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Report on

The socio-economic impact of the computerised patient record systems at the University Hospitals of Geneva

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About EHR IMAPCT

The EHR IMPACT study was commissioned by DG INFSO and Media, unit ICT for Health, and will result in ten independent evaluations of good practice cases of interoperable electronic health record (EHR) and ePrescribing systems in Europe and beyond. The goal of the study is to support ongoing initiatives and implementation work by the European Commission, Member States governments, private investors, and other actors. The study aims to improve awareness of the benefits and provide new empirical evidence on the socio-economic impact and lessons learnt from successfully implemented systems.

Full project title

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Computerised patient records (CPR) systems at the University Hospitals of Geneva (HUG)

Socio-economic impact and lessons learnt for future investments in interoperable electronic health record and ePrescribing systems

Geneva, Switzerland

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The study team

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Abbreviations

ADT	Admission-Discharge-Transfer
CEN	European Committee for Standardisation (Comité Européen de Normalisation)
CEO	Chief Executive Officer
CHF	Swiss Franc
CIS	Clinical Information System
CPOE	Complete Order Entry
CPR	Cardiopulmonary Resuscitation
CPR	Computerised Patient Record
DICOM	Digital Imaging and Communications in Medicine
DSS	Decision Support System
EHR	Electronic Health Record
EHRI	Electronic Health Record Impact
GDP	Gross Domestic Product
HIS	Hospital Information System
HPO	Health Provider Organisation
HUG	University Hospitals of Geneva
ICT	Information and Communication Technology
ICU	Intensive Care Unit
LIS	Laboratory Information System
NANDA	North American Nursing Diagnosis Association
NIC	Network Interface Controller (Network Card)
NOC	Network Operation Centre
OECD	Organisation or Economic Cooperation and Development
PACS	Picture Archiving and Communication Systems
PF	Patient Facts
SIM	Subscriber Identity Module
SOA	Service-Oriented Architecture
WHO	World Health Organisation

EXECUTIVE SUMMARY

The computerised patient record (CPR) systems at the University Hospitals of Geneva (HUG) is analysed as one of ten implemented and ongoing European good practice cases in the context of the EHR IMPACT (EHRI) study. EHRI investigates the socio-economic impact of eHealth utilisation, with specific focus on interoperable Electronic Health Record (EHR) and ePrescribing systems in Europe.

Organised as a consortium of hospitals, HUG is the major public healthcare facility in the Geneva region and adjacent France. Offering a complementary service portfolio, HUG covers the whole spectrum of outpatients and primary, secondary and tertiary inpatients care, including long-term rehabilitation and psychiatry. On an annual budget of CHF 1.4bn, HUG manages over 48,000 admissions and 800,000 outpatient visits each year, with a base of more than 2,000 beds, over 7,000 care professionals, and 10,000 employees.

Based on a mostly administrative predecessor hospital information system, the CPR system today integrates clinical and non-clinical processes into a patient centred care service. It covers complete order entry (CPOE) for all orders including lab, drug, radiology, and care; unified clinical documentation; administrative information; access management; imaging; and laboratory information. The CPR itself is always the result of a real-time query of all relevant databases in the system.

After planning started in 1998, the system has been developed and implemented gradually since 2000, in order to facilitate user involvement and individualisation in the different departments. Supported by an infrastructure covering over 7,000 computers, the CPR has reached a high usage level among care providers everywhere across the HUG, amounting to over 25,000 times a record is accessed a day in 2007.

Improved quality of care and efficiency are the most prominent benefits of the CPR system at HUG. While time savings and cost avoidance can be primarily assigned to the healthcare provider organisation's (HPO) benefits, patients mainly benefit from the improved quality of care. Healthcare professionals mostly profit from better employed time, better work satisfaction because of the improved availability of information in real time, and the lower exposure to risks. The identified costs of the CPR system include the financial investment for ICT, but also any negative impact of implementing and using the system. The latter include the extra time and cognitive effort to use the CPR system, disruptions in the implementation stage, in which processes take rather more time than less, as well as extra time for ward rounds and forgone income for avoided procedures. Health insurances face a higher bill because of better billing procedures related to the CPR system.

It is reasonable to assume that the CPR at HUG is entirely about interoperability, so the cost and benefits reflect this single feature. This judgement attributes the expanding utilisation of the data to effective interoperability.

The socio-economic evaluation of the CPR system identified that annual net benefits were first realised in 2004 some 7 ears after the start and some four years after initial implementation of the first functionalities. From year nine, 2006, the margin is substantial and increasing, indicating a strong, sustainable positive impact. The delayed realisation of benefits is due to the fact that the EHRI methodology includes all costs including pre-development planning. The relatively slow build-up of benefits in the first three to four years is consistent with the approach towards ensuring acceptance before changing working practices. The gradual build-up may also indicate the reduced risk that was achieved by the internal development strategy, which focuses on robustness and reliability of all implemented features of the system.

Cumulative benefits exceeded total costs in 2007 and demonstrates a stable upward trend. The gap of three years between realisation of annual and cumulative net benefits is consistent with observations at other sites and can be attributed to the relatively fast increase in the net benefit margin once annual benefits start exceeding annual costs. The cumulative cost curve increases gradually over the first five years of planning and development. The rate of increase accelerates in the period 2002-2005, reflecting the substantial increase in the number of users and utilisation. The rate of increase of cumulative benefits stabilises after 2006, at a rate significantly higher than the stable rate of increases costs. This indicates the long-term economic sustainability of CPR at HUG.

The annual net benefit to costs ratio, the relationship between the net socio-economic impact of the evaluated system to its negative effects, is slightly positive and rises to +1.79 at year thirteen, 2010. The cumulative ratio increases steadily over the life-cycle and turns positive in 2007, year ten. By 2010, the cumulative net benefit to cost ration reaches +0.65, meaning that for every CHF 100 worth of negative impact, there are CHF 165 worth of positive impact. The ratio can also be understood as a rate of socio-economic, yet not purely financial, return over a given period. This indicates an overall socio-economic return from the CIS and HUG of about 65% over a lifecycle of 13 years.

Estimated costs are distributed almost entirely between HUG, as an HPO, and the canton of Geneva and health insurance companies as a third parties. Disruptions and inconveniences to care providers account for a small share of the costs. Patients are not negatively affected by the system. The largest share both in costs and benefits accrues to the HPO, with about 60% and 90% respectively. The canton of Geneva is the only stakeholder not receiving enough benefits to cover the incurred costs. This phenomenon can be explained by the nature of the canton as a political entity representing the state, or the social planner. Thus, investments should and are justified by benefits to citizens and society as a whole. In this sense, the canton should compare its investment to the overall benefits realised, including those to the HPO.

A finding from HUG that is in line with most comparable sites is that benefits are mainly in quality of care and not in extra cash. Approximately 83% of total costs of the system are extra finance, facing an equivalent of only 3% extra financial benefits. The analysis shows a financial position where extra cash of more than CHF 63 million is invested over thirteen years to realise CHF 4.3 million of financial benefits. This means that at least CHF 59.3 million, some 57% of the potentially redeployed resources, have to be actually released for a financial return to be achieved. However, the investment has already been worthwhile from the socio-economic perspective, which justifies not only the investment as a whole, but also the financial contribution of the state. Considering HUG alone, over CHF 32 million of extra cash and nearly CHF 13 million of redeployed resources stand against CHF 3 million of extra income and some CHF 103 million of resources that can be redeployed. Bridging the purely financial gap by releasing finance from redeployed resources is one of the goals of HUG's management. This is considered challenging, yet not unrealistic, especially in the longer turn.

Economic sustainability is a primary indicator of success. The current achievement of the CPR systems at HUG from a socio-economic point of view is positive and robust. The annual net socio-economic benefit from the system at this point in time has reached a stable size and will continue to improve the cumulative position.

The three main lessons for future investors can be summarised as follows:

- Investors need deep pockets and a lot of patience. Up to ten years and CHF 63 million total costs for the CIS at HUG needed to be invested and financed.
- Investors need to know what they get. The benefits, the value of which exceeds the costs by nearly CHF 50 million over the life cycle of thirteen years, are mainly in quality of care and potential liberation of scattered resources, not in extra cash.

- Investors need to know what can go wrong. Realistic risk management is essential for the realisation of net benefits. At HUG, major risks were associated with technology failure and with acceptance of the system by users. The identification of risks is the first step towards their mitigation.

The clinical information systems at HUG illustrate in a profound way what electronic health records, combined with ePrescribing in a wider sense, can do for healthcare provision in a hospital environment. This case study shows good practice that can be taken as a benchmark for similar investments. At the same time, readers should be aware that the results achieved at HUG are above average; an artefact of the EHRI study design. The general conclusion from the case study is that investing in EHR and ePrescribing systems for hospitals is a worthwhile endeavour, provided the investment is well grounded and an integral part of the organisation's strategy.

1 Background

1.1 Health system setting

Switzerland has a GDP per capita 15% - 20% above that of the big West European economies[1]. It is thus not surprising that the country can afford an extremely well developed healthcare system[2]. According to OECD statistics, it is the third most expensive in the world. Only the USA and Germany spend a higher proportion of their national economic output on healthcare. In 2006, Switzerland spent 11.4% of its GDP on healthcare services.[3]

The organisation of healthcare in Switzerland falls into the responsibility of the cantons, which are the states of the Swiss Confederation. There are 26 cantons in Switzerland, six of which are semi-cantons, acting autonomously in matters of health and healthcare. Among others, they are responsible for health regulation, hospital accreditation and finance, along with disease prevention and health education. The result is 26 slightly different health systems.[4] Voters participate directly in the political process of the cantons through referenda and direct democracy mechanisms. Thus, preferences of potential patients determine the structure of the system to a degree found in few other countries.[5]

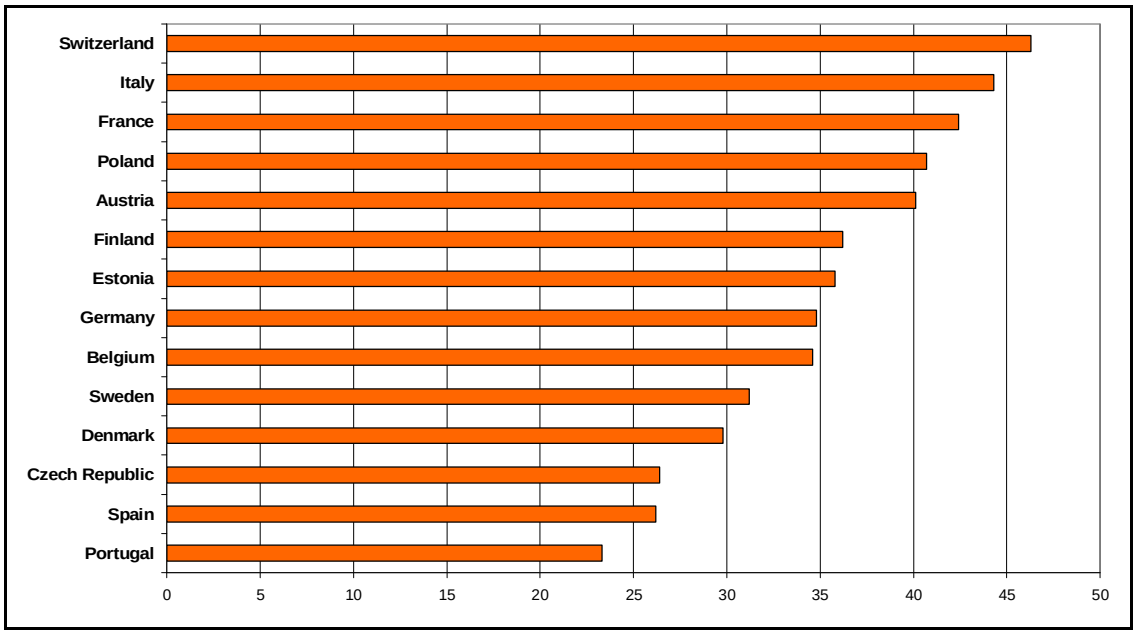
The Swiss healthcare system is funded through a combination of public and private sources, with a proportion of private sources that is one of the highest in Europe[6] (41.5% in 2005)[7]. Every citizen is required by the federal law to obtain compulsory basic health insurance. He or she can choose from over 90 insurance carriers, registered and regulated by the Swiss Federal Office of Public Health. Premiums are independent of income and paid directly to the insurer. Insurers are not allowed to earn profits on the compulsory health insurance, but can profit from selling supplemental insurance.[8] It is estimated that between 25% and 40% of the population purchases supplemental insurance[9], but the standard of medical care cover provided under compulsory insurance is considered high.[10]

Independent practice physicians provide most ambulatory care. In principle, patients can choose their physician or dentist freely, though most have a regular doctor.[11]

The Swiss population benefits from a generous hospital infrastructure. In 2004, there were a total of 345 hospitals with 5.7 beds per 1000 population. Average length of hospital stay is comparatively high. The proportion of total healthcare expenditure spent on hospital care is the highest in Europe (see chart below).[12]

[1] CIA World Factbook, 2000
[2] The Swiss Healthcaresystem (2002), Civitas Institute
[3] World Bank online (2009): http://ddp-ext.worldbank.org/ext/ddpreports/ViewSharedReport?&CF=1&REPORT_ID=10315&REQUEST_TYPE=VIEWADVANCED&HF=N
[4] WHO, 'Highlights on Health in Switzerland', World Health Organisation, 2001
[5] The Swiss Healthcaresystem (2002), Civitas Institute
[6] Jacobs, R and Goddard, M., Social Health Insurance Systems in European Countries
[7] WHO Core Health Indicators 2007
[8] http://www.bag.admin.ch/themen/krankenversicherung/00263/00264/02424/index.html?lang=en
[9] WHO, 'Highlights on Health in Switzerland', World Health Organisation, 2001
[10] Health Insurance in Europe, Comite Europeen des Assurances, 1997
[11] The Swiss Healthcaresystem (2002), Civitas Institute
[12] The Swiss Healthcaresystem (2002), Civitas Institute

Chart 1: Total inpatient expenditure as % of total health expenditure



Source: WHO[13]

Hospitals are operated either by public entities, such as cantons or local authorities, or private institutions, which can be managed on a profit-making or non-profit basis.

Each canton plans hospital care according to local needs and generates a list of accredited hospitals, which are entitled to reimbursement under the compulsory insurance.[14] These official canton hospital lists are drawn up based on bed requirements. The target number of beds per 1000 population is varying between 2.6 and 3.5 beds (for 2005).[15] A health service provider organisation that is not on the list does not receive reimbursements under compulsory insurance schemes. Private hospitals that are included in the canton's hospital list can receive reimbursement for services under the compulsory health insurance.[16] However, new private organisations can find it hard to get on local cantonal lists.[17] In theory, there is competition between hospitals, but some argue that in practice, there is a choice in type of hospital and level of privacy, but no real competition.[18]

1.2 Place of EHR, ePrecribing and interoperability in the framework

Since the organisation of healthcare in Switzerland is canton-based, the development of a unified eHealth system is a significant challenge. In January 2006, the Federal Council commissioned the Federal Department of Home Affairs to submit a concept with measures for a national eHealth strategy. The draft strategy was drawn up within the framework of a joint project by the Federal Office for Public Health, the Federal Office of Communications

[13] World Health Organization, Regional Office for Europe, European health for all database
[14] Jacobs, R and Goddard, M., Social Health Insurance Systems in European Countries
[15] Jacobs, R and Goddard, M., Social Health Insurance Systems in European Countries
[16] Jacobs, R and Goddard, M., Social Health Insurance Systems in European Countries
[17] The Swiss Healthcaresystem (2002), Civitas Institute
[18] Zweifel, presentation to the Health Policy Reform Group, 2001

(Coordination Office Information Society) and the Conference of Cantonal Health Directors. The Federal Council adopted the eHealth strategy for Switzerland on 27 June 2007[19].

According to the strategy, starting from 2015 a personal lifelong electronic patient record is to be available in Switzerland.[20] This will be introduced on a phased basis. The objective is improved efficiency, quality, and security. The prerequisites are strong privacy, data security, and clear information governance rules. This task is to be resolved in cooperation with the cantons and private organisations.

All cantons consider the introduction of such a national health roadmap as being either "important" or "very important". Although the implementation of concrete eHealth projects is a task for the cantons, some similar top down initiatives in cantonal and federal health policymaking have been successful in the past, such as the 1994 revision of sickness insurance laws, which established the compulsory insurance.

[19] http://www.bakom.admin.ch/themen/infosociety/01689/index.html?lang=en
[20] eHealth ERA report – March 2007

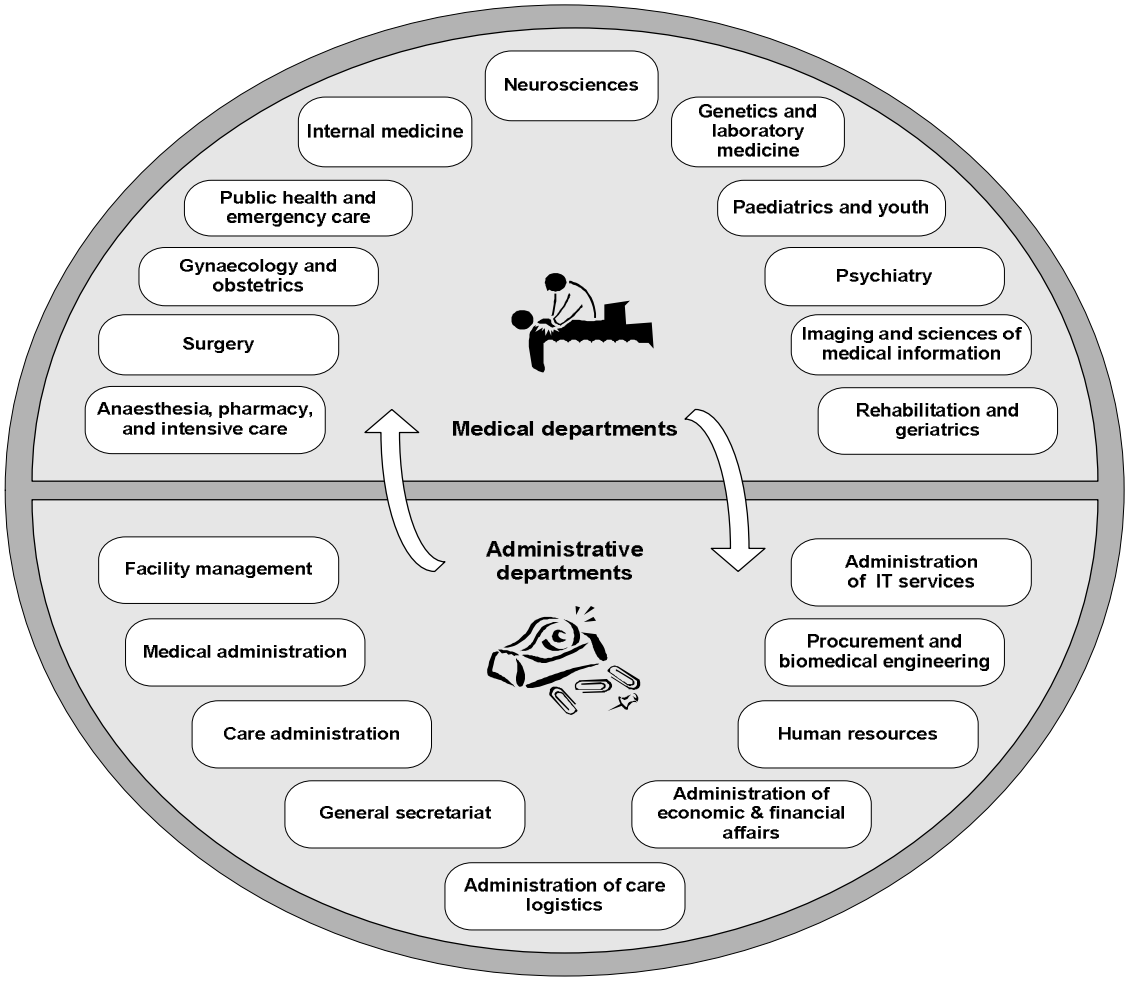
2 The CPR and clinical information system at the University Hospitals of Geneva

2.1 Organisation involved

This case study focuses on a consortium of public hospitals in Switzerland – the University Hospitals of Geneva (HUG). HUG is the major public healthcare facility in the Geneva region and adjacent France. In its current form, HUG was created in 1995, when all four public hospitals in Geneva were merged with a decision of the canton parliament. The merged hospitals were not competing, but rather complementary in their service portfolio, so now HUG covers the whole spectrum of outpatients and primary, secondary and tertiary inpatients care, including long-term rehabilitation and psychiatry.

The consortium consists of 7 public and teaching facilities in four campuses and more than 30 ambulatory facilities in the state of Geneva. HUG manages over 48,000 admissions and 800,000 outpatient visits each year, with a base of more than 2,000 beds, over 7,000 care professionals, and 10,000 employees, with an annual budget of nearly 1.4bn CHF.

Figure 1: HUG's organisation structure



2.2 Context of the initiative and eHealth dynamic

The University Hospitals of Geneva (HUG) have a long history of using information technologies in the hospital, mainly due to the pioneer work of Prof. Jean-Raoul Scherrer, who designed and implemented one of the first hospital information systems (HIS) in Europe in the seventies. It should be noticed that up to the nineties HIS were mainly administrative, including only admission-discharge-transfer (ADT) management and medico-technical applications, such as laboratory information system (LIS) and picture archiving systems. In this section, we briefly touch on the history of HUG's information system, the experience from which is invaluable for the current system and future developments.

2.2.1 Context and strategy

Building on the past

The university hospitals of Geneva have historically been a pioneer and frontrunner in using information and communication technology (ICT) in a hospital setting. Diogenes, the self-developed system used till the late nineties was one of the very first hospital information systems[21]. It supported mostly administrative applications such ADT, billing, human resources and stock management. Medico-technical applications included LIS and PACS, as well as a computerised order entry system for laboratory tests. Diogenes was continuously refined and upgraded in a very homogeneous manner, yet mostly using a client-server approach based on the C language and X-Windows. The Intensive Care Units (ICU) where using a third party, commercial, computerised patient record (CPR) system that had no interoperability with the rest of the HIS, with the exception of ADT. Small and numerous vertical applications with no integration where used in many places. Some of them were commercial; some of them were built in-house by users.

Around 1995, a first attempt to build a unified CPR was launched. Because of internal rules, the system had to be completely unconnected to the HIS. This constraint led to the first implementation of a Service-Oriented Architecture (SOA). The first client, launched towards the end of 1996, was communicating using SGML and in-house developed HTTP servers. A benefit of the component-based architecture was to allow developers of the CPR with different backgrounds in programming languages to employ their respective language expertise while keeping interoperability requirements.

At the same time, in 1995, the canton of Geneva decided to unify the then four public hospitals into one unique entity, the University Hospitals of Geneva. Two years later, in 1997, the Canton Parliament took the decision to finance a major investment in IT at HUG. One third of the overall sum was dedicated to elements of the hospital information system that support clinical processes. In 2002, the STRATISSE strategic plan for IT in the HUG has been adopted. It poses the foundation of a new architecture, based on thin clients and Java application servers. While adopting these rules, the Clinical Information System (CIS) in addition enforced the already existing SOA and components based architecture. At the end of 2000, a message-oriented middleware was added to the CIS.

Current strategy

Professor Antoine Geissbühler, MD, Medical CIO of HUG and professor Christian Lovis, MD MPH, who leads the Unit of Clinical Informatics, are the drivers behind the development of the CIS, including the CPR functions.

[21] Geissbühler A, Lovis C, Spahni S, Appel RD, Ratib O, Boyer C, Hochstrasser DF, Baud R., A humanist's legacy in medical informatics: visions and accomplishments of Professor Jean-Raoul Scherrer. Methods Inf Med. 2002;41(3):237-42.

The strategy leading the development of the CIS has been founded on several pillars:

Objectives

- The CIS must improve safety and quality of care first;
- The CIS must help care providers first;
- The CIS must be completely integrated in the HIS and is the heart of the HIS;
- The CIS must be useful for all stakeholders, including logistics of care and hospital management.

Buy or build

- Build an interoperable platform as the backbone of the system;
- Buy existing industrial components proven to be robust and interoperable;
- Build interoperability mechanisms to allow the systems to communicate seamlessly;
- Build all systems that cannot be bought or do not have the expected functionalities;
- Avoid large versioning. Instead, provide constant small improvements. This avoids education gaps and too risky releases.

Architecture

- Component-based, message oriented middleware;
- Service oriented;
- Human-machine interfaces are independent components in order to allow very user-specific screens.

Deployment

- First deploy CIS functionalities matching existing processes, only later use the CIS to change processes;
- Deploy small functionalities widely;
- For large functionalities, avoid pilots: deploy smoothly but constantly.

Functional requirements

- Involve users massively;
- Never develop or deploy without having the support and engagement of leaders from the clinical settings
- Help users understand a vision of an integrated, interoperable information system, while reaching their specific goals, through assisting the clinical sponsors for the realisation of the project.

Much of the ongoing work consists of parametrising the system to fit the clinicians' needs. For example, some 20 pathway-teams, consisting of physicians, nurses, and many other categories of professions involved, are currently defining clinical pathways.

Next steps

The ongoing developments include improvements or deployment of existing systems, such as deploying real-time in-room data acquisition with touch-screens in operating theatres, and increasing decision-support functionalities in CPOE. In addition, the following elements are planned and in development:

- Unified order entry that includes nursing care, which is a direct link between the physician's orders and the nursing care pertaining to this order. Currently nurse and physician order systems are connected, but not integrated;
- Unified ward scheduling system that includes all care for every patient in the ward;
- Problem list oriented records;

- Nursing charts;
- Bedside scanning for drug administration;
- Direct link between drug order, drug administration and stock management;
- Knowledge management tools;
- Extension of the communication portal with the community network, especially towards allowing direct access for patients to their record;
- Direct link between clinical documentation and billing.

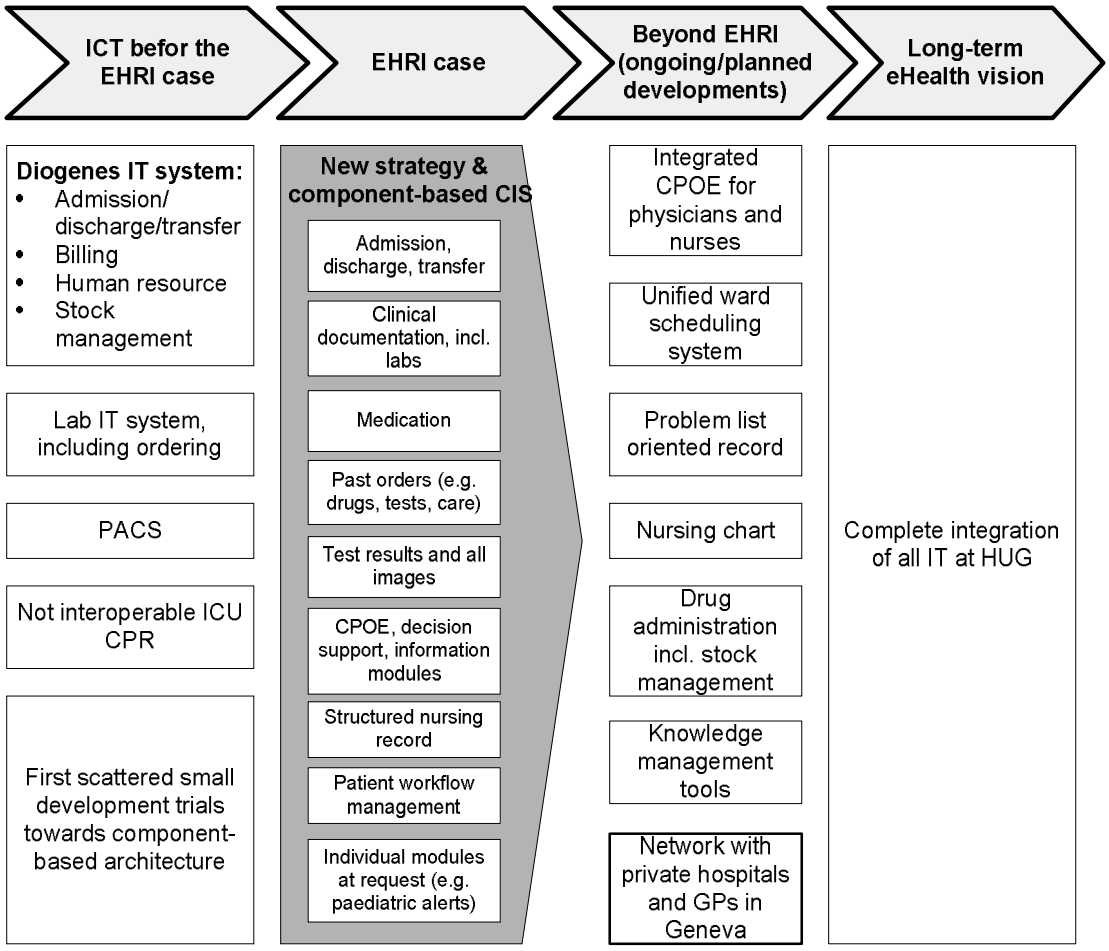
Medium-term plans include further developments on the communication platform to increase functionalities to support longitudinal care with GP's and the community network and improve interoperability with the logistics of care applications, mostly towards global track, trace and scan solutions.

The long-term plan is the complete integration of all IT in the HUG, with the CIS as cornerstone, tightly embedded in the HIS.

eHealth dynamic

Continuous development is an integral feature of the CIS strategy. It involves both extending existing functionalities, as well as absorbing existing unconnected vertical systems. This continuous development has created an eHealth dynamic at HUG, which builds on small steps in a flexible strategy, following a clear long-term vision. The eHealth dynamic of developments is illustrated in Figure 2 below. It shows the historical development of implementing IT at HUG, which provided a vital technological basis and organisational culture facilitating the developments included in the scope this evaluation. The figure also illustrates the next steps in the development of CPR and CIS, which evolve within the dynamic of developments, but are not included in the scope of the current evaluation.

Figure 2: eHealth dynamic at the University Hospitals of Geneva



2.2.2 Situation as of summer 2008

In summer 2008, the CIS, which is the basis of the CPR system, is used everywhere across the HUG and covers the following:

- Complete order entry (CPOE) covering all types of orders is deployed across all HUG, but psychiatry, covering drugs, care, lab, radiology, consultation, etc. Where it is deployed, there are no written orders on paper at all;
- Workflow engine that pilots the CIS components for clinical pathways;
- All laboratory documentation is available in the CIS;
- The radiology department is completely filmless, images are available in the CIS in all HUG, around 70,000 images are acquired every day;
- Several other multimedia sources are in the CIS, such as gastroenterology, cardiology, oto-rhino-laryngology; total body images in dermatology, pathology images, etc.
- A structured nursing record using international nomenclatures (NIC, NOC and NANDA) is available at all HUG wards. The nursing chart is not yet computerised.
- Structured and semi-structured clinical documentation is widely deployed, including progress notes. All discharge summaries and intervention reports are computerised. The process towards paperless clinical documentation is still ongoing.
- A social care record is deployed across all HUG;
- An intensive care record system, including neonatology, is deployed in all ICU;

- Operation theatre management covers all forty-plus theatres;
- A patient workflow management module is deployed across adult and paediatric emergency rooms;

A first version of the communication platform that allows sharing documents with GP's is in operation.

2.3 The health services affected

The CIS is a central part of clinical and working practices at HUG and thus affects all health services provided – from registration to discharge and long-term care. Within the scope of the evaluation fall all clinical processes, as well as impacts of the CPR on a number of managerial tasks, such as monitoring, planning, and reporting to third party payers and judicial authorities. Some of these tasks fall into the category of information re-use, to an extent allowed by data protection and information governance regulations.

The evaluation does not include links to external, private hospitals and GPs, as these are in their early stages on both technical and organisational level. Also not included are internal further developments not yet in full operation, such as those described above. Utilisation of the system for teaching purposes and clinical research in the university faculty is also not part of the evaluation, since the focus has been chosen to be on the impact on health and care-related services.

2.4 Components and functionalities

The CIS is used in different settings with a customised user interface according to each context. One way to use the system is the "patient-oriented view", which from a user's point of view is comparable to a conventional record-based system. In the patient-oriented view, each window of the CPR interface is restricted to information about one and only one patient. Another view is "collection of patients" oriented. This can be the list of the patients scheduled in an operation theatre, or the list of the patients that must be seen during the night shift. In the latter case, information for each patient will vary according to the medical service and the profile of the user, amongst others. In the patient-oriented view, depending on the access management profile and the user's preferences, a selection of the following data items can be seen and updated:

- Current and past admission, discharge, and transfer information.
- Complete order entry (CPOE) covering all types of orders with past and present orders;
- Running clinical pathways;
- Structured information on laboratory tests and results;
- All radiology images, many other images;
- The complete structured nursing record;
- Structured and semi-structured clinical documentation, all discharge summaries, most reports;
- Social care record;
- Intensive care record;
- Numerous paper-based scanned records;
- The tracing of all access to the current record.

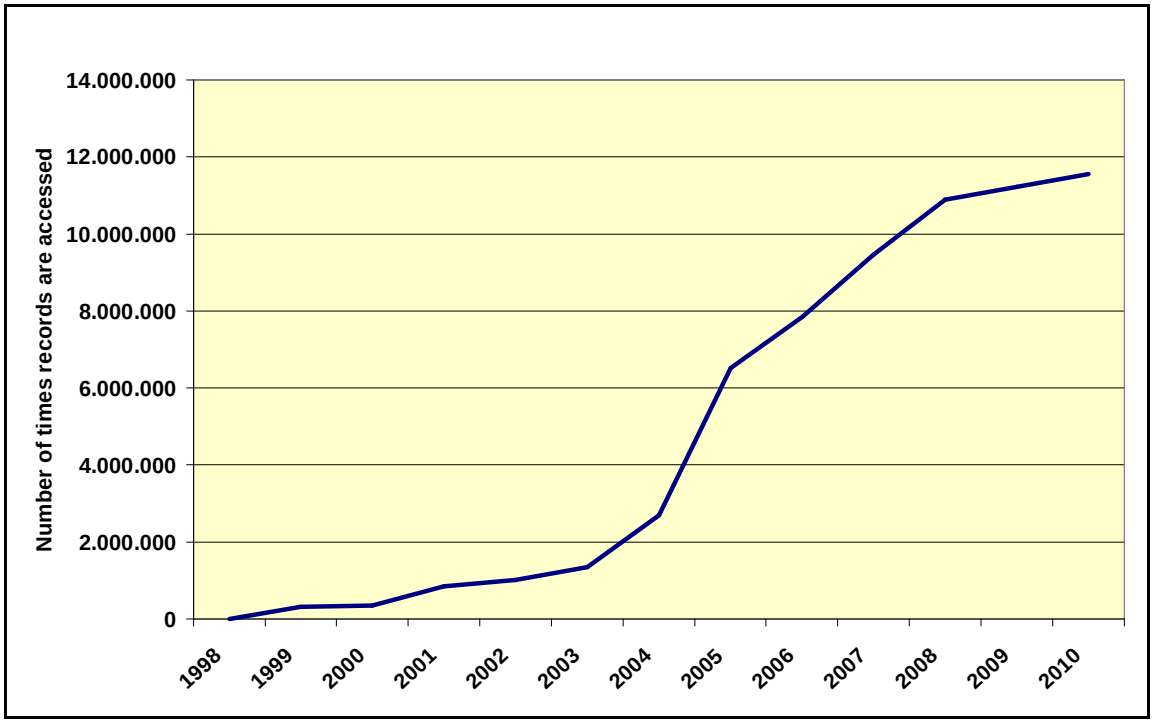
A very restrictive role-based access management system has been developed that allows only care providers to access the record within a care relationship. That means that only the records of those patients one is taking care of can be accessed. In case of emergency, a "broken window" mechanism allows escaping these constraints, but this access will be further reviewed.

2.5 The system in practice

All care providers from all functions, including physicians, nurses, medical clerks, social care providers, physiotherapists, nutritionists, etc, use the system. About 12 millions documents and 130 million structured facts are available.

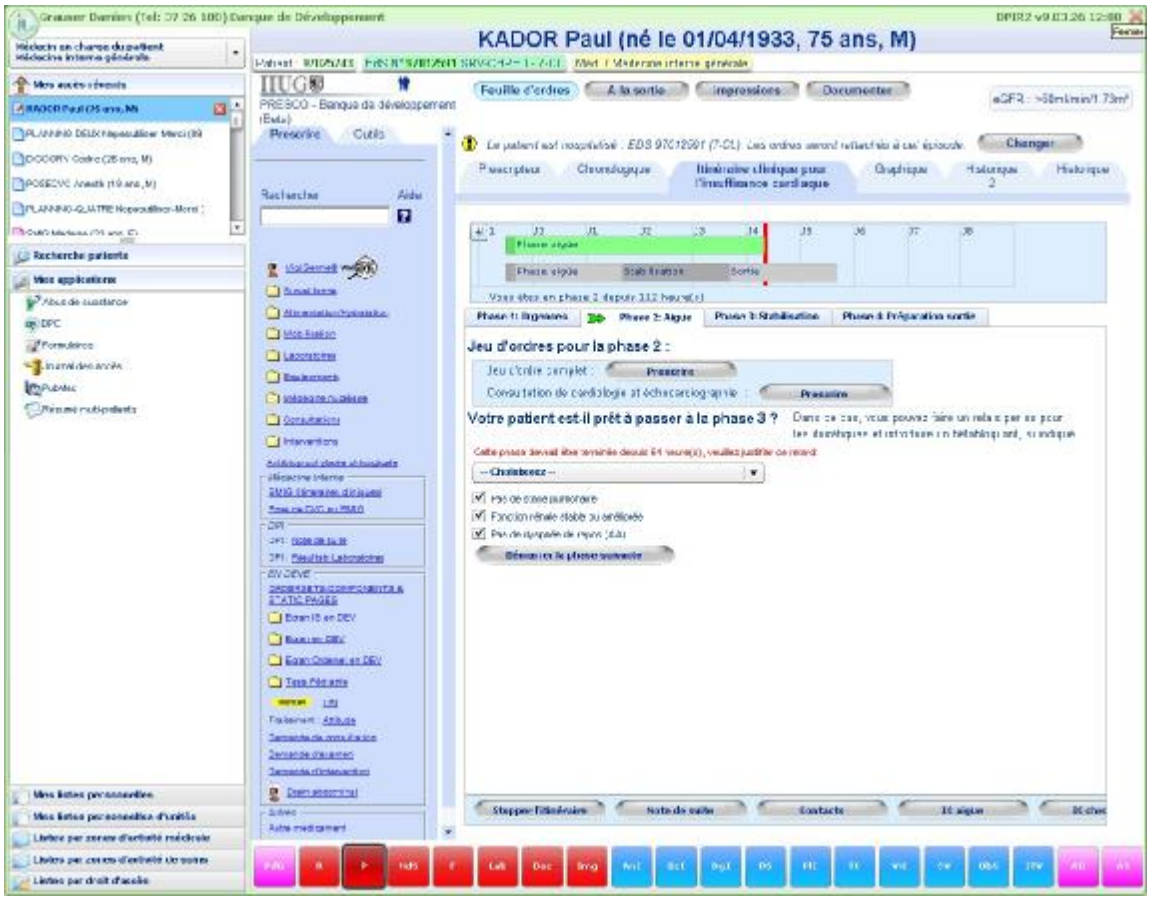
The utilisation rate has been steadily increasing since the introduction of the system. Records are opened every day, 7 days a week, around the clock, with never less than 500 records accessed each hour. By 2007, the number of times a record is accessed has reached more than 25,000 logins a day. The increase is mainly driven by the stepwise implementation and diffusion of the system across the whole hospital. In order to keep the implementation and change management efforts manageable at each point in time, and to allow for individualisation of functions to the specific needs of certain departments, implementation followed a gradual path. Since paper is taken out as an option after a short transition time, each ward that gets the system installed and staff trained immediately becomes a source of active users. This high usage level has been made possible by a very strong infrastructure with more than 7,000 computers, including at least one wireless mobile laptop per ward.

Chart 2: Utilisation of HUG's CPR system



The components of HUG's CPR system include data from all available databases, since the CPR itself is constructed individually each time it is accessed. The CPR is not stored on one server as a single file of directory. The CPR is always the result of a real-time query of all relevant databases in the system, the results of which are displayed in different sections of the same screen, as illustrated in the screenshot below.

Figure 3: Screenshot of a patient record



When a certain record is called up, the system calls all components that are part of the user's profile. Each component sends queries to the individual databases at which the data is stored according to its type – documentation, lab results, etc. Queries are managed according to access rights and interfaces based on the clinical role of the person performing the query and are always restricted to a specific patient. Each care professional category has their personalised user interface depending on their function and position, but also depending on personal favourites, which can be defined by the user. There is a notification system that allows tracing of everything that is done on the system. Every component can subscribe individually to certain types of notifications, such as a particular type of order being put through the system.

When data is entered in a field, it is automatically transmitted to and stored in the appropriate database to which the specific part of the interface is linked. It thus becomes available for access by those in possession of the respective rights. This allows instant information sharing and simultaneous access for second opinion consultations.

2.6 Technology

2.6.1 Overview

The hospital information system strategic plan STRATISSE developed in 2002 has put down the foundations for the information systems architecture, based on using the JAVA language, internet browser technologies as thin client and distributed application servers. In addition,

but specifically to the clinical information system, this has been organised along two main axes:

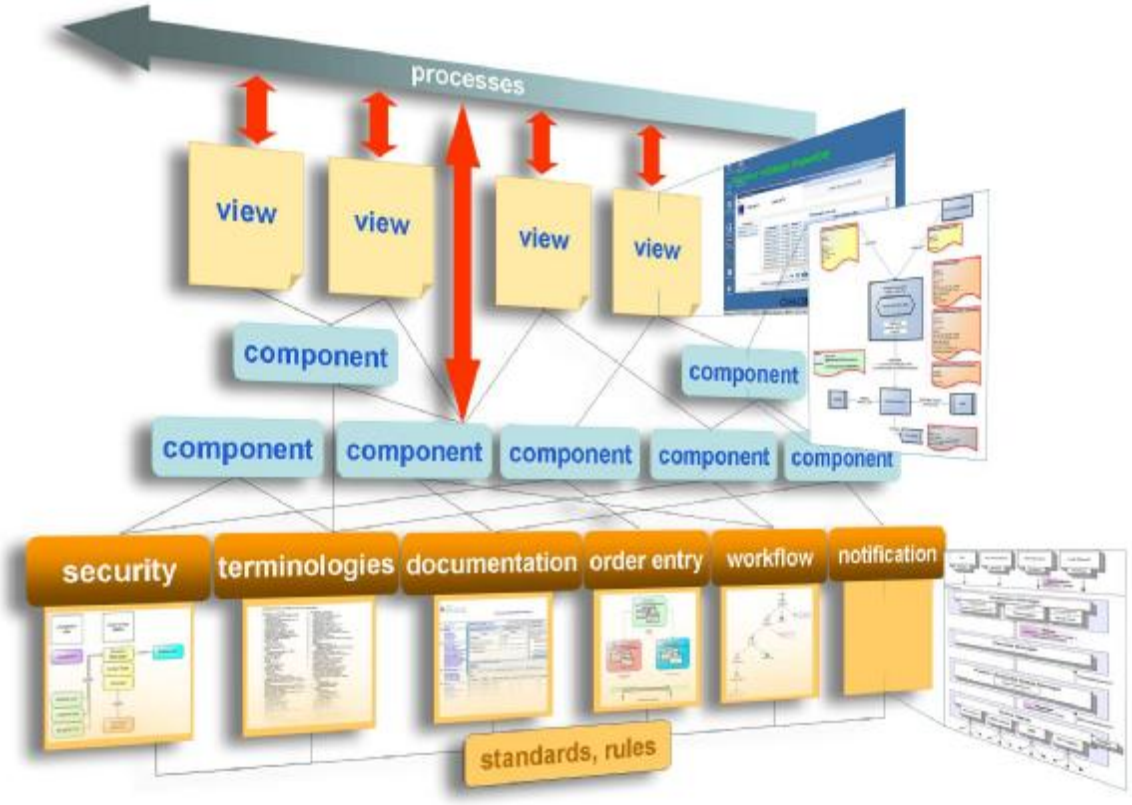
- Transversality - the need for abolishing the frontier between clinical and administrative visions of the information system, towards an integrated environment. This implies the transversal use of many functional foundations, such as access rights management, traceability, workflow, resources management, scheduling, etc.
- Longitudinality - the necessity to be able to follow the citizen's journey through a complex and fragmented health and healthcare system implies the development of a longitudinal view of the computerised patient record, and the convergence and integrability of the hospital within a community healthcare system.

The clinical middleware has been organised on some important strategic decisions:

- Distributed open components
- Independent and specific visual components
- Events and message-based interactions
- Business oriented web services
- Strong ability to tightly integrate third-party and commercial solutions.

Figure 4 illustrates how these strategic decisions translate into the technical architecture of the CIS.

Figure 4: Technical structure of CIS at HUG



Source: HUG

The system is architecturally built in four very strong layers:

1) The database layer. Each component has its own data sources, and only this component can access to these data. Therefore, if any other component needs these data, it has to use the services provided by the owner component.

2) The foundation components. These components are the major and shared foundation of the CIS. It is a limited set of components with very important functions, such as security, workflow, scheduling, notification, etc. These components have no user interfaces, except for technical purposes. Several of these components are third-party systems (such as scheduling), or open-source components (such as workflow).

3) The business components. These components use the foundation components and provide specific business logic. Some of these components allow the physician order entry for radiology, or the clinical data management for nurses. Again, these components have no user-interface. They provide services that will be used by the visual components.

4) The visual components layer provides the user interfaces. They use all underneath components to get data, logic, behaviour, etc. in order to build specific and pertinent views and data acquisition systems for profiles and specific users.

Interoperability

An important and interesting feature of this architecture is that interoperability is a fundamental requirement. As all components are completely independent and can only communicate through standardised http/XML services or standardised XML messages, a common framework of protocols and semantic formalisations has to be used. Most of this has been achieved using existing standards whenever possible. Otherwise, an internal formalism named HUG-XML has been developed and shared by all components. As interoperability is a major and intrinsic characteristic of the system itself, integrating third-part applications that follow standards is easily achieved.

Fast user interface development

An important aspect that drives acceptance is the ability to give quick answers to users' requests. The CIS architecture at HUG facilitates such possibilities because user interfaces are produced by independent components. Each of these components is an HTML server producing rich-content web pages, including technologies such as Flex and Adobe Flash. These pages can themselves be combined into single pages, using frames for example. The common security framework allows single sign-on on all these pages, while the in-house developed thin client insures a seamless synchronisation. Thus, users do not notice that they are interacting with numerous independent components and they feel as working with a single and coherent application. Further, this approach facilitates the very fast development of completely new interfaces without the need of deep programming skills.

Attribute-values entities

The complete clinical documentation components suite is based on attribute-values entities. They share a unique single shared dictionary of about 12,000 different variables, named *Patient Facts (PF)*, that are used to build all formularies and documents of the CIS. These PF can be regrouped into groups, and groups into dataContexts. One document or one formulary is always linked to one dataContext. This organisation is very similar to the CEN 13606 archetype concept.

2.6.2 Security and confidentiality

In order to ensure the best protection to patients' privacy, while ensuring the best operational model and respecting legal constraints, a complete process for rights management has been put in place. This process is based on four pillars:

a) An institutional committee in charge of defining and validating the concepts and profiles of rights

b) A standardised and unified computerised access management allowing centralisation of the definition of the profiles and decentralisation of the attribution to users

c) A standardised track and trace computerised system in charge of tracking and consolidating all access to identified data that allows all accesses to be reviewed

d) Institutional procedures to review, validate, or sanction inappropriate accesses.

In addition, the track and trace utility produces a list of all users that accessed to a record, which is available directly in the record and, therefore, visible to the patient.

The system is a role-based access management system, which in addition is constrained by a real-time, calculated presence of a therapeutic relationship. It supports a broken window mechanism for emergency needs. According to the type of information accessed, a rigorous authentication process including a smartcard and passwords is required. This is in particular the case for all accesses to patient related information.

2.7 Level of interoperability

Of the three EHRI interoperability classifications of potential interoperability, limited connectivity and extended actual connectivity[22], HUG reaches the highest, extended and actual. The CIS and CPR system connect all existing systems within HUG, across disparate geographical locations. This integration of systems goes beyond simple connection and conformance to standards to real inter-operation. Experience shows that realising interoperability satisfactorily requires such a focus on a concrete application context, going beyond the simple implementing specific technology standards.

The interoperability, interoperation, and thus facilitated collaboration cover local teams of doctors, nurses, other health professionals, and management and administrative actors. Informal carers and patients have no direct access, which is in line with the design and philosophy of the system – to support health professionals at HUG in their daily work. The classification according to type of connectivity is summarised in Table 1 below.

[22] EHR IMPACT (2008): Methodology for evaluating the socio-economic impact of interoperable EHR and ePrescribing systems, Bonn (Available online: http://www.ehr-impact.eu/downloads/documents/EHRI_D1_3_Evaluation_Methodology_v1_0.pdf)

Table 1: Scope of interoperability at HUG[23]

Type of connectivity	Characteristics	HUG
Single site	People within teams and between teams in one organisation	Yes
Multi-site	People within teams and between teams in one organisation	Yes
Regional	People, teams and organisations in one region	No
National	People, teams, organisations and regions in one country	No
International	People, teams, organisations, regions and countries	No

[23] EHR IMPACT (2008): Methodology for evaluating the socio-economic impact of interoperable EHR and ePrescribing systems, Bonn (Available online: http://www.ehr-impact.eu/downloads/documents/EHRI_D1_3_Evaluation_Methodology_v1_0.pdf)

3 Case analysis

3.1 Stakeholders

Stakeholders fall under the four groups defined by the EHR IMPACT methodology[24]. Out of the first group, patients, informal carers and other people, the CIS system at HUG affects mainly patients. Informal carers and healthy people are not directly affected, since the system is designed to support health professionals at the point of care. Also, while patient-centric, the CIS has formal carers as the target user group. Neither patients, nor healthy people, including informal carers, have direct access to the records. They have to ask a member of hospital staff for access. Thus, the impact on this group of stakeholders is restricted to patients, who receive better care as a result of health professionals being empowered in their work.

Health service teams in HUG's case include over 7,000 doctors, nurses, social workers, clerks and other professionals using the CIS. As primary users, their work is significantly affected by the introduction of the system. They are also vital for success, since they have the power to boycott the system, if they feel a negative net effect. The impact differs among the subgroups and there is also certain diversity according to the individual clinical roles. Often, the cost for a given action, for example due to data entry, and the benefit, such as accessing information, do not affect the same person. This is illustrated by care order entry, where it takes time without direct benefit (except decision support) for the physician and saves time without direct cost for the nurse. The interdisciplinary differences are driven by specific requirements and care needs. Impact on individual team members includes distress caused by changes at the implementation phase, as well as any positive effect on work satisfaction.

GP's and some other actors of the community network who access patient record in real-time are also beneficiaries. However, because the access has only recently been enabled, these links are outside the scope of this evaluation.

The Health Provider Organisation (HPO) is the HUG consortium. The positive impact on the HPO includes managerial issues such as utilisation and allocation of resources, as well as having a very powerful instrument to improve care quality, safety, and efficiency. The burden is mostly around direct investments and cost on human resources, such as education. The management of HUG falls under this broader stakeholder group. Impact on time, calling for re-deployment of resources, as well as changes in financial flows are examples of effects on HUG as an HPO.

Third parties in this case study include the canton parliament, which is responsible for providing and agreeing to a large part of the overall financial investment, the health insurance companies, and the judicial system, which has access to information they did not have at all or at least not with the speed they have today. Insurance companies are affected asynchronous to HUG in terms of changes in financial flows.

3.2 Process change

The introduction of the CIS was primarily designed to support HUG's professionals, care providers and other professionals, in their daily work. An important aspect of the strategy was

[24] EHR IMPACT: Methodology for evaluating the socio-economic impact of interoperable EHR and ePrescribing systems, Bonn (Available online: http://www.ehr-impact.eu/downloads/documents/EHRI_D1_3_Evaluation_Methodology_v1_0.pdf)

to use the CIS to change processes, but not as a first intention, in order to better manage resistance due to the introduction of the CIS versus resistance to process change. Only when the system has become a "must have" part of the daily work, it has been used to change processes. Changes fall under the following categories:

- Speed and ease of access to clinical information about the patient;
- Clarity of information;
- Confidence in decision-making, both for diagnosis and medication prescriptions;
- Data aggregation procedures;
- Speed and ease of access to information for managerial purposes;
- Conveyor for process understanding and process changes.

Most of these categories do not reflect real process changes, but changes in the outcomes of existing processes. As is discussed below, the impact on clinical workflow and practices is minimised at the introduction and progressively made stronger. Working practices did have to adapt in order to fully implement, utilise, and reap the benefits from the system. However, when the system was adopted, it has been used to change practices. Nowadays, the CIS is considered as the most important instrument to change clinical processes and practices in the HUG.

3.2.1 Workflow

Overall, the effect on workflow is variable. The CIS was designed to be able to support existing process as well as introduce major changes in the processes, including patients' workflow. For example, the Panorama system that shows real time patients status, location, and care activity in the ER was firstly only used as a useful display, then progressively used and adapted, to improve patient workflow. For example, alerts have been introduced when waiting time was exceeding certain limits according to emergency level, or measure of waiting time to get a consultation used to get more reactivity from consultant services. There is anecdotal evidence that in some cases the CPR can lead to a reduction in overall length of hospitalisation, but no sound evidence for a statistically significant hospital-wide impact is detected. A specific exception is the ER department, where the rate of increase in length of stay per patient shows a slight decrease after the implementation of the CIS.

3.2.2 Clinical practices

Clinical practices are guided by a combination of professional knowledge and experience and their real application according to numerous determinants, such as availability of resources and time, ability to comply with rules, etc. The CIS is neither meant to, nor capable of replacing physicians or nurses, but rather influence their clinical practice in helping them to know the best or required way to do things, and sometimes to force them to comply with these rules. The changes concerning clinical practices are rather of qualitative nature.

These effects can be grouped in the following categories:

- Privacy. The CIS enforces the regulation about privacy and helps detecting inappropriate behaviour.
- Documentation. The CIS enforces the rules that require to properly documenting care and clinical activities. The CIS helps to access this documentation.
- Order entry. The CIS helps to enforce that orders are entered in a proper manner.
- Decision-support. The CIS helps better, more informed, decision-making at numerous levels by providing right information to the right person at the right time. Information is

available faster and ubiquitously. The order-entry feature supports several types of decision assistance, such as drug-drug and drug-patient interaction alerts, and specific tools, such as imaging tools and access to different knowledge bases.

- Guidelines and order sets. Complete guidelines and order sets for physicians and nurses are available that decrease variability in care of specific conditions and enable faster data acquisition.
- Clinical pathways improve and enforce the complete organisation and planning of conditions such as heart failure, from admission to discharge.

The CIS is now perceived by numerous actors as a major instrument to improve clinical practices. Many user groups have been created spontaneously and work at making suggestions, either for improving the system, or for implementing new functionalities to improve practices, such as care guidelines or diagnosis algorithms.

3.2.3 Working practices

In contrast to clinical practices and workflow, where impact and changes have been little at the beginning and are increasing rapidly after several years, the introduction of the CIS at HUG has had notable impact on working practices immediately after the first deployment. The most important two changes were a) the way to put data in the patient record, mostly when this is done by direct care providers such as physicians and nurses; and b) the way to access information, such as past diagnostic results, radiology reports, discharge letters and other clinical information on patients.

The way data was entered in the patient record has been dramatically changed, as providers who used to write on paper had to type data on computers. In order to minimise this impact at the beginning of the deployment, the first system was based on data that was not entered by direct care providers, such as laboratory results, radiology images and numerous reports and discharge summaries entered by clerks. This approach allowed to deploy widely the first system and to build a culture among direct providers to use the system to get important information. Then only, functionalities requiring data acquisition by direct care providers have been introduced progressively, ending with CPOE.

Access to information was a true problem before the introduction of the CIS. Paper records were stored in various places, local archives, then central archives, and often “lost” in clerks’ or providers’ offices. The physical search for records used to follow the path of physicians asking for a record and nurses, junior doctors, medical secretaries, or students walking to the archives. In case recent records were required, they would be there and would be available to the doctor within 24 hours. Records from older hospital visits would be stored in central archives. The process of receiving this kind of records took up to three days. All these procedures gradually became obsolete with the introduction of the CIS, and tend to disappear since the scanning of paper records fills historical gaps.

Another prominent example of changes in working practices is the omission of the practice by nurses, pharmacists, and non-professional support staff to follow physicians and other professionals. The reasons for such following included clarifying illegible handwriting and unclear abbreviations, mostly about order entry. A further omitted practice is calling various information suppliers, such as the laboratory, to get the status of results.

A change that has only a minimal impact from a socio-economic point of view, but still needs to be mentioned is the way to enter the process of finding patient data. Whereas without CIS, care providers would start looking for records or ordering medications or procedures straight away, now they need to log in every time they have not been actively using the system for a

specified time. The impact of this additional effort has been identified as negligible in comparison to the overall effort reduction.

The CIS also allows shared and location-independent use of records, which was not possible in a paper-based environment. Before the introduction, records could only be seen and updated by one person at a time. Since the implementation of the CIS, care providers can act on the record simultaneously, or discuss while reading the same information in real time from different locations. In addition, more time-intensive write-ups are regularly done later in the evening or at night. With paper, physicians had to go back to the ward where the patient was, or take the record away, disenabling any other treating professional from accessing it. The CIS allows physicians to access the record and take decisions and actions from anywhere. This has been identified as an important time benefit, but also a convenience and satisfaction benefit for physicians.

A feature that is becoming increasingly important is the link between the CIS and other functionalities of the HIS, mostly around 1) resource planning; 2) logistics 3) chart abstraction and 4) billing. This integration allows improving efficiency and saving time. Instead of manually processing thousands of paper records in order to construct specific reports for these purposes, the reports are made available through a few mouse-clicks.

Finally, the CIS has a major impact on the ability to use information for secondary usage. These usages are numerous. The production of reports for internal use or various external bodies, such as the canton or the Federal Public Health authority is eased, even though it is not fully automated. The same applies to epidemiological registries, such as the Swiss HIV cohort, where the transmission of data has been completely automated. Clinical research is also an important benefit of the CIS, which is used both for retrospective studies by giving access to very large amounts of data, and to widely implement new and prospective studies. The CPOE, for example, is a wonderful tool for interventional studies that pertain to care and treatment. The CIS is also increasingly used for activity reports inside the HUG, for example to measure precisely the number of consultations provided by one service to another.

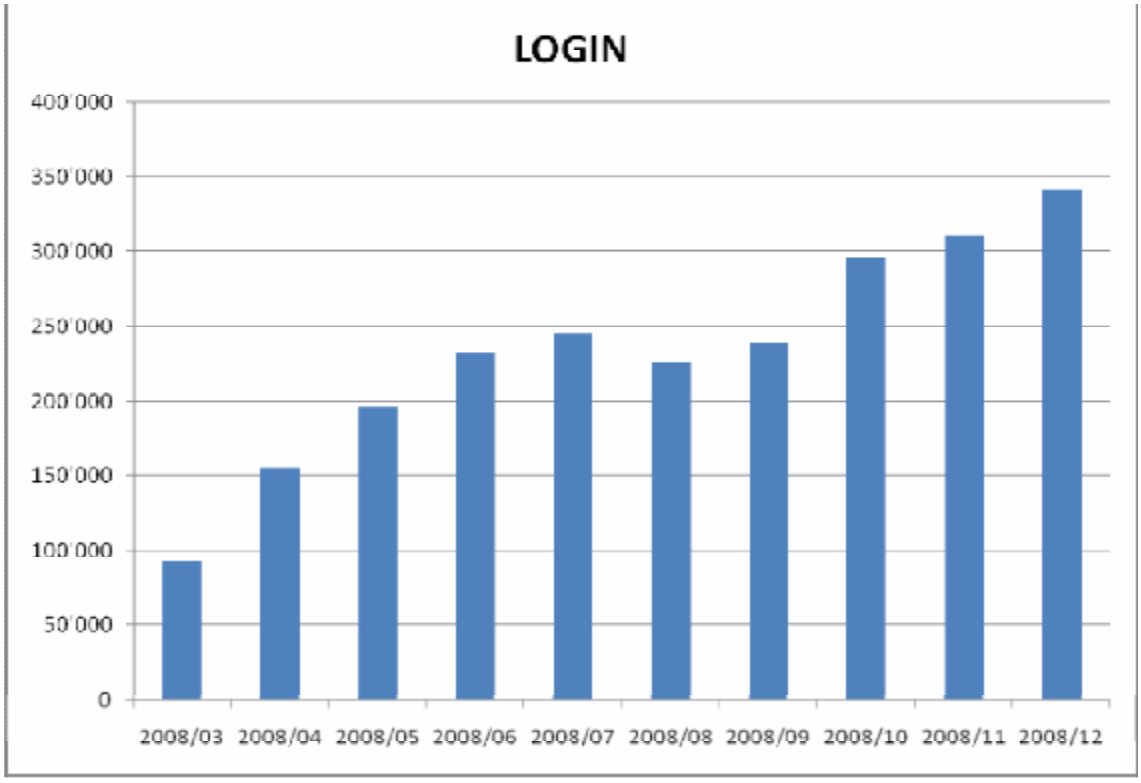
3.2.4 Reaction and acceptance of users

The situation of HUG is somewhat special regarding acceptance, because the HUG have a long tradition of innovation and use of IT, especially leading edge technologies. This is an important part of the historical legacy. Therefore, resistance is often minimal, and users have a good acceptance of cutting-edge systems despite their problems. With this initial advantage, increases in functionalities have always been used to counter-balance the effort needed to interact with computers, mostly around data entry and constraints practice. The Service of Medical Informatics (SIM) has always been trying to bring benefit for the direct users and to involve users in the process of developing and deploying the system. For example, CPOE was only deployed in a service if there were physicians and nurses playing the role of leaders and champions. Altogether however, this significant organisational position can take some ten years to achieve. One of the critical roles of clinical informaticians is therefore to help users understand possible future steps in the development of the information system, in order to reach higher degrees of integration and interoperability, as well as process reengineering.

It is interesting to emphasise that, while the SIM had to deploy a huge energy to involve users in the functional requirement process in the early 2000, now the contrary is observed. Users create spontaneously working groups and propose functional requirements to the SIM, which now faces the challenge to deliver them. Some interesting features have been observed in the rate of usage of the system. New medical staff is hired twice a year, in autumn and spring. In comparison with the rest of the year, the usage rate of the system increases more during these two periods. This is probably due to the fact the new features introduced in the system

are considered as normal by these new users and used routinely, whereas medical staff used to use the older practices are more reluctant to change. Another part of the explanation is that new recruits belong to a first generation of people grown up during the digital age of the information society.

Chart 3: Active users per month



Source: HUG 2008

Meanwhile, user acceptance has reached a stable high level across the whole of HUG. All interview partners, who were eager to see further improvements in the system, made it clear that demands are only in addition to something that already helps them a lot. An indicator of the acceptance and usefulness of the CPR system is that in February 2008, for the first time doctors specified their needs and wants out of own initiative, without being asked explicitly for this by the service of medical informatics.

3.3 Timeline and milestones

Because of the fact that most of the CIS is an in-house development, timeline and milestones are very progressive. The timeline given below is just an indication, as most of the deployments have been made progressively.

1980's	ADT for all patients, developed by the hospital
	Laboratory results and reports written by clerks for all departments
2000	New architecture
	Start of the deployment of the structured clinical documentation
	Start of the deployment of structured nursing care record

2002	CPOE for hospital of rehab
	Unified HL7-V3 ADT
2004	CPOE for the hospital of geriatrics
2005	CPOE for the hospital palliative care
2006	CPOE for the department of medicine
	ER workflow management
2007	CPOE for the departments of paediatrics and gynaecology-obstetrics
	Operating theatre management
	Start of the scanning of old paper-based records
2008	CPOE for the department of surgery
	Unified scheduling management
	End of deployment of the nursing care record
2009	CPOE for the department of psychiatry.

The time scope of the evaluation reflects the scope defined in Chapter 2. Thus, the evaluation starts in 1998, when the idea of the current version of CIS at HUG was first envisaged, and includes all milestones up to the current position, described in Section 2.2.2. The EHR IMPACT timeline extends to 2010 in order to allow for the impact of latest developments and implementations to be reflected. However, costs and benefits of actives currently on the agenda, such as the 2009 CPOE for psychiatry milestone, are not part of the quantitative evaluation.

3.4 Supporting take-up

Supporting take-up at HUG has two main components: a) governance, or support of top management, and b) support at the implementation level.

3.4.1 Governance

There is a strong governance culture leading information technologies at HUG. The IT Commission (CSI) sets the global strategy, allocates resources, and sets priorities in the context of the strategic plan of the institution. The president of the commission is the CEO of HUG. The head of the IT department and the chief medical information officer are non-voting members of this commission. A technical group that has to review all projects according to their technical characteristics helps this commission.

The CSI has three working committees, one for each of the major IT needs at HUG: the human resources IT committee, the administrative and billing IT committee, and the clinical information committee. The medical director of HUG is president of the clinical information committee.

All IT projects at HUG must be presented, accepted and prioritised in their respective committee, and then by the CSI in order to be accepted. This includes specific departmental projects, eventually funded by private or research funds. All projects must have clear user requirements and should prove the benefit of the project. User groups lead the projects.

This governance structure has been a very important aspect of the success of the CIS at HUG, enforcing the support by the various heads of the HUG. Top management at HUG is convinced

that eHealth will bring the expected efficiency gain in healthcare. The HIS is a major enabler in improving efficiency and quality of care. Because of the pressing financial and other resource constraints, IT slowly enters every other target of the organisation. eHealth is increasingly identified to be part of the answer, or one of the answers, to coping with a widening gap between output and resources in the health sector.

Currently, the CIS is underused in term of its potential, mostly due to the lack of sufficient user understanding of its capacities and with the difficulty in adding knowledge to the system. With clinicians increasingly taking a more active role, this is already changing.

The system at HUG is not about doing the same things better, but about doing things differently, even though the process of change often involves a simple switch from paper to "e" as a first step. For example, the gynaecology department has been equipped with a module including e-forms identical to the paper forms used before. Within two years, the working practices were completely re-organised and optimised by using the potential of the system and changing the forms to fit the new practices.

3.4.2 Supporting implementation

In general, pilot deployments are rarely done at HUG, to avoid the spiral of improvements that leads to very specific solutions that are difficult to deploy more widely. A deployment plan is made, and the first places are, internally in the SIM, considered as pilots and special energy given to improve the system. Nevertheless, this is done without compromising the overall deployment schedule.

Deploying new functionalities is often more expensive than developing them. It requires a lot of human resources, both on the side of the SIM and the support and teaching group, and on the side of users. Implementation is time consuming because of change management requirements. HUG has adopted the following step-wise approach to implementation:

- Prepare

  The preparation can be a heavy process. For example, parametrising the CPOE for the service where it will be deployed can take months. It took more than one year to prepare the drug dictionary to be able to manage all dosage decision support for pediatrics, including usual dosage according to age or gestational age, weight and size, minimal and maximal dosage, etc. Then, the deployment itself has to be prepared, scheduled, and infrastructure made available, including mobile computers.
- Inform

  All stakeholders must be clearly informed, all processes reviewed.
- Train

  All users, including staff, must be trained to use the specific module to be deployed.
- Clarify

  Any points not covered by the informing and training activities are addressed before implementation.
- Implement

  Implementation now meets a prepared user environment, aware of the changes to come.
- Continuous support on site

Because of its intensity, the implementation process cannot be run simultaneously in all departments. Thus, deployment is gradual, as has been made clear in the previous section.

Coverage is considered as more important than depth at the first stages of implementation of a new functionality, in order to reinforce the culture of using the CIS for all care providers. Depth is only being addressed after the first phase of implementation. This has led to a significant utilisation, which drives the benefits, but also to an important problem concerning the use of available functionalities. Physicians and nurses acknowledge that they do not use numerous functionalities and would like to learn more about what the system can do and how.

3.5 Benefits

Analysing the benefits resulting from the CPR systems at HUG against the background of the three main types of eHealth benefits, quality, access and efficiency[25], improved quality of care and efficiency benefits play the most important role. While time savings and cost avoidance can be primarily assigned to the HPO's benefits, patients mainly benefit from the improved quality of care. Healthcare professionals mostly profit from better employed time, better work satisfaction because of the improved availability of information in real time, and the lower exposure to risks.

There are numerous positive impacts of the CIS, confirmed by all actors interviewed. Benefits from the CPR system at HUG include, among others:

- Increase and ease of information access;
- Increase in quality of information, especially of structured documentation and orders;
- Increased level of services, such as tools for images or visualisation of shared scheduling;
- Time savings because information is available quickly and is complete; facilitated by tools accelerating some processes such as order sets or pre-filled forms;
- Increased quality of care because of decision support mechanisms;
- Avoidance of over-prescribing laboratory and radiology examinations;
- Increased availability of activity dashboards, that help governance at various levels;
- Increased availability of quality indicators;
- Availability of monitoring tools, such as automated "Methicillin-resistant Staph. Aureus" follow-up dashboards.

These and other positive impacts were identified through numerous interviews with users, as well as analysis of internal statistics and studies made available by HUG. The following analysis of the benefits for each stakeholder group provides a more thorough picture of the positive impact of the CIS system at HUG. The methodology for quantification of the impacts is addressed in section 3.7 below and in Annex 2 of this report.

3.5.1 Patients, informal carers and other people

Through the CPR system, patients at HUG benefit from enhanced patient safety, time savings through avoided admissions, better care due to enhanced continuity of care, improved drug interaction control, and generally better informed clinical decisions. Based on providing the entire healthcare staff with any (vital) information on the patient, whenever required, HUG's patients experience a reduced risk of harm. For example, medication history and current medications are part of the patient's record and can be effortlessly checked. Together with

[25] EHR IMPACT: Methodology for evaluating the socio-economic impact of interoperable EHR and ePrescribing systems, Bonn (Available online: http://www.ehr-impact.eu/downloads/documents/EHRI_D1_3_Evaluation_Methodology_v1_0.pdf)

the automated decision support feature of the CPOE part of the system, this helps doctors to prescribe more accurately than when relying on the memory and recall of some patients. As a result, adverse drug events can be avoided. One further contributing factor to better care are more structured, complying and better validated care plans, which among others prevent messy handovers between care providers.

There are two types of information needed by doctors – critical, and non-critical. The faster availability of critical information allows physicians to take more informed decisions at the point and time of care. Further, information considered non-critical may turn out to be critical after all. Without the CPR functions of the CIS, professionals would not access this information at all. Because of the easiness of access, they now do access all information needed. This results in better decisions and a higher quality of care.

The value of this benefit to the patient is monetarised through willingness to pay measures. These provide a summarising proxy of the above described aspects, improved patient safety and enhanced care. The proxy is a monetary value assigned to emotional aspects accounting for the biggest share assigned to patients' benefits.

Further, time saving aspects of the CPR system and its functionalities involve transferral procedures. After transferral, patients are spared the repeated questioning about basic health indicators and past and current treatments, including medications.

3.5.2 Health services teams

The health services teams working with the system, and among them the care providers, are of special importance for estimating the impact of the CIS. All clinical staff has to adapt to changing workflows and processes, and invest in terms of education and time needed for data entry. The gains must outweigh the extra effort required. Overall, care provider staff benefits from

- Being able to focus on clinical tasks, instead of searching for information;
- Not having to chase colleagues to decipher illegible handwriting;
- Feeling of being less vulnerable and exposed to risks, because of the decision support embedded in the CIS.

An important and not expected element was the fact the electronic records were found to be more reliable because there were no lost documents or documents from wrong patients in them. Further, the CIS provides physicians and nurses quickly with critical information and decision support they need for reducing the risk of adverse events, and allows them to pay more attention to individual patients.

Benefits to health service team members are valued using proxies of willingness to pay measures. This is because in this category of stakeholders the focus is on people as individuals, rather than as HUG employees. The WTP proxies reflect the personal satisfaction and benefit to users, clearly communicated to the evaluation team during numerous interviews.

Physicians

The CIS is of value to physicians in several situations. An important point mentioned by interview partners is about having an easy and fast access to all information pertaining to a patient. In the paper-based record, because of the time needed to get the record, and the size of the record with information not easy to find, physicians were likely to take decisions without having had access to all relevant information. With the CIS, they can easily check up the records, use the tools to find, sort, and group information. For example, in the paper

record, laboratory results were scattered in many encounters, with many sheets for each encounter. In the CIS, there is a spreadsheet-like viewer that consolidates all laboratory results, including all past results. According to interviewed physicians, in up to 20% of the cases, the information turns out to be important after all, but would not have been detected without the CIS. This means a lower exposure to risk, better and faster decision processes and, potentially, fewer errors.

Wireless laptops on movable tables, used during the ward round, contribute to reducing risk of errors, by enabling access to information and order entry at the bedside. The system facilitates decisions during order entry, ensures well-formed orders and immediate transmission. Overall, the order entry process may take more time for physicians, but it is found clearer and more precise. In the situations where order sets have been designed by the clinicians, order entry is found faster and easier. Decision support during order entry is particularly appreciated. This includes drug-drug interactions, but also alerts when drugs or exams are not required, for example because they are already ordered.[26]

On the other hand, physicians report time saving thanks to the fact that the record is always available. They, on average, need to ask someone else about a given case between one and five times a day[27]. Most of the time, it is enough for the respondent to see the record without seeing the consulter. In this case, the CIS saves between 10 and 20 working hours per year for each physician by avoiding time-consuming searching after and calling on colleagues or patients, moving to the wards looking at the information, etc. Access to the record from any location is also much appreciated during nights on duty, as it helps avoid walking to each ward when nurses call.

Another appreciated feature is to be able to re-use data that has already been entered, this being particularly true for order entry in case of patient transfer from another ward, as they can re-use the existing orders. Another instance in which similar benefits occur is when a patient is re-admitted after discharge.[28]

Many other features have been mentioned, such as patient lists that ease the follow-up of patients for consultants, new dynamic ways to organise information, or new tools to manipulate information, such as for DICOM images.[29]

Nurses

Easier access to the patient record is also identified as an important benefit to nurses, mostly because the paper record was most of the time in physicians' hands. Another benefit pertains to order entry. Because of the CPOE, orders are clear, well-formed, and legible, so that nurses do not have to look for physicians to get complete information. Without the system, according to nurses interviewed, this situation would have occurred around three times a day for each nurse.

The computerised record provides much more structured information, especially in the nursing part of it. This helps keeping the record clear and orderly, while in a paper-based environment it is easier to lose papers, or to put documents in the wrong record. Another advantage is that the system allows nurses to have a better overview on the work to be done on the ward; it helps the organisation of work. Orders given by and in the system provide immediate feedback, such as size of the sample for blood analysis. Without the system, nurses would often have to seek clarification because of illegible abbreviations and handwriting, which is time consuming and frustrating. This aspect was assessed to be of great

[26] Source; Interviews with physicians
[27] Source; Interviews with physicians
[28] Source; Interviews with physicians
[29] Source; Interviews with physicians

importance for the nurses and contributes enormously to their work motivation and satisfaction. [30]

These changes bring forth lower exposure to risk, as well as safer care. Hence, nurses are more comfortable with their work, particularly with drug administration. Such a work environment with clear (communicative) structures and conditions, enabling satisfactory compliance with duties, and facilitates teamwork between different professional categories, as mentioned during the interviews.

3.5.3 Healthcare Provider Organisations (HPOs)

Given that the CIS was designed to support work at HUG, it is not surprising that a number of positive impacts affect the organisation itself.

Time savings & human resources

According to the physicians interviewed, they "loose" time on ward rounds, about 30 minutes per week for data entry as CPOE takes more time then hand-written or oral orders, but gain time on looking for information and getting decision help later on. The net saving is about 2 hours per physician per week. This leads to impressive cumulative time savings from the CIS. Therefore, and despite the first-glance impression, an important benefit for the HPO are time savings of the staff. This time saving is scattered on numerous people and reallocation to other productive activities is left to each individual. Nevertheless, the time saved has a value, which is calculated by using pay rates. Whether this value is redeployed or not is a separate issue that we will return to in section 3.8 below. The same can be said about nurses, as mentioned earlier. The nurses do not have to chase records or physicians because of lack of, or ambiguity about information, for example on prescriptions. Another example is ordering, where an internal study on over 100 nurses from several departments across HUG showed a mean real reduction in time of 2 minutes and 4 seconds per order. Shared electronic records ease teamwork and avoid a lot of time spent on looking for information and on physically walking through the hospital when in need of a second opinion.

A further time saving is observed during transfers of patients between units and sites of HUG, which normally requires re-transcription /re-admission and data collection. The CIS being shared, this is no longer needed. This saves more than 10 minutes per patient in avoided time for asking about details, such as medications, for a nurse. In addition, there are no more re-transcription errors. The scale of the impact is illustrated by the example of one of the rehabilitation units located in another hospital location than the main site, which has more than 70% of all patients being transferred from the general internal medicine unit at the main site.

An unexpected benefit concerns the archives. The CIS helps stopping the need for expanding storage space and human resources needed to manage paper-based archives. Paper based records are transferred to a central archive with some 8km of shelves. Old records papers are asked for in 5-10% of all cases. Before the introduction of the CIS, 2 full time equivalents (FTEs) where devoted to records' search in the ER alone. The ongoing scanning procedure for old paper files is expected to reduce the current resources needed even further.

Avoiding duplicative activity

Another expected benefit is savings from reduction in tests and drug usage, though this has not been explicitly measured in this study. Estimates had to rely on the judgement of physicians and nurses about their changed behaviour.

[30] Source; Interviews with nurses

Reduction in tests is expected because of three reasons: a) physicians see all results in real-time; b) there are no more lost results; and c) there are rules that alert the physicians if it is unnecessary to repeat a test, such as duplicate tests or too short intervals between two tests.

Reduction in drug prescription is expected because of the rules during order entry, such as duplicate drug in the same family, or propositions to ease the treatment. According to the physicians interviewed, there are about 20% more orders of laboratory tests in the paper environment compared to CIS environment; 5% over-ordering of MRI's, 10% over-ordering of CT-scans and 15% over-prescription of X-Rays. It should be stressed that these numbers do not point to malpractice on a massive scale in conventional hospitals. Most of the avoided prescribing and ordering has only become possible through the information availability enabled by the CIS. Without the CPR system, physicians would need to order those test in order to secure the quality of care to the patients.

Risk

For the HPO, an important aspect is the reduction of risk exposure when patients are transferred to a new ward, and even more when transferred to another hospital of the consortium, resulting from the ubiquitous availability of the record. Further, there is a better handover process between shifts. In addition, decision support embedded in the CPOE avoids many errors, especially around drug order entry.

The CIS has also proven being very useful in judicial enquiries. With all accesses and actions being traced, the HPO is in a better position to answer some enquiries, especially when pertaining to breaches of patient's privacy.

Billing & resources

Coding clinical information for billing purposes has been considerably eased with the CIS. Specific user interfaces have been built for coders so that they can access all the information relevant for coding. All documents and information required have been identified and are specially tracked in the CIS, so that the most complete set of data is always available at the time of coding. Control procedures have also been put in place to ensure complete and exhaustive coding.

A striking example of the impact is given by the radiology department, where the introduction of the radiology information system within the CIS improved billing by CHF 0.5 million of previously forgone income a year. Another example is the obstetrics unit, where some automatic encoding procedures based on the clinical record allow redeploying one full time equivalent of coding staff to other activities.

Automation of coding and billing increases the cash flow and reduces the workload in billing services.

A further benefit to HUG is the liberation of resources from the rare occasion of avoided admissions. The immediate availability of information can lead to patients being helped immediately instead of hospitalised for a day. This is particularly the case during nights, when paper records are more difficult to access. In paper-based environments, patients have to be hospitalised and stabilised for the night, until the record is made available in the morning. This saving has a corresponding item on the cost side, as the avoided admissions also mean forgone income for HUG. There is no hard evidence for this impact at HUG, yet a provision for it is made on the basis of experience at other sites[31].

Medical management

[31] Private research by TanJent and empirica shows strong indications for this effect. The quantitative estimates are kept conservative and, with less than 1% of the impact, do not have a critical influence on the overall evaluation results.

The medical board of the HUG has a strong overview of the hospitals' activity. It can influence working practice and behaviour much easier, such as changing drug prescription habits. Quality measurements are also made and followed easier.

Administrative management

The structured nursing record contains all planned and realised nursing care interventions. This allows the management to plan resources needed in each ward, and analyse care provision and resources needed. Many other planning tools are available, such as operation theatre planning, radiology planning and consultations.

Supporting strategic decision making through information provision, such as institutional dashboard, is an additional benefit provided by the CPR system. Through real-time modelling, various scenarios, for instance about beds and patient allocation, can be simulated and their impact on healthcare quality, resource capacity and requirements, and patient demands can be recognised. The CPR allows for example to know in real-time nursing resources needed to take care of each patient in the HUG, thus facilitating and improving resource allocation.

3.5.4 Third parties

The avoided cost of admission, already described above, is a small, but tangible benefit to the health insurance companies.

A relatively small positive impact is observed for judicial institutions, which benefit from the improved speed and quality of the available reports from HUG.

The Geneva canton benefits only indirectly from the CIS at HUG, as the population receives better care and thus enjoys a better quality of life, as well as potentially some more tangible effects such as reductions in sick leave. As a policy maker, the canton is also interested in HUG being more efficient and effective, as well as at the forefront of modern hospital care provision. However, these effects are of second and third order, where the causal link between the evaluated system and the effects becomes uncertain. The EHRI evaluation methodology focuses on first order effects only.

HUG will be an important actor in the medical informatics community network being built in the Canton with the aim to provide a complete shared patient record for all providers and all citizens.

3.6 Costs

There are two major types of costs associated with eHealth activities. One is the investment-related extra expenditure, effort, and opportunity costs, and the other is any negative impact from the utilisation of eHealth systems. In the specific case, the first type is mainly borne by HUG and the canton of Geneva, whereas the second type is spread among all stakeholder groups.

3.6.1 Patients, informal carers and other people

The direct costs to patients are nil. One example of potential indirect costs is related to the risk of breach in privacy, such as transmission of information to third parties. However, internal information governance rules, addressed in section 3.9 below, provide a safe-guard against fraud. Further, because the automated sharing of information with entities outside HUG is still in its beginning, the risk of errors in that respect is not considered to be

significantly higher than without the CIS. Thus, this aspect is included in the overall contingency estimation of the costs. In the future, as information sharing between entities becomes a routine practice, this issue should be analysed in further detail.

3.6.2 Health services teams

A clear cost for care providers is the time and cognitive effort needed to use the system. Further, there is a temporary inconvenience to doctors, nurses and other users arising from disruptions during the implementation stage of new functionalities.

According to interviews with professionals, at the early stages of implementation a healthy distrust seems to be dominating, so physicians and other professionals ordering drugs, test, or treatment review the entries before submission. However, a potential danger that should be monitored has also been identified: over-reliance on the system, such as with dose control for drugs, lowers the vigilance and may be cause of errors.

Regarding general adaptation to using computers for typing in clinical reports, it must be emphasised that before the introduction of CIS many physicians had to type most reports, progress notes, etc. using typewriters, so typing was not a severe challenge.

3.6.3 Healthcare Provider Organisations (HPOs)

The main bulk of ICT investment is financed by the canton of Geneva. Consequently, the costs borne by HUG are mainly concerning operational and organisational aspects.

HUG covers operational costs for all IT, including the CIS and its CPR system. HUG is also paying for the integration of third party modules and systems, such as the RIS or the ICU CPR system, into the CIS concept. Other ICT costs to HUG include the cost of obsolescence.

Organisation changes consist of the healthcare professionals' engagement and time commitment to the system's development and implementation. Healthcare staff's continuous engagement in the continuing development process adds up to 3 days on average per involved staff member per year. This is time needed for specifications, system parameterisation, and discussions about future developments of the system. Additional costs of implementation include a period of disruption, in which processes may take more time rather than less, but more importantly the time needed for training and education. Every physician at HUG has to attend a two-hour class on how to use the system. This adds up to a substantial amount of redeployed resource, since this time falls under the physicians' working time.

The other items on the cost side for HUG are negative impacts from the system. The main factors are the extra time physicians spend on ward rounds, and the forgone income from a small number of avoided admissions, as already discussed in section 3.5.3 above.

3.6.4 Third parties

The canton of Geneva contributes a large share of expenses through a share of the investment budget contribution to HUG's overall investments.

A negative impact on insurance companies corresponds to the benefit to HUG from improved billing procedures.

3.7 Socio-economic analysis

3.7.1 Summary of methodology

The theoretical foundation for an EHR IMPACT (EHRI) evaluation is cost benefit analysis (CBA)[32]. The UK Treasury's Green Book[33] and Germany's WiBe[34] specify the CBA methodology as an appropriate tool for analysing the impact of investments and activities in domains of public interest, including healthcare. CBA enables the impact on all stakeholders to be included in a socio-economic evaluation and the financial implications estimated over the selected timescales, extending from 1998 to 2010 for the EHRI evaluation. Three datasets are: statistics, costs and benefits.

Statistics include data about the population affected by the EHR or ePrescribing solution, the number of users, eHealth transactions, and changes in healthcare activity. Indicators can be available from healthcare provider organisations (HPO), but not always for the whole evaluation life-cycle, so some estimation is needed. These assumptions are held separately from data of actual activity, increasing transparency and helping identify critical assumptions. A feature of the EHRI methodology is that information gathering has to rely on existing data and expert estimates. It is beyond the temporal and budgetary constraints of the study to perform detailed observational studies in order to investigate precise changes in time allocations or in quality of care. Thus, the results are to be interpreted within their order of magnitude instead of absolute values. Despite this limitation, the evaluations provide a sufficient level of rigour to support the qualitative analyses and the conclusions on the overall impact and performance of the evaluated sites.

Information on monetary values of all relevant costs and benefits described in the above sections is seldom readily available from HPOs because their statistical and financial records do not record most of these routinely. Unit costs of resources need to be estimated at constant prices over the whole investment life-cycle of design and development, engagement, testing, implementation, operation and change. Estimates of all stakeholders' involvement rely on assumptions about the time allocated to these activities. Doctors' time redeployed from other activities and additional costs, such as new project teams are examples. Actual payments to ICT suppliers are usually the bases for the estimated ICT costs over whole life-cycles.

Estimating the monetary value of impact uses several techniques. Time savings of staff and numbers of tests can be estimated from unit cost calculations. Quality gains have five categories of better-informed patients, timeliness of care, effectiveness of care, patient safety and streamlined care. Some of these can be estimated using unit cost calculations, such as avoided hospital admissions. Intangible benefits, such as the value to patients and organisations, rely on willingness to pay estimates inferred from stakeholder behaviour, usually with very small values for some patients who enjoy a new benefit. The same technique is used for benefits to healthcare professionals who can be adamant that eHealth could not be removed because it benefits their working days. The same technique is also used for intangible negative impacts such as irritations and inconvenience. Intangible benefits for HPOs, such as reductions in risk exposure, are valued using insurance-based models. Benefits from efficiency gains are valued using estimates of the changes in unit costs from productivity improvements. Some benefits realise cash benefits, such as identifying increased activity that

[32] EHR IMPACT (2008): Methodology for evaluating the socio-economic impact of interoperable EHR and ePrescribing systems, Bonn (Available online: http://www.ehr-impact.eu/downloads/documents/EHRI_D1_3_Evaluation_Methodology_v1_0.pdf)
[33] HM Treasury (2003): The Green Book: Appraisal and Evaluation in Central Government; available at: http://www.hm-treasury.gov.uk/media/05553/Green_Book_03.pdf
[34] http://www.wibe.de/html/konzept-uberblick.html (4.8.2008)

can be billed. Estimates of extra activity multiplied by prices provide the monetary value. Details on the impact indicators and the quantification methods involved in this particular case study are presented in Appendix 2.

These techniques provide baseline estimated costs and estimated benefits, where costs include all negative impacts and benefits all positive impacts. Contingency adjustments are used to reflect the reliance on estimation. They increase costs and reduce benefits. Contingencies can be as high as 70% for some baseline monetary values. Adjusted estimated costs and benefits are discounted to net present values then tested for sensitivity to identify the impact of the reliance on estimates on the findings.

The overall impact is measured by the estimated monetary values of annual and cumulative benefits, and so net benefits over time. These show the time taken to realise net benefits and their scale. They also reveal the distribution of the costs and benefits between stakeholders and the distributions of extra finance, redeployed finance and non-financial costs and benefits. Judging eHealth impact requires the focus on relative, not absolute monetary values, especially cost benefit ratios and correlations of costs, benefits and eHealth utilisation.

3.7.2 Net benefits

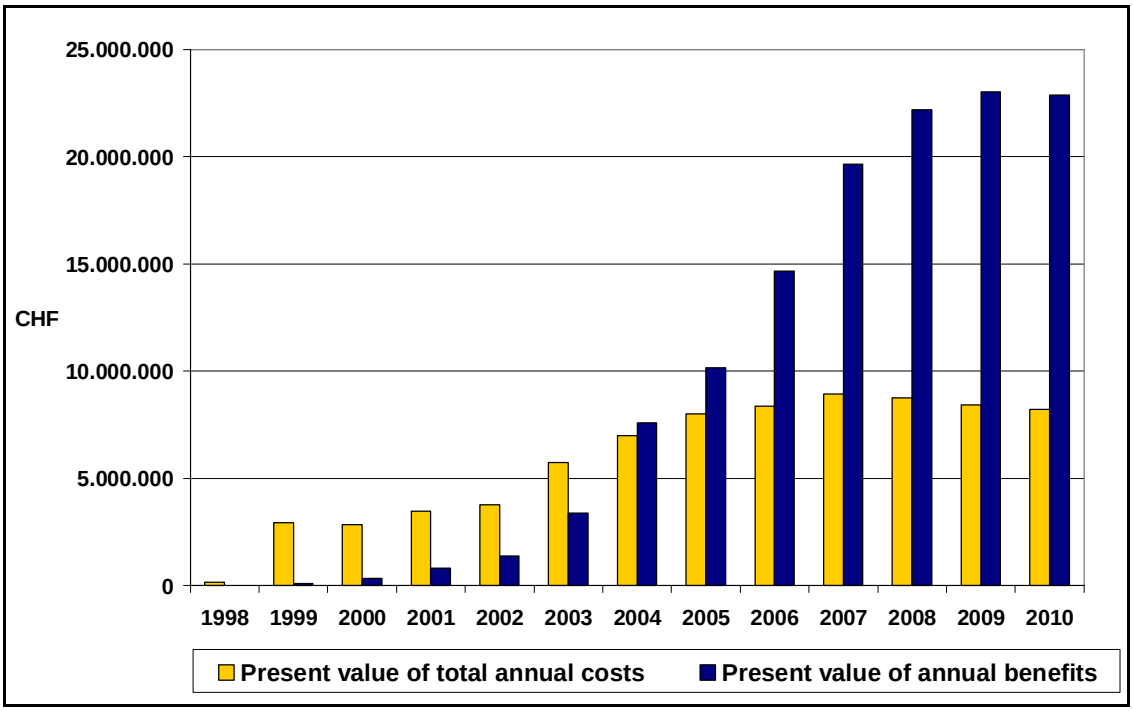
Net benefit over time is the critical measure of the overall socio-economic impact of eHealth systems. It identifies when and by how much, benefits exceed costs over time. Two important features of the net benefit estimates need to be stressed. First, the net socio-economic benefit is a monetary measure of the net value of all positive and negative impacts, not a measure of financial returns and thus not a Return on Investment (ROI) measure. A brief analysis of the financial impact follows in the distribution of costs and benefits into different categories, including financial, in section 3.8 below. Second, as noted above, the value of the conclusions lies in the overall position and performance, not in the absolute values presented (cf. Section 3.7.5 on sensitivity of results).

The estimated costs and benefits are the aggregated monetary values of the positive and negative impacts of the CIS at HUG as described in sections 3.5 and 3.6 respectively. The process of assigning a monetary value to each impact indicator is presented in detail in Appendix 2.

3.7.2.1 First year annual net benefits

Chart 4 below shows the present values of estimated costs and benefits for each individual year over the relevant life-cycle.

Chart 4: Estimated annual cost and benefits



Estimated annual net benefits took seven years to be realised, some four years after initial implementation of the first functionalities of the new architecture – structured clinical documentation and nursing care records. From year nine, 2006, the margin is substantial and increasing, indicating a strong, sustainable positive impact. This timescale is relatively long compared to average timescales found in other eHealth IMAPCT based evaluations[35]. However, the timescale is in line with cases of similar scale and complexity.

The delayed realisation of benefits is due to the fact that the EHRI methodology includes all costs including pre-development planning. The relatively slow build-up of benefits in the first three to four years is consistent with approach towards ensuring acceptance before changing working practices. Further, the period 2004-2006 was a period of large scale deployment of CPOE and DSS functionalities (cf. section 3.3), with a respective impact on utilisation. The gradual build-up may also indicate the reduced risk that was achieved by the internal development strategy, which focuses on robustness and reliability of all implemented features of the system.

The observed flattening of both, cost and benefit curves towards the end of the period, 2008-2010, has three main causes. On the cost side, current and further future developments are left out of the estimations, since their benefits would be realised with a time lag beyond the EHRI timeframe. Thus, development costs decrease to close to nil, leaving only operational and maintenance costs on a continuous basis. On the benefits side, we can observe a status very close to full deployment of all available functionalities. Consequently, increases in annual benefits resulting from increased utilisation levels due to further deployment across HUG were expected to cease. The third aspect affecting the curves is the technical conversion of results into present values, allowing a comparison accounting for the different value of money over time.

The significant net benefit margin achieved from year nine onwards is critical long-term economic viability. Having realised the benefits, they are likely to be sustained above this

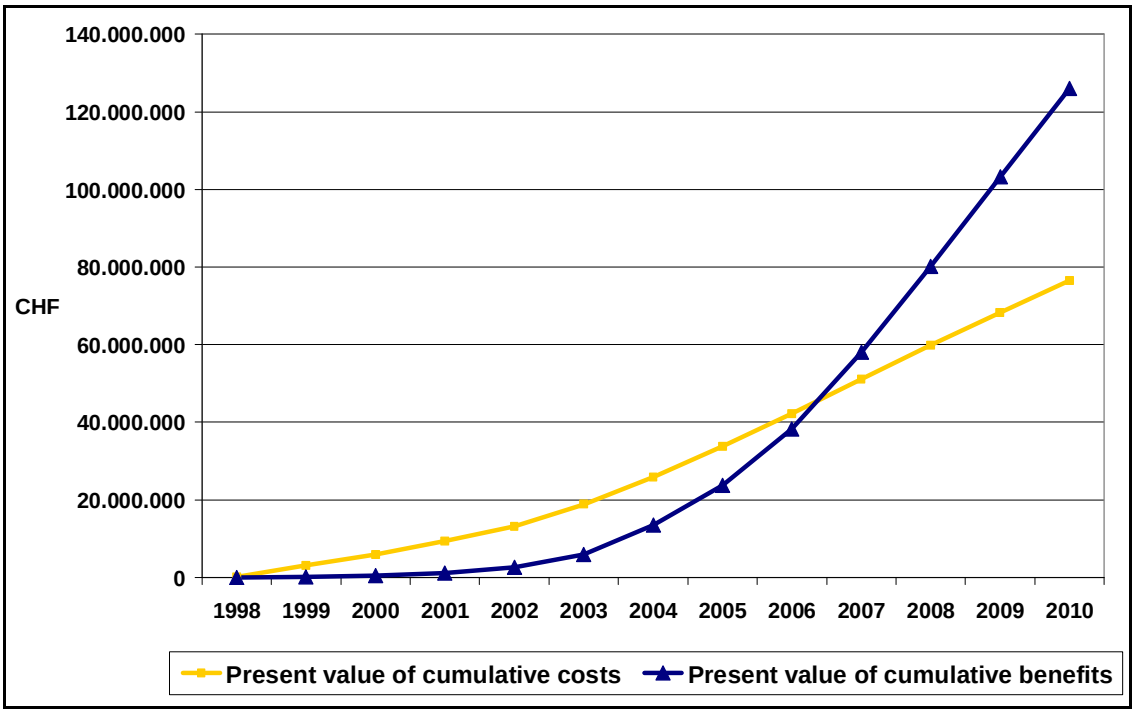
[35] The eHealth IMPACT average time to annual net benefits was 4 years, cf., reports at www.ehealth-impact.eu

rate beyond 2010, the end year of the EHRI evaluation period, and thus drive the cumulative economic performance of the system.

3.7.2.2 First year cumulative net benefits

Aggregating the annual costs and benefits to cumulative values shows the overall socio-economic impact over time. The respective costs and benefits curves are depicted in Chart 5.

Chart 5: Estimated cumulative cost and benefits



The CIS at HUG, including its CPR, ePrescribing, general CPOE, and other features, yields a positive cumulative net socio-economic benefit in 2007, year ten of the life-cycle and eight years after initial implementation began. The gap of three years between realisation of annual and cumulative net benefits is consistent with observations at other sites and can be attributed to the relatively fast increase in the net benefit margin once annual benefits start exceeding annual costs.

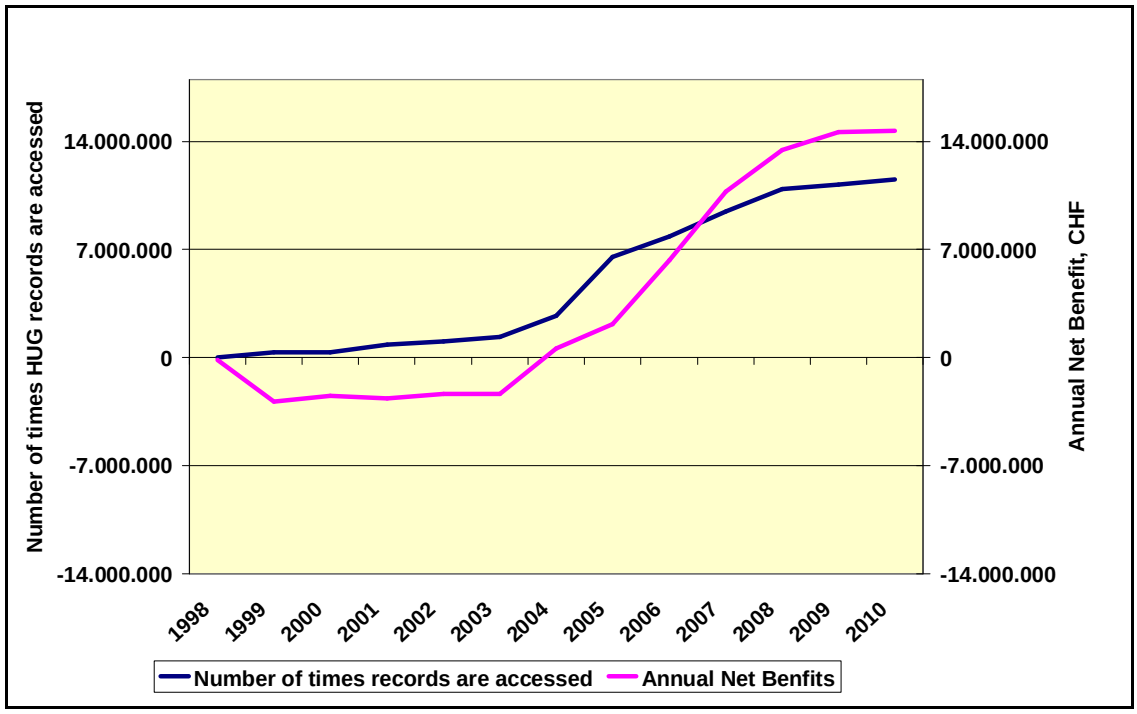
The cumulative cost curve increases gradually over the first five years of planning and development. The rate of increase accelerates in the period 2002-2005, reflecting the substantial increase in the number of users and utilisation resulting from large scale deployment of CPOE and DSS functionalities. The stable rate of increase of cumulative costs reflects the stabilised level on annual basis, shown in Chart 4.

Only the use of the system leads to positive impacts, which explains the low level of benefits during the first five years of the life-cycle, and first three years of following initial implementation. The surge in the rate of increase comes with a reasonable lag to the equivalent phenomenon in the cost curve, starting in 2003. The rate of increase of cumulative benefits stabilises after 2006, at a rate significantly higher than the stable rate of increase in costs. This is a critical relationship for the long-term economic sustainability of the CIS at HIG. Having realised net benefits, these are likely to rise even further beyond 2010, the end year of the EHRI evaluation period.

3.7.2.3 Net benefits and utilisation

Generally, annual benefits and utilisation can be seen as broadly correlated. If the CIS is not used, then benefits will not be realised. However, the obverse is not always true. Just because a system is used, it does not automatically mean that benefits accrue unless it provides usable and useful information. In this setting, matching the utilisation and net benefits curves after implementation can reveal some of these relationships. Before implementation, annual net benefits are invariably negative, with utilisation as zero.

Chart 6: Link between net benefit and utilisation



The annual net benefit curve switches into positive at year seven and rises each subsequent year to 2010. The utilisation curve rises throughout the period, with accelerating peaks between 2003 and 2005. The annual net benefits follow a similar pattern. The correlation of utilisation to benefits is about +0.99 and to net benefits is about +0.97, both very high correlations. They indicate that the economic impact of the CIS has been substantially achieved by its increasing utilisation. It is important to note, that the quantification of impact indicators has relied on data other than utilisation[36], which means that this result is not a methodological artefact.

3.7.2.4 Net benefit to cost ratio

The net benefit to cost ratio provides a comparison of the net socio-economic impact of the evaluated system to the costs, including any negative impact. A positive ratio indicates a worthwhile endeavour from a socio-economic perspective. A ration of zero equals an implicit break even point at which the overall socio-economic impact is zero.

At year seven, the annual net benefit ratio to costs is slightly positive and rises to +1.79 at year thirteen, 2010. The cumulative ratio increases steadily over the life-cycle and turns positive in 2007, year ten. By 2010, the cumulative net benefit to cost ration reaches +0.65,

[36] See Appendix 2.

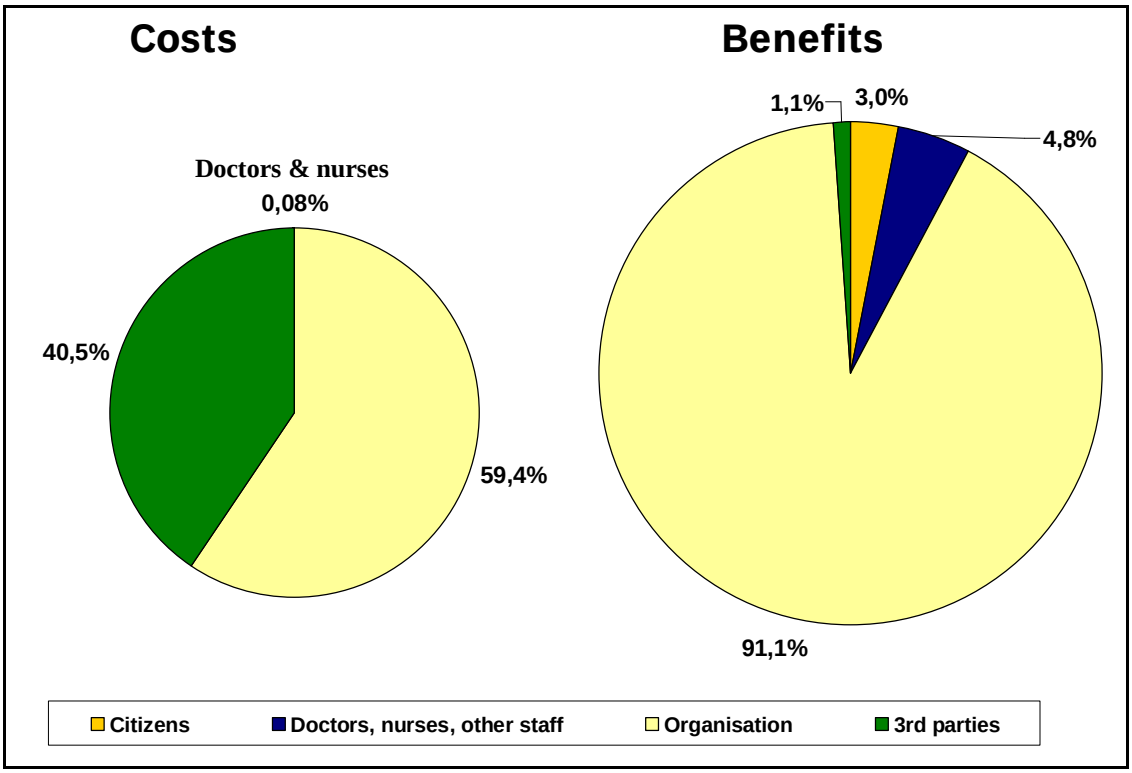
meaning that for every CHF 100 worth of negative impact, there are CHF 165 worth of positive impact.

The ratio can also be understood as a rate of socio-economic, yet not purely financial, return over a given period. This indicates an overall socio-economic return from the CIS and HUG of about 65% over a lifecycle of 13 years.

3.7.3 Distribution of costs and benefits to stakeholders

Chart 7 below shows the distributions of costs and benefits between the main stakeholder groups. The organisation in this case is HUG. The category "doctors, nurses, and other staff" refers to HUG's employees as individuals, not as employees. Thus, only impacts such as private time invested or saved, and inconvenience or feeling of comfort, are attributed to this group. As already addressed, "citizens" in this case refers to patients at HUG. In this particular case, there are two main subgroups of third parties. These are health insurance companies and the canton authorities of Geneva.

Chart 7: Costs and benefits per stakeholder group



Estimated costs are distributed almost entirely between HUG, as an HPO, and the canton of Geneva and health insurance companies as a third parties. Disruptions and inconveniences to care providers account for a small share of the costs. Patients are not negatively affected by the system.

The distribution of benefits reflects the costs distribution, which is a distinct feature of successful eHealth implementations. An unusual observation is that one stakeholder, the canton, apparently does not reap enough benefits to cover the incurred costs. In fact, the value of the direct impact to canton is negative throughout the life-cycle. This phenomenon can be explained by the nature of the canton as a political entity representing the state, or the social planner. Thus, investments should and are justified by benefits to citizens and

society as a whole. In this sense, the canton should compare its investment to the overall benefits realised.

Another argument is that the canton contribution is a share of the overall investment budget of HUG, which is exclusively provided by the state, since HUG is a public organisation. Comparing the joint costs to the canton and HUG to the benefits to HUG yields a positive net benefit. All other stakeholder groups enjoy a positive net benefit throughout the period, as expected by theory.

3.7.4 Sensitivity analysis

The sensitivity analysis consisted of 18 separate tests, focusing on all possible estimated variables that the outcomes of the socio-economic analysis could be sensitive to. Such variables include a number of probabilities based on secondary literature[37], as well as estimates of willingness to pay values inferred from behaviour, and estimated time changes for which no scientific proof was available. Further, the possibility that the HIS accounts for a smaller proportion of the positive impacts than assumed by the model was tested.

The tests involved changing the values of blocks of variables included in the calculation of the monetary values of costs and benefits towards a pessimistic scenario. Values were lowered or increased by between 50% and 500%, depending on the variable in question, and in a direction potentially reducing the net benefit over time. The discount rate has been tested for sensitivity at plus 100% and minus 50% of the EHRI rate of 3.5%.

The overall results of the socio-economic analysis are not sensitive to any individual block of estimations. The impact of manipulating assumptions is minimal, with highest impact involving a deferral of annual or cumulative net benefits by one year; in one occasion by two years. The overall socio-economic impact for the EHRI evaluation timeline, measured by the cumulative net benefit to cost ratio in 2010, worsens within a range of up to 0.51, still leaving a comfortable positive result of 0.14.

The results of the sensitivity analysis thus show that the conclusions drawn from the socio-economic analysis are robust, and do not depend on individual estimations or assumptions.

3.8 Financing and financial impact

3.8.1 Financial impact

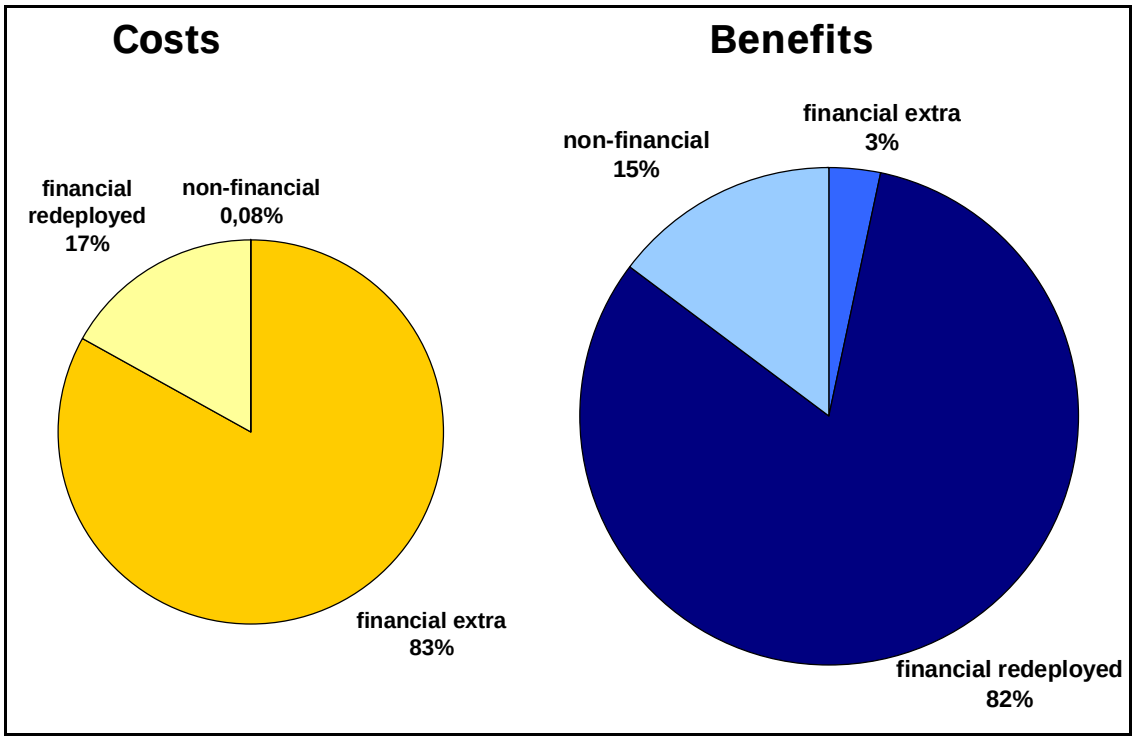
The financial impact of the CIS shows a very different picture to the cost benefit performance. Each cost and benefit has been assigned to a category of extra finance, non-financial, or redeployed finance to show the financial implications of the investment. Results are depicted in Chart 8 below. The financial classification of benefits shows that only 3% of the benefit, CHF 4.3 million, is extra released finance. This is compared to 83%, or CHF 63.6 million, of extra financial costs related to the investment over the period of 13 years.

The remaining 17% of the costs are redeployed resources from other activities, and only a marginal part of the costs can be classified as non-financial. 82% of the benefits can potentially be redeployed into productive resources, with the remaining 15% being completely non-financial. With a few exceptions, such as where a specific person changes their focus of work, the benefits in the redeployed category are found in many small pockets and cannot

[37] Cf. Reference list

easily be redeployed as a set of corporate decisions. Releasing the potential financial benefit from redeploying resources is a difficult managerial challenge.

Chart 8: Financial and non-financial impact



Taken together, the analysis shows a financial position where extra cash of some CHF 63.6 million is invested over thirteen years to realise CHF 4.3 million of financial benefits. This means that at least CHF 59.3 million, some 57% of the potentially redeployed resources, have to be actually released for a financial return to be achieved. However, the investment has already been worthwhile from the socio-economic perspective, which justifies not only the investment as a whole, but also the financial contribution of the state.

Considering HUG alone, CHF 32.6 million of extra cash and CHF 12.8 million of redeployed resources stand against CHF 2.9 million of extra income and some CHF 103 million of resources that can be redeployed. Bridging the purely financial gap by releasing finance from redeployed resources is one of the goals of HUG's management. This is considered challenging, yet not unrealistic, especially in the longer turn.

3.8.2 Financing arrangements

The overall annual investment budget at HUG is about CHF 140m, or some 12% of the overall HUG annual budget of CHF 1.2bn. IT investments are planned and presented as part of the general investment proposals to the canton parliament in four years cycles. The canton parliament is responsible for deciding on public investments of more than CHF 1 million. As a public institution, HUG also draws from these resources.

The budget of the department of medical informatics at HUG is covered to 50% by the extra funds coming from the government, and to 50% by HUG's internal sources. This does not include the time and effort invested by doctors and nurses, which is either redeployed or non-financial cost. This set up works on a four year lifecycle, with a significant amount of flexibility regarding the timing of expenditure. The current cycle runs to 2010.

Currently, the short to medium run plan is to create real financial savings or extra income by using the system and re-invest the extra resources. Operating costs should then be covered by HUG alone along an amortisation-based model.

3.9 Legal aspects

In order to comply with data protection and other legislation regulating the handling of sensitive personal data, the CPR system employs an information governance structure based mainly on a role-based access management system.

In order to use the system, users must have an active profile. Profiles are granted for a given period. Rotating physicians, for example, have an active profile in their medical service for the length of the rotation, usually 3 months. All active profiles expire automatically after 12 months or the end of the contract, if the latter ends before that time, and must be renewed.

Access to a patients' information is only granted if the care provider has an active profile and is in charge of the patient. That means that a nurse, for example, can only access the records of patients that stay at her ward. Some profiles allow access to patients' data without being explicitly in charge. This is done by an escape mechanism named "broken window". All accesses made in this situation are manually reviewed.

The information that can be accessed, and the actions that can be taken, are under the control of the pre-set rights included in the profile. A user can have several active profiles at the same time. So, for instance, one can be a physician in charge of patient care, a physician head of medical service, and a clinical researcher at the same time. However, when accessing the system, the person has to define the role in which he or she is acting at that moment.[38]

All accesses to any clinical data from any application is tracked centrally and is visible, in real-time, in the patient record available to care providers and the patient him/herself. This is a first important step towards giving the patient control over his or her own medical data.

[38] Christian Lovis, Stéphane Spahni, Nicolas Cassoni, Antoine Geissbuhler: Comprehensive management of the access to the electronic patient record: Towards trans-institutional networks. In: International Journal of Medical Informatics, Vol. 76, 2007, pp 466-479

4 Conclusions

The CIS at HUG illustrates in a profound way what electronic health records, combined with ePrescribing in a wider sense, can do for healthcare provision in a hospital environment. This case study shows good practice that can be taken as a benchmark for similar investments. At the same time, readers should be aware that the results achieved at HUG are above average; an artefact of the EHRI study design. The general conclusion from the case study is that investing in EHR and ePrescribing systems for hospitals is a worthwhile endeavour, provided the investment is well grounded and an integral part of the organisation's strategy. The investment and all negative impacts are more than covered by the benefits of using the system.

4.1 Future potential

The current achievement of the CIS at HUG from a socio-economic point of view is impressive. The CPR has achieved a level of impact that gives the opportunity to HUG's executives to begin to reflect the on current, concrete achievements, and the future role of the system in HUG's strategy and investment plans. It will be essential to expand investment in supporting the changes and developments in HUG's resources, in order to exploit fully the new knowledge from the CIS on planning, organisation, and delivery of services.

A common feature of this, and other success stories, is that the drive for improvement is continuous. The annual net socio-economic benefit from the system at this point in time has reached a stable size and will continue to improve the cumulative position. The real future potential, however, lies in the immediate and planned future developments of the system.

For the care providers, important aspects include speed, ease of use, access to embedded knowledge, and further decision support features. The heads of the medical and clinical informatics department share the same objectives, and add the following:

- Extension towards ambulatory care
- Interoperability with the community network
- Process management
- Unified scheduling and resource management
- Tight integration with the logistics of care
- Better knowledge management system and decision support tools
- Better whiteboards for the management
- Increased automatic billing

It is important that forecast net benefits for HUG's CIS are not extrapolated to indicate a potential performance from these developments. They will have their own cost and benefit curves that need to be estimated and assessed as part of future investment decisions. The socio-economic performance of the current functionalities and scope of the CIS offers a sound foundation and a high level of reality about the long time scales needed to secure net benefits from these next stages. At the same time, the analysis also shows the importance of managing benefits in order to exploit the potential and redeploy resources in order to convert potential into real benefits.

4.2 Transferability

Transferability can and should be examined at several levels. A conclusion of the eHealth IMPACT study[39] was that the purely technical components of eHealth are more easily transferred to other contexts than the organisational features. And even this does not secure transferability of success.

Usually, technological transferability refers to the possibility to install the ICT in another setting. Unlike commercial systems, the CIS at HUG was developed within a very specific context and in response to the very specific needs at HUG. Nevertheless, the open architecture based on components and strong interoperability makes transferability a very reachable goal. The CIS is currently being installed in all public hospitals of the canton of Ticino, another state in Switzerland. As with commercial products, an adaptation to local contexts will be necessary. The component based architecture allows such adaptations to be made with relatively low effort.

The organisational transferability depends as much on the system to be transferred, as on the setting in which it is to be transferred. The healthcare sector is well known for its peculiarities and for local specificities in working and clinical practices determined by care professionals. It would be wrong to try and transfer the CIS in all its details at once. However, the implementation approach of securing acceptance before changing working practices is transferable. It also provides a reason for optimism in dealing with the main problem of organisational transferability described above.

These enabling conditions point to a relatively high level of transferability of the CIS at HUG to other contexts. The risks associated with an actual transfer seem to be associated more with the receiving side rather than with the flexibility of the system. It took a combination of high-level, visionary people at the political, the clinical, the technical and the operational level, supported by people who excel in health informatics to succeed. This combination of people and circumstances is difficult to achieve on purpose.

4.3 The role of interoperability in realising the benefits

Interoperability is a central feature of the CIS system at HUG. On a technical level, it is interoperability that makes the electronic patient records and the CPOE features possible. The CPR is created each time access is required, building on the data stored and managed at different databases and systems. Without interoperation, i.e. the actual use of interoperability, the philosophy of the system would be only theoretical. Semantic interoperability is easier to achieve within a hospital than on larger scale projects, yet it is far from trivial. Consultations and engagement of doctors and nurses in the process of planning and development of the system were critical to ensuring that carers understand and interpret the information provided by the CIS in the right way. Specification of content, such as lists of warning signals and recommendations for drug prescriptions to children, are the responsibility and within the power of users. The resulting agreement on the semantics of the content is essential for the usability, and thus for utilisation and benefit realisation.

It is reasonable to assume that the CIS at HUG is entirely about interoperability, so the cost and benefits reflect this single feature. This judgement attributes the expanding utilisation of the data to effective interoperability.

[39] www.ehealth-impact.eu

4.4 What it means for decision makers

The implications for decision makers are numerous and serve both as encouragement and guidelines. HUG is an example of successful investment in interoperable systems storing and managing health data and ordering procedures, including the prescription of drugs. At the same time, the lessons from HUG make it clear that success is by no means an automatic consequence of investments in eHealth.

4.4.1 Useful experience

A number of aspects from HUG's experience can be useful for decision makers in planning and managing investments in interoperable EHR and ePrescribing systems.

CIS versus a CPR system

Most of the benefits at HUG are the result of a combination and interplay between systems. A simple CPR system consisting of comprehensive records for each patient as a sum of all available information would most probably not have led to a socio-economic return. The benefits are related to the right amount, kind, and quality of information being at the right time in the right place. Also, the input of information is more than simple typing instead of writing. Automatic entry of laboratory test results, images, reports, and orders and prescriptions into the systems allow the avoidance of duplicative documentation processes associated with some stand alone CPR systems. A success factor was a complete change in the working arrangements, data access, and data sharing between wards. Thus, a useful EHR system must be a CIS and go beyond the mere recording of all possible information.

Predecessor ICT systems and experience

The familiarity of management and staff with computerised applications, starting with the predecessor system Diogenes had an impact on the pace of development and on acceptance by users. On the one hand, the experience with the old system provided the HUG medical informatics team with invaluable lessons regarding the practical issues of dealing with a computer system at HUG. These lessons included positive experience, such as tangible support with day-to-day work, and features that can be improved, such as the openness and flexibility of the technical architecture of the system. On the other hand, Diogenes meant that a computer on a ward was not a new thing altogether. Thus, the new system was only in parts replacing completely non-computerised systems. Compared to other sites, this is an advantage when it comes to user acceptance and resistance to change.

ICT and change

The governance structure described in section 3.4.1 has been a very important aspect of the success of the CIS at HUG, ensuring support by the various heads of the HUG. An important feature of the strategy was to use the CIS to change process, but not as a first intention, in order to better manage resistance to the introduction of the CIS versus resistance to process change. Only when the system has become a "must have" part of the daily work, it has been used to change processes. Nowadays, the CIS is considered as the most important instrument to change clinical processes and practices in the HUG.

Economic sustainability

Economic sustainability is a primary indicator of success. The CIS at HUG has already achieved this position as is clear from the stable upward trend in cumulative net benefits. The factors securing this position are not unique to HUG, but are reinforced by HUG's experience:

- Optimal costs / benefits relationship over time
- Sustainable financing over an appropriate life cycle, even if this is over ten years[40]
- Business cases for all stakeholders – each stakeholder group must benefit at least as much as the extra effort it has to invest
- Management of all financial returns – eHealth generates little extra cash and thus the financial returns need to be extracted from redeployment of liberated resources[41,42,43]
- Effective risk management and mitigation can make the difference between success and failure. Many risks can be identified in advance[44], but the challenge is not to ignore them, driven by over-optimism and enthusiasm.

4.4.2 Summary of lessons

The three main lessons can be summarised as follows:

Investors need deep pockets and a lot of patience

Up to ten years and CHF 63 million total costs for the CIS at HUG needed to be invested and financed.

Investors need to know what they get

The benefits, the value of which exceeds the costs by nearly CHF 50 million over the life cycle of thirteen years, are mainly in quality of care and potential liberation of scattered resources, not in extra cash.

Investors need to know what can go wrong

Realistic risk management is essential for the realisation of net benefits. At HUG, major risks were associated with technology failure and with acceptance of the system by users. The identification of risks is the first step towards their mitigation.

[40] Cf. Kaushal, R. (et. al.) (2006): Return on investment for a computerized physician order entry system, J Am Med Inform Assoc., (13)3, pp.261-266.
[41] Cf. Amarasingham, R./Diener-West, M./Weiner, M./Herbers, J./Lehmann, H./Powe, N. (2006): Clinical Information Technology (CIT) Capabilities in Four U.S. Hospitals: Testing a New Structural Performance Measure, Medical Care, (44), pp.216-224.
[42] Cf. Amarasingham, R.(et. al.) (2007): Measuring Clinical Information Technology in the ICU Setting: Application in a Quality Improvement Collaborative, J Am Med Inform Assoc., (14)3, pp. 288-294.
[43] Cf. Amarasingham, R./ Plantinga, L./Diener-West, M./Gaskin, D.J./ Powe, N.R. (2009): Clinical Information Technologies and Inpatient Outcomes, A Multiple Hospital Study, Arch Intern Med., (169)2, pp.108-114.
[44] For example, cf. Han, Y.Y. (et. al.) (2005): Unexpected Increased Mortality after Implementation of a Commercially Sold Computerized Physician Order Entry System, Pediatrics, (116)6, pp.1506-1512

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Appendix 1: Summary of evaluation data

EHRI generic data summary	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
HUG	CHF	CHF	CHF	CHF	CHF	CHF	CHF	CHF	CHF	CHF	CHF	CHF	CHF
Estimated COSTS													
Citizens	0	0	0	0	0	0	0	0	0	0	0	0	
HPOs													
Doctors, nurses, other staff	0	0	0	977	1.741	7.953	8.620	4.311	9.641	15.649	6.936	4.197	3.5
Organisation	162.219	0	0	715.746	1.101.711	3.159.286	4.502.493	5.604.407	6.042.038	6.666.736	6.035.772	5.799.854	5.671.9
Third parties	0	2.938.407	2.839.040	2.743.034	2.650.274	2.560.652	2.474.060	2.390.396	2.309.561	2.231.460	2.706.000	2.614.493	2.526.0
Present value of total annual costs	**162.219**	**2.938.407**	**2.839.040**	**3.459.758**	**3.753.726**	**5.727.891**	**6.985.173**	**7.999.113**	**8.361.240**	**8.913.846**	**8.748.708**	**8.418.543**	**8.201.6**
Present value of cumulative costs	**162.219**	**3.100.626**	**5.939.666**	**9.399.424**	**13.153.150**	**18.881.040**	**25.866.213**	**33.865.326**	**42.226.566**	**51.140.411**	**59.889.119**	**68.307.663**	**76.509.2**
Estimated BENEFITS													
Citizens	0	0	16.490	24.527	40.486	80.312	238.098	296.959	466.253	593.564	642.827	674.680	651.8
HPOs													
Doctors, nurses, other staff	0	0	0	16.051	55.120	221.689	393.325	462.938	654.398	956.506	1.058.832	1.116.135	1.156.4
Organisation	0	82.859	329.448	763.861	1.283.435	3.063.883	6.955.911	9.126.726	13.284.217	17.870.470	20.239.728	21.000.622	20.845.5
Third parties	0	0	0	0	0	0	0	258.704	255.083	244.145	235.889	227.912	220.2
Present value of annual benefits	**0**	**82.859**	**345.938**	**804.440**	**1.379.041**	**3.365.884**	**7.587.334**	**10.145.327**	**14.659.952**	**19.664.684**	**22.177.275**	**23.019.349**	**22.874.0**
Present value of cumulative benefits	**0**	**82.859**	**428.797**	**1.233.237**	**2.612.278**	**5.978.162**	**13.565.496**	**23.710.823**	**38.370.775**	**58.035.459**	**80.212.734**	**103.232.084**	**126.106.1**
Net benefits													
Present value of annual net benefits	**-162.219**	**-2.855.547**	**-2.493.102**	**-2.655.318**	**-2.374.685**	**-2.362.007**	**602.161**	**2.146.214**	**6.298.712**	**10.750.839**	**13.428.567**	**14.600.806**	**14.672.4**
Present value of cumulative net benefits	**-162.219**	**-3.017.766**	**-5.510.869**	**-8.166.187**	**-10.540.872**	**-12.902.878**	**-12.300.717**	**-10.154.503**	**-3.855.791**	**6.895.048**	**20.323.615**	**34.924.421**	**49.596.8**
Net benefits over cost ratio - annnual	-1,00	-0,97	-0,88	-0,77	-0,63	-0,41	0,09	0,27	0,75	1,21	1,53	1,73	1,
Net benefits over cost ration - cumulative	-1,00	-0,97	-0,93	-0,87	-0,80	-0,68	-0,48	-0,30	-0,09	0,13	0,34	0,51	0,
Number of records	0	0	711.825	9.639.165	21.764.199	23.395.689	26.547.360	32.716.160	37.536.536	50.219.026	50.231.333	50.243.640	50.255.9
Number of times records are accessed	0	310.243	345.097	845.933	1.023.415	1.348.993	2.694.561	6.514.191	7.849.919	9.462.943	10.890.245	11.216.952	11.553.4

Distributions	**Costs**		**Benefits**						**Type of costs**		**Type of benefits**	
Citizens	0,00%		2,95%						**financial extra**	83,15%		3,47
HPOs									**financial redeployed**	16,77%		81,87
Doctors, nurses, other staff	0,08%		4,83%						**non-financial**	0,08%		14,66
Health provider organisation	59,42%		91,07%									
Third parties	40,50%		1,14%									
Base year: 2008; Discount rate:												
3,5%												

Appendix 2: Cost and benefit indicators

Table 2: Cost indicators and variables

Stakeholder group	Cost indicator	Clarification	Variables
HPO – healthcare staff	Disruption during implementation stage for nurses	Inconvenience from changes during implementation	Number of new users (nurses); WTP
	Disruption to doctors form extra time from ward rounds	Inconvenience from extra time spend on ward rounds for doctors	Relevant number of doctors; WTP
	Disruption during implementation stage for doctors	Inconvenience from changes during implementation	Number of new users (doctors); WTP
HPO – ICT costs	Operational cost of CIS/CPR		Share of clinical solutions' operational budget going to CIS/CPR
	Integration of RIS with CIS	extra cost, as stand alone RIS is cheaper	Share of RIS cost needed for integration into CIS
	Obsolescence	Share of IT equipment replaced	Obsolescence rate; value of IT equipment
HPO – organisational issues	Doctors' engagement in development		Number of doctors engaged in the system's development; number of days per doctor; share of FTE doctors
	Doctors' average time spent on implementing CPR	Including training	Number of new users (doctors); number of days engaged in the implementation process per doctor; share of FTE doctors
	Nurses' engagement in development		Number of nurses engaged in the system's development; number of days engaged in the development process per nurse; share of FTE nurses
	Nurses' average time spent on implementing CPR	Including training	Number of new users (nurses); number of days engaged in the implementation process per nurse; share of FTE nurses
	Strategic planning	Time for designing systems; fund raising, etc. before development started	Share of FTE management
	Procurement staff	Procuring commercial systems&modules	Time spent on procuring ICU CPR; share of FTE manager
	Avoided admissions	Foregone income to hospital	Relevant number of A&E patients; rate of admission avoidance; reimbursement rate for one day of hospitalisation
	Extra time	Doctors need extra time on ward rounds for typing in information	Extra time needed per time period and doctor; relevant number of doctors; share of FTE doctors

Stakeholder group	Cost indicator	Clarification	Variables
Third parties	Canton: contribution to investments		Share of clinical IT budget (investment) going to CPR-related clinical solutions, excluding systems such as PACS and RIS
	Insurance: Extra expenditure due to higher bills	Result of better billing procedures at HUG	Equivalent to benefit to HUG, based on accounting records

Table 3: Benefit indicators and variables

Stakeholder group		Benefit indictor	Clarification	Variables
Patients, carers & other individual people		Patient safety	Reduced risk of harm when patient doesn't know his medication or the dosage	Relevant number of inpatients; WTP
		Time saving	Avoided repeat questioning about medications and health status in case of transfer	Relevant number of patients transferred to another site; average time for nurses asking patients about medications and other details now available in CPR; minimum wage
		Avoided admissions	Time saving through avoided days of hospitalisation	Relevant number of A&E patients; rate of admission avoidance; minimum day wage
		Avoided admissions	Emotional benefit from avoided admissions	Relevant number of A&E patients; rate of admission avoidance; WTP
		Better care	A result of better informed decisions by doctors; a more structured compliance and validation of nursing care plans, and DSS support	Relevant number of in patients; WTP
HPO - health-care staff	***Nurses***	Better work satisfaction	Nurses chose their job for reasons other than bureaucratic tasks, such as searching for and filing in records	Number of nurses using the CIS; WTP
		Comfort and reassurance	Feeling safer, less vulnerable, more comfortable with their work, particularly with drug prescriptions	Number of nurses using the CIS; WTP
		Less frustration because of clarity of orders and records	Nurses not having to chase doctors for clarifications	Number of nurses using the CIS; WTP
		Lower exposure risk	Including the potential for fewer complaints	Number of nurses using the CIS; WTP
		"Making life easier"	By the integrated presentation of different reports and images	Number of nurses using the CIS; WTP

Stakeholder group		Benefit indictor	Clarification	Variables
	Doctors	Not having to search for data	Physicians now know within seconds whether the information is available	Number of doctors using the CIS; WTP
		Not having to guess while waiting for data	Especially when critical data is missing, before CIS physicians had to act on less information than they would like to while waiting for it	Number of doctors using the CIS; WTP
		Less re-thinking and re-typing	The DSS features lead to less repetitive typing and re-thinking, especially from real time records update instead of ex-post write-ups	Number of doctors using the CIS; WTP
		Lower exposure risk	Including the potential for fewer complaints	Number of nurses using the CIS; WTP
		"Making life easier"	By the integrated presentation of different reports and images	Number of doctors using the CIS; WTP
HPO – organisation		Reduction of exposure to risk of clinical negligence due to better clinical governance	Coming from assurance that critical information is always available where needed Including lower risk of errors when transferring patients into a different HUG site	Relevant number of inpatients; probability of a near miss because of missing critical data (knowingly critical); cost of a near miss (to HUG); probability of death because of missing critical data (knowingly critical); cost of death (to HUG) related to an adverse event
		Avoided admissions	Liberated resources / opportunity costs	Relevant number of A&E patients; rate of admission avoidance; cost of one day of hospitalisation post an A&E visit
		Archives stopped growing	No extra storage needed. But as some of the effect could have been achieved with the existing stand-alone systems, estimates are conservative	Extra storage space needed for paper records if no CIS was available; annual rent for additional storage space
		Time savings for archivists	As records available 24/7 at wards	Number of times a record is accessed; percentage of times a record would have been looked up; archivist time to find a record; share of FTE archivist
		Nurses' time saving	For repeated questioning of patients about medications etc.	Number of patients transferred to a different site; average time for nurses asking patients about medications and other details from now available in CPR; share of FTE nurse
		Nurses' time saving	From typing in doctors' notes after ward visits	Number of doctors using CIS; extra time physicians need for ward rounds; share of FTE nurse
		Nurses' time saving	From not having to search patient records in A&E	Observed time saving; FTE nurse
		Nurses' time saving	From not chasing doctors for clarifications, e.g. handwriting	Number of nurses using CIS; number of times clarification is needed per time unit and nurse; time saving per incidence for the nurse; share of FTE nurse

Stakeholder group	Benefit indictor	Clarification	Variables
	Nurses' time saving	From finding relevant info quicker in EPR compared to paper records	Number of accesses to records; estimated time saving per access; share of FTE nurse
	Nurses' time saving	From order entry	Number of orders, average time saving per order, share of FTE nurse
	Doctors time saving	From ward round – immediate access to information instead of recalling, searching, and waiting for it	Time saving from ward round; relevant number of doctors; share of FTE doctors
	Doctors' time saving	From handling discharge letters – building on already existing information instead of re-writing each time	Relevant number of inpatients; time saved; share of FTE doctors
	Doctors' time saving	From not being chased by nurses clarifications	Number of nurses using CIS; number of times clarification is needed per time unit and nurse; time saving per incidence for the physician; share of FTE doctors
	Doctors' time saving	Sharing records instead of walking across the wards	Number of times sharing records substitutes walking across the wards per doctor; relevant number of doctors; share of FTE doctors
	Doctors' time saving	From compiling reports for judicial enquiries	Time saved for compiling reports for judicial enquiries; share of FTE doctors
	Extra income	Resulting from better billing procedures	Based on accounting records
	Redeployed resources	Encoding staff now only dealing with complicated cases	Redeployed time; share of FTE encoding staff
3rd parties	Insurances: Avoided admissions	Cost saving	Relevant number of A&E patients; rate of admission avoidance; reimbursement rate for one day of hospitalisation after A&E visit
	Judicial authorities: Time saving	Avoided interviews etc. for compiling reports for judicial enquiries	Time saved; share FTE judicial staff