital size, ownership and market competition positively affect the adoption of IT.

"Clinical information technology in hospitals: A comparison between the state of Iowa and two provinces in Canada" [JAANA M et al. (2005)]

[PARÉ G and SICOTTE C (2001)] and [JAANA M et al. (2005)] also investigated hospitals in two countries with respect to the use of information technology. In particular, they focused on IT sophistication. [PARÉ G and SICOTTE C (2001)] introduced a measurement to assess information technology sophistication by analyzing "functional sophistication", "technological sophistication" and the "integration level" of hospital information systems.

- Functional sophistication refers to processes supported by computer-based application systems. A binary measure was used, every computerized process (e.g. inpatient pre-admissions, bed availability estimation, results reporting, operations' booking) was scored with 1.
- Technological sophistication declares how extensively certain technologies (e.g. voice recognition systems, bar coding, extranet links, PACS) are used in respective departments of a hospital. A scale ranging from zero to 7 was introduced, zero means "not available", 1 represents "barely used", 7 indicates "extensively used".
- Integration level investigates to what extent the computer-based systems are integrated with other systems both internally and externally (e.g. integration among patient management applications, integration between patient care systems and external entities computerized systems). Again a 1-7 scale measures whether the systems are integrated "not at all" up to "very much".

[PARÉ G and SICOTTE C (2001)] applied the introduced measurement to hospitals in the two largest provinces of Canada. Finally, [JAANA M et al. (2005)] used the measurement to assess the IT sophistication of hospitals in Iowa, USA, and then compared the results of the Canadian and the US-American study. The studies based on questionnaires sent to the respective hospitals. Therefore, like in [HARUKI Y et al. (1999)] the surveys also acquired information about general characteristics of the surveyed hospitals and the responding persons.

The questionnaires were analyzed with the help of statistical tests. The authors reveal differences in the IT sophistication of hospitals in Iowa compared to Canada. Hospitals in Iowa adopt more technologies, but the support of processes and the integration of patient management activities are lower than in Canada. At both locations technological sophistication is only weakly developed.

3 Approach

In this thesis two hospital information systems are compared. Whereas hospital information systems within one country may have many similarities due to similar healthcare markets, crossing country borders could reveal interesting differences of hospital information systems in different countries. Therefore a Japanese and a German HIS were chosen for the comparison. Comparing just two hospitals implies that this work is not meant to be a study that comes to general conclusions about all hospital information systems in Germany and Japan. Rather, Japanese as well as German health informatics professionals can gain a first insight into hospital information systems of the respective other country. For that purpose this thesis provides with the results of comparing two representatives of HISs in both countries with respect to certain criteria.

Before starting the comparison a structured method to compare hospital information systems has to be established. 3LGM² models (see 2.3.2) and the Reference Model for the Domain Layer of Hospital Information Systems (see 2.3.3) were determined as a basis for the comparison. Therefore the method to be developed for comparing the HIS depends on criteria that are assessable by means of the 3LGM² approach. In Chapter 4 possible criteria introduced in 2.4, 2.5 and 2.6 are selected according to their analyzability by 3LGM² and the methodological procedure to apply the criteria is developed.

For using the developed method to compare hospital information systems 3LGM² models of the hospital information systems of Chiba University Hospital and the University Hospital of Leipzig are required. Chapter 5 describes how a 3LGM² model of Chiba University Hospital was devised for this research during a 6-week stay at the Department of Medical Informatics and Management (Chiba University Hospital). A 3LGM² model of the University Hospital of Leipzig, which is shortly described in chapter 5.3, is already available and hence, can immediately be used for the comparison. The organizational environments in which both HISs are maintained are introduced in Chapter 6.1 in order to understand the results of the comparison presented from Chapter 6.2 to 6.4. For every criterion, descriptions of both HISs are given, similarities and differences are pointed out and the respective consequences for both HIS are discussed. A summary answering the questions posed in 1.4 follows in chapter 7. Finally, the significance of a comparison by means of 3LGM² models is discussed in chapter 9 which also suggests further aspects worth examining in terms of comparisons of hospital information systems.

4 A method for comparing HISs on the basis of 3LGM² models

As introduced in chapter 1 the comparison of the hospital information systems is based on 3LGM² models (cf. 2.3.2) and the Reference Model for the Domain Layer of Hospital Information Systems (cf. 2.3.3). The first step towards a method for comparing hospital information systems concentrates on excluding criteria that cannot be analyzed by means of 3LGM² and identifying those criteria that are assessable with the help of 3LGM² models. Finally, the applicability of the 3LGM² tool and the Reference Model for the Domain Layer for a structured comparison according to the selected criteria is examined. The objective of this chapter is a catalogue of comparison criteria for a comparison by means of 3LGM² models.

4.1 The 3LGM² tool and the Reference Model for the Domain Layer in the context of the comparison

With the help of the three-layer graph-based metamodel the elements of a hospital information system architecture and their relationships can be described on the domain layer, the logical tool layer and the physical tool layer. For the domain layer of a HIS, which is assumed to be similar in different hospitals, the Reference Model for the Domain Layer determines enterprise functions and entity types to be valid in every hospital.

Below the key features of 3LGM² and the 3LGM² tool as well as the Reference Model for the Domain Layer of Hospital supporting a structured comparison of HISs are summarized.

The three-layer graph-based metamodel and the 3LGM² tool,

- provide a clear terminology for the components of a HIS by assigning the elements of a HIS to certain element classes
- provide a functional perspective on a HIS as well as perspectives on the logical and physical IT infrastructure according to the three layers
- provide graphical analyses, the calculation of key figures and the extraction of tables that focus on architecture elements and the relationships between them
- support a uniform graphical representation of HISs

(cf. 2.3.2).

The reference model for the domain layer of hospital information systems

- provides unique concepts for enterprise functions and entity types on the domain layer of a HIS
- is a means for comparing HISs starting from equal enterprise functions that are supported in different ways in different HISs

- is documented as a 3LGM² model

(cf. 2.3.3).

Providing a static view on the architecture of a hospital information system a 3LGM² model restricts the range of criteria for comparing different HISs. Therefore possible criteria for a comparison are identified below.

4.2 Identification of criteria

Sections 2.4, 2.5 and 2.6 introduced different approaches for categorizing, assessing, evaluating and comparing hospital information systems. At this point these approaches are reviewed according to their relevance for a comparison by means of 3LGM². Initially, a rough collection of criteria assessable by 3LGM² models is composed. In 4.5 this collection is further specified by working out a method to compare HISs.

Ad 2.4 Classification criteria for hospital information systems

In section 2.4 architectural styles for the logical tool layer and the physical tool layer [HAUX R et al. (2004)] of an information system were introduced. Because 3LGM² models describe the architecture of an information system, architectural styles helping to categorize HIS can be selected for a catalogue of comparison criteria.

Ad 2.5 Quality criteria for hospital information systems

A wide range of quality criteria for hospital information systems was presented in section 2.5. [HAUX R et al. 2004] distiguish between quality of structures, quality of processes and outcome quality.

For assessing quality of structures, key figures like the Functional Redundancy Rate [WINTER A et al. (2007b)] and the Degree of Heterogeneity [BRIGL B et al. (2005)] are suitable (cf. 2.5.1). The measures for Functional Redundancy and Functional Undersaturation according to [BRIGL B et al. (2005)] are neglected in favor of the Functional Redundancy Rate according to [WINTER A et al (2007b)] because the newer key figure is easier to interpret in terms of consequences for the information systems. As the key figures were defined based on the concepts of 3LGM² they are relevant for a comparison by means of 3LGM².

The assessment of the fragmentation of an information system [HASSELBRING W (2000)] and integration, for example according to [WENDT T (2006)], play an additional role for comparing information system architectures based on 3LGM² (cf. 2.5.1). However, the measures introduced by [WENDT T (2006)] are not adoptable because they are based on the extended metamodel $3LGM^2_A$ which is not yet implemented in the 3LGM² tool. Thus, a sufficient procedure for assessing integration in current 3LGM² models has to be worked out when introducing the method for the comparison.

Measuring the quality of processes which focuses on information processes is of minor importance for the comparison because 3LGM² models mainly focus on the static view of an information system. However, criteria like the “leanness of information processing tools” and “single recording, multiple usability of data” (cf. 2.5, [HAUX R et al. (2004)]) can to some extent be assessed by 3LGM². The leanness of information processing tools, for example, will implicitly be referred to when examining the functionality of subsystems later on. Data recorded once and used multiple times is an aspect of data integration and can therefore be covered by assessing integration. Thus, quality of processes can partly be examined by a comparison based on 3LGM² models.

Outcome quality relates to the fulfillment of a hospital’s goals and the fulfillment of the stakeholder’s expectations (cf. 2.5, [HAUX R et al. (2004)]). An assessment in terms of 3LGM² models is not possible. Outcome quality can rather be examined by interviewing the users of an information system as it was done in ([AMMENWERTH E et al. (2007)], cf. 2.5.2).

In 2.5.3 a collection of quality criteria for hospital information systems was introduced. According to the structure (see Table 3) of the paper by [VAN DEN BOSCH B et al. (2002)], which focuses on concrete realizations and structural issues of a HIS, further possible criteria for a comparison by 3LGM² models are identified.

Structure of [VAN DEN BOSCH B et al. 2002]	
1	Architecture and integration of the HIS
2	Content-related structure
3	Availability of the computer system
4	Archiving
5	Security
6	Key Issues in Project Management
7	PACS
8	Telematics

Table 3. Major criteria for the comparison (cf. 2.5.3)

Criteria related to ‘1 Architecture and integration’ were already identified as relevant for the comparison. Besides categories for information systems and integration [VAN DEN BOSCH et al. (2002)] regard technical options for data exchange by a certain syntax or standards as a major architecture-related topic. As communication standards are an essential element type describing the communication between application components on the logical tool layer of a 3LGM² model, the use of communication standards is also a suitable criterion for a 3LGM²-based comparison.

‘2 Content-related structure’ according to [VAN DEN BOSCH B et al. (2002)] refers to data organization and functionality of the HIS. Matters of data organization like assuring the integrity of patient numbers rather deal with data quality than architectural aspects of a hospital information system as a whole and can therefore not be assessed in a 3LGM² model. In turn, the idea to examine the functionality of a HIS appears to be a suitable criterion for a comparison based on 3LGM² models and the Reference Model for the Domain Layer. The functions defined on the domain layer are related to application components on the logical tool layer. Thus, the functionality of application components can derive from 3LGM² models. For example, '4 Archiving', '7 PACS' and '8 Telematics', could be considered from a functional perspective. However, a detailed examination of these topics is neglected in favor of a more comprehensive consideration of the information systems.

Concerning '3 Availability', [VAN DEN BOSCH et al. (2002)] state techniques to limit unavailability like hardware redundancies and the use of clusters. On the physical tool layer of a 3LGM² model the use of these kinds of techniques can be examined.

Security measures like authentication techniques and authorization policies ('7 Security') cannot directly be modeled by means of 3LGM². It would merely be possible to define enterprise functions that address security issues and model the application systems and technologies that support these functions. However, the reference model for the domain layer on which the modeled information systems will be based does not contain appropriate enterprise functions. Thus, security is not discussed within the comparison by 3LGM² models.

'6 Key issues in project management' is an important aspect of information management, but does not help to describe a hospital information system and is therefore disregarded.

Finally, chapter 2.5 shortly introduced accreditation organizations for hospitals. Accreditation criteria for hospital information systems cannot be taken into account as comparison criteria because they are either not publicly available in the case of JCAHO or they are too general as shown for the KTQ criteria (cf. 2.5.4).

Ad 2.6 Comparison Studies

The comparison studies from [BURKE DE et al. (2002)] and [HARUKI Y et al. (1999)] focus on the functionality of computer-based application systems which has already been taken to consideration as comparison criterion. Especially the division of subsystems into clinical, administrative and strategic systems according to [BURKE DE et al. (2002)] could be analyzed with the help of the Reference Model for the Domain Layer. As well, measuring the functional sophistication by examining whether processes like 'bed availability estimation' are supported by computerized subsystems in [JAANA M et al. 2005]] serves a similar purpose as the studies by [BURKE DE et al. (2002)] and [HARUKI Y et al. (1999)]. The assessment of technological sophistication according to [JAANA M et al. (2005)] and the integration level on Likert scales is very detailed and cannot adequately be adopted for a comparison by 3LGM² models.

Another important aspect both in [HARUKI Y et al. (1999)] and [JAANA M et al. (2005)] is the examination of the hospitals' characteristics before presenting the results of the comparisons. As this way of proceeding will help to interpret the results of the comparison, the comparison should be initiated by a short characterization of the hospitals.

Identified criteria according to 2.4 – 2.6

Finally, relevant criteria for a 3LGM²-based comparison are (in the order of appearance in this chapter):

- Architectural style of the logical tool layer [HAUX R et al. (2004)]
- Architectural style of the physical tool layer [HAUX R et al. (2004)]
- Key figures for quality of structures (Functional Redundancy Rate [WINTER et al. (2007b)], Informational Redundancy, Degree of Heterogeneity, Degree of Computer Support [BRIGL B et al. (2005)])
- Fragmentation [HASSELBRING W (2000)]
- Integration [WENDT T (2006)]
- Use of communication standards [VAN DEN BOSCH B et al. (2002)]
- Functionality of Subsystems [VAN DEN BOSCH B et al. (2002)] (administrative, clinical, strategic systems [BURKE DE et al. (2002)])
- Availability [VAN DEN BOSCH B et al. (2002)]

In addition, an introduction to the comparison by describing the hospitals and their organizational structures will form the introduction to the comparison based on 3LGM² models.

The next step is to structure the criteria and to develop a method to assess them by 3LGM² models.

4.3 Defining a procedure for the comparison

4.3.1 Initiation of the comparison

As mentioned in 4.2 the comparison will be initiated by characterizations of both hospitals. Thus, section 1 is not an immediate part of the comparison of hospital information systems, but the preparation and preliminary consideration for doing so. The characterizations might help to understand the results of comparing the HISs.

1 Basic facts about the hospitals and information management

1.1 Short characterization of the hospitals
- 1.1.1 Key figures (beds, clinics, patients, staff)
- 1.1.2 Organizational and spatial structure
- 1.1.3 Strategic Goals

1.2 Information Management
- 1.2.1 Organizational Structures of information management
- 1.2.2 Characterization of information management

First, the hospitals will be considered as a whole.

- **Economical key figures**, i.e. numbers of beds, clinics, patients and staff are typical characteristics of hospitals which help to estimate the hospital's size.
- The **organizational and spatial structure** of a hospital might have an influence on the organization of a hospital information system. For example, central, hierarchical structures could lead to a more homogeneous HIS than decentral and flat organizational structures.
- Hospitals usually define **strategic goals** that determine the overall goals to be achieved by the hospital like safe patient treatment or the education of medical staff. As information management in hospitals should contribute to these strategic goals according to [HAUX R et al. (2004)], the inspection of strategic goals might give clues to understand the hospital information system.

In addition to the general characterization of the hospitals the structures of information management will be examined.

- The **organizational structures of information management** can help to understand the priority of the HIS within the hospital or in certain departments where parts of the HIS are maintained.
- Information management in a hospital deals with the management of the components of the hospital information system and therefore helps to understand an information system. Thus, the **characterization of information management**, for example by the information management styles introduced in 2.2, and the description of decision-making processes concerning the development of the hospital information systems establish a basis for the comparison of hospital information systems.

Characterizing the hospitals as well as considering information management within the hospitals has only descriptive and no interpreting character. That means, in terms of the feature characteristics tables and textual descriptions (e.g. in the case of key figures) or only textual descriptions are used to present the characteristics of the hospitals and information management.

4.3.2 A method for comparing HISs on the basis of 3LGM^2 models

In the following a method for comparing hospital information systems on the basis of 3LGM² models is developed. The criteria identified in 4.2 are integrated into a structured catalogue of criteria. Furthermore, all criteria shall be categorized according to their assessability by 3LGM² models and it is determined how the 3LGM² and the 3LGM² tool support the assessment of the related characteristics of the HISs.

The following agreements hold for categorizing the criteria:

- For every criterion the level of measurement is stated. The level of measurement determines the scale on which the criterion can be measured. Key figures like the Functional Redundancy Rate can mostly be measured on a metric scale. For some criteria such an exact assessment is not possible, thus ordinal scales can help. All the ordinal scales to be used are based on a 4-point scale and range from '1' in the sense of 'not supported/used' to '4' in the sense of 'completely supported/used'. '2' means 'supported/used in less than the half of the possible cases' and '3' means 'supported/used in more than the half of the possible cases'. Finally, for some criteria nominal answer sets are sufficient.

- Furthermore, a division into subjective and objective criteria is chosen. Objective criteria are based on an objective measure (e.g. a key figure), whereas subjective criteria can be concluded from a 3LGM² model but there are no means for an objective assessment. For example, those criteria which are based on ordinal scales cannot be determined by a defined key figure and are therefore assessed subjectively.

- For every criterion the formal set of answers will be given. That may be a figure, a rank from 1 to 4 or a short textual description, depending on the chosen scale for the criterion.

As major sets of criteria a division according to the three layers of 3LGM² was chosen. That division is convenient for a comparison based on 3LGM² models, but it has no meaning for the comparison itself. That means the subcriteria assigned to a major set of criteria are mainly related to one of the layers - namely the domain layer, the logical tool layer or the physical tool layer.

- With regards to **Functionality of application systems** a set of criteria that explicitly uses the Reference Model for the Domain Layer of HIS is summarized. More precisely, the relationships between the enterprise functions on the domain layer and the application components on the logical tool layer are examined.

- **Architecture of the Logical Tool Layer** encompasses those criteria that can mainly be analyzed on the logical tool layer of a 3LGM² model. In addition, the relationships to the other layers might help to examine the feature characteristics of the criteria.
- Finally, the **Architecture of the Physical Tool Layer** comprises those criteria assessable on the physical tool layer of a 3LGM² model.

2 Functionality of application systems

2.1 Adoption of Clinical systems
2.2 Adoption of Administrative systems
2.3 Adoption of Strategic systems
2.4 Coverage of the functionality of a subsystem of HIS 1 in HIS 2

The first major set of criteria focuses on the functionality of application systems. The functionality of certain subsystems follows directly from inter-layer-relationships between the logical tool layer and the domain layer. Thus, for a comparison it is important to consider the use of the same functions on the domain layer in different models.

2.1-2.3 Adoption of clinical, administrative and strategic systems

According to [BURKE DE et al. (2002)], the application systems available in a hospital can be divided into clinical systems, administrative systems and strategic systems. For the information systems to be compared, the adoption of computer-based subsystems belonging to clinical, administrative and strategic systems has to be examined. Possibly, similar conclusions to those in ([BURKE DE et al. (2002)], cf. 2.6), such as the joint availability of certain subsystems, can be drawn from that inspection.

First, to find clinical, administrative and strategic systems within a 3LGM² model based on the Reference Model for the Domain Layer of HISs, the functionality of these systems has to be concretely defined in terms of the functions of the Reference Model for the Domain Layer. I.e. clinical, administrative and strategic functions within the reference model have to be identified. Hence, clinical systems can be defined as those systems which support clinical functions, administrative subsystems support administrative functions etc.

Thus, the enterprise functions defined in the reference model for the domain layer must be assigned to clinical, administrative and strategic functions. As the reference model for the domain layer has a similar division into subfunctions, the assignment is immediately possible.

Clinical systems are those computer-based application components supporting all enterprise functions hierarchically organized among the function “1. Patient Treatment” (cf. Appendix A – The hierarchy of functions of the Reference Model for the Domain Layer of HIS). Because the subordinated functions “1.1.2 & 3.1.2 Patient Identification and Identification as Recurrent”, “1.1.3 & 3.1.1 Administrative Admission” and “1.1.6 & 3.1.3 Information Services” can be seen as administrative functions within the reference model they are also subordinated to the function “3. Hospital administration” in the sense of a polyhierarchy.

Administrative systems are, according to [BURKE DE et al. (2002)], computer-based application components that support tasks that do not directly affect patient care, e.g. billing and human resources systems. Thus, application components that support the functions subordinated to “2. Supply Management, Scheduling and Resource Allocation” as well as those functions comprised under “3. Hospital Administration” should be taken into account as administrative systems.

Strategic Systems support decision making at top level. [BURKE DE et al. 2002] lists executive information systems and cost accounting systems as strategic systems. Thus, systems that support “4. Hospital Management” can immediately be attributed to strategic systems. However, systems for “3.4 Controlling” and “3.5 Cost and Results Accounting” ought to be strategic systems, although the functions are subordinated to “3. Hospital Administration” within the reference model.

Consequently, by means of extracting enterprise functions together with the related application components out of a 3LGM² model, clinical, administrative and strategic systems can be identified. According to the sets of functions covered by administrative, clinical and strategic systems in the HIS models the adoption of these application systems is assessed on a 4-point ordinal scale. For example, the adoption of clinical systems is deduced from the number of functions among “1. Patient Treatment” that are supported by computer-based application components. The value ‘1’ on the ordinal scale means that the subfunctions of “1. Patient Treatment” are not supported by available clinical systems, ‘2’ means that less than the half of the subfunctions are supported, ‘3’ means that more than the half of the subfunctions are supported and ‘4’ indicates that all the subfunctions of “1. Patient Treatment” are supported by computer-based clinical systems. The ordinal scale is mainly used to mark a difference between different HISs which could go down when only listing all systems that support clinical tasks.

Whereas the division into administrative, clinical and strategic systems gives a first overview of the computer-based subsystems of the hospitals, the next step focuses on the functionality of a more limited set of application components in different HISs.

2.4 Equivalence of the functionality of a subsystem of HIS 1 in HIS 2

For a set of functions that is supported by a certain application component within one HIS it will be determined what set of application components within the other HIS covers these functions.

Because of the previous knowledge that the so-called 'Electronic Medical Record system' is the central and seemingly most important subsystem of the Hospital information system of Chiba University Hospital, the comparison of a subsystem's functionality shall concentrate on the Japanese EMR system and its equivalent within the HIS of the University Hospital of Leipzig. For the hospital functions supported by the Japanese EMR system a set of subsystems that implements the same range of functions within the HIS of the University Hospital of Leipzig has to be identified.

For that purpose, again, graphical analyses of the 3LGM² tool or analyses via XSLT, which extract enterprise functions together with the application components by which the functions are supported, can be used. The result will be presented as nominal sets of application components in two different models. As a result, an objective assessment of the criterion is possible.

3 Architecture of the Logical Tool Layer

3.1 Architectural style of the logical tool layer
3.2 Use of communication standards
3.3 Fragmentation of the information system
3.4 Exemplary assessment of Informational Redundancy and Data integration
3.5 Access integration
3.6 Functional redundancy rate
3.7 Degree of computer support
3.8 Degree of heterogeneity

The second major set of criteria aims to discuss architecture-related characteristics of the information systems to be compared.

3.1 Architectural style of the logical tool layer

First, to generally categorize the architecture of the logical tool layer, the information systems are classified with respect to the architectural style of the logical tool layer introduced in ([HAUX R et al. (2004)], cf. 2.4.1). It will be determined whether the HISs have the characteristics of a DB^1 or a DB^n architectural style.

Although alone the graphical representation of the logical tool layer of a 3LGM² model by itself illustrates how many databases exist within the modeled information system, further information is necessary for assigning the architectural style of the logical tool layer to a DB^1 or a DB^n style. That additional information can be gained by extracting the dataset types stored in the databases and the transmitted information over communication interfaces between different application components from a 3LGM² model. The same information stored redundantly in different databases is an indicator for a DB^n style. Systems which do not have a database should be examined in terms of the messages they communicate with other application components having a database system. The message types and event types transmitted over communication links might indicate a database access. However, a certain modeling style is assumed for an assignment to a DB^1 or a DB^n architectural style.

Thus, the assignment to a DB architectural style will be based on a subjective assessment. According to [HAUX R et al. (2004)], mixtures of DB^1 and DB^n are common, which leads to a nominal answer set for the architectural style of the logical tool layer, namely‘DB^1’, ‘DB^n’ and ‘mixed form’.

3.2 Use of communication standards

As a next step, the component interfaces will be inspected with regards to the use of communication standards. That means, for the component interfaces it has to be determined whether they use common communication standards like HL7, DICOM or vendor-based communication standards or whether proprietary interfaces are implemented.

The use of communication standards or the implementation of proprietary interfaces can be analyzed with the help of graphical analysis functions or exports via XSLT. For example, an HTML report can be generated by the 3LGM² tool which lists, for every communication standard, the interfaces and communication links where it is used within the modeled HIS.

As there are no key figures to assess the use of communication standards a subjective ordinal scale will be used, ranging from ‘1’=’no use of communication standards’ over ‘2’=use of communication standards at less than the half of the interfaces’ and ‘3’=use of communication standards at more than the half of the interfaces’ to ‘4’=’complete use of communication standards’.

3.3 Vertical fragmentation

It is determined whether the information systems are vertically fragmented according to the description in ([HASSELBRING W (2000)], cf. 2.5.1).

On the basis of application component configurations 3LGM² models can be examined according to vertical fragmentation. An application component configuration consists of an enterprise function and organizational units together with the application components used for fulfilling the enterprise function (cf. 2.3.2). That means, if the same enterprise functions are supported by different application components in different organizational units, horizontal fragmentation is indicated. For example, functions together with the organizational units where they are performed and the application components by which the functions are supported can extracted from a 3LGM² model by XSL reports.

For assessing the vertical fragmentation a 4-point ordinal scale is adopted with ‘1=not vertically fragmented’ to ‘4=completely vertically fragmented’. ‘2’ and ‘3’ distinguish between HISs with few vertical fragments and many vertical fragments with respect to the number of application component configurations which are assigned to a small set of organizational units.

3.4 and 3.5: Exemplary assessment of Informational Redundancy, Data Integration and Access Integration

Horizontal fragmentation can be worked against by integration of the information system. In 4.2 the assessment of integration according to [WENDT T (2006)] turned out to be not yet analyzable by the current version of 3LGM². Therefore another procedure to assess integration by the current metamodel must be found.

Whereas data integration and access integration can to some extent be assessed by current 3LGM² models, for semantic integration, presentation integration, functional integration and context integration (see definitions in 2.5.1) meaningful analyses are not possible in the current 3LGM² version. For example, there are no means to model whether data and user interfaces are represented in the same way in different application systems, which is a major requirement for presentation integration.

With respect to data integration and access integration an exemplary assessment for a representative set of model elements seems to be practicable. First, to assess data integration it is necessary to know in what application components the same information is needed. That can, for example, be analyzed by means of calculating the informational redundancy of entity types (cf. 2.5.1) in a 3LGM² model. If the informational redundancy of an entity type is greater than 0, then it is stored in different databases which belong to different application components. The 3LGM² tool can for this purpose analyze in which database systems a certain entity type is stored. Between these application components having a database system, data integration has to be established. That means multiple input of the same data has to be avoided by sending data from the master system to the application systems where it is needed. That, in turn, can also be assessed with the help of an analysis function of the 3LGM² tool which determines the communication links over which the entity type in form of a message type is sent. If the entity type is not communicated over communication links it can be assumed that data integration is not fulfilled. As there are no means to assess the overall data integration of a 3LGM² model of an information system, for the comparison an important example for data integration in a hospital is chosen: Patient master data is usually recorded when a patient is administratively admitted. Then, if the patient has to go to departments where specialized department systems are used, e.g. a Radiology Department, his patient master data should be available there and not to be entered again. The assessment by means of 3LGM² will be done as follows.

The informational redundancy of the entity type ‘Patient master data’ of the reference model for the domain layer is determined and then it is checked whether the entity type is communicated from the master database system to selected other databases of application components where it is stored. The data integration between the clinical documentation system and the RIS, the LIS and the Pathology Information System are chosen for the analysis because these are application systems which are available in both HIS and in all of these application systems patient master data, i.e. data to identify patients, is needed.

Second, access integration is to be proved. According to ([HAUX R et al. (2004)], cf. 2.5.1) access integration is achieved if application components are available where they are needed for fulfilling a certain task. Within a 3LGM² model an application component has to be chosen for which application component configurations indicate where application components are available and for what task they are used. Simultaneously physical data processing such as PCs or laptops are needed at the locations to use the application components. That means, the physical data processing component configurations (cf. 2.3.2) of the application components, which are needed to fulfill the task, have to be considered with respect to clients in the form of PCs or laptops. Because an overall assessment is not possible, again a representative example for access integration is chosen.

For the comparison of the HIS of Chiba University Hospital and the University of Leipzig the most important systems for medical documentation will be examined regarding the support of the function ‘1.4 Execution of nursing procedures’ because, especially for executing nursing procedures, access integration at the sickbeds on a ward is necessary.

Both data integration and access integration can be either ‘fulfilled’ or ‘not fulfilled’ for the chosen examples.

3.6., 3.7. and 3.8 Functional Redundancy Rate, Degree of Heterogeneity, Degree of Computer Support

Finally, the architecture of the logical tool layer will be described by key figures according to [WINTER A et al. (2007b)] and [BRIGL B et al. (2004)] (cf. 2.5.1). The functional redundancy rate, the degree of computer support and the degree of heterogeneity were chosen to provide an indication of the structural quality of the architectures.

The Functional Redundancy Factor can be calculated by an option of the 3LGM² tool. The degree of computer support can be determined by extracting the number of all application component configurations separated into computer-based and paper-based application component configurations. The ratio of the number of computer-based application systems to the total number of application components can then be calculated. A measure for the heterogeneity of the information systems with regard to the number of different software products can be obtained from the model browser. With the calculation of defined key figures an objective assessment is possible. All three key figures can be quoted on metric scales, whereas the functional redundancy rate and the degree of heterogeneity are measured on a scale from 0 to 100%.

4 Architecture of the Physical Tool Layer

4.1 Architectural style of the physical tool layer
4.2 Use of techniques to limit unavailability

Finally, the third set of criteria concentrates on the physical tool layer of a 3LGM² model. As the metamodel allows many degrees of freedom for modeling the physical tool layer, different modelers can develop very different modeling styles for the logical tool layer what reduces the comparability. Hence, only few criteria will be assessed.

4.1 Architectural style of the physical tool layer

Regarding physical data processing components a division into mainframe architectures and the different types of client-server architectural styles ([WINTER A et al. (2005)], cf. 2.4.2) helps to classify the HISs. Clues for mainframe-based architectures and client-server architectures can be found on the physical tool layer of a 3LGM² model. Extracting the relevant information is, for example, supported by exports via XSLT which create a HTML table of all physical data processing components together with their names, types and location from the physical tool layer of a 3LGM² model. The hospital information systems to be compared are then assigned to a 'mainframe-based architecture', 'client-server architecture' or a 'mixed form'.

4.2 Use of techniques to limit unavailability

Application systems should preferably work without breakdowns. That means the underlying technologies have to guarantee a high availability. For this purpose the comparison can examine which of the techniques and measures listed in ([VAN DEN BOSCH B et al. (2002)], cf. 2.5.3) are used to ensure the availability of the computer system.
With regards to the availability of computer-based systems the physical tool layer, in particular the physical data processing components, of 3LGM² models have to be studied. It is possible to assess the use of the following techniques from the physical tool layer of a 3LGM² model.

- Hardware redundancies (e. g. RAID)
- Clusters
- Replication servers

Moreover, because of the inter-layer relationships between the physical and the logical tool layer, it is assessable what application components are installed on the individual physical data processing components. That implies, for instance, that for a physical data processing component which does not use a technique to avoid unavailability possible failures of related application components can be illustrated within the 3LGM² tool.
As answer sets for the use of techniques to limit unavailability the available techniques are listed.

4.4 The catalogue of criteria

The result of 4.3 is a catalogue of comparison criteria for HIS which is composed as follows.

Major set of criteria[1]	Subcriterion	Level of measurement	Assessment	Set of formal answers
2. Functionality of computer-based subsystems	2.1: Adoption of clinical systems	ordinal	subjective	{⦿○○○;⦿⦿○○; ⦿⦿⦿○; ⦿⦿⦿⦿}[2]
	2.2: Adoption of administrative systems	ordinal	subjective	{⦿○○○;⦿⦿○○; ⦿⦿⦿○; ⦿⦿⦿⦿}
	2.3: Adoption of strategic systems	ordinal	subjective	{⦿○○○;⦿⦿○○; ⦿⦿⦿○; ⦿⦿⦿⦿}
	2.4: Coverage of the functionality of the EMR system within the UKL-KIS	nominal	objective	{EMR system; {<Set of application components of the UKL-KIS>}}
3. Architecture of the logical tool layer	3.1: Architecture style of the logical tool layer	nominal	subjective	{DB^1, DB^n, mixed form}
	3.2: Use of communication standards	ordinal	subjective	{⦿○○○;⦿⦿○○; ⦿⦿⦿○; ⦿⦿⦿⦿}
	3.3: Horizontal Fragmentation	ordinal	subjective	{⦿○○○;⦿⦿○○; ⦿⦿⦿○; ⦿⦿⦿⦿}

[1] The numbering starts with '2.' because '1.' is 'Basic facts about the hospitals and information management.
[2] For the ordinal scales a graphical representation was chosen with 1= ⦿○○○, 2=⦿⦿○○, 3=⦿⦿⦿○ and 4=⦿⦿⦿⦿.

	3.4: Data integration between RIS, LIS, Pathology Information System and the clinical documentation system according to the entity type “Patient Master Data”	nominal	subjective	{fulfilled; not fulfilled}
	3.5: Access integration concerning nurses’ access to the clinical documentation system on wards	nominal	subjective	{fulfilled; not fulfilled}
	3.6 Functional Redundancy Rate	metric	objective	{0…100%}
	3.7 Degree of computer support	metric	objective	{0…100%}
	3.8 Degree of heterogeneity	metric	objective	{0…n}
4. Architecture of the physical tool layer	4.1: Architectural style of the physical tool layer	nominal	objective	{mainframe-based architecture; client-server-architecture; mixed form}
	4.2: Techniques to limit unavailability	nominal	objective	{Hardware redundancy; cluster; replication server; mixed form}

Table 4. Catalogue of comparison criteria for 3LGM² models

When presenting the results for every criterion the formal answer will be followed by descriptions of the respective feature characteristics of both HISs. For nominal and ordinal criteria the descriptions will usually be more detailed in order to explain how the characteristics manifest themselves in the 3LGM² models of the HISs. For example, the architectural style of the logical tool layer (DB^1 and/or DB^n) cannot be discussed without knowing further details about the data stored in one or more databases and related application components. Also assigning a value from 1 to 4 to the use of communication standards does not indicate what communication standards are used for which purpose. The ordinal criteria are also not meant to be a qualitative assessment, but a quantitative assessment which needs to be discussed. Therefore descriptions for both HISs will provide the relevant background information based on the models. On the contrary, metric criteria like the degree of heterogeneity provide values that can directly discussed in comparison with each other.

The conclusions for every criterion will be discussed after the descriptions of both HIS.

Thus, the following structure for examining every criterion is used:

<name of the criterion>

	Chiba	*Leipzig*
<name of the criterion> (<level of measurement>, <assessment>)	<ValueJ>	<ValueG>

Chiba:

For nominal and ordinal criteria concrete manifestations of <ValueJ> are shown with the help of the model. Metric criteria are commented on shortly.

Leipzig:

For nominal and ordinal criteria concrete manifestations of <ValueG> are shown with the help of the model. Metric criteria are commented on shortly.

Discussion:

The similarities and differences relevant to the criterion are discussed and conclusions for the feature characteristics are drawn.

4.5 Summary

A structured catalogue of criteria for comparing hospital information systems on the basis of 3LGM² models and the Reference Model for the Domain Layer was developed. Among three major sets of criteria, namely the functionality of application systems, the architecture of the logical tool layer and the architecture of the physical tool layer, 15 sub-criteria were defined which can be analyzed by means of 3LGM² models. To initiate the comparison and to have a basis for interpreting the results of the comparison, basic information about the hospitals to be compared and information management within the hospitals will be provided.

Before analyzing the HIS of Chiba University Hospital and the HIS of the University Hospital of Leipzig in terms of the 15 criteria, descriptions of the HISs in the form of 3LGM² models are needed. While a 3LGM² model of the HIS of the University Hospital of Leipzig is already existing, a model of the HIS of Chiba University Hospital has to be created from scratch. In order to be able to apply the comparison criteria, it is also necessary to use the Reference Model for the Domain Layer. For the Japanese model it is important to base upon it from the beginning of modeling. It is advantageous that the 3LGM² model of the HIS of the University Hospital of Leipzig already contains the Reference Model for the Domain Layer and does therefore not have to be changed before comparing it to the Japanese model.

5 Modeling the HISs to be compared

For the concrete comparison of the hospital information systems of Chiba University Hospital and the University Hospital of Leipzig only the hospital information system of Chiba University Hospital has to be modeled from scratch by means of 3LGM². 5.1 and 5.2 explain how the modeling phase was prepared and to what extent the plan could be realized. Furthermore, intricate modeling decisions are described.

A model of the HIS of the University Hospital of Leipzig is already available and shortly introduced in 5.3.

5.1 A Procedure Model for modeling the HIS at Chiba University Hospital

It was aimed to follow the procedure of planning initiation and collecting data about an information system introduced in [SPEWAK SH and HILL CH (2001)], (cf. 2.3.4). Nevertheless, as this study did not aim at planning a new enterprise architecture but rather at acquiring a model of the current state of the HIS of Chiba University Hospital, the steps L1.1 to L1.7 of [SPEWAK SH and HILL CH (2001)] introduced in 2.3.4 were adapted to the needs of modeling the current state of an information system. Therefore the steps L1.1 to L1.7 from chapter 2.3.4 were executed as follows.

L1.1* Determining scope and objectives for modeling the HIS of Chiba University Hospital
The scope and the objectives as described in the introduction of this thesis were given to the Department of Information and Management at Chiba University Hospital in advance.

L1.2* Initial meeting with the cooperation partners from Chiba University Hospital
During a first meeting with the Japanese cooperation partners in Germany the project was set in motion. A duration of 6 weeks was agreed upon for a stay of the author of this thesis at Chiba University Hospital.

L1.3* Adapt a methodology.
The general procedures for collecting data and modeling the Hospital information system of Chiba University Hospital were specified and later fixed in the workplan (Table 5).

L1.4* Choosing a toolset.
As a tool for modeling the Hospital information system of Chiba University Hospital the 3LGM² tool was determined in advance.

L1.5* Assembling the team.
The help of the staff of Chiba University Hospital, especially of the Department of Information and Management, was essential for

understanding the Hospital information system of Chiba University Hospital (cf. Table 5).

L1.6* Preparing a workplan for modeling the HIS of Chiba University Hospital.
The workplan/schedule was prepared. For each of the six weeks the schedule lists the planned tasks and staff members of the department who might help to answer questions arising while executing these tasks (Table 5). In turn, the workplan follows the steps of 'Business Modeling' and 'Current systems & Technology' introduced in 2.3.4.

L1.7* Obtain commitment.

The schedule was presented to the Department of Medical Information and Management of Chiba University Hospital in advance to guarantee the feasibility of the study. Furthermore, the objectives of the study were discussed in a first presentation at the beginning of the period of six weeks at Chiba University Hospital.

WEEK	TASKS	INVOLVED PERSONS
Week 1	"Get to know and understand the hospital" • Getting an overview of the organizational structure of the hospital (organizational units and important persons) • Understanding the hospital's business strategy and strategic goals and their impact on information management • Identifying contact persons for interviews, getting in contact with them • Collecting first material • Evaluating the expectations of the Department of Medical Information and Management in terms of a model of the information system	Professor Takabayashi / Professor Suzuki, other staff of the Department of Medical Informatics and Management
Week 2	"Data collection (1)" • Ensuring the applicability of the German "Reference model for the domain layer" which includes enterprise functions and entity types for the domain layer of hospitals • Adapting the reference model if necessary and using it as a starting point for data collection/modelling	Professor Takabayashi / Professor Suzuki or other staff of the Department of Medical Informatics and Management, possibly other contact persons

	• Collecting material/documents (e.g. about application components, communication standards, underlying technologies) • Translating the documents • Interviews with contact persons (e.g. doctors, nurses, IT staff) if necessary and possible	like doctors and nurses
Week 3	“Data collection (2) and start of modeling” • Continuing data collection / interviews and translation • Arranging the collected data • Beginning to transfer the collected data into a 3LGM² model	Staff of the Department of Medical Informatics and Management, other contact persons
Week 4	“Core modelling phase” • Preparing a 3LGM² model of the information system of the Chiba University hospital	
Week 5	“Completion of the model” • Clarification of last questions • Last modeling tasks • Checking the quality of the model • Summarizing information about the hospital/ the information system which is not directly part of the model	Staff of the Department of Medical Informatics and Management, other contact persons
Week 6	“Presentation of results and time buffer” • Presentation of the information system model • Handing over the model • Time buffer for possible delays	Professor Takabayashi / Professor Suzuki, other staff of the Department of Medical Informatics and Management

Table 5. Schedule for Chiba

According to [SPEWAK SH and HILL CH (1992)] the first steps planned for the first two weeks include the creation of a preliminary business model (see 2.3.4, L2.1.1-L2.1.3), i.e. the documentation of the organizational structure together with the enterprise functions. However, using a reference model that already defines enterprise functions for hospitals changes the scope such that the overall applicability of the reference model for the Japanese hospital has to be checked. The Enterprise Survey (see 2.3.4, L2.1.4-L2.1.8) that is aimed at completing the business model concerning enterprise functions and the information used by them also plays a minor role within the plan because besides enterprise functions the reference model contains entity types which represent the information communicated in a hospital. From the second week on the plan envisages collecting data about Current Systems and Technology (see 2.3.4, L2.2.1-L2.2.8). On the one hand, that data can be collected in the form of written system documentations, on the other hand by interviewing staff of the Department of Medical Informatics and Management or staff (doctors, nurses and technical staff) from other departments. In both cases language problems carried a risk and had to be expected. Therefore detailed plans for data collection could not be worked out in advance from Germany. The data collection was planned to be followed by turning the data into the 3LGM² model of the Hospital information system of Chiba University Hospital. During the fifth week it should be mainly checked with the help of the staff of the Department of Medical Informatics and Management whether the collected data and the model were correct. After entering possible changes the model should be presented to the department in the last week.

5.2 Practical Implementation of the Procedure Model

For modeling the hospital information system of Chiba University Hospital the author spent approximately six weeks (June 6th until July 20th 2007) at the Department of Medical Informatics and Management belonging to Chiba University Hospital. During this time it was tried to model the HIS of Chiba University Hospital in accordance with the proposed schedule. In most parts, the plan could be followed, particular activities and slight changes are summarized in the following chapters that relate to the planned tasks of the plan for the single weeks.

5.2.1 Week 1: Get to know and understand the hospital

The first week helped to gain an overview about Chiba University Hospital, its economical key data and organizational structure as well as the information management style and structures. The results of checking the setting in which the hospital information system is embedded are presented in chapter 6.1. Furthermore, tours through the hospital guided by Professor Takabayashi and the introduction to staff of different departments in their working environments helped to get a first impression of the information system of Chiba University Hospital.

5.2.2 Week 2 and 3: Data collection

Concordance with the sequence of the plan:

It turned out that the chronological order “First collecting all material, then modeling” would not have been effective because between getting new documents and making interviews there was enough time to enter collected data into the 3LGM² model. Apart from that the sequence of the plan could be followed.

Interviewing staff at Chiba University Hospital:

Within the Department of Medical Informatics and Management there was at least one contact person available at all times. Hence, interviews and consultations could be planned on short notice and uncomplicated. The following information within the scope of interviews within the department.

- Basic information about the hospital including organizational structures, business strategy, way of information management (Week 1 and 2, Professor Takabayashi, Professor Suzuki)
- Enterprise functions and entity types (For this purpose the applicability of the Reference Model for the Domain Layer was analyzed, Week 1 and 2, Professor Takabayashi, Professor Suzuki).
- Information about the application systems, especially the EMR system, the functions which they support, their communication links and databases (Weeks 2 to 4, Mr Kyo MD from TSMED, Professor Takabayashi, Professor Suzuki)
- Information about the functionality of the nursing part of the EMR system (Mrs Suetaka, nursing manager)
- Information about physical data processing components and networks (Week 3 and 4, Mr Kyo MD)

As Professor Takabayashi and Professor Suzuki are also practicing doctors at Chiba University Hospital, further interviews with doctors of particular departments were not carried out, also due to time constraints.

Interviews outside the Department of Medical Informatics and Management were carried out in those departments where specialized department systems are used and administrated, i.e. in diagnostic departments and the pharmacy department. These interviews had to be scheduled and were mostly carried out in company of Professor Suzuki or Professor Takabayashi due to language barriers. Within the six weeks interviews in the following departments could be arranged:

- Radiology Department (2007-06-20)
- Pathology Department (2007-06-30)
- Laboratory Department (2007-07-11 and 2007-07-12)
- Pharmacy Department (2007-07-11)

All interviews were prepared by creating forms and questionnaires. Because many of the interviews could be combined with a tour through the hospital or its departments and the demonstration of the application systems, much additional information could be collected.

Usability of the system documentation:

As expected all the system documentation was only available in Japanese. With the help of the persons mentioned above overviews of the application systems and their communication links as well as network charts could be translated to English. Using the Japanese system overviews together with their English translations proved to be helpful during the interviews both inside and outside of the Department of Medical Informatics and Management.

The reference model of the domain layer in the context of data collection

While establishing whether the enterprise functions of the reference model for the domain layer are suitable to describe the HIS of Chiba University Hospital, it was investigated which application component supported the confirmed enterprise functions. Thus, with the help of the reference model, application components on the domain layer and their relationships with the domain layer could be identified. On the basis of documents about the application systems it was then asked what enterprise functions they support. By that bidirectional questioning style a greatest possible completeness should be achieved.

5.2.3 Week 3 and 4: Modeling

Collected information relevant to the model had to be adequately translated into the modeling language. Important decisions to be made during modeling the hospital information system of Chiba University Hospital according to the plan in 5.1 are summarized below.

Using the Reference Model for the Domain Layer of Hospital Information Systems

The Reference Model for the Domain Layer of Hospital Information Systems was only available in German. For that reason it had to be translated to English before travelling to Chiba. With the help of the descriptions of hospital functions in [HAUX et al. (2004)] the correct names of enterprise functions and entity types as well as their descriptions could be migrated into an English version of the reference model. In this thesis only the English translations of reference model elements are used.

On the whole, the suitability of the Reference Model for the Domain Layer of the HIS of Chiba University Hospital could be verified. That suitability was established for both the applicability of the enterprise functions and the entity types defined in the reference model. However, some changes had to be made for modeling the Hospital information system of Chiba University Hospital correctly. The following changes concern the enterprise functions:

- **Increasing the level of detail**: The enterprise functions within the reference model for the domain layer are intended to be universally applicable. That leads to the necessity to refine some functions in order to model the relationships to application components of a concrete HIS adequately. However, as a generic comparison tool relies on a uniform domain layer, inserting new elements into the domain layer seems to be inappropriate. Nevertheless, when refining the functions of the reference model by inserting new subfunctions, the comparability by means of the superordinated functions remains. Moreover, as the model of the HIS of the University Hospital of Leipzig was already available when the HIS in Chiba was modeled, the same subfunctions as added to the reference model within the UKL-KIS model could be adopted to the model of the hospital information system of Chiba University Hospital. Thus, the comparability remained, partly even on a more detailed level of the hierarchy of functions than provided by the reference model. Altogether, 30 subfunctions were added to the reference model within the model of the hospital information system of Chiba University Hospital. For example, “1.4.1 Execution of Diagnostic and Therapeutic Procedures” was on the next level refined to “Execution of Diagnostic Procedures” and “Execution of Therapeutic Procedures”. These two functions were further refined according to the diagnostic and therapeutic procedures offered at Chiba University Hospital (see Figure 9). As another example, the functions of the pharmacy department could have been modeled only insufficiently by the reference model for the domain layer. The pharmacy management is only represented by the not further refined function “2.1.2 Material and Pharmaceuticals Management”. Therefore, that function was further refined into “Blood bank and transfusion management”, “Materials and Pharmaceutical Supply” and “Pharmacy Management”. The latter function, in turn, was divided into subfunctions again. But besides supplying inpatients and outpatients with drugs, the Pharmacy Department at Chiba University Hospital plays an important role in finding the right doses according to laboratory results and providing patients individually with information about their drugs and drug doses. Thus, an active participation in patient treatment is indicated. That was expressed on the domain layer by subordinating the respective subfunctions of “Pharmacy Management” to “1. Patient treatment” and its subfunctions, too. For example, “Dose finding” was also subordinated to “1.2 Decision making, Planning and Organization of Patient Treatment”. Furthermore, the entity type “Blood Finding” was related to the function “Dose finding” by the “uses” relationship.

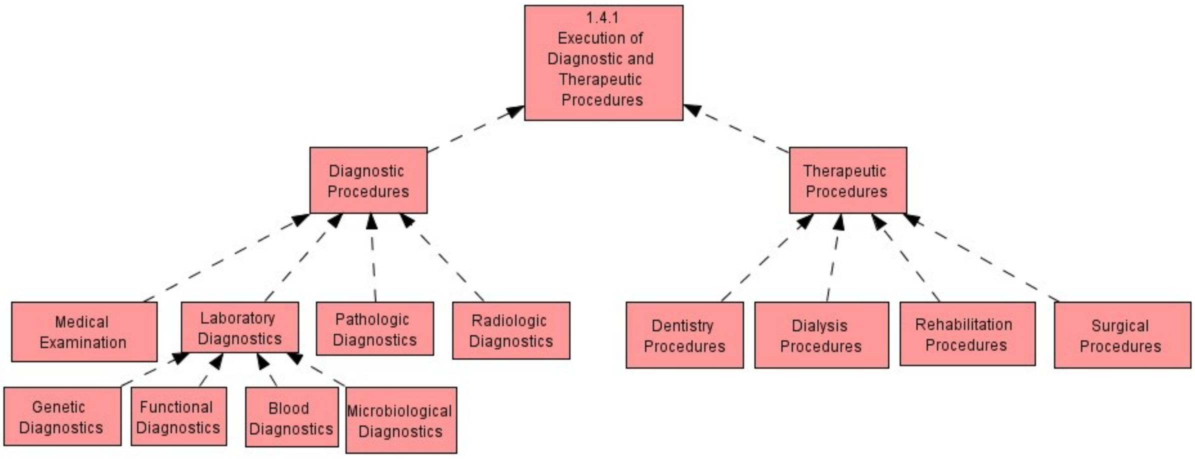

Figure 9. Hierarchy of functions under 1.4.1

- **Deleting functions:** Within the reference model for the domain layer the enterprise function "3.8 Information management" is subdivided into "3.8.1 Strategic Information Management", "3.8.2 Tactical Information Management" and "3.8.2 Operational Information Management". Even if it was possible to assign tasks of information management within the Hospital information system of Chiba University Hospital to these planning horizons it would not reflect the principles of information management within the Department of Medical Informatics and Management (see 6.1.2.2). Thus, these subfunctions were deleted and subordinate functions like "Specifying Application Systems", "System Monitoring" and "Information System User Management" were created.

Similar changes were necessary for the entity types.

- **Increasing the level of detail:** Some entity types of the reference model for the domain layer had to be further refined. To continue with the example in Figure 9, whereas in the reference model for the domain layer the entity type "Findings" is updated by the enterprise function "1.4.1 Execution of Diagnostic and Therapeutic Procedures", within the model of the Hospital information system of Chiba University Hospital, for example, the subordinate entity type "Pathology Findings" is updated by the enterprise function "Pathologic Diagnostics". More specific to the Japanese Hospital, the entity type "Bill" was divided into "Patient Bill" and "Insurance Bill" because the in Japanese healthcare system patients have to pay 30% of their medical costs (elder people: 10%). Altogether 14 new subordinated entity types were modeled .

- **Deleting entity types:** For the definition of entity types within the reference model for the domain layer the HL7 Reference Information Model was used by [HUEBNER-BLODER G et al. (2005)]. However, for the internal communication between subsystems in the Hospital information system of Chiba University Hospital HL7-formatted patient data does not play a role. Therefore, some entity types were deleted because they had no equivalent in the Hospital information system of Chiba University Hospital. In particular, patients at Chiba University Hospital have a unique identification number, but case numbers are not in use. The reference model for the domain layer splits “ADT information” into “Patient master data” and “Case”. In order to adequately model the hospital information system of Chiba University Hospital the entity type “Case” was deleted and “ADT information” and “Patient Master Data” were joined.

- **Defining new entity types**: In contrast to enterprise functions, some entity types having no superordinate entity type coming from the reference model were defined. For example, patients who come to Chiba University Hospital for the first time have to pay a fee of 2000 ¥ (approx. 12 €). If a patient does not come to the hospital for three months he is counted as a new patient again. The “Patient Fee” was entered as a new entity type which is used and updated by the function “1.1.3 & 3.1.1 Administrative Admission”. As the comparability of the different HIS models mainly refers to the same enterprise functions in different HISs the definition of new entity types does not endanger the comparison of both HIS models.

To distinguish between enterprise functions and entity types of the reference model and those elements added, user-defined property fields for enterprise functions and entity types were created that mark whether the enterprise functions and entity types belong to the Reference Model for the Domain Layer.

Simplified data types and message types

For representing entity types on the logical tool layer by dataset types and message types mostly simple names like “<name_of_entity_type> dataset” and “<name_of_entity_type> message” respectively, were chosen. In the case of message types it depended on the low use of standardized messages between the subsystems within the Hospital information system of Chiba University Hospital. For a detailed description of the message types, interviews with the implementers of the respective interfaces would have been necessary. Because the exact database schemes of the databases were not accessible, naming the dataset types the way described above seemed to be practical.

Accessing a database from different subsystems

The EMR system accesses a database which can also be accessed by other application systems. There is no clear procedure for modeling this detail in 3LGM² models. As the EMR database is assigned to the EMR system communication links from the other application systems accessing the database to the EMR system, were modeled. The component interfaces belonging to these communication links were highlighted by yellow color to have a contrast with other interfaces which do not stand for a database access. The transmitted information was designated by the message type ‘Access to MUMPS database’.

Database vs. Digital Document Archive

The EMR system does not only access a database system, but also a digital document archive within the Hospital information system of Chiba University Hospital. Whereas the EMR database system contains all datasets entered into the EMR system, the document archive consists of pdf, text and spreadsheet documents which were created within the EMR system or in other subsystems and then sent to the EMR system, e.g. pathology findings and dialysis reports. Additionally, the database of the EMR system links to documents stored in the document archive. This situation was modeled by defining the “Document Archive” as a subordinate computer-based application component of the EMR system. Both the EMR system and the document archive have a database system even if the document archive is no database system in the classical sense of being composed of a database and a database management system. However, the digital archive is both a data sink and a data source and was therefore modeled as a database system. Whereas the digital archive database system contains certain pdf, text and spreadsheet datasets, the EMR database contains amongst others a “Document archive index dataset” which represents the links to the documents stored in the document archive.

User-defined property fields

Property fields for the element types of a 3LGM² model support the structured capture of element-specific properties which seem to be relevant to the modeler and the user of the model. The extensive use of additional property fields was avoided within the Japanese model because predominantly a greatest possible completeness of the model with respect to all element types was aimed at. Thus, user-defined property fields were only created in two cases. For functions and entity types radio buttons indicating the adaptation of the reference model for the domain layer were created. For computer-based application components a single line for inserting the vendor’s name was introduced.

5.3 A model of the UKL-KIS

A 3LGM² model of the hospital information system of the University Hospital of Leipzig was already available. Therefore an extensive data collection and modeling phase as it was done in Chiba did not take place. The “UKL-KIS model”, as it is referred to in [WINTER A et al. (2007a)] has grown over the past years and now contains 20 submodels describing the current state of the information system of the UKL. The most important submodel for the comparison is the so-called “IST” submodel (a model of the actual state of the UKL-KIS) which gives an overview of the whole information system. On the domain layer the IST submodel contains the functions and entity types of the reference model for the domain layer including refinements which particularly hold for the UKL KIS. The total view of all major application systems used in different departments of the UKL, their interfaces and communication links is provided on the logical tool layer of the IST submodel. On the physical tool layer the most important servers and server clusters are modeled.

5.4 Summary

During the stay at Chiba University Hospital comprehensive information about the hospital information system and some additional information about the hospital in general and information management was collected. As far as possible according to the metamodel 3LGM² the information was modeled with the help of the 3LGM² tool. The result is a 3LGM² model of the HIS of Chiba University Hospital. See the next two pages for the logical and the physical tool layer of the HIS of Chiba University Hospital. The domain layer is mainly determined by the enterprise functions given in Appendix A.

Additional information about the HIS of Chiba University Hospital, that could not adequately represented in a 3LGM² model is summarized in chapter 7. The HIS of the University Hospital of Leipzig did not need to be modeled as the so-called “UKL-KIS” model has already been available.

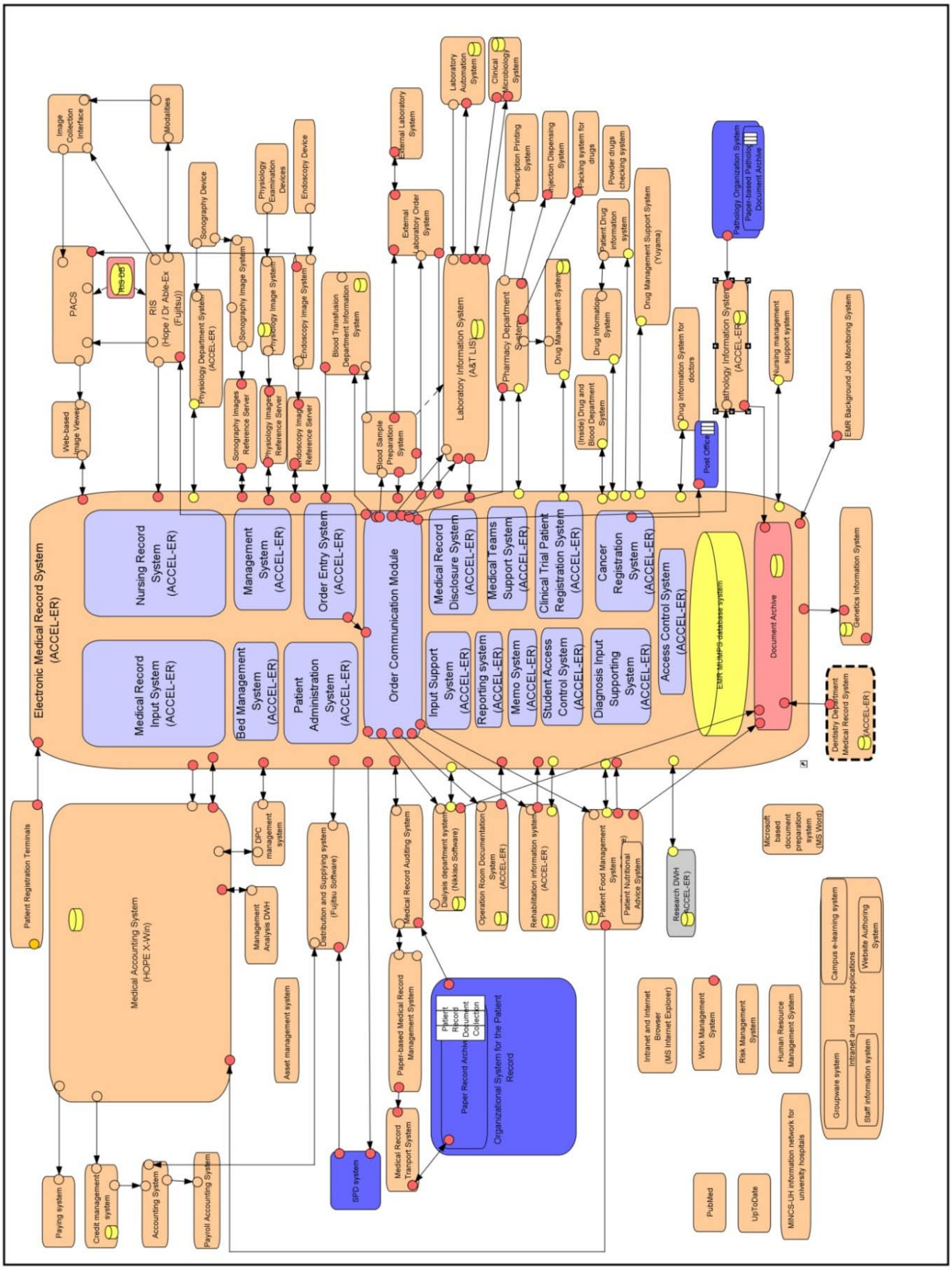

Figure 10. The logical tool layer of the HIS of Chiba University Hospital

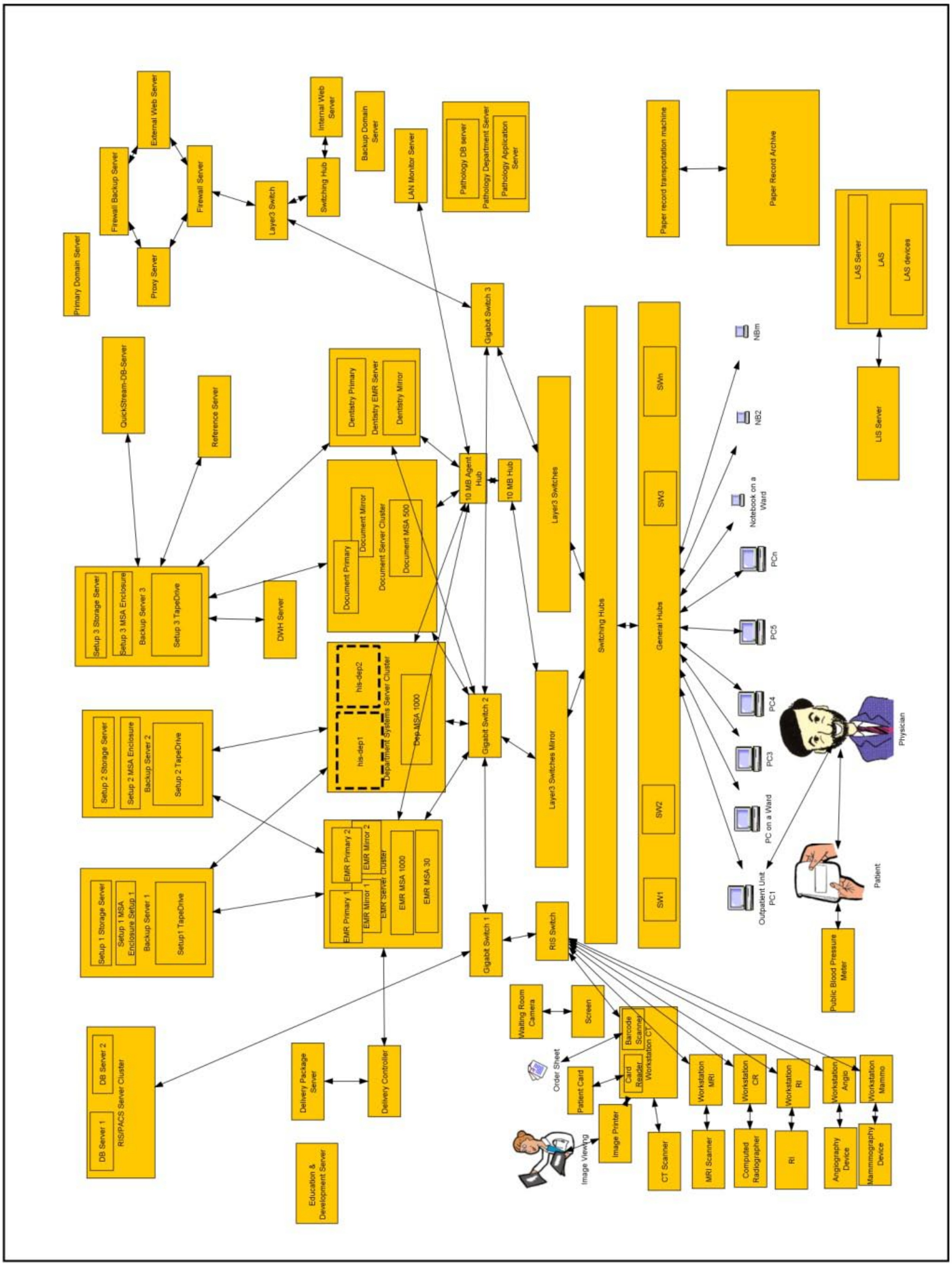

Figure 11. The physical tool layer of the HIS of Chiba University Hospital

6 Results of the comparison

As mentioned in chapter 4.4 the section "1 Basic facts about the hospitals and information management" of the catalogue of criteria does not immediately deal with the comparison of the information systems but with the background from which the HISs arise. This background might help to interpret the characteristics of the HISs . Presenting the characteristics of both hospitals has a purely descriptive character, i.e. the characteristics are only discussed together with the HIS characteristics presented in 6.2, 6.3 and 6.4.

These HIS characteristics result from the comparison based on 3LGM² models. For every criterion the characteristics of both HISs are described in order, followed by a discussion of consequences from the respective characteristics. The figures presented in this chapter are taken from the 3LGM² models of the compared hospital information systems.

6.1 Basic facts about the hospitals and information management

6.1.1 Short Characterization of the hospitals

6.1.1.1 Key figures

	Chiba University Hospital	*University Hospital of Leipzig*
Beds (bed occupancy)	835 (88%)	1258 + 101 for daypatients (83,8%)
Clinics	30	28
Staff	924	Approx. 3000
Outpatients	456,000/year 1,800/day	277,000/year
Inpatients	740/day	Approx. 45,000/year + 2,300/year as daypatient

Chiba:

With 835 beds and 30 clinics Chiba University Hospital is a maximum care facility providing both inpatient and outpatient treatment. The high number of patients treated every day faces a comparatively low number of staff. The total number of inpatients per year of Chiba University Hospital is not available because it is not relevant for a Japanese hospital in the context of accounting. The numbers were provided by the Department of Medical Informatics and Management.

Leipzig:

The University Hospital of Leipzig is a German maximum care facility. Compared to Chiba University Hospital there is stronger emphasize on inpatient treatments as illustrated by the provision of over 1300 beds. The number of 277,000 outpatients per year makes up 60% of the outpatients treated in Chiba University Hospital. The number of staff is high compared to the Japanese hospital. The numbers are taken from [UNIVERSITÄTSKLINIKUM LEIPZIG AÖR (2007a)].

6.1.1.2 Organizational and Spatial Structure

	Chiba University Hospital	*University Hospital of Leipzig*
organizational structure	hierarchical structure	matrix structure[3]
spatial structure	central	decentral

Chiba:

Chiba University Hospital has 22 medical services and 14 central diagnostic services which are integrated into a hierarchical structure. Furthermore, there are supporting services and institutions like the inhouse pharmaceutical service, a nursing division, administrative services, medical welfare services and the Chiba center of clinical research. As a university hospital Chiba University Hospital contains both wards and outpatient clinics.

All departments and divisions of Chiba University Hospital are situated in one central complex of buildings at the Inohana campus.

Leipzig:

According to [UNIVERSITÄTSKLINIKUM LEIPZIG AÖR (2004)] there are five business divisions[4], five divisions[5] and ten staff positions[6] which report to the board of management. The 28 clinics, which comprise both inpatient and outpatient clinics, are assigned to business divisions. The divisions, in turn, have administrative and supporting functions, e.g. information management, financial accounting, human resource management and facility management. The staff positions are responsible for pharmaceutical services, data safety, quality management, hygiene etc.. The organizational structure is best characterized as a matrix structure. Consequently, different facilities can have equal decision-making competences.

Historically, the University Hospital of Leipzig had a decentral spatial structure, i.e. different clinics and institutes are situated in separate buildings. 80% of the clinics and institutes are concentrated around the campus at Liebigstraße. Most of the remaining departments are within a radius of about 5 km.

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3 [UNIVERSITÄTSKLINIKUM LEIPZIG AÖR (2007b)]
4 „Geschäftsbereiche“ (German)
5 “Bereiche” (German)
6 “Stabsstellen” (German)

6.1.1.3 Strategic goals

Strategic goals of	
Chiba University Hospital [CHIBA UNIVERSITY HOSPITAL]	*University Hospital of Leipzig* [UNIVERSITÄTSKLINIKUM LEIPZIG AÖR 2004]
o Safe medical treatment with regard to human dignity o Development and practice of advanced medical treatment o Contribution to society and community health o Educating medical staff of the next generation	o Maximum medical care on international quality level for the inhabitants of the Leipzig Region o Ensuring the quality of medical care by international competitive medical research in cooperation with the Medical Faculty o To safeguard the next generation of medical professionals for the free state of Saxony by scientific education according to modern medical standards in cooperation with the Medical Faculty

Chiba:

The major goal of Chiba University Hospital is to provide safe medical care while keeping ethical principles in mind. As a maximum care facility and University Hospital it offers an advanced, high-level medical treatment, does research activities and also educates and trains physicians and nurses. With these principles Chiba University Hospital aims to contribute to society and community health.

Leipzig:

The University Hospital of Leipzig stresses its regional importance in the Federal State of Saxony. Above all, it aims to offer internationally competitive medical treatment to the inhabitants of the Leipzig region. Furthermore, as a University Hospital it is dedicated to research activities and educates the medical professionals of the next generation.

6.1.2 Information Management

6.1.2.1 Organizational Structures of Information Management

Chiba:

The Department of Medical Information and Management is responsible for information management within Chiba University Hospital. As its name implies the department not only concentrates on information management but is also responsible for management and hospital development as a whole. The staff and responsibility hierarchy is as follows:

- Head of the Department (Professor Takabayashi)

- Four persons are responsible for information management as a whole: Professor Takabayashi, Professor Suzuki, Mr Kimura (external company), Mrs Suetaka (nursing manager)
- One person for financial controlling
- One manufacturer's agent of the Electronic Medical Record System who is responsible for monitoring the EMR system
- Two health information managers that check the patient records both computer-based and paper-based with respect to the compliance with legal requirements
- Five coding specialists for checking the DPC[7] codes
- Non-permanent external staff, e.g.
    - for smaller IT projects like the introduction of HL7 CDA-based CD-ROMs for the communication with other healthcare institutions
    - healthcare management consultants

Thus, there are five people within the department who direct, plan and monitor the hospital information system. Additionally, the head of the Department for Welfare and Medical Intelligence works closely with them in the areas of standardization, codings and integrated care. The main responsibility of the Department of Medical Information and Management of Chiba University Hospital is on the EMR system and some smaller subsystems. However, the Medical Accounting System, the Distribution and Supplying System and the IT infrastructure, i.e. the network and servers, are maintained by a group of five persons who belong to the office staff of the hospital. The Department of Medical Information and Management, on the other hand, belongs to the medical departments of the hospital. The two persons mainly responsible for information management are also practicing medical doctors at Chiba University Hospital. Departments specialized in diagnostics like the Laboratory Department and Radiology Department have their own staff to administrate their systems.

Leipzig:

Information Management at the University Hospital of Leipzig is mainly the responsibility of the "Bereich 1 – Informationsmanagement"[8] of the University Hospital. Under the head of the Bereich 1 there are three competence teams – namely the competence teams for clinical information systems, administrative systems and the IT infrastructure. There are 32 people who are responsible for information management: among them there are three

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[7] DPC (Diagnosis Procedure Combination) can be seen as the Japanese counterpart of DRG (Diagnosis Related Groups). A DPC consists of ICD 10 codes, the so-called K-code for the operation method and the J-code for procedures and complications.

[8] „Bereich 1 – Informationsmanagement" is the division for information management in the University Hospital of Leipzig.

to four department heads, ten application managers, five people for the maintenance of servers and networks, three people for hardware and seven people at service desks. Additionally, there are eight to nine student assistants. In certain divisions like the laboratory department, the radiology department and the pathology department there are local system administrators.

Further influence on information management is exerted by

- The IT and organizational consultancy of the management board
- The Institute for Medical Informatics, Statistics and Epidemiology (IMISE) of the Medical Faculty
- The Data Security Officer

[UNIVERSITÄTSKLINIKUM LEIPZIG (2004)].

6.1.2.2 Characterization of Information Management

Chiba:

Information Management is essentially determined by the periodical replacement of the Electronic Medical Record System, the Medical Accounting System and other subsystems. The government promotes the introduction of recent application systems by yearly funds. Hence, the Department of Medical Information and Management made the strategic decision to replace the EMR system and some neighboring systems every five years. For that reason ahead of the replacement a specification is done. The specification is based on a qualitative analysis which results from interviews with users and the functionalities offered by the old system which are to be maintained. E.g. the specification of the EMR system is done by staff of the Department of Medical Information and Management, technical office staff is responsible for the specification of the Medical Accounting system. After finishing the specifications, a call for tenders is initiated. The most reasonable vendors are chosen afterwards. In the past years TSMED (Toshiba Sumiden Medical Information Systems Corporation) and Fujitsu emerged as the main vendors.

Besides the total replacement of systems every five years there are smaller projects with external partners. E.g. in 2007 an external company was charged with a project for the communication between hospitals. Since this year patients are given a CD with their medical record in HL7 CDA format. Thus, physicians in other institutions or the patients themselves can access their medical data.

The daily operation of the information system is also chiefly monitored by the Department of Medical Information and Management. I.e. the users (doctors and nurses) contact the department if there are any problems with the EMR system. Furthermore, the monitoring of communication jobs of the EMR system is managed by a manufacturer’s agent. For the

Medical Accounting System the same tasks are taken over by the five persons who belong to the office staff of the hospital.

In the course of the introduction of new application systems the Department of Medical Information and Management also organizes the training of the staff.

Overall, information management at Chiba University Hospital contributes to the hospital's strategic goals.

Leipzig:

Information Management

- is responsible for planning the information system of the Medical Faculty
- directs the further development of the information systems' architecture and its operation based on the plan
- monitors the compliance with the plan as well as the operation so that the goals of the hospital can be achieved

[UNIVERSITÄTSKLINIKUM LEIPZIG (2005)].

Bereich 1 for Information Management divides between strategic, tactical and operative tasks of information management (cf. 2.2). At the strategic level Bereich 1 cooperates closely with the IMISE. Important results of the cooperation are strategic plans which determine the further development of the information system for two or three years. In the strategic plans single projects to be executed during the next years are specified. Such projects concern, for instance, the introduction or replacement of certain subsystems or the introduction of new technologies. The execution of the projects is seen as a tactical task and is mainly done by project groups of Bereich 1. Besides tactical and operative projects for the University Hospital, Bereich 1 is also a service provider for the Medical Faculty of the University of Leipzig.

Having introduced the environments of the HISs of Chiba University Hospital and the University Hospital of Leipzig by describing basic facts about the hospitals and information management, the comparison of the HISs can start.

6.2 Functionality of computer-based subsystems

6.2.1 Adoption of clinical systems

	Chiba	*Leipzig*
Adoption of clinical systems (ord/subj)	⦿⦿⦿⦿	⦿⦿⦿⦿

Chiba:

In the 3LGM² model for all functions of the Reference Model for the Domain Layer among ‘1. Patient Administration’ (cf. Appendix A – The hierarchy of functions of the Reference Model for the Domain Layer of HIS) computer-based clinical application systems are available.

Especially the EMR system, based on AccelWin from TSMED, modeled on the logical tool layer of the 3LGM² model, is of great importance for the support of patient treatment. Most of the medical and nursing documentation (e.g. 1.1.4 Medical Admission, 1.1.5 Nursing Admission, 1.4.2 Execution of Nursing Procedures), order entry (1.3.1 Preparation of an Order) and ward management functions (1.1.6 Information Services) are supported by the EMR system. See Figure 12, which is taken from the 3LGM² model of the HIS of Chiba University Hospital, for the patient treatment-related functions that are supported by the EMR system. (Dashed lines visualize is-part-of-relationships.) Most of the functions are exclusively supported by the EMR system.

However, functions related to admission, discharge and transfer of a patient (1.1.2 Patient Identification and Identification as Recurrent, 1.1.3 Administrative Admission, 1.5 Administrative Documentation and Billing) are supported by the Medical Accounting System basing on HOPE X-Win from Fujitsu. According to a 3LGM² report there are functional redundancies with the EMR system (functions 1.1.2 and 1.1.3 of the Reference Model for the Domain Layer).

For the support of diagnostic and therapeutic procedures (1.4.1 Execution of Diagnostic and Therapeutic Procedures) there are several specialized department systems. In the following diagnostic and therapeutic procedures and the systems by which they are supported are listed.

- Radiological Diagnostics: RIS (Radiology Information System), PACS (Picture Archiving and Communication System)
- Laboratory Diagnostics (Microbiological and Blood Diagnostics): LIS (Laboratory Information System)
- Physiological Diagnostics (e.g. Endoscopy, Sonography): Physiology Department Information System
- Pathological Diagnostics: Pathology Information System

- Genetics Diagnostics: Genetics Information System
- Rehabilitation: Rehabilitation Information System
- Surgery Planning and Surgical Procedures: Operation Room System
- Dialysis: Dialysis Department System

As well, the Pharmacy Department System supports to some extent ‘1.2.1 Decision Making and Patient Information’ because it decides upon the doses and provides the patients with information about their medication (cf. 5.2.3).

Hence, the criterion was rated with 4 points.

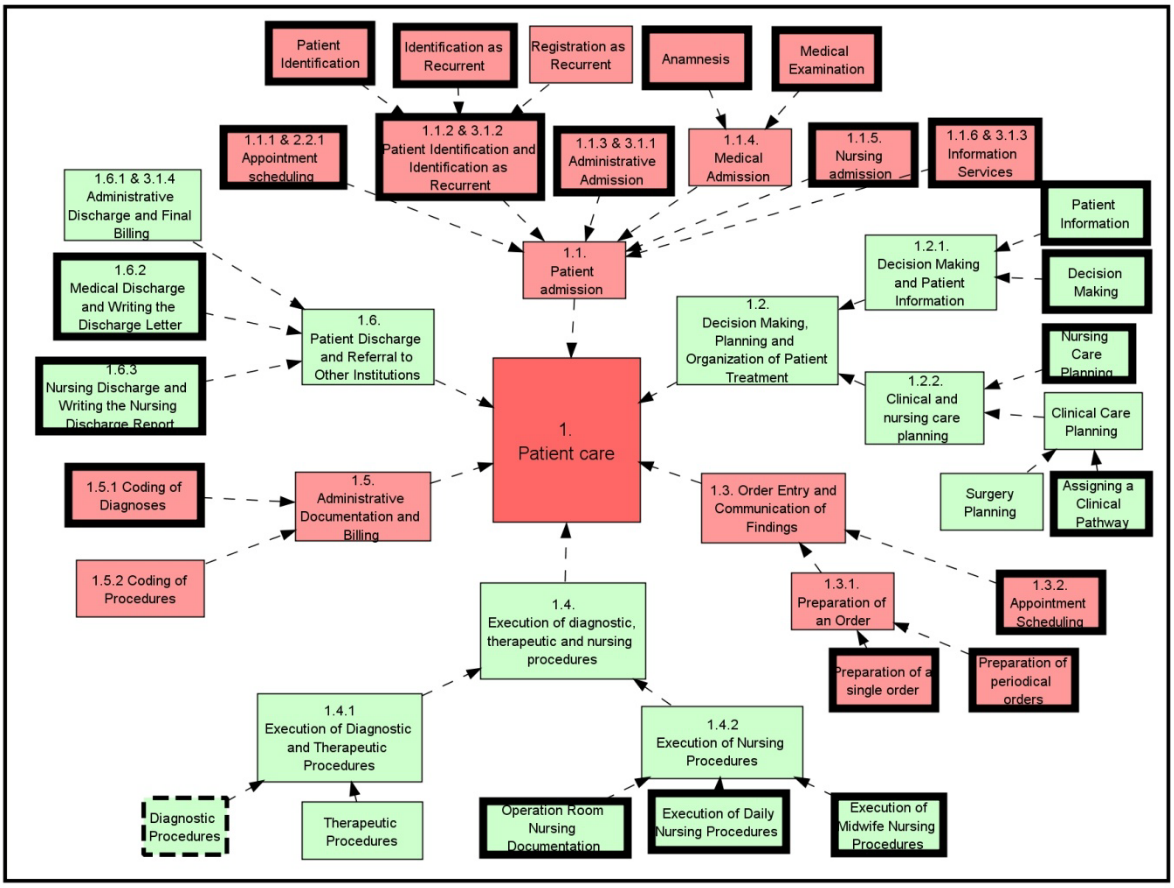

Figure 12. Functions among "1. Patient Treatment" supported by the EMR system are highlighted

Leipzig:

According to the 3LGM² model of the HIS of the University Hospital of Leipzig all subfunctions of ‘1. Patient Treatment’ are supported by computer-based application components. The Patient Administration System based on the R/3-module[9] IS-H from

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[9] R/3 is developed by SAP as an Enterprise Resource Planning (ERP) System, initially it had no medical background.

SAP in combination with the i.s.h. med-based clinical documentation system[10] are the most important systems for the documentation of patient-related data in the University Hospital of Leipzig. Whereas IS-H supports administrative tasks related to admission, discharge and transfer of patients, i.s.h med is used for the clinical documentation.

i.s.h. med and IS-H support

- 1.1.1 Appointment Scheduling (not exclusively)
- 1.1.2 Patient Identification and Identification as a Recurrent (exclusively)
- 1.1.3 Administrative Admission (not exclusively)
- 1.1.5 Nursing Admission (exclusively)
- subfunctions of 1.2.1 Decision Making and Patient Information (not exclusively)
- subfunctions of 1.2.2 Clinical and Nursing Care Planning (not exclusively)
- 1.4.1 Execution of Nursing Procedures (not exclusively)
- Subfunctions of 1.5 Administrative Documentation and Billing (not exclusively)
- 1.6.2 Medical Discharge and Writing the Discharge Letter (exclusively)

If a function is not supported exclusively it means that there are also other application systems that support the function in the University Hospital of Leipzig. For example, 1.2.1 Decision Making and Patient Information is supported by the application components shown in Figure 13 which is the result of a 3LGM² analysis. That analysis result is also an indicator functional redundancies in the HIS of the University Hospital of Leipzig.

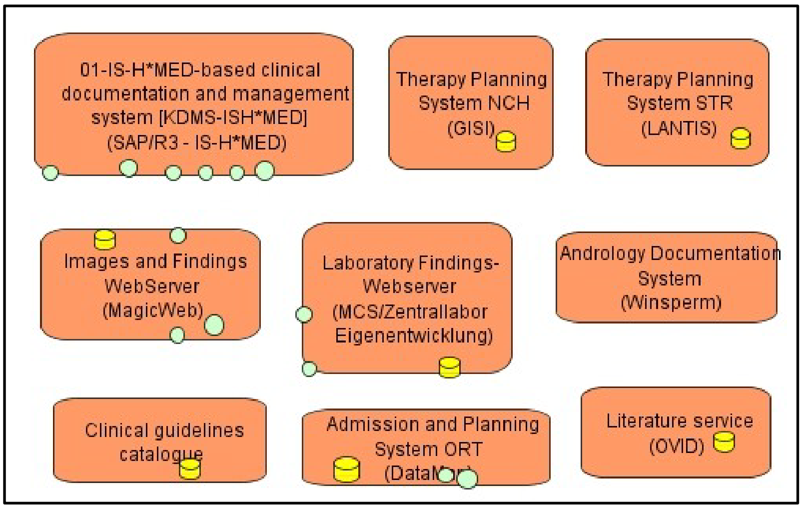

Figure 13. Application components supporting function 1.2.1

[10] i.s.h. med is a clinical workstation system integrated into the ERP system of SAP and developed by Siemens Medical Solutions GSD GmbH and T-Systems Austria.

Furthermore, there are a lot of other application components supporting “1.4.1 Execution of Diagnostic and Therapeutic Procedures”. An overview of these application components is given below.

- Operation Planning: MCC based clinical documentation system
- Intensive Care Tasks: COPRA based patient data management system
- Laboratory Diagnostics: 5 Laboratory Information Systems supporting different laboratory examinations
- Pathologic Diagnostics: Pathology Information System
- Blood Bank Management: Blood Bank Management System IMZ
- Radiological Diagnostics: RIS/PACS
- Lung function diagnostics: Pulmonology Documentation System
- Sonography and Endoscopy Diagnostics: Endoscopy and Sonography Documentation System

Thus, 4 points were assigned for the adoption of clinical systems.

Discussion:

Although both HISs were formally rated with 4 points, different characteristics of the clinical systems lead to the assessment.

The EMR system of Chiba University Hospital supports the medical and nursing documentation, order entry and ward management functions. Thus, it fulfills the tasks of a Clinical Documentation System according to ([HAUX R et al. (2004)], cf. 2.1.2).

Whereas in the HIS of Chiba University Hospital one application system can cover the majority of subfunctions under ‘1. Patient Treatment’, in the HIS of the University Hospital of Leipzig a greater number of application systems is needed. On the one hand, these further application components fulfill specialized tasks like choosing guidelines for medical treatment, on the other hand there are functional redundancies. That means the same functions are supported by different application components in different organizational units, what also indicates horizontal fragmentation (see 6.3.3). For a detailed comparison of the functionality of the EMR system and the set of equivalent application systems in the HIS of the University Hospital of Leipzig see 6.2.4.

The variety of application components used for “1. Patient Treatment” in the University Hospital of Leipzig has to be interpreted with respect to the organizational structure of the hospital (see 6.1.2.1). The matrix structure leads to fragmented decision-making powers so that different clinics can partly decide about the systems they use. In Chiba University Hospital the hierarchical, centralized structure facilitates the introduction of hospital-embracing application systems.

However, in both hospitals departments specialized in certain diagnostic or therapeutic procedures have their own department information systems what is geared to sophisticated procedures which can only adequately supported by specialized department systems.

6.2.2 Adoption of administrative systems

	Chiba	*Leipzig*
Adoption of administrative computer-based subsystems (ord/subj)	⦿⦿⦿○	⦿⦿⦿○

Chiba:

The 3LGM² model shows that there are only few administrative functions under “2. Supply Management, Resource Planning and Work Organization” and “3. Hospital Administration” which are not supported by computer-based application components within the HIS of Chiba University Hospital, e.g. “2.1.4 Laundry Management” and “3.7 Facility Management”. Therefore 3 of 4 points were assigned.

Administrative functions related to the administration of patient master data and medical accounting are handled by the Medical Accounting System which collects all billing information about patient treatment and calculates patient and insurance fees. However, the administrative tasks which do not directly affect patient treatment are supported by a variety of smaller application systems. For example, the subfunctions of “2.3 Human Resource Management” are, according to the 3LGM² model of the HIS, supported as follows.

- 2.3.1 Administration of Human Resource Master Data: Human Resource Management System
- 2.3.2 Human Resource Planning: Nursing Management System
- 2.3.3 Work Organization and Time Planning: Work Management System
- 2.3.4 Payroll Accounting: Payroll Accounting System

In summary, a value of 3 was chosen to rate this criterion.

Leipzig:

Almost all administrative functions under “2. Supply Management, Resource Planning and Work Organization” and “3. Hospital Administration” are supported by computer-based application components within the UKL-KIS model. As only functions such as “2.1.4 Laundry Management” and “3.1.2 Administration and Provision of Medical Records” are not handled computer-based, 3 of 4 points on the ordinal scale were assigned.

According to the 3LGM² model, important roles for administrative functions play the R/3-based applications. As R/3 was developed as an Enterprise Resource Planning (ERP) system it covers many functions related to resource planning and accounting. To get an impression about the functionality of R/3, Figure 14, presenting the results of a 3LGM² analysis, highlights subfunctions supported by R/3.

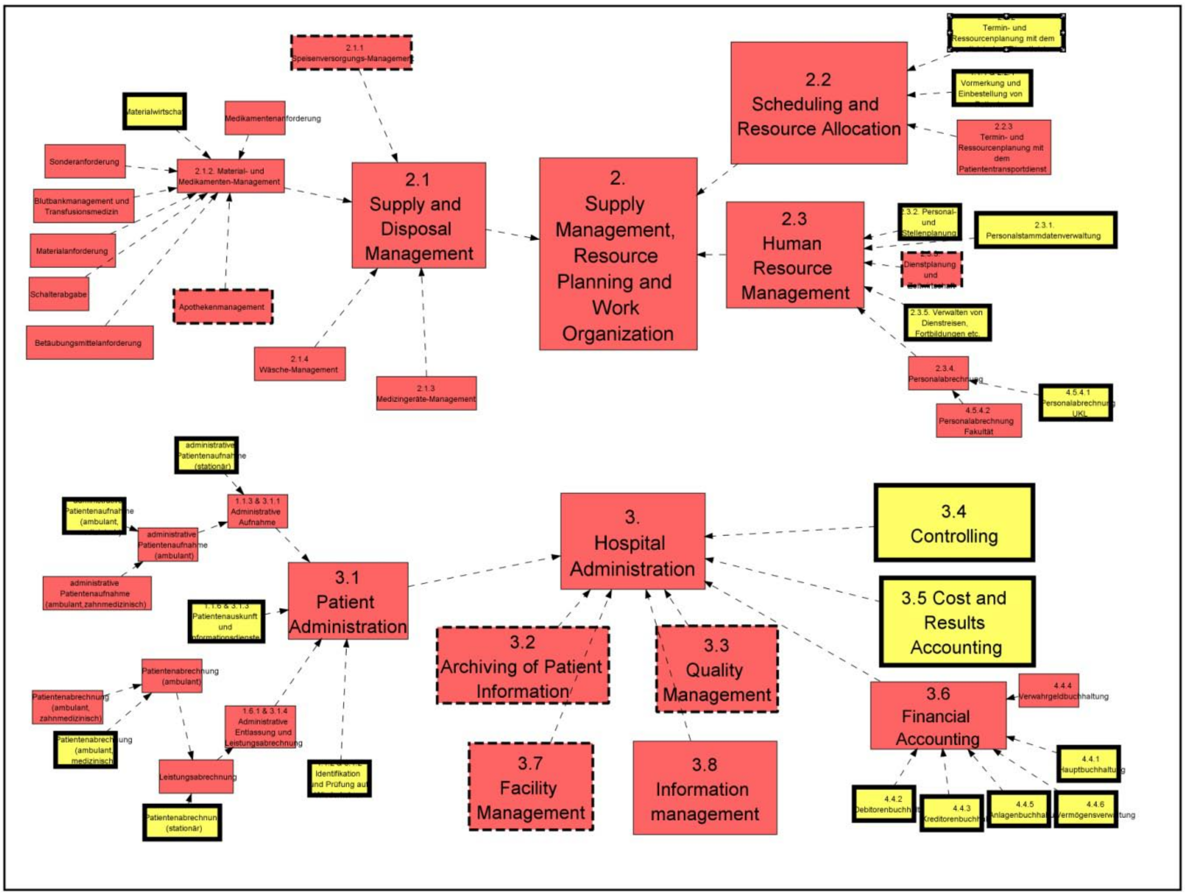

Figure 14. Rough overview of the functions supported by SAP's R3 (yellow color stands for support by R/3)

However, the remaining functions are supported by a variety of smaller systems specialized on a single function.

Discussion:

Again, both HISs were rated equally although the administrative functions are covered by sets of application systems which are very different with respect to the range of provided functionalities.

Compared to the University Hospital of Leipzig in Chiba University Hospital a stricter separation between clinical and administrative systems could be observed. Whereas the EMR system supports the clinical tasks, the Medical Accounting System and some other application systems are responsible for supply management, resource allocation and hospital administration. That separation is also expressed by the organizational structures of information management (see 6.1.2.1). The clinical systems are maintained by the

Department of Medical Informatics and Management and the administrative systems are maintained by a working group of the office part of the hospital. On the contrary, R/3 and its modules in the UKL-KIS aim at covering both clinical and administrative functions. Nevertheless, as they do not support all of the clinical and administrative functions, many further application systems are used.

Interestingly, with respect to administrative functions there is no single application system in Chiba University Hospital which can cover as many functions as the R/3 based ERP system within the HIS of the University Hospital of Leipzig.

6.2.3 Adoption of strategic systems

	Chiba	*Leipzig*
Adoption of strategic computer-based subsystems (ord/subj)	⦿⦿⦿○	⦿⦿⦿○

Chiba:

According to the 3LGM² model, for “3.4 Controlling” Chiba University Hospital uses a Management Analysis Data Warehouse. By the analysis functions of the 3LGM² tool it is apparent that the management data warehouse uses the data stored in the database system of the Medical Accounting System to generate statistics e.g. about the consumption of drugs. “3.5 Cost and Results Accounting” as another strategic function is supported by the Medical Accounting System. The subfunction “Public Relations and Corporate Communications” of “4. Hospital Management” is supported by intranet and internet applications, for example by an authoring tool for the website of Chiba University Hospital. However, other decision-making functions related to hospital management are not supported by computer-based application components. Therefore the criterion was rated with 3 of 4 points.

Leipzig:

In the HIS of University Hospital of Leipzig for “3.4 Controlling” and “3.5 Cost and Results Accounting” R/3-CO and a Business Warehouse (BW) from SAP can be used. Under “4. Hospital Management”, the subfunction “Public Relations and Corporate Communications” is supported by an authoring tool for maintaining the website of the University Hospital of Leipzig. Another subfunction of “4. Hospital Management” is “Defining a business strategy” which is not supported by an application component. Thus, 3 of 4 points were given.

Discussion:

The types and the number of strategic systems which are used in both HISs are very similar. According to [BURKE DE et al. (2002)] (cf. 2.6) strategic systems can only be adopted if there are clinical and administrative systems which provide the data for strategic systems. Because both HISs possess a wide range of clinical and administrative systems (see 6.2.1 and 6.2.2), relevant electronically stored data can be communicated to strategic systems.

6.2.4 Coverage of the functionality of the EMR system within the UKL-KIS

	Chiba	*Leipzig*
Functional coverage of the EMR system's functionality in the HIS of the University Hospital of Leipzig	EMR system	i.s.h. med-based Clinical Documentation and Management system Patient Administration System (SAP R/3 - IS-H, IS-H) Order management system (MCC-Termin) Appointment Management system MKG (MS Outlook) Microsoft based word processing system (MS Word) Organizational Systems of the clinics [paper-based] Andrology documentation system Therapy Planning System NCH Admission and Planning System ORT Therapy Planning System STR Paper-based system for ward management Nursing Standard Directory Order management system (MCC-Termin) Order service [paper-based]

Chiba / Leipzig:

The EMR system is the core system of the HIS of Chiba University Hospital which covers a wide range of functions for the medical and nursing documentation (see 6.2.1).

The following table lists the functions that are exclusively supported by the EMR system in Chiba University Hospital (first column) and the application systems that support the respective tasks within the University Hospital of Leipzig (second column). The table was created with the help of 3LGM² reports.

Function exclusively[11] covered by the EMR system of the HIS of Chiba University Hospital	Application systems of the HIS of the University Hospital of Leipzig which support the task
1.1.1 & 2.2.1 Appointment scheduling	i.s.h med-based Clinical Documentation and Management system Patient Administration System (SAP R/3 - IS-H, IS-H) Order management system (MCC-Termin) Appointment Management system MKG (MS Outlook)
1.1.4. Medical Admission[12]	(see following two lines)
Anamnesis	Microsoft based word processing system (MS Word) Anamnesis Documentation System (MCC-ANAM)
Medical Examination	Organizational Systems of the clinics [paper-based]
1.1.5. Nursing admission	Patient Administration System (SAP R/3 - IS-H, IS-H)
1.1.6 & 3.1.3 Information Services	i.s.h med-based Clinical Documentation and Management systems
1.2.2. Clinical and nursing care planning[13]	(see following two lines)
Clinical Care Planning (Creating a Care Plan, Assigning a Clinical Pathway)	Andrology documentation system Therapy Planning System NCH Admission and Planning System ORT Therapy Planning System STR
Nursing Care Planning (Creating a Care Plan, Assigning a Nursing standard)	Paper-based system for ward management Admission and Planning System ORT Nursing Standard Directory
1.3.1. Preparation of an Order	Order management system (MCC-Termin) Order service [paper-based]
1.4.2 Execution of Nursing Procedures	i.s.h med-based Clinical Documentation and Management system
1.6.2 Medical Discharge and Writing the Discharge Letter	i.s.h med-based Clinical Documentation and Management system
1.6.3 Nursing Discharge and Writing the Nursing Discharge Report	i.s.h med-based Clinical Documentation and Management system

Table 6. Coverage of the functionality of the EMR system within the UKL-KIS

[11] The functions 1.1.2 & 1.1.3, which are missing in this list, are supported by the EMR system, but they are also supported by the Medical Accounting System.
[12] Although „Anamnesis“ and „Medical Examination“ are not contained in the reference model they are the only subfunctions of “1.1.4 Medical Admission” defined both in the Japanese and the German model. Thus, comparability is guaranteed.
[13] In turn, selected subordinated functions of “1.2.2 Clinical and Nursing Care Planning” in both models had to be considered for guaranteeing comparability.

Discussion:

Altogether, there are 14 different subsystems of the UKL-KIS that cover the functionality provided by the EMR system of the HIS of Chiba University Hospital. As already mentioned in 6.2.1, the i.s.h. med-based clinical documentation system does not provide such a wide range of functionality as the EMR system and therefore, further application systems are needed. Additionally, there are many functional redundancies so that even if a function is supported by i.s.h. med there can be other application systems which support the same task in certain departments.

6.3 Architecture of the Logical tool layer

6.3.1 Architectural style of the logical tool layer

	Chiba	*Leipzig*
Architectural style of the logical tool layer (nom/obj)	mixed form	DB^n

Chiba:

Although the HIS of Chiba University Hospital does not only contain one database according to the 3LGM² model, there are many indications of a DB^1 architecture style. The centre of the HIS is an EMR system that has in the 3LGM² model the most communication links to other application components. The EMR system accesses a database storing all patient-related data. That underlying database for the EMR system as well as some further subsystems is a MUMPS[14] database (also “M database”). In particular, within the 3LGM² model there are 13 communication links with other application components modeled that represent access to the central MUMPS database, e.g. almost all application components of the Pharmacy Department and the Laboratory Information System (see Figure 10 in 5.4). Most of the 13 application systems are supplied by the vendor of the EMR system. However, not all subsystems can read and write in the MUMPS database, e.g. the Medical Accounting System or the Radiology Information System. They have independent databases and consequently store patient-related data redundantly. For those systems the 3LGM² analysis results concerning the storage of the entity type “Patient master data” are similar as shown in Figure 15 for the UKL-KIS. Thus, the most appropriate characterization of the HIS of Chiba University Hospital concerning the DB style is a mixture of DB^1 and DB^n style.

[14] MUMPS (Massachusetts General Hospital Utility Multi-Programming System) is an interpreted programming language developed in the 1970ies for the use in medical applications. Especially in the US it was the most frequently used programming language for medical record systems. Nowadays, it is said to be still in widespread use under the name M [SHORTLIFFE EH and BLOIS MS (2006)].

Leipzig:

The computer-based part of the UKL-KIS has a typical DB^n style. There are a variety of application components from different vendors having database systems where patient-related data is stored redundantly. Figure 15 shows a clipping of the logical tool layer of the “IST” model of the UKL-KIS, in which databases that store the entity type “Patient Master Data” are highlighted. To avoid multiple input and keeping data in different database systems consistent a communication server for the exchange of data is used which leads to a “star architecture style”. The communication server directs asynchronous communication between the application components.

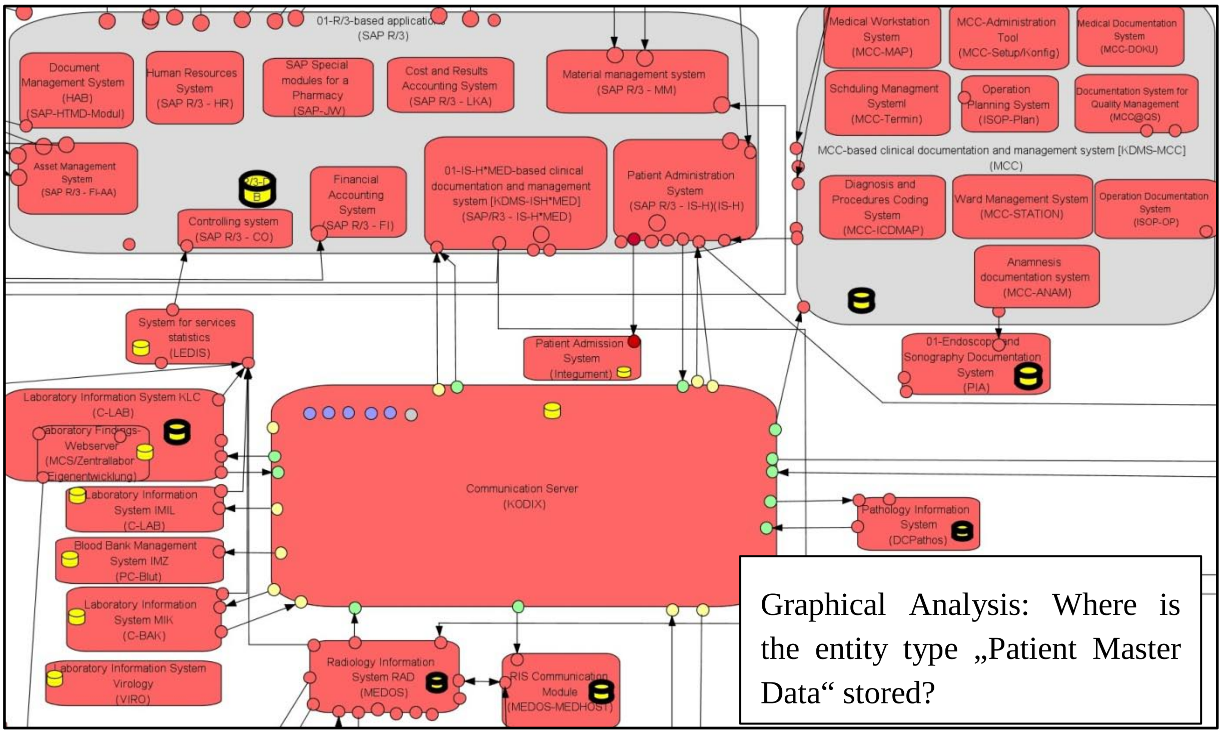

Figure 15. Databases which store the entity type „Patient master data“ are highlighted (clipping of the UKL KIS model)

Discussion:

Generally, a DB^1 architectural style a priori ensures that all application systems access current data [WINTER A et al. (2005)] and can for this reason be seen as the more efficient solution. As shown for the HIS of Chiba University Hospital the DB^1 style works as long as there are application systems from one vendor. By contrast, as the HIS of the University Hospital of Leipzig consists of many application systems from different vendors, a DB^n architectural style is inevitable. The main condition for the functioning of a DB^n architectural style is a means for keeping data consistent which is redundantly stored in different application systems. In the HIS of the University Hospital of Leipzig the communication server fulfils that function. Additionally, the communication server can help to minimize the number of interfaces compared to the “spaghetti style” ([HAUX R et al. (2004)], see 2.4.1). Coming back to the HIS of Chiba University Hospital, a plain

DB[1] style could not be found. Consequently, there is also redundant storage of data in different databases which needs to be kept up to date. That in turn leads to the implementation of interfaces for pairs of application components.

6.3.2 Use of communication standards

	Chiba	*Leipzig*
Use of communication standards (ord/subj)	⦿⦿○○	⦿⦿⦿○

Chiba:

The 3LGM² model shows that especially for the communication of application systems from different vendors the HIS of Chiba University Hospital has a lot of proprietary interfaces which do not use HL7 or the like. In the HIS of Chiba University Hospital HL7 is currently used only for the communication with an external laboratory. The RIS, the PACS, modalities and an Image Viewer use DICOM messages for the communication between each other. In summary, 2 points indicating “less use than in half of the possible cases”.

Interestingly, to avoid a high number of proprietary interfaces to be implemented, for some application systems the EMR system serves as kind of communication server by forwarding messages from one subsystem to another. For example, for four departmental systems billing information is sent to the Medical Accounting System via the EMR system (see Figure 16 which shows the results of four graphical analyses within the 3LGM² model that highlight communication links transferring billing information of diagnostics departments).

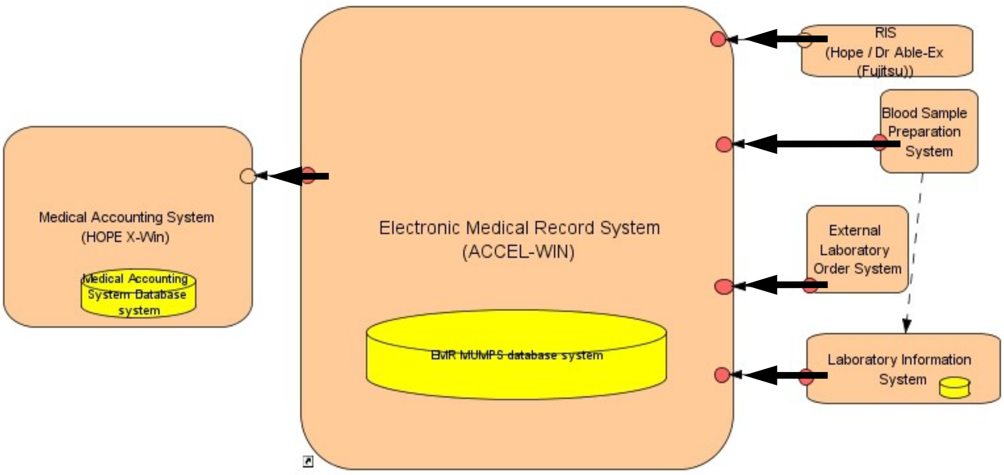

Figure 16. Billing information is sent via the EMR system (simplified clipping of the Japanese model)

Leipzig:

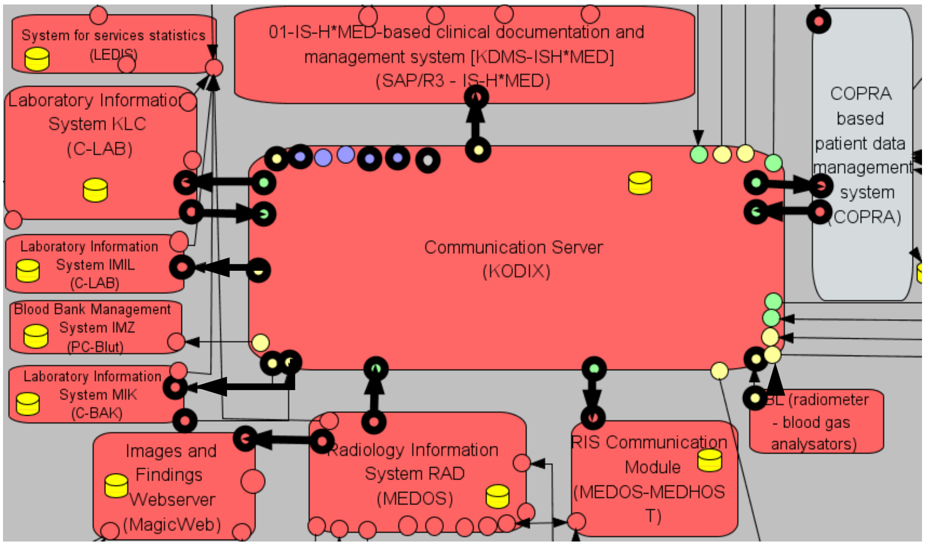

Figure 17. Bold elements indicate interfaces and communication links using HL7

Within the HIS of the University Hospital of Leipzig communication standards are widely used. Communication between the most important subsystems of the HIS is implemented using HL7 messages. See Figure 17 taken from the UKL-KIS which highlights the interfaces and communication links using HL7. Application components of the Radiology Department, i.e. the Radiology Information System, the PACS, modalities and the Images and Findings Server communicate by means of the DICOM standard. As in more than the half of possible cases communication standards are used, '3' points were assigned.

Discussion:

Generally, the HIS of the University Hospital of Leipzig is characterized by a higher adoption of common communication standards. That results from the variety of application systems from different vendors which need to exchange data between each other. The implementation of interfaces becomes easier if communication standards are used. Furthermore, the use of communication standards makes it less complicated to attach new components to the HIS and to establish communication links to other health information systems. Within the HIS of Chiba University Hospital there are other conditions. Since a centralized architecture with a MUMPS database which can quite easily be accessed by other application components has been used for a long time, there has been no need for the implementation of communication standards like HL7. However, for establishing regional or national healthcare networks the demand for standardized interfaces is currently increasing. For the HIS of Chiba University Hospital, this is apparent in the usage of HL7 to establish communication links to an external laboratory and the introduction of CDs with HL7-CDA conform data for patients who change to another healthcare institution (cf. 6.1.2.2.). However, even within the hospital the implementation of proprietary interfaces between application systems from different vendors such as the interface between the EMR System from TSMED and the RIS from Fujitsu can cause great expenditures.

6.3.3 Fragmentation of the information system

	Chiba	*Leipzig*
Fragmentation of the information system (ord/subj)	⦿⦿○○	⦿⦿⦿○

Chiba:

According to the application component configurations in the 3LGM² model, the EMR system of Chiba University Hospital avoids fragmentation of application components that support patient care within all medical clinics. However, departments specialized on diagnostic or therapeutic procedures, such as the Laboratory Department or Operation Rooms have their own department systems, i.e. own application architectures and physical data processing components. Therefore the criterion was rated with 2 points.

Leipzig:

The UKL-KIS model reveals some vertical fragmentation artifacts. In the HIS of the University Hospital of Leipzig some clinics use different applications, both computer-based and paper-based, for the documentation of patient-related data. Although the i.s.h. med-based clinical documentation systems is available in every clinic according to its related application component configurations, for example, the “Execution of Nursing Procedures” is supported by i.s.h med only in the Neurosurgery Department, in all other clinics there are paper-based documentation systems which can also differ from each other. Also, diagnostic and therapeutic departments have specialized department systems and hardware. Thus, 3 points indicating a high fragmentation were assigned.

Discussion:

For facilitating the special tasks of diagnostic service units (e.g. laboratory, radiology and pathology departments) and therapeutic service units (e.g. intensive care units, operation rooms, rehabilitation centers) architectural fragments with specialized application systems and technologies are probably unavoidable. Therefore both hospital information systems have those highly specialized systems which can communicate with their clinical documentation systems over component interfaces. Also, both hospitals employ additional staff for maintaining the department systems (see 6.1.2.1).

However, the degree of penetration concerning the main systems for medical documentation is different in both hospitals. Whereas the EMR system of the HIS of Chiba University Hospital promotes horizontal integration whilst it is used in all clinics including outpatient units for the medical and nursing documentation, the SAP IS-H in combination with i.s.h. med is used to variable extents in different clinics. That is geared to the more decentralized organizational structure of the University Hospital of Leipzig (cf. 6.1.1.2). Historically, the single clinics of the UKL are more independent and have more decision powers than the clinics in Chiba University Hospital. That led to the implementation of different department-specific subsystems supporting patient treatment.

6.3.4 Informational Redundancy and Data integration

Informational Redundancy and data integration is exemplary observed between the clinical documentation systems and the RIS, the LIS and the Pathology Information System.

	Chiba	*Leipzig*
Data integration (ord/subj)	fulfilled	not fulfilled

Chiba:

In the HIS of Chiba University Hospital Patient Master Data is stored in eight databases because the Informational Redundancy of the entity type (cf. 2.5.1) adds up to ‘7’ in the 3LGM² model. The eight databases include the databases of the EMR system, the RIS, the LIS and the Pathology Information System. Besides the database system of the EMR system, the database system of the Medical Accounting System is modeled as a master for “Patient Master Data”, i.e. in both systems patient master data can be entered. According to the 3LGM² model, over a bidirectional communication link the data can be exchanged. The communication with the RIS, the LIS and the Pathology Information System is established from the order communication module of the EMR system. Patient Master Data is sent via orders to the RIS, the LIS and the Pathology Information System. Thus, the demands for data integration (see 4.3.2) are fulfilled.

Leipzig:

As already shown in 6.3.1 ‘Patient Master Data’ is stored in seven database systems (Informational Redundancy=6, cf. 2.5.1). For the RIS and the LIS data integration is guaranteed, but the Pathology Information System does not receive patient master data by electronical messages according to the 3LGM² model: Figure 18 highlights the database systems that store “Patient Master Data” and the communication links over which “Patient Master Data” is transmitted. The IS-H-based Patient Administration System sends patient master data to the communication server. From there it is forwarded to the Laboratory Information System (left) and the RIS Communication Module (bottom) which finally directs the data to the Radiology Information System. The communication link from the Communication Server to the Pathology Information System is not highlighted. Thus, data integration between the clinical documentation system and the Pathology Information System is not established.

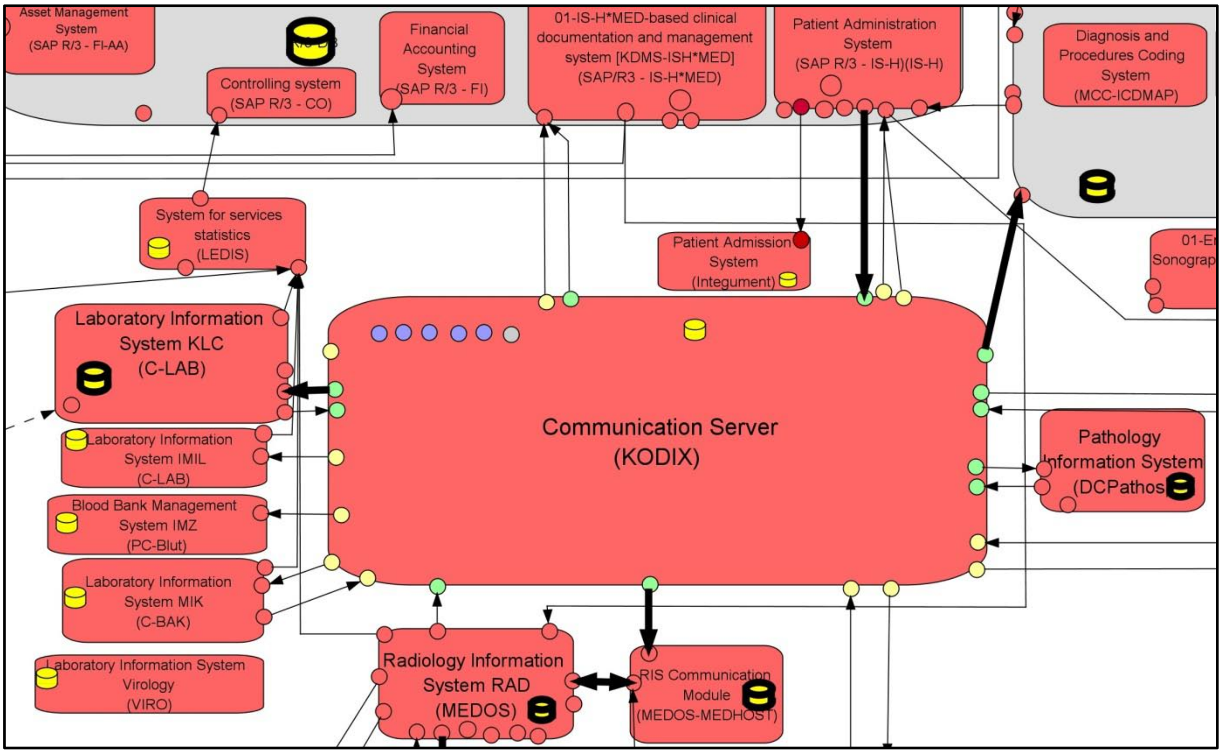

Figure 18. Storage and transmission of "Patient Master Data"

Discussion:

Whereas in the HIS of Chiba University Hospital data integration with respect to the entity type “Patient Master Data” is established between the EMR system, the RIS, the LIS and the Pathology Information System, in the UKL-KIS the Pathology Information System does not receive patient master data over a communication link. In worst case it means that the data has to be entered manually into the Pathology Information System what can negatively affect data integrity.

6.3.5 Access Integration

As an example of access integration the availability of the application systems which serve for the nursing documentation on wards is examined.

	Chiba	*Leipzig*
Access integration (ord/subj)	fulfilled	not fulfilled

Chiba:

In Chiba University Hospital the Nursing Record System, which is a module of the EMR system, supports the nursing documentation. In every clinic, what implies every ward, the Nursing Record System is available. That becomes obvious when looking at 3LGM² application component configurations for “1.4.2 Execution of Nursing Procedures”. In addition, the nurses can use mobile devices in the form of notebooks for their documentation at the sickbeds.

Figure 19 is an extract of the 3LGM² model of Chiba University Hospital which shows by what application component the nursing procedures are supported and what is the physical basis for the nursing record system. It becomes obvious that a PC or a notebook on a ward can be used to access the EMR system that contains the Nursing Record System as a module.

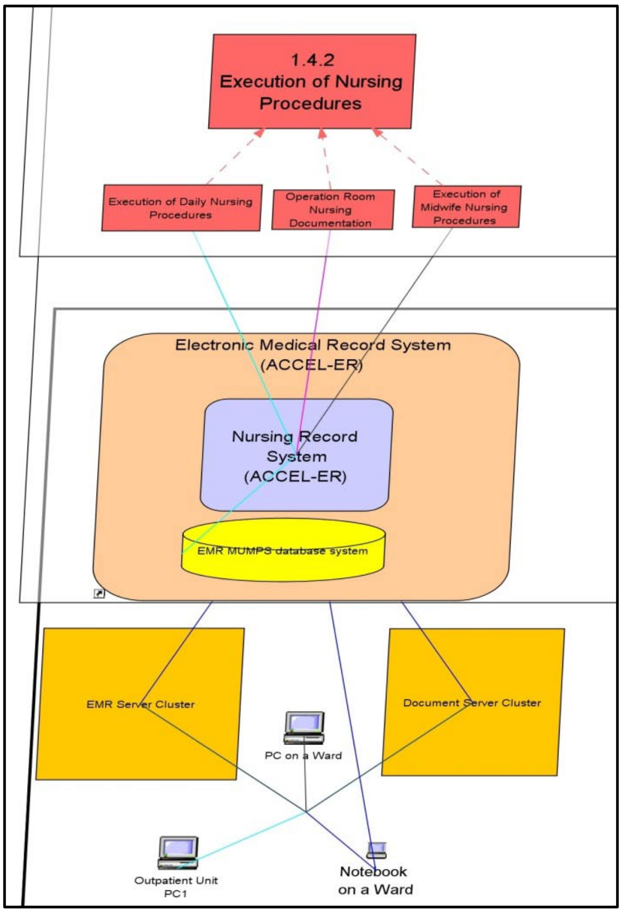

Figure 19. The support of nursing procedures on the logical and physical tool layer

Leipzig:

At the Department of Neurosurgery of University Hospital of Leipzig the nurses can use tablet PCs and notebooks for the nursing documentation within the i.s.h. med-based clinical documentation system. However, according to the modeled application component configurations in the 3LGM² model, tablet PCs for nurses are only available at the Department of Neurosurgery for “1.4.2 Execution of Nursing Procedures” within the UKL-KIS model. The documentation at sickbeds within other departments can only be done paper-based. Therefore access integration is ‘not fulfilled’

Discussion:

Although in both hospitals the most important systems for medical documentation support the nursing documentation at sickbeds, at the University Hospital of Leipzig mobile devices for nurses are only available at one department. In this case, access integration is better realized within the HIS of Chiba University Hospital. However, the total access integration of the HISs cannot be concluded from that example.

6.3.6 FRR

	Chiba	*Leipzig*
FRR (met/obj)	missing	missing

Chiba / Leipzig:

The calculation of the Functional Redundancy Rate has turned out to be not sound enough yet to come to reasonable values for both HISs. However, the functional redundancy can to some extent be discussed by means of the characteristics already described in this chapter.

Discussion:

In 6.3.3 the HIS of the University Hospital of Leipzig was described as a very fragmented information system, caused by the decentral organizational structure of the hospital (cf. 6.1.1.2). That led to department-specific application systems that support similar functions in different clinics what accounts for functional redundancies. Furthermore, when examining the adoption of clinical systems in 6.2.1, almost all subfunctions of “1. Patient Treatment” were not exclusively supported by the hospital-wide used clinical documentation system based on i.s.h med, but also by department-specific application systems.

For the HIS of Chiba University Hospital (cf. 6.3.3) a lower fragmentation could be proved which is promoted by the centralized organizational structure that helps to implement hospital-wide used application systems. In particular, the EMR system is used in all clinics for the medical and nursing documentation and hence, supports a wide range functions under “1. Patient Treatment” exclusively (cf. 6.2.1 and 6.2.4).

Thus, especially concerning systems for the clinical documentation, the HIS of the University of Leipzig can be considered as a HIS with more functional redundancies than the HIS of Chiba University Hospital. According to ([WINTER A et al. (2007b)], cf. 2.5.1), if there are application systems that could be omitted without losing functionalities in a HIS, costs could be reduced when these application systems were shut down.

6.3.7 Degree of computer support

	Chiba	*Leipzig*
$DCS(is)$ (met/obj)	0,97	0,92

Chiba/Leipzig:

Although the values for the degree of computer support could be calculated with the help of the 3LGM² tool the correctness must be questioned. In both HIS models paper-based application components were not modeled as comprehensively as computer-based application components. Furthermore, the borders of paper-based application components are difficult to determine, the granularity of modeling singly depends on the modeler. Hence, for the better comparability of models a standardized procedure for modeling paper-based application components would be helpful (cf. chapter 9).

Thus, it is restrained from discussing the degree of computer support based on the measure DCS.

6.3.8 Degree of Heterogeneity

	Chiba	*Leipzig*
$HG(is)$ (met/obj)	$10 \leq HG(is_{Chiba}) \leq 67$ • 10 different software products • 33 modeled software products • 90 application components	$123 \leq HG(is_{Leipzig}) \leq 217$ • 123 different software products • 125 modeled software products • 219 application components

Chiba:

As the degree of heterogeneity is the number of different software products in a HIS, every application component in a 3LGM² model should be assigned a software product to determine the exact number. Because not for every application component in the HIS of Chiba University Hospital the underlying software product is modeled, the calculated number must be interpreted relative to the total number of application components and the number of application components where a software product could be assigned. In total, there are 90 computer-based application components, to approximately one third of them a software product was assigned. Among the 33 modeled software products there are 10 different software products. Thus, at most 67 different software products are available in Chiba University Hospital.

Leipzig:

A similar situation arises when examining the UKL-KIS model. Not for all computer-based application components a software product was assigned, therefore the number of modeled software products, the number of different software products and the total number of application components was determined. For the UKL-KIS the number of different software products lies between 123 and 217.

Discussion:

With respect to the number of different software products both HIS are heterogeneous. However, a higher heterogeneity within the HIS of the University Hospital of Leipzig becomes obvious. A lot of different software products from different vendors (cf. 6.2) lead to the high degree of heterogeneity.

Although the HIS of Chiba University Hospital can also not be regarded as homogeneous, the software product ACCEL-ER from Toshiba which underlies the EMR system and some other subsystems like the operation room system and the rehabilitation information system promotes homogeneity for the computer-based support of patient treatment in different clinics (cf. 6.2).

6.4 Architecture of the Physical Tool Layer

6.4.1 Architectural style of the physical tool layer

	Chiba	*Leipzig*
Architectural style of the physical tool layer (nom/obj)	Client-server architectures	Client-server architectures

Chiba:

According to the 3LGM model's physical tool layer, the HIS of Chiba University Hospital has typical client-server architectures. The servers belong to a network to which also the clients in the form of personal computers or laptops are linked. Because there is a distinction between application and database servers for the EMR system, but also combined database and application servers, e.g. the Pathology Information System server, 3-tier and 2-tier architectures are the prevailing architectural styles. For the majority of the servers a central server room is assigned as location in the 3LGM² model, but some departments, e.g. the Pathology Department have a local server.

Leipzig:

In the German HIS, client-server architecture styles are dominant on the physical tool layer of the 3LGM² model. The underlying hardware for the SAP R/3 modules is a 3-tier architecture consisting of a database-server tier, an application-server tier and a client tier. Most of the clients are standard PCs; only at the Department of Neurosurgery thin clients in the form of tablet PCs are used. The German HIS has a central electronic data processing centre (EDPC) where most servers are operated. However, some departments (e.g. the Pathology Department) have their own small server room.

Discussion:

Both hospitals use client-server architectural styles on the physical tool layer. As the client-server style allows departmental client-server configurations locally scattered smaller electronic data processing centers can be set up. Additional operating costs result from maintaining several EDPCs (cf. [WINTER A et al. (2005)]). For this reason both the HIS of the University Hospital of Leipzig and the HIS of Chiba University Hospital operate central facilities where servers are maintained.

Nevertheless, especially diagnostic departments have local servers for their specialized department systems. That illustrates the local responsibility for operational security as well as data security and safety issues which can only be managed by skilled staff (cf. 6.1.2.1) and, thus, can cause additional costs.

In the HIS of the University Hospital of Leipzig with the use of thin clients in one department a first step towards lower maintenance costs for clients has been done.

6.4.2 Techniques to limit unavailability

	Chiba	*Leipzig*
Techniques to limit unavailability (nom/obj)	mixed form	mixed form

Chiba:

At Chiba University Hospital clusters and hardware redundancies in form of RAID1 are the prevailing techniques to limit unavailability. In the 3LGM² model of the HIS there are three server clusters: a cluster for the EMR system, a cluster for certain department systems, their databases and interfaces and a cluster for documents. The Dentistry Information System Server and the web server of Chiba University Hospital use RAID1, i.e. the hard disks are mirrored and store the same data redundantly.

Leipzig:

At the University Hospital of Leipzig both clusters and other hardware redundancies are used to ensure a high availability. For example, according to the 3LGM² model, the Pathology Information System and the RIS and PACS databases have clusters as a physical basis. Furthermore, many physical data processing components are described as highly redundant in the 3LGM² model of the UKL-KIS such as the physical basis for the SAP modules and the COPRA-based patient data management system, but also linking elements like switches.

Discussion:

In hospitals permanent availability of application systems, especially the avoidance of long breakdowns, is very important. In worst case, human life could be endangered if, for example, a patient data management system breaks down and vital signs cannot be monitored continuously. Therefore in both HISs different techniques to limit unavailability are used. Hardware Redundancies generally provide the possibility to switch over to the redundant component in the case of failures. For RAID1 the total availability increases with the number of mirrors. Clusters, which are used in both hospitals, usually consist of at least two computer systems and two disk systems. Thus, a cluster is a special form of hardware redundancy. Either, if a computer system fails, or if a disk system fails, the respective mirror will take over the task of the failing part. However, if software running on cluster needs to be updated, then the cluster has to be stopped [cf. VAN DEN BOSCH B et al. (2002)].

7 Supplement: The HIS of Chiba University Hospital

By interviewing staff of the Department of Medical Informatics and Management and other departments of Chiba University Hospital comprehensive information for modeling the Hospital information system of Chiba University Hospital on the three layers by means of 3LGM² was gathered. The information contained in the 3LGM² model is outlined according to the specified comparison criteria in 6.2, 6.3, and 6.4.

However, useful additional information that cannot adequately be represented in a 3LGM² model should not be neglected. For this reason the following case study gives an introduction to the HIS of Chiba University Hospital from the view of the users who work with or have to rely on the interaction of the components of the HIS. As the EMR system is the master application within the medical departments of Chiba University Hospital a short description is given. The following information can be seen as an addendum to the formal results of the comparison in chapter 6.

A case study: The processing path of an outpatient at Chiba University Hospital

Let Mrs. Tanaka be an outpatient of Chiba University Hospital who is affected by rheumatoid arthritis. When she came to the hospital for the first time she was administratively admitted by entering her master data into the Medical Accounting System. She was assigned a unique patient number and she got a patient card to be exclusively used within Chiba University Hospital. Now, because she is already a patient she checks in at one of the terminals in the entrance area if she comes to the hospital. The terminals are connected to the EMR system, thus, the physician who gave her the appointment can see if she comes to his consultation hour according to the schedule. While Mrs. Tanaka is sitting in the waiting room she is expected to measure her blood pressure at one of the set up blood pressure meters. A small sheet containing her blood pressure is printed out so that she can take it with her to the physician. The physician belongs to the 70% of the physicians who use the EMR system exclusively to document all patient-related information. Within the physician's room the physician does the medical examination and enters the results and conclusions into the EMR system as SOAP notes. SOAP stands for "Subjective", "Objective", "Assessment" and "Plan". The physician has to enter the patient's subjective impression of her health and objective health parameters, e.g. blood pressure and weight. The "Assessment" is a first diagnosis following from the subjective and objective health symptoms. The "Plan" decides upon the next steps of the treatment, e.g. blood tests or prescribing medicine. As Mrs. Tanaka did a blood test at Chiba University Hospital a few days before, the physician can also access her latest laboratory data in the EMR system and can see how the medicine prescribed over the last year affected her blood test results, because the laboratory data and the medication curves can be visualized in one diagram. Today the physician decides upon radiological imaging of her left hand and prescribes a new medicine. For these reasons the doctor writes a radiology order as well as a drug order in the EMR system. At once, with the help of the EMR system he makes an appointment at the Radiology Department one hour later. The orders are automatically transferred to the Pharmacy Department System or the Radiology Information System, respectively. Mrs. Tanaka gets the printed orders with her and walks to the Radiology Department. When it is her turn the barcode on the radiology order sheet is scanned in at the RI (Radiological Imaging) workstation. Now within the RIS the patient context is established and the imaging can start. When the images were taken, the images are both printed out and stored in the RIS database system and can then be activated from the EMR system over a web-based image viewer. After the radiological examination Mrs. Tanaka has to go and get the prescribed drugs at the Pharmacy Department. Again a barcode on the prescription sheet is read and then her drugs together with a drug information sheet are prepared. For this purpose the pharmacy department displays the individual medication history and clinical laboratory data in order to check contraindications and find the right dosage. When her patient number occurs on a monitor in the waiting area she can go to the counter and fetch the medicine. At the end she has to pay her patient's bill at one of the Automated Teller Machines (ATM) in the entrance area of the hospital.

The EMR system

The most important part of the Hospital information system of Chiba University Hospital is the Electronic Medical Record (EMR) System based on AccelWin[15]. The EMR system has several modules for the inputting and displaying patient related data. Besides modules for the clinical documentation there is a specialized nursing system which completely replaced the paper-based documentation of nurses. Providing a wide range of functions for the clinical documentation and the nursing documentation, the system offers an integrated view of the patient history at Chiba University Hospital. E.g. there are different means for structured data input, the medical information and the nursing information can be displayed in one window, different test results of a patient can be combined in one report to support decision making. Furthermore, doctors and nurses in different clinics have the possibility to adapt the system to their needs, i.e. they can define templates for the input of disease-specific data. However, the clinical modules are used similarly for stationary and ambulant cases of treatment. E.g. for entering a SOAP note a physician on a ward and a physician in an outpatient unit open the same template provided by the EMR system. Both physicians can also retrace the whole patient history, either in chronological order or arranged according to problems.

[15] AccelWin is a software product from TOSHIBA Sumiden Medical Information Systems. In July 2007 it was replaced by the latest version of TSMED's EMR system (Happy Accel) within Chiba University Hospital. Because data collection was mostly finished at that time, the ACCELWin system is described within this work.

8 Summary

This chapter summarizes the thesis by proving the compliance with the objectives and answering the questions posed in chapter 1.4.

Ad Objective 1:

It is an objective of this work to compare the HIS of Chiba University Hospital with the HIS of the University Hospital of Leipzig.

Q1.1: What are differences and similarities of the two examined HISs?

Regarding the functionality of subsystems the following differences and similarities became apparent. Both the hospital information systems of Chiba University Hospital and the University Hospital of Leipzig dispose of a variety of clinical and administrative application systems. In Chiba University Hospital most clinical tasks are supported by an Electronic Medical Record System (AccelWin, TSMED), the patient-related administrative tasks are supported by a Medical Accounting System (Hope X-WIN, Fujitsu). Regarding the most important system (R/3, SAP) within the HIS of the University Hospital of Leipzig the distinctions between the support of administrative and clinical tasks are blurred. The modules of R/3 together (including the i.s.h med module) serve both as administrative and clinical systems. However, the functionality provided by the Japanese EMR system cannot be covered by the functionality of the i.s.h. med-based clinical documentation system in the University Hospital of Leipzig. 16 systems both computer-based and paper-based of the University of Leipzig are necessary to cover the functionality provided by the EMR system of Chiba University Hospital what indicates a higher heterogeneity among the clinical systems of the University Hospital of Leipzig. However, having available clinical and administrative information in a digital format both hospitals can feed strategic systems like data warehouses which are used in both hospitals.

On the logical tool layer considerable differences could be found. Whereas the University Hospital of Leipzig has a pure DB^n style, the HIS of Chiba University Hospital has a mixture of DB^1 and DB^n style, i.e. there is one database system that can be accessed by a number of application systems, but there are also application systems which have an own database system. Within the Japanese HIS communication standards like HL7 are lowly adopted, they are just used for the communication with external healthcare institutions. On the contrary, in the German HIS HL7 is internally used for the communication via a communication server. The HIS of Chiba University Hospital is fewer fragmented and has a lower Functional Redundancy Rate than the HIS of the University Hospital of Leipzig. However, heterogeneity is inherent to both hospital information systems and can only be overcome by establishing integration between different application systems, e.g. between the systems for medical documentation and the specialized department systems of diagnostic or therapeutic units.

Regarding the physical tool layer similarities could be observed. In both HISs client-server-architectures are the prevailing architectural style. The permanent availability of the servers is ensured by the use of clusters or other forms of hardware redundancies.

For detailed descriptions of the characteristics of both HISs refer to chapter 6 which presents the results of comparing the hospital information systems of Chiba University Hospital and University Hospital of Leipzig.

Q1.2: What conclusions derive from different characteristics of both HISs?

The conclusions from every single comparison criterion regarding the functionality of the HIS's subsystems and the architecture of the logical and the physical tool layer are discussed in chapter 6.

Conclusions became obvious when relating the different criteria to each other while considering the environment in which the hospital information systems are settled. The basic facts about the hospitals and information management (see 6.1.1) helped to discuss the characteristics of the hospital information systems. The following descriptions show some connections between the organizational structures of the hospital and mutual characteristics within the both HISs.

As Chiba University Hospital has a centralized, hierarchical organizational structure, a less fragmented HIS with fewer functional redundancies than that of the University Hospital of Leipzig could develop. The hospital-wide used EMR system with a MUMPS database which can be also accessed from some other subsystems and a manageable number of subsystem vendors lead to a more homogenous HIS where the use of communication standards was not necessary.

On the contrary, the University Hospital of Leipzig has a decentral matrix structure which lead to a more fragmented information system. Different organizational units often use specialized department systems from different vendors what often leads to functional redundancies. However, the heterogeneity of the HIS lead to the use of communication standards between the most important subsystems.

Ad Objective 2:

It is an objective of this work to develop a method for a structured comparison of hospital information systems by means of 3LGM² and the Reference Model for the Domain Layer of Hospital Information Systems.

Q2.1: What are suitable criteria for a comparison of two HIS by 3LGM² models and the Reference Model for the Domain Layer?

This question is answered in chapter 4. The criteria for comparing hospital information systems by 3LGM² models have to orientate on the elements and the relationships between elements that can be modeled on the three layers of 3LGM². With the help of the Reference Model for the Domain Layer the support of the same enterprise functions in different HIS was examinable. Thus, mainly the functionality of application systems, architectural concepts, means of communication between the application components and technologies which underlie the application components within different information systems are addressed by a comparison based on 3LGM² models. The major sets of criteria were reduced to “Functionality of Application Systems”, “Architecture of the logical tool layer” and “Architecture of the physical tool layer”. For a detailed listing of all criteria see 4.4.

Especially for examining the functionality of application systems the Reference Model for the Domain Layer was not renounceable because it could be observed by what application components the same enterprise functions are supported in different HIS. But also for assessing criteria that manifest on the logical tool layer like data integration or access integration is was important to base on the same enterprise functions and entity types on the domain layer.

Q2.2: To what extent are the identified criteria measurable by means of 3LGM²?

Possible criteria for a 3LGM²-based comparison which were identified in 4.2 had to be assigned to different scales on which they can be measured within a 3LGM² model. Whereas key figures like the Functional Redundancy Rate and the Degree of Computer Support can be determined on a metric scale, for other criteria such as the fragmentation of the information system and the use of communication standards there are no key figures available. They were assessed on ordinal scales. The assessment can be interpreted in the sense of ‘1=no use/support’ to ‘4=complete use/support’. For some criteria like the architectural style nominal answer sets proved to be most appropriate. The metric and nominal criteria can mostly be derived objectively from a 3LGM² model, for the ordinal criteria only a subjective assessment proved to be suitable (see 4.3.2).

Ad Objective 3:

It is an objective of this work to model the HIS of Chiba University Hospital by means of 3LGM² and the Reference Model for the Domain Layer of Hospital Information Systems.

Q3.1: Which procedures should be applied in order to model the HIS of Chiba University Hospital?

As a theoretical foundation for collecting data about the Japanese in order to create a 3LGM² model the method described in [SPEWAK SH and HILL CH (1992)] was chosen. Thus, the project initiation for modeling the HIS of Chiba University Hospital was followed by data collection and a modeling phase. The detailed procedure model which lists for every week spent at the Department of Medical Informatics and Management of Chiba University Hospital the single tasks towards a model of the HIS, is described in 5.1.

Q3.2: Is the Reference Model for the Domain Layer of hospital information systems suitable for modeling the HIS of Chiba University Hospital?

On the whole, the Reference Model for the Domain Layer proved to be suitable for modeling the Japanese HIS although it had only been used for modeling HISs in the German-speaking area before.

For coming to that answer the suitability of the enterprise functions and the entity types had to be proved. The enterprise functions are suitable as far as they are formulated very generally. However, especially for some enterprise functions subordinated to “1. Patient Treatment” the granularity of enterprise functions on the same hierarchy level is very different. For example, while “1.1.4 Medical Admission” and “1.1.5 Nursing Admission” are separate enterprise functions “1.2.2 Clinical and Nursing Care Planning” is summarized under one enterprise function. Thus, many functions had to be refined as it had been done in the UKL-KIS model, too. Furthermore, few functions were deleted because they were not suitable for describing the Japanese HIS. Also for the entity types the level of detail was increased and few of them were deleted. Furthermore, additional entity types were introduced to model the HIS of Chiba University Hospital adequately. For a more detailed description, see 5.2.3.

However, as most modifications on the reference model were refinements in the form adding subelements to the enterprise functions and entity types, the comparability by means of the super-ordinate functions remained.

9 Discussion and Outlook

3LGM² models can be used for planning, documenting and analyzing the architecture of an information system. Modeling the HIS of Chiba University Hospital by means of 3LGM² and comparing it to the 3LGM² model of the UKL-KIS, architectural similarities and differences (e.g. architectural styles) of both hospital information systems could be identified.

In order to increase the significance of comparison based on 3LGM² models, further key figures such as the Functional Redundancy Rate, which allow a formal assessment of certain HIS characteristics, would be helpful. For example, regarding the functionality of application systems, measures were not available. Therefore ordinal and nominal answer sets had to be used to assess them. Possibly, the idea to examine the coverage of functionality by application components in different HISs, as it was done for clinical, administrative, strategic functions and the functionality of the EMR system of Chiba University Hospital compared to an equivalent set of application components within the UKL-KIS, can be extended in order to develop a new measure. For defined sets of enterprise functions equivalent sets of application components in different HISs could be determined. That measure could be used for assessing an aspect of the leanness of information processing tools according to [HAUX R et al. (2004)]: for a certain task or a set of related tasks a doctor or a nurse should have to use as few application components as possible. However, the use of such key figures requires models that meet particular minimum standards.

Therefore, modeling guidelines or procedure models would be helpful for the modelers. Although the Reference Model for the Domain Layer helps in starting the modeling process, for the logical tool layer and the physical tool layer there are no guidelines that support modeling decisions, e.g. according to the granularity of the modeled elements. In the case of modeling the HIS of Chiba University Hospital the already available 3LGM² model of the HIS of the University Hospital of Leipzig could be taken as a reference to find a corresponding modeling style, also against the backdrop of the later comparison of both HIS. But especially for modeling paper-based application components the modeler is faced with certain problems. For example, paper-based application components are difficult to demarcate from each other. Whereas application systems are often determined by the underlying software products which can be used at defined workplaces, paper-based application components can comprise a workplace, a room, a department or the whole institution. Modeling decisions regarding paper-based application components strongly depend on the relevance which the modeler attaches to the paper-based application components. As the experiences with modeling the HIS of the University Hospital of Leipzig and the HIS of Chiba University Hospital show, paper-based application components are often modeled insufficient in particular when compared to the modeling of computer-based application components. Therefore in the comparison (cf.

chapter 6.3.7) the values calculated for the degree of computer support did not provide a basis for meaningful conclusions about the real computer support in both hospitals. Also, an assessment of media cracks would not have provided interpretable results.

Hence, in order to compare different models, possibly from different modelers, a standardized procedure for modeling becomes even more important to guarantee comparability of the models.

With respect to the results of the comparison, there was no decision in favor of one of the HISs examined done. For assessing the overall quality and performance of both hospital information systems further investigations would be necessary.

First, 3LGM² models show what application components and technologies are available within the HIS. But it cannot be determined to what extent they are really used by those who ought to work with them. To answer these kinds questions, [MUELLER U and WINTER A (2005)] introduced a monitoring infrastructure based on key performance indicators to assess the utilization degree of certain application systems.

Second, the quality of a hospital information system reflected in the satisfaction of its users which cannot be measured by a 3LGM² model. That means, the hospital staff like physicians, nurses and administrative staff could be asked to answer surveys about the fulfillment of their expectations with respect to the application systems and technologies they use. This kind of approach for measuring the outcome quality of a HIS was presented in [AMMENWERTH E et al. (2007)].

Thus, a combination of comparisons of the architectures, the utilization degree of application systems and evaluations of a system’s stakeholders could help to assess the overall quality of a HIS.

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Figures

Figure 1. Three-dimensional classification of information management activities [WINTER A et al. (2001)] ... 8

Figure 2. UML diagram of the domain layer within 3LGM² (taken from www.3LGM.de) ... 11

Figure 3. UML Diagram of the Logical Tool Layer within 3LGM² (taken from www.3lgm.de) ... 12

Figure 4. UML diagram of the Physical Tool Layer within 3LGM² (taken from www.3lgm.de) ... 13

Figure 5. Components of Enterprise Architecture Planning according to [SPEWAK SH and HILL CH (1992)] ... 15

Figure 6. The DB^1 architecture style ... 18

Figure 7. DB^n architectural style with communication server ... 19

Figure 8. Example of a matrix SUP ... 24

Figure 9. Hierarchy of functions under 1.4.1 ... 56

Figure 10. The logical tool layer of the HIS of Chiba University Hospital ... 60

Figure 11. The physical tool layer of the HIS of Chiba University Hospital ... 61

Figure 12. Functions among "1. Patient Treatment" supported by the EMR system are highlighted ... 69

Figure 13. Application components supporting function 1.2.1 ... 70

Figure 14. Rough overview of the functions supported by SAP's R3 (yellow color stands for support by R/3) ... 73

Figure 15. Databases which store the entity type „Patient master data" are highlighted (clipping of the UKL KIS model) ... 78

Figure 16. Billing information is sent via the EMR system (simplified clipping of the Japanese model) ... 80

Figure 17. Bold elements indicate interfaces and communication links using HL7 ... 81

Figure 18. Storage and transmission of "Patient Master Data" ... 84

Figure 19. The support of nursing procedures ... 85

Tables

Table 1. Typical application components within a hospital 7

Table 2 Architectural Quality Criteria according to [BRIGL B et al. 2004] 23

Table 3. Major criteria for the comparison (cf. 2.5.3) 34

Table 4. Catalogue of comparison criteria for 3LGM² models 47

Table 5. Schedule for Chiba 51

Table 6. Coverage of the functionality of the EMR system within the UKL-KIS 76

Appendix

Appendix A – The hierarchy of functions of the Reference Model for the Domain Layer of HISs

- 1. Patient care
  - 1.1. Patient admission
    - 1.1.1 & 2.2.1 Appointment scheduling
    - 1.1.2 & 3.1.2 Patient Identification and Identification as Recurrent
    - 1.1.3 & 3.1.1 Administrative Admission
    - 1.1.4. Medical Admission
    - 1.1.5. Nursing admission
    - 1.1.6 & 3.1.3 Information Services
  - 1.2. Decision Making, Planning and Organization of Patient Treatment
    - 1.2.1. Decision Making and Patient Information
    - 1.2.2. Clinical and nursing care planning
  - 1.3. Order Entry and Communication of Findings
    - 1.3.1. Preparation of an Order
    - 1.3.2. Appointment Scheduling
  - 1.4. Execution of diagnostic, therapeutic and nursing procedures
    - 1.4.1 Execution of Diagnostic and Therapeutic Procedures
    - 1.4.2 Execution of Nursing Procedures
  - 1.5. Administrative Documentation and Billing
    - 1.5.1 Coding of Diagnoses
    - 1.5.2 Coding of Procedures
  - 1.6. Patient Discharge and Referral to Other Institutions
    - 1.6.1 & 3.1.4 Administrative Discharge and Final Billing
    - 1.6.2 Medical Discharge and Writing the Discharge Letter
    - 1.6.3 Nursing Discharge and Writing the Nursing Discharge Report

- 2. Supply Management, Scheduling and Resource Allocation
  - 2.1 Supply and Disposal Management
    - 2.1.1 Food Supply Management
    - 2.1.2. Material and Pharmaceuticals Management
    - 2.1.3 Management of Equipment
    - 2.1.4 Laundry Management
  - 2.2 Scheduling and Resource Allocation
    - 1.1.1 & 2.2.1 Appointment scheduling
    - 2.2.2 Scheduling and Resource Planning with the Medical Service Provider

        - 2.2.3 Scheduling and Resource Planning with the Ambulance Service
    - 2.3 Human Resource Management
        - 2.3.1. Administration of Human Resource Master Data
        - 2.3.2. Human Resource Planning
        - 2.3.3. Work Organization and Time Planning
        - 2.3.4. Payroll Accounting
        - 2.3.5. Administration of Business Trips and Further Training

- 3. Hospital administration
    - 3.1 Patient Management
        - 1.1.2 & 3.1.2 Patient Identification and Identification as Recurrent
        - 1.1.3 & 3.1.1 Administrative Admission
        - 1.1.6 & 3.1.3 Information Services
        - 1.6.1 & 3.1.4 Administrative Discharge and Final Billing
    - 3.2 Archiving of Patient Information
        - 3.2.1 Opening a Patient Record
        - 3.2.2 Administration and Provision of Medical Records
    - 3.3 Quality management
        - 3.3.1 Internal Quality Management
        - 3.3.2 Fullfillment of Registration Requirements
    - 3.4 Controlling
    - 3.5 Cost and Results Accounting
    - 3.6 Financial Accounting
    - 3.7 Facility Management
    - 3.8 Information Management
        - 3.8.1 Strategic Information Management
        - 3.8.2 Tactical Information Management
        - 3.8.3 Operational Information Management

- 4. Hospital Management

- 5. Research and Teaching
    - 5.1 Research Management
    - 5.2. Execution of Research Activities
    - 5.3. Knowledge inquiry and literature management
    - 5.4. Publishing and Presenting
    - 5.5 Teachings

- 6. Miscellaneous Functions

Erklärung

Ich versichere, dass ich die vorliegende Arbeit selbständig und nur unter Verwendung der angegebenen Quellen und Hilfsmittel angefertigt habe.

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Franziska Jahn