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— A Case Study on Process Orientation of Information Logistics —

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This case study on process orientation of information logistics¹ follows the structural framework of business engineering case studies. Business engineering case studies are targeted on delivering descriptions of transformation projects from traditional business solutions to new solutions that rely on information technology [Senger/Österle 2002: 13, 14-17]. To meet these requirements, the case study is structured as follows: Section 1 presents key facts and figures about Brigham and Women's Hospital as well as about Partners HealthCare System, Inc. Its main purpose is to introduce the context of the case study. Section 2 outlines the initial ordering process at Brigham and Women's Hospital before the transformation project. This description of the starting point is crucial to understanding the main challenges that drove the development of computerized physician order entry. Section 3 details the transformation project itself. It reports on the course of action taken by the project team at Brigham and Women's Hospital in order to design and implement a computerized physician order entry system. Section 4 describes the main features of this new IT-enabled solution that now supports the ordering process at Brigham and Women's Hospital. It also reports on user satisfaction and usage patterns. Section 5 draws a comparison between the initial solution and the new solution. It then concludes the case study by summarizing and accentuating the main findings.

¹ Comprehensive information on this concept can be found in [Bucher/Dinter 2008a; Bucher/Dinter 2008b].

1 Organizational Profile

Brigham and Women's Hospital (BWH) is a major urban hospital and teaching affiliate of Harvard Medical School, located in the Longwood Medical and Academic Area of Boston, Massachusetts. The 750-bed hospital has consistently been ranked as one of the top medical centers in the United States for more than ten years. Together with its affiliate community health centers and clinics, BWH offers extensive services to both inpatients and outpatients.

The hospital looks back on a long and rich history. Today's BWH was formed in 1980 through the merger of three major Harvard teaching hospitals. Its mission is to serve the community needs by "providing the highest quality health care to patients and their families, [by] expanding the boundaries of medicine through research, and [by] educating the next generation of health care professionals"². Each year, BWH admits approximately 44,000 inpatients, serves more than 950,000 outpatients, and treats some 54,000 patients in its emergency department. BWH currently employs some 12,000 people, primarily in medical and nursing services, research, administration, and management.³

In 1994, BWH and Massachusetts General Hospital joined to form Partners HealthCare System, Inc. (PHC), an integrated system that offers patients in the Boston area high-quality care via its various hospitals, health centers, and physicians. As of today, PHC is the largest non-profit health care network in New England. PHC is dedicated to delivering its patients the best possible care while being most cost-effective. To this end, PHC and its affiliate medical entities make use of the latest developments in information technology.

The Partners HealthCare System Clinical Informatics Research & Development (CIRD) group's mission is to contribute to the overall quality and efficiency goals of PHC by keeping the clinical information systems at PHC and its affiliate medical entities at the cutting edge of knowledge and technology. CIRD is responsible for applied research in the field of clinical information systems, for strategy setting with respect to clinical systems, and for the design and development of those systems. CIRD staff is comprised of academics and professionals from various pertinent disciplines such as medical science, nursing, pharmaceuticals, computer science, and business administration.

This case study deals with the design and implementation of a computerized physician order entry (CPOE) system for inpatients at BWH. The design and implementation of the system, in

² Internet resource, <http://www.brighamandwomens.org/general/mission.aspx> (accessed April 14, 2008)

³ Internet resource, http://www.brighamandwomens.org/general/about_us.aspx (accessed April 14, 2008)

the following also referred to as “transformation project”, was initiated in 1992 by BWH’s Vice President for Information Systems who later became Vice President and Chief Information Officer at PHC. The project was initially expressed as high-level objective of BWH’s medical leadership and was overseen by the Department of Information Systems at BWH. Later on, the area of application was enlarged little by little and CPOE was implemented in all of PHC’s acute care and rehabilitation hospitals. These subsequent projects, which are not in the main focus of the present case study, were handled primarily by CIRD.

2 Initial Situation

Both division of labor and the resulting job specialization are inherent characteristics of any modern business organization. The process-oriented management approach is aimed at replacing function-oriented separation of work through operational processes that span both functional and organizational boundaries. As a matter of course, these characteristics apply to the health care sector and especially to hospitals, too.

There are at least four major occupation groups in a hospital: physicians, nurses, medical and pharmaceutical technicians, and administrative and supporting staff. All of these groups can be further subdivided and refined. Since BWH is a teaching affiliate of Harvard Medical School, there are, for example, medical students who assist the physicians and nursing students who support the nurses. The group of medical and pharmaceutical personnel comprises all staff of ancillary areas such as pharmacy, laboratory, radiology, and electrocardiography.

As a result of job specialization on the one hand and integrated processes on the other hand, there is a lot of interaction between members of the different occupation groups. Teamwork and cooperation is needed in order to deliver high quality medical care for the hospital’s patients. At any given time, one or multiple physicians are responsible for a patient. Physicians – the patients’ primary care providers – are supported and assisted by various members of the other occupation groups in the hospital. In order to entrust others with certain tasks, physicians typically write orders. Orders can be written for many different purposes, e.g. in order to commission medication, blood products, laboratory tests, radiology tests, general care, or administrative services. The case study at hand deals with the reorganization and improvement of this ordering process.

Figure 1 depicts the initial ordering process at BWH, i.e. the process as it was before the transformation project, in a generic and simplified way. The activities and the process flow vary slightly depending on the particular class of order. However, the generic process serves well for the purpose of illustration.

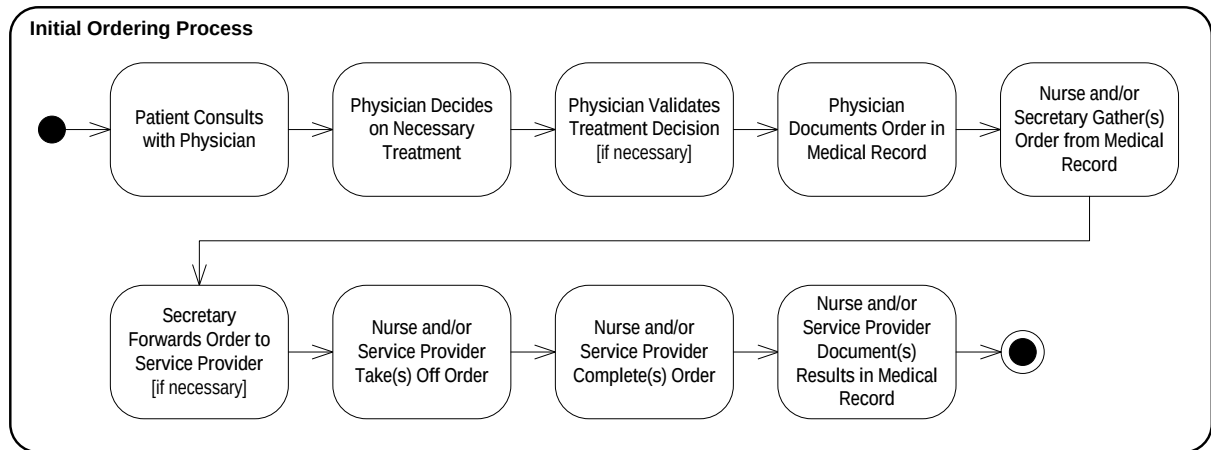


Figure 1: Initial Ordering Process at BWH (generic, simplified)

The process generally started off when a patient consulted with a physician or, for the case of inpatients, when a physician saw a patient during ward round. During or after the consultation, the physician decided on any measures or treatments that were indicated for any given patient. Before writing orders for those measures or treatments, the physician might have wanted to validate the decision with the help of medical guidebooks, personal notes, or by simply asking somebody else – typically a senior physician – for advice or help. Neither computerized applications nor online references or internet resources were available to support the ordering process and the inherent decision making by that time. For that reason, physicians had to write their orders on paper, typically within the order section of a patient’s medical record. These written orders were gathered from the medical records by the responsible hospital unit’s nurses and/or secretaries. If necessary, i.e. if an order was to be (partially or fully) completed by an external service provider (e.g. medication that had to be ordered from the pharmacy, diagnostic studies that had to be performed by specialist departments, or specimen that had to be analyzed in the laboratory), the order was forwarded accordingly. Again, there was little or no computer support at all available for this task. Depending on the order class and on its priority, the outstanding order was then taken off by a nurse and/or by the responsible service provider who completed it accordingly. Finally, both the completion of an order and any results arising therefrom (e.g. diagnoses, protocols, or test results) were documented in the patient’s medical record.

3 Transformation Project

CPOE is considered to represent a so-called “transformational technology” since it changes the ordering process and hence the way how physicians make order-related decisions by providing substantive decision support in the context of process execution. It therefore also requires all persons involved in the ordering process to change their work routine and to “behave differently” [Lee et al. 1996: 51].

The transformation project, i.e. the design and implementation of a CPOE system to replace the initial, mainly paper-based ordering process at BWH, was aimed at reaching various project goals (cf. e.g. [Teich et al. 1993: 99-100]): Computerized ordering should be faster than the initial ordering process, it should provide the physician with comprehensive patient- and order-related information, it should serve as a tool for monitoring the status of any order that has been entered, it should secure quick and efficient routing of orders to the nurses and/or to any responsible service provider, it should be able to handle all different kinds of orders, it should enable and support order entry by medical students and nurses, it should offer decision support in terms of providing feedback and alerts, and it should be easy to learn and to operate.

In order to meet these project goals, the following procedure for the introduction of process-oriented information logistics in connection with CPOE was pursued at BWH:

- ***Obtaining top level support:*** The CPOE project was initiated as early as in 1992 by BWH’s Vice President for Information Systems who expressed it as high-level objective of the hospital’s medical leadership. The project’s initial focus was on improving the ordering process by doing away with paper-based, handwritten ordering. At this early stage, the project was not particularly aimed for the integration of decision support functionalities into the ordering process. Nevertheless, the existence of a powerful and influential promoter within BWH’s management team turned out to be crucial for the project’s success and ability to complete in time as well as in budget.
- ***Drafting an initial vision of CPOE:*** Initially, one single person, a well-known physician and medical informatician at BWH, was entrusted with the CPOE project and appointed project manager. This person had expert knowledge not only with regard to the hospital working procedures but also in matters of state-of-the-art clinical information systems. The project manager sketched an initial vision of what the system would do as well as how it would work and look like. By that time, the vision was laid out on the basis of the

project manager's own personal experience from working as a physician at BWH for many years. It was used as a blueprint for the subsequent development not only of CPOE but also of many other decision support applications at BWH. Moreover, it served as an efficient means of communication to help people at BWH understand the basic idea behind CPOE, the system's functions, and its potential benefits.

- ***Establishing a project team:*** Due to the complexity and the size of the project, a small project team was set up to support the project manager. The team was initially comprised of three informaticians that were responsible for the system's design, for setting up the required hardware, and for programming. Later on, the group was completed with the addition of two persons who were primarily responsible for testing. Every now and then, the core project team was joined by members of user workgroups which included physicians, nurses, and medical and pharmaceutical technicians. These professionals were included in order to collect their key requirements with respect to the ordering process.
- ***Sketching the functional specifications:*** The project team sketched the functional specifications of the system based on the initial vision of CPOE. By that time, the functional specifications already made explicit reference to clinical decision support functionalities that were to be embedded into the context of the ordering process. To this end, knowledge bases and dictionaries had to be established and/or made accessible to the system. Each of the ordering forms that are visible to the CPOE system's end users is underlain by a dedicated dictionary. The system specification also included non-functional requirements such as system performance, reliability, and a backup concept for unexpected downtimes.
- ***Collecting the input of user workgroups:*** Ordering at BWH is a complex and diversified process. In order to assess the needs of all involved stakeholders, joint workgroups of physicians, nurses, clinical technicians, and informaticians from the core project team were established. Each of those focus groups attended to a particular class of order or a particular aspect of the to-be workflow, e.g. medications, laboratory tests, diagnostic studies, or the nursing workflow. Their primary task was to put comments into the CPOE development process, both with respect to their key needs (especially regarding the information required for decision support) and to their main caveats about the new ordering process and the underlying information system.
- ***Revising the functional specifications:*** The comments of the user workgroups were seized on by the core project team. The user feedback was taken into account when

making revisions to CPOE system's functional specifications. A prominent example of a suchlike revision was the decent and user-friendly design of the ordering forms which employs displays and procedures that the hospital staff has already been familiar with and recognized right away. Furthermore, workflow enhancements were made that rendered the CPOE system usage approximately time neutral when compared to the initial ordering process at BWH. In fact, collecting the input of to-be users of the CPOE system and revising the system's specifications accordingly was an iterative process that was repeated multiple times.

- ***Setting up hardware infrastructure:*** The CPOE system was designed and implemented to run on the existing microcomputer network at BWH. For that reason, there was almost no additional hardware to be installed for meeting the needs of CPOE. The existing client-server platform was (and to this day still is) used for all of the clinical applications that jointly constitute the Brigham Integrated Computing System (BICS). Of course, the infrastructure is constantly expanded and updated to account for newly arising requirements. BICS workstations are located throughout the hospital as well as in associate medical centers and satellite practices. The clients are served by multiple main servers. Copies of the main servers' data are kept on shadow servers to ensure high system reliability.
- ***Designing and implementing a prototype:*** Most of the CPOE system's hardware and software components were in place within less than one year after project kickoff. In order to avoid acceptance problems of the new ordering system, potential users were continuously consulted and involved in the system's development. In particular, the decision points of the ordering process, the information required for decision support, and the respective decision rules were elaborated not only by informaticians but also by a physician, a nurse, and a pharmacist. A CPOE prototype was built in order to evaluate the functionalities of the new system and to learn about its strengths and weaknesses in the first place.
- ***Piloting the prototype:*** Two successive pilots of two weeks each were performed within carefully selected units of BWH.⁴ The first pilot was performed on a small special unit with small numbers of both patients and staff as well as with low patient turnaround. The second pilot was performed on a regular station at BWH. During both pilot studies, members of the core development team served as trainers and observers. Furthermore, the

⁴ Comprehensive information on these pilots can be found in [Teich et al. 1994].

users had the opportunity to provide feedback by means of a “feedback” option that was integrated into the prototype and during a debriefing at the end of each pilot. Both perceived advantages and disadvantages of CPOE lead to multiple design modifications.

- ***Testing, adapting and refining the prototype:*** Before as well as after the pilot studies, members of the core project team were constantly testing, adapting, and refining the CPOE prototype. Due to the complexity and the novelty of the requirements, the project team chose an iterative, agile approach to system development. The project team met once a week to discuss upcoming tasks and to agree on work packages. Approximately half of the development time was spent on the iterative design of the ordering forms, i.e. of the CPOE frontend, and half of the time was dedicated to the design and implementation of the underlying knowledge bases, dictionaries, and support functionalities.
- ***Providing training on a voluntary basis:*** Before putting the system into operation, training was provided to the prospective users. However, whereas training was mandatory for all nurses, the physicians were not required to attend a training session. Instead, they were given the opportunity to experiment within a test environment of the CPOE system and to explore the system’s functionality. During the sessions as well as during the first weeks after the introduction of CPOE, support staff was immediately available whenever assistance was required. In a later study, neither satisfaction with nor perceived usefulness of CPOE were found to be related to the attendance of training sessions [Lee et al. 1996: 49-50]. This finding might be attributed to the decent and intuitive design of the new ordering process itself as well of its underlying transactional and decision support systems.
- ***Going into operation:*** The new CPOE process and system went into operation for the first time in the spring of 1993. The whole development project took merely about one year and a half from start to finish. CPOE was introduced in each one of BWH’s units at a time. Medical services started with CPOE in May 1993, surgical and orthopedic services followed in late 1993. Later on, all inpatient services as well as ambulatory care, emergency care, and intensive care introduced CPOE. Once introduced, CPOE usage was mandatory since it is essential for the patients’ safety not to have orders in more than one place or system at a time. For that reason, all pending orders had to be transcribed into the new CPOE system at the day and the time of the switch between the old and the new ordering process.

- ***Adapting the system for units with different needs:*** Due to the staged introduction of CPOE in the individual units of BWH, it was possible to redesign the system for units that had special needs. For example, the project team had to work with surgical services that required a different kind of design. In particular, CPOE had to be adapted for the surgical intensive care unit since it did not cover the ordering workflow of that particular unit in the best possible way. Suchlike minor adaptations could be made easily and were of utmost importance in order to secure acceptance and satisfaction on the part of the prospective users. To work out this issue, the CPOE project team collaborated closely with the unit's physicians and nurses who served as primary contacts for the redesign of the ordering process and the identification of the information required for decision support.
- ***Providing ongoing support and maintenance:*** After the introduction of the new ordering solution at BWH, ongoing support has been provided by specifically trained nurses. The tasks related to maintenance and further development of CPOE remained in the hands of BWH's Department of Information Systems. The most important challenge in this respect has turned out to be the maintenance of the knowledge bases and dictionaries that underlie the CPOE system and its decision support functionalities. These knowledge bases have to be maintained by professionals that regularly update the information, especially on medications, laboratory tests, and diagnostic studies. These tasks are very complex, time consuming, and require expert knowledge and highly diligent work. For that reason, the medication knowledge base has become a commercial product by now that is maintained by two full-time pharmacists.

4 New Solution

Figure 2 depicts the new ordering process at BWH, i.e. the process as it is after the completion of the transformation project. As described above in conjunction with the initial ordering process, the generic and simplified representation of the process serves well for the purpose of illustration. The activities and the process flow vary slightly depending on the particular class of order.

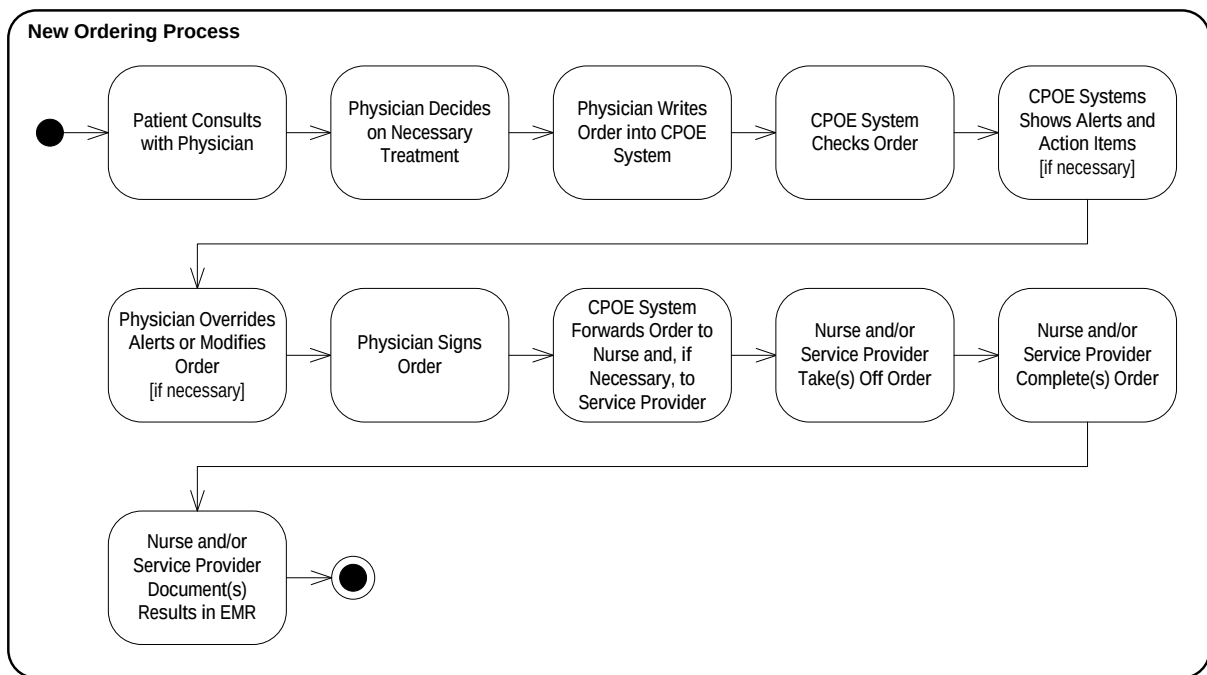


Figure 2: New Ordering Process at BWH (generic, simplified)

The first two activities of the new ordering process are in accordance to the initial ordering process as explained above. The process is initiated by an interaction between a physician and a patient and the consequent physician's decision making about measures or treatments that are indicated for a given patient. In contrast to the initial ordering process, the physician may then proceed and write the resulting orders directly into the CPOE system. Since any BICS workstation may be used for order entry, the physician does not necessarily need to go to the patient's floor, find the correct medical record, and turn to the ordering section. To write an order, physicians simply need to go to the nearest workstation, sign on, and identify the respective patient. After an order has been initiated by selecting a general class of order (e.g. medications, laboratory tests, radiology, electrocardiography, diagnostic studies, general care, respiratory, blood products, hyperalimentations, vital signs/monitoring, or diet), the CPOE system will provide supplemental, non-patient-specific information about that class of order (e.g. standard dosages, frequencies, or general warnings).

Once the order has been written, the CPOE system further checks the order against various patient-specific data elements (e.g. diagnoses, existing medication, known allergies, laboratory results, or other pending orders). To this end, data from the patient's electronic medical record (EMR), which is highly integrated with the CPOE system, is accessed and analyzed. Depending on the general class and the individual type of order, there are certain points in the ordering process where the order is checked against the patient's data. For example, when ordering medication for a given patient, the CPOE system will first, upon entry of the medication name, check for potential allergies and medication interactions.

Subsequently, upon entry of the patient-specific dosage information, the system will check for potential dosing problems. If the CPOE system detects potential problems, it will display a message or, depending of the problem's severity, an alert to the physician.

The CPOE system may present decision-relevant information to the physician in three different ways: as supporting information, as high-level alert, or as low-level alert. Supporting information is intended to enable the physician to make correct choices before encountering a problem, i.e. before an alert is fired. It is shown as a small box on the screen that indicates important information up front. Exemplary data of this type are a patient's current hemoglobin or drug levels. High-level alerts are intended to alert the physician to something of serious concern, e.g. to a patient's allergy to a medication which has been ordered or to a test that has been ordered but is not indicated for a given patient's diagnosis. High-level alerts are displayed as full-sized boxes on the screen. In contrast to the display format of supporting information and low-level alerts, these full-sized displays are so-called modal dialog boxes, i.e. the physician has to deal with the alert before moving on in the ordering process. Finally, low-level alerts are intended to notify the physician about many kinds of things which are informational and could be alerts but usually are not. Low-level drug interactions are a prominent example of this kind of alerts. Although there are thousands upon thousands of those low-level drug interactions listed in the pharmaceutical literature, most of those are unimportant in a given situation. Similar to supporting information, low-level alerts are displayed as small, non-modal dialog boxes. If necessary, low-level alerts can be escalated to the high-level format.

All of those interventions that make for clinical decision support in the context of the ordering process are characterized by four features: The users of the CPOE system are told what they have done that the system is reacting to, they are informed about the level of concern, they are provided with as much information as possible to allow them to make a correct decision based on that particular intervention, and they are given one or multiple action items. These action items allow for cancelling an order, keeping an order as it is, or changing an order to account for the decision support that has been provided.

Finally, after the physician has completed and signed the order, it is forwarded to the responsible hospital unit's nurses and, if necessary, to external service providers. BICS is a highly integrated system that allows for the direct routing of orders to the responsible units. Any pending order is instantly added to the worklists of those in charge of order completion. Nurses and/or service providers then take off those orders and complete it accordingly. Both

the completion of an order and any results arising therefrom are documented in the patient's EMR. Again, as the EMR is part of BICS, the entry of any kind of result data might trigger an alert to inform the physician in charge about changes in the patient's medical condition. These proactive alerts are generated and handled by an event engine – another form of clinical decision support at BWH which is, however, not in the main focus of this case study.⁵

From the very beginning of the CPOE system's introduction and the associated changes in the ordering process at BWH, user satisfaction and acceptance was fairly high. The users of the system, primarily physicians, nurses, and staff of order-processing ancillary areas, were generally understanding what the CPOE system was trying to do and were willing to give it a chance. This general positive attitude was significantly impacted by BWH's open and personal communication, effective problem resolution processes, and top management support.

The most serious concern about CPOE was the feeling that the system was initially slowing down the users when entering orders. This perception may be attributed to the fact that the users at first needed to become familiar with the new ordering process at BWH. Naturally, learning a new procedure incipiently takes more time than doing what one has learnt and intimately assimilated over the past years of one's professional career.

An empirical study on user satisfaction and self-reported usage patterns carried out in the first year after the system's rollout at BWH found that users were generally satisfied with CPOE. Slight but nevertheless significant differences in the overall levels of satisfaction were found to exist between physicians and nurses as well as between hospital units that had been working with CPOE for different amounts of time and therefore had different levels of experience [Lee et al. 1996: 46, 50]. However, neither self-reported prior computer experience nor attendance of CPOE training sessions were found to have significant impact on user satisfaction [Lee et al. 1996: 49-50]. Even though CPOE is considered to represent a "transformational technology" [Lee et al. 1996: 51], overall satisfaction was found to be most

⁵ Process-oriented information logistics is defined as "the embedding of analytic information and/or analysis capabilities into the context of operational processes" [Bucher/Dinter 2008a: 2]. It is aimed at supporting and improving the execution of an organization's operational processes, in particular focusing on non-automated business and support processes that require human interaction and decision making [Bucher/Dinter 2008a: 1-2]. The concept of process-oriented information logistics must therefore be distinguished from other approaches that primarily focus on the monitoring and controlling of process execution and the detection of unusual incidents. These approaches are commonly referred to as "business activity monitoring" or "corporate performance management". Decision support in the context of computerized physician order entry at Brigham and Women's Hospital is an excellent example of process-oriented information logistics as it is aimed at supporting physicians in making correct choices when entering orders. The event engine, by contrast, does not support the execution of an ongoing process but rather triggers a new activity by alerting a physician about unusual patterns it has detected in a patient's data.

strongly correlated with efficiency characteristics such as the system's impact on productivity, its speed, and its ease of use [Lee et al. 1996: 46]. The transformational factors (which are, for example, related to improvements in the quality of care) were found to be less strongly correlated with overall user satisfaction [Lee et al. 1996: 46, 52]. Off-floor ordering from any BICS workstation in the hospital, preset department order sets, and preadmission orders were found to be the system's features with the highest perceived usefulness and, at the same time, the highest self-reported frequency of use [Lee et al. 1996: 49].

5 Summary of Main Findings

At the time of data collection for this case study, the CPOE system has been in place at BWH for almost 15 years. It stands to reason that the application looks dated after such a long period of time. However, it still works well and has remained pretty much unchanged with respect to its basic functionalities ever since its introduction. Major changes and regular updates have been made solely to the knowledge bases and dictionaries that underlie the ordering forms and thus represent the basis for decision support in the context of the ordering process.

Ever since its introduction, CPOE constitutes an integral part of BICS. BICS is the primary clinical information system at BWH, handling the majority of the hospital's computing needs [Teich et al. 1999: 197-198]. The two principles "workflow support" and "clinical decision support" represent, among others, important guidelines for the development of BWH's clinical information systems [Teich et al. 1999: 198]. These two principles, which also stand for the fundamental idea of the process-oriented information logistics concept, have been realized in the design and implementation of CPOE to their fullest extent.

When compared to the initial situation at BWH, the new CPOE solution provides a huge number of advantages – to the hospital with its physicians, nurses, and other staff as well as to the patients [Teich et al. 1993: 99; Teich et al. 1994: 316-317; Teich et al. 1999: 200, 205-206]. Prominent benefits that can be realized due to integrated decision support functionalities in the context of the ordering process are, for example, direct cost savings through interventions that result in behavior modifications on the part of physicians (such as substituting excessively expensive drugs or reducing diagnostic studies and laboratory tests that are not indicated for a given patient), optimized work routines through easy and integrated access to all order-related information and through various shortcuts (such as the usage of default settings, order templates, and order sets) as well as significant improvements

in the quality and safety of medical care through various safety interventions (such as warnings on allergies, drug dosing, application frequencies, and potential medication interactions). CPOE with decision support thus makes a significant contribution to medication error prevention [Bates et al. 1998: 1311; Bates et al. 1999: 313] and is conducive to improving physicians' prescribing practices [Teich et al. 2000: 2741].

In retrospect, CPOE has proven to be the single most successful field of IT application with respect to health care quality improvements at BWH [Teich et al. 1999: 199].

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