DEVELOPING A WEB-BASED MIS SYSTEM FOR OCCUPATIONAL HEALTH

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Abstract: Occupational Healthcare (OH) is about the promotion and maintenance of the physical, mental and social well-being of employees. It aims to protect staff from workplace risks, but also to manage the effect of any health issues on their work. Given the cost of absence through illness to both the organisation and the individual, and given the government legislation that exists in this area, OH is of increasing importance to organisations and many now outsource this service. This paper discusses how a Knowledge Transfer Partnership (KTP) project between a university and an OH provider led to the development of a web-based Management Information System (MIS) for Occupational Health that allows organisations to better manage their OH provision and sickness absences. The system is currently being evaluated in a large public sector organisation and early feedback is positive.

1 INTRODUCTION

Occupational Healthcare (OH) is about the promotion and maintenance of the physical, mental and social well-being of employees. It aims to protect staff from workplace risks, but also to manage the effect of any health issues on their work. OH is of increasing importance to companies. For example, in the UK each week (HSE, 2005):

- one million workers take time off because of sickness and most return to work within days; but
- around 17,000 people reach their sixth week of statutory sick pay; and
- at this point, almost one in five people will stay off sick and eventually leave work.

Work is essential to health, well-being and self-esteem. When ill health causes long-term sickness absence, a downward spiral of depression, social isolation and delayed recovery make returning to work less likely. Reducing long-term sickness absence helps maintain a healthy and productive business and safeguards jobs.

While there is UK and European legislation that makes it the responsibility of companies to ensure the health and safety of their staff, it is also in the companies' best interests to look after the staff's health and well-being. For example, the 2008 Confederation of Business Industry (CBI) report, as cited by Leaker (2008), found the direct cost of absence in 2007 was £13.2 billion, around £517 for each employee and that indirect costs added another £263 for each employee. When these indirect costs are added to the direct costs, the CBI estimates the UK lost £19.9 billion to absence in 2007. In their absence management survey report for 2009, the Chartered Institute of Personnel and Development (CIPD) estimated that the average cost of absence per employee per year was £692 (£784 for public sector employees) (CIPD, 2009) and that 7.4 working days were lost for every member of staff per year (9.7 days for public sector organizations and 9.4 days for non-profit organizations). Given these statistics, it is not surprising that the market for outsourced Occupational Health has grown in recent years. MBD has estimated that the UK market for OH provision grew by 34% in the period between 2003 and 2007 to a value of £394 million (MBD, 2009). In 2007, an estimated 53% of UK occupational health services were outsourced to private companies and MBD forecast that the UK

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market for OH provision will increase by 16% between 2007 and 2012.

One approach to managing sickness absence has been outsourcing to "Day-one" reporting systems, which require employees who are unwell to call a telephone number manned by OH professionals and provide details of what is wrong with them and how long they expect to be off. This enables the employer to manage absence more effectively, for instance, by arranging cover where necessary. The service can also help employers to identify any sickness patterns or recurring health problems with staff. This paper discusses an alternative approach that provides companies with an online information system to help them manage their occupational health requirements. In the next section, we examine issues around the management of Electronic Health Records (EHRs) and in Section 3 present the requirements that have been gathered from client companies and the key design decision for the platform around EHRs and security. The final section briefly provides some feedback obtained from a first installation of the product at a large public sector organisation in the UK.

2 PREVIOUS RESEARCH

A basic challenge of software systems in modern medical informatics is their use of (open) standards for communication allowing different types of clinical applications to interact (Eichelberg *et al*., 2005). Although the initial version of the platform will be closed (ie. there will be no transfer of information into or out of the system from or to another external system), the company were keen that the system would be extensible in the future. There are a number of standards bodies in the medical informatics area. Health Level 7 (HL7) is a not-for-profit organisation, accredited by ANSI as a Standards Developing Organizations (SDO) whose specifications pertain to all aspects of clinical and administrative data in health services. Its current Version 3 defines (XML) messages based on a common object-oriented Reference Information Model (RIM) and a Clinical Document Architecture (CDA) based on XML to specify the encoding, structure and semantics of clinical documents for exchange (Hooda, Dogdu, and Sunderraman, 2004).

The HL7 RIM has the following base classes (HL7, 2009):

- Act: represents actions that have happened, are happening, or are scheduled to happen.
- Entity: represents physical things or beings such as persons, places, or devices.
- Role: represents the role that Entities play as they participate in a healthcare act.
- RoleLink: represents a connection between two Roles.
- Participation: represents the association between a Role and an Act (for example, the context of an Act, such as who performed it, for whom it was performed, or where it was performed).
- ActRelationship: represents the association between two Acts (for example, the relationship between an order for a blood test and the result of a blood test).

Most of these classes have subclasses that further refine the class. For each base class in RIM, the subclasses form a hierarchy rooted in the base class. For example, the class LivingSubject is a subclass of Entity, and the class Person is a subclass of LivingSubject. Part of the RIM is shown in Figure 1.

The CDA specification states that the content of the document consists of a mandatory textual part (which ensures the contents are in a human readable format) and optional structured parts (for software processing). Different CDA levels allow for different levels of granularity of presented clinical information. At the simplest, level, Level One, a document is represented through a structured header and a body; at Level Two, sections of clinical processes and activities have been separated by markups; and Level Three finally provides basic medical concepts using codification schemes such as SNOMED (Systematized Nomenclature of Medicine) and LOINC (Logical Observation Identifiers Names and Codes) to represent concepts. CDA documents are validated against the XML schema for that level (Blobel, Engel, and Pharow, 2006).

Unlike other standards, HL7 CDA does not specify services or protocols that are used to exchange a document. From the perspective of HL7 messages, a CDA document is just a multimedia object than can be exchanged as a MIME package.

*open*EHR (www.openehr.org) is an open standards specification that describes the management and storage, retrieval and exchange of health data in Electronic Health Records (EHRs). The primary focus of *open*EHR is not the exchange of data between EHR-systems; this is the primary focus of message standards such as HL7 and ISO13606 (discussed shortly). *open*EHR has produced a number of specifications that focus on both the content/structure of EHRs and the underlying technology. *open*EHR uses a two-level model for EHRs: the first level, the *reference model*, provides a general framework in which any clinical

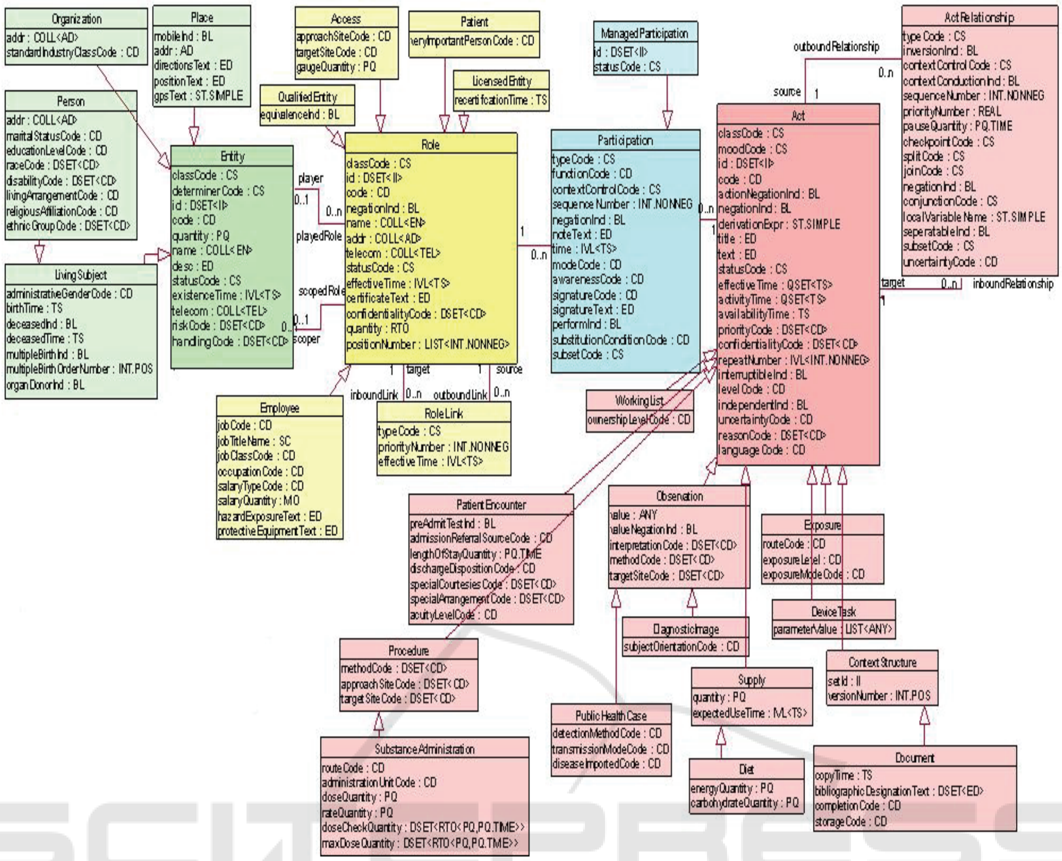

Figure 1: HL7 Reference Information Model.

information can be safely stored and exchanged; the second level, provides rules for how specific clinical concepts are to be used in the health record. These rules (or *archetypes*) represent the clinicians' agreed requirements for data sharing. The reference model specifies the overall structure of the EHR, how contextual information is recorded, how clinical information is organized and safely managed (Bott, 2004). Each EHR consists of a number of *compositions*, which are used to capture information around an event, such as a lab test result or a GP appointment. The EHR can also organize these compositions into a set of optional folders, typically used to group events around an episode of care

Electronic Health Record Communication (EHRCom) European Standard (EN 13606) is another EHR specification from the technical committee on Health Informatics of the European Committee for Standardization (CEN/TC 251). EHRCom is based on the older pre-standard (ENV 13606) and many concepts have been adopted from *open*EHR. The standard defines an architecture for communicating part or all of the EHRs of a single patient, making sure that (a) the original clinical meaning intended by the author of the record is preserved and (b) the confidentiality of the data as intended by the author and the patient is not breached (Begoyan, 2008). It does not specify the internal structure or database design/schema of the EHR. EHRCom consists of:

- The Reference Model – a generic model for communicating part of an EHR between heterogeneous systems;
- Archetype Interchange Specification – constraint-based approach for defining clinical *business objects* that are built from the Reference Model (adopted from *open*EHR);
- Reference Archetypes and Term Lists – an initial set of inter-reference model conversion archetypes (mapping to *open*EHR and to the HL7 V3);

  Security Features – measures and models to share the access control, consent and auditability of EHR communications;
- Interface Specification – message and service interfaces to enable EHR and archetype communication.

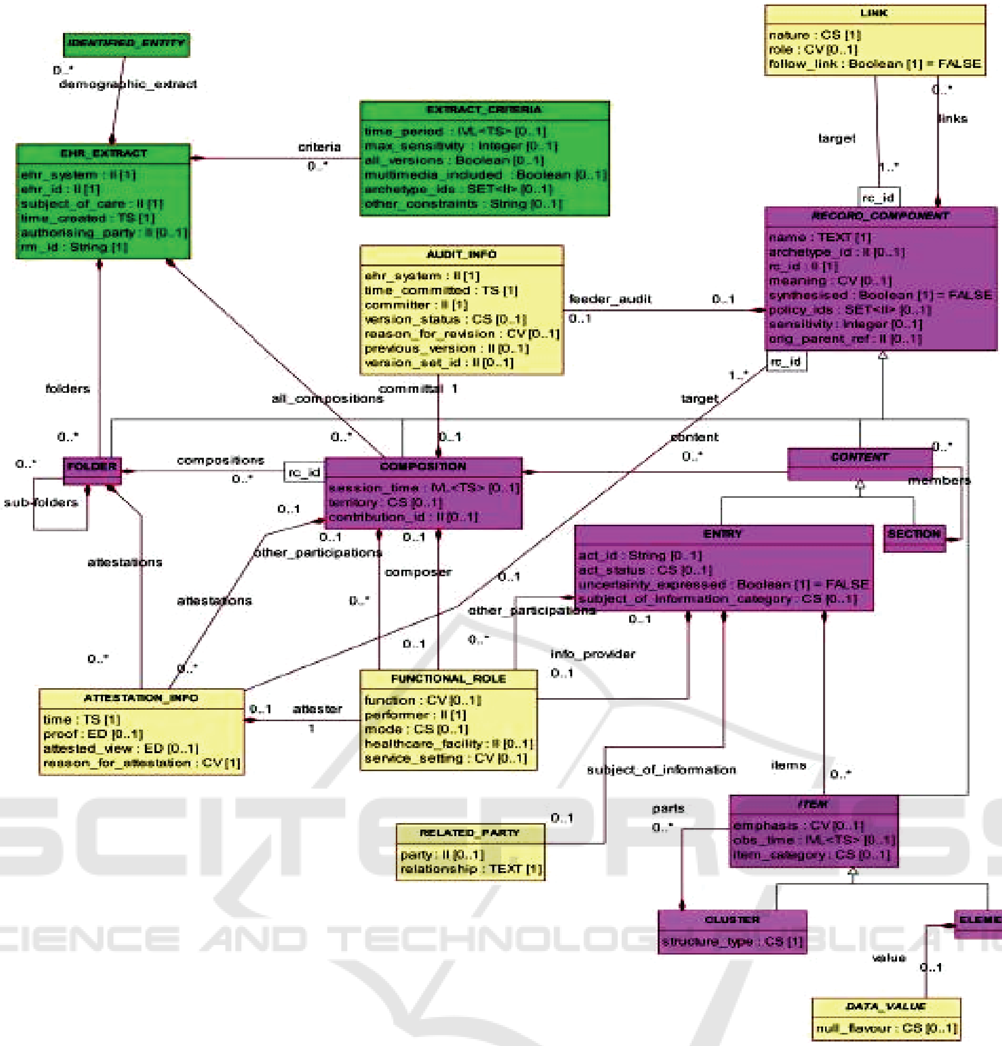

Figure 2: EN13606 Reference Model.

The EHR Reference Model defines the core classes shown in Table 1, which closely align with those in the *open*EHR Reference Model, and the corresponding class diagram is shown in Figure 2.

As there is more than one standard, it is still difficult to achieve interoperability. To address this document sharing problem, an industry initiative called Integrating the Healthcare Enterprise (IHE) specified the Cross Enterprise Document Sharing (XDS) Profile. The basic idea of IHE XDS is to store healthcare documents in an ebXML registry/ repository architecture to facilitate their sharing. IHE XDS is not concerned with document content; it only specifies metadata to facilitate the discovery of documents (IHE, 2009).

3 STERLING HEALTHCARE AND STERLINGCONNECT

Sterling HealthCare is a Scottish SME that provides an extensive range of Occupational Health, physiotherapy and training services to match each client's requirements. Highly qualified OH medical staff advise on a range of medical issues including legislation compliance, monitoring employee health through workplace audits and health "surveillance", and promoting good health at work. Sterling HealthCare has 12.5% of the market in Scotland and their physiotherapy division, Physicare, trade with the majority of Local Authorities in Scotland. The physiotherapy division also provides throughout the UK clinics, moving and handling training and assessment services to other public and private

Table 1: EHR Reference Model.

EHR Hierarchy component	Description	Examples
EHR_Extract	Top-level container of part or all of the EHR of a single subject of care, for communication between a Provider and a Recipient.	
Folder	High level organisation within an EHR, with divisions related to care provided for a single condition, by a clinical team or institution, or over a fixed time period such as an episode of care.	Diabetes care; Gartnavel Hospital, GP Folder.
Composition	Set of information committed to one EHR by one agent, as a result of a single clinical encounter or record documentation session.	Progress note; laboratory test results form; referral letter; clinic visit;
Section	EHR data within a Composition that belongs under one clinical heading, usually reflecting flow of information gathering during a clinical encounter, or structured for the benefit of future human readership.	Past history; family history; allergy information.
Entry	Information recorded in an EHR as a result of, for example, one clinical action, one observation, one clinical interpretation.	A symptom; one test result; a diagnosis; blood pressure measurement.
Cluster	Means of organising nested multi-part data structures such as time series, and to represent the columns of a table.	Audiogram results.
Element	The leaf node of the EHR hierarchy, containing a single data value.	Systolic blood pressure; heart rate; drug name.

sector clients.

The company identified an opportunity to expand its business activities but was restricted by the limitations of the manual systems they currently had in place. The development of a bespoke web delivery platform (SterlingConnect) would allow Sterling HealthCare's clients to manage employee absences, make OH referrals, and generally have access to statistical information on OH data. The platform would also allow Sterling HealthCare staff to access and process information from any location, thereby significantly reducing the level of administrative staff input.

However, the company did not have the technical knowledge to develop the system and approached a local university to help. With funding from the UK Technology Strategy Board through KTP (Knowledge Transfer Partnership), the company and the university have collaborated to develop the system. KTP is one of Europe's leading programmes combining graduate recruitment with knowledge exchange. Its benefits are proven across a range of measures, whether company development and profitability, knowledge exchange between universities and business, or job creation. During the 2007/08 financial year, almost £95 million was committed by the UK Government to new KTP Partnerships in the form of grant support and company contributions. At the year-end the portfolio comprised over 1,000 individual projects, facilitating the exchange of knowledge between the UK knowledge base and companies across the spectrum of size and business sector. Latest information shows that, on average, the business benefits that can be expected from a single KTP project are (TSB, 2008):

- an increase of over £222,000 in annual profits before tax;
- creation of three new jobs;
- an increase in the skills of existing staff.

A Partnership works by employing one or more high calibre 'Associates' (recent graduates), to transfer the knowledge the company is seeking into the business. Each Associate works in the company on a project that is core to the strategic direction of the business. Through contact with businesses, the knowledge base partner (academic institution) gains relevant and improved understanding of the challenges companies encounter which, in turn, stimulates business-relevant teaching material and new research themes. KTPs are an important funding mechanism in the UK and have direct benefits to both industry and academia, as shown in Table 2.

3.1 Participatory Design

While Sterling HealthCare had extensive knowledge of the OH market and their clients and staff, it was critical that all stakeholders who would use the system should have input into the specification of the system requirements. Moreover, it was important for both the company and clients that there was early sight of the platform being developed to ensure it met the desired requirements. As a result, it was decided at a very early stage in the project that the development of the platform would be underpinned by Participatory Design principles with users and other stakeholders playing a prominent role in all the stages relating to design, development and evaluation. The benefits of Participative Design are that it can provide better project control, better communication, more satisfied users and participants, lessens the need for costly corrective action post implementation and can provide more innovative and creative solutions than might have otherwise been possible (Kensing and Blomberg,

Table 2: Benefits of industry/academia collaboration through KTP (adapted from Edwards, 2005).

Benefits	Industry	Academia
Knowledge Transfer	Acquire new knowledge and expertise	Better understanding of industrial requirements and business imperatives
Enhanced performance	Increased profitability through new products, services and processes	Up-to-date research and teaching materials and more relevant curriculum
Essential resource	Use of high calibre personnel	Increased staff
Additional finances	Subsidised funding (67% for SMEs)	Supplements core funding
Dissemination	Publicity and promotion	Learned publications
Additional opportunities	Access to wider university facilities and potential for an on-going relationship	Student placements/projects; potential for on-going relationship; pump-prime new research themes

1998; Cherry and Macredie, 1999).

The requirements led to the identification of the following main subsystems: Client, Patient and Appointments subsystem; Referral subsystem; Occupational Health Reports subsystem; Human Resources subsystem; security subsystem; Electronic Health Records subsystem. The main functionality revolves around authorised personnel (eg. line managers and HR staff) being able to refer their staff for an OH service.

A number of different types of referrals were to be supported including:

- Absence Management
- Pre-Employment Screening
- HAVS (Hand Arm Vibration Screening):
- Audiometric Testing
- Respiratory
- Musculoskeletal
- Vehicle-related (LGV; PCV; Fork Lift Driver; Taxi Driver)
- Working at Heights
- Working with Lead/Asbestos.

The system maintains information on the availability of OH professionals and OH clinics and schedules an appointment for the referred employee with a suitable OH professional at an appropriate clinic (which may be within the organisation's premises or external to the organisation). The system generates an email/appointment letter for the employee. Following the consultation, the system may schedule another appointment if the OH professional requests it. The system generates a letter for the employee providing a report from the consultation, as prepared by the OH professional. OH reports are available online for line managers/HR to view. In addition, managers/HR are able to view all current and historical reports/health surveillance results on each employee, view statistical data regarding departmental utilisation of OH services, view OH service adherence to performance targets, among other data. The system will provide reminders when some action is due (eg. an employee is due for an annual health check). Moreover, in the UK it is a legal duty of employers to report certain injuries/illnesses under RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations) (HSE, 2008) and the system provides advice to line managers/HR when this occurs.

3.2 Electronic Health Records (EHR)

The storage and retrieval of EHRs was a key component of the system and an appropriate EHR standard had to be selected. There is some harmonisation between the EHR standards we examined in Section 2 (for example, the *open*EHR Reference Model uses the CEN 13606 Reference Model, which in turn is used in HL7 CDA) and further harmonisation is likely. As a result, it was decided to model the health records after EN 13606 and, when communication with external systems is eventually required, to use HL7 V3 Messaging

3.3 Security

Clearly given the sensitivity of the data being stored, security was of paramount importance in the design of the system. Again, many of the standards discussed in the previous section address security to some degree. The *open*EHR approach to security is based on the following two premises as proposed by the British Medical Association (Anderson, 1996):

- Informed consent: patients have a right to expect that personal information will not be passed on to another party unless they agree.
- Relevance of access: people should only have access to the patient's health record if it can be established that they are currently engaged in provision of care for the patient, at the current time.

In particular, privacy settings can be set on selected parts of the EHR, not just the whole entity. There are a number of policy principles in *open*EHR such as

(Beale and Heard, 2008):

- *Indelibility*: Health record information cannot be deleted; logical deletion is achieved by marking the data in such a way as to make it appear deleted.
- *Audit trailing*: All changes made to the EHR including content objects as well as the EHR status and access control objects are audit-trailed with user identity, timestamp, reason, optionally digital signature and relevant version information.
- *Anonymity*: The content of the EHR is separated from demographic information so that theft of the EHR provides no direct information on the identity of the patient.
- *Access control lists*: access should be both relevant and time-limited (ie. during the current period of care and possibly for some period afterwards). An access control list can be defined for the EHR indicating both identified individuals and categories of users, possibly using role types or particular staff groups. A *gate-keeper* should control access to the EHR access control settings. All changes to the list are audit-trailed as for normal data.
- *Privacy*: patients can mark parts (compositions) in the EHR as having one of a number of levels of privacy.

Other security policy principles not directly specified by *open*EHR but which should be included in an EHR deployment are:

- *Access Logging*: Read accesses to EHR data should be logged.
- *Non-repudiation*: Allow digital signing of changes to the record. Communications (EHR Extracts) can also be digitally signed.
- *Certification*: a mechanism should be provided to allow a level of trust to be formally associated with user signing keys.

The requirements around security, privacy, confidentiality and accountability in HL7 are extensive and include (Kratz, n.d.):

- Authentication: use of Digital Signatures.
- Authorization/Access Control: use of Digital Signature, Access Control Lists.
- Integrity: use of Encryption, Digital Signatures, Check Values.
- Confidentiality: use of Encryption, Key Escrow.
- Accountability: use of Audit Trails, Logs, and Receipts.
- Non-repudiation: use of Encryption, Digital Signatures.

Much of what *open*EHR and HL7 specify are relevant to our system. For our (session-oriented) application we have used SSL, SPKM, HTTP-S and Digital Certificates. Each user has a specified username/password and has access to a limited set of data (eg. line managers can only access data for staff they manage) and employees can restrict what parts of an EHR line managers have access to. Every record access is controlled through an access control list and all access (including reading data) is recorded in an audit log. No record is ever deleted and all time-based information is maintained so that accurate records are always available. For example, if a medical report is prepared for an employee called Ann Smith who subsequently marries and changes her name to Ann Jones, at some time in the future when the medical report is viewed again, the original name will be shown.

3.4 Implementation

The system has been implemented in Microsoft ASP.NET 3.5 and a centralized SQL Server 2008 database. The system is fully database driven and to allow different clients to use different terminologies all labels, identifiers, text and messages are taken from the database. Similarly, all questions (eg. pre-employment questions) are taken from the database so that each client can modify the questions that are asked. In effect, each web page is fully generated dynamically at runtime. Reports are generated in Crystal Reports. For illustration, a screen shots from the Referral subsystem is provided in Figure 3.
Availability and reliability were key considerations and an external hosting company was selected that could satisfy the availability and reliability requirements and provide an appropriate Service Level Agreement.

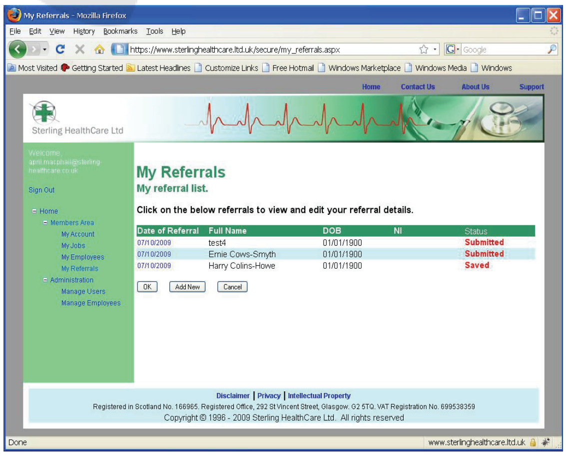

Figure 3: Status of Referrals for Line Manager.

4 CONCLUSIONS

This paper has discussed the development of a web-based Occupational Health system and, in particular, examining the choice of standard for storing Electronic Health Records (EHRs). The first version of the system has been fully tested by one of the large Councils within Scotland with over 1,000 staff and has been well received by all users. We attributed the positive feedback to the use of a Participatory Design methodology as outlined at the start of Section 3. The main comments were around the administration options and reports, which were quite limited in this first version. For example, HR wanted to be able to modify line management arrangements (for example, an existing line manager may leave the organisation and the staff have to be assigned to a new line manager). In addition, the organisation would like to be able to customise the form data (eg. static text for labels, questions in a pre-employment questionnaire) stored in the database (at present, this is carried out by Sterling HealthCare technical staff prior to installation). Encouragingly, there have been very little comments on the main functionality and no major bugs have been detected. A second version of the system has been provided with extended reporting and the system is now in full use at the Council. It is anticipated that the system will be rolled out to other Councils in the UK during the first half of 2010.

The next phase is to complete the full implementation and add enhanced administration functions. Thereafter, an iPhone service will be added to allow OH professionals to dictate their findings following a consultation and for the dictation to be stored within the employee's EHR in the database.

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