On the design of an electronic health patient registration system for South Africa

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Abstract

ICT investments in South Africa's public healthcare have not resulted in the efficiencies envisaged as health information systems lacks interoperability. The approval of the eHealth strategy in 2012, introduces a roadmap for hospital information systems interoperability, thus, increase return on investment in ICT spending and improve the collection and quality of health data. *EHealth Foundations* priority area is one of 10 strategic priorities defined in the eHealth strategy and requires a central patient register for health information systems. This paper describes the requirements and challenges the project team considered in designing the electronic health patient registration system.

Keywords

Information systems, eHealth, Health patient register, Public health.

Introduction

Investments into the public health sectors information communication and technology (ICT) and health information systems (HIS) have not materialise in the expected high investment returns that were anticipated. ICT and HIS within the public health system have not, up to now, adequately supported business processes resulting in the inability to effectively monitor and evaluate the performance of the South African national health system. One of the identified problems is the lack of technology policy frameworks and regulations to support ICT procurement and management processes (Kirigia, Sambo, Nganda, Mwabu, Chatora, & Mwase, 2005; South African National Department of Health, 2010).

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According to the Minister of Health, the eHealth Strategy for South Africa is a roadmap to guide the public health sector from the current situation to a well-functioning health information system (South African National Department of Health, 2012). The eHealth Strategy adopts the World Health Organization definition for eHealth, that is the use of information and communication technologies for health to, for example, treat patients, conducting research, educating the health workforce, tracking diseases and monitoring public health(World Health Organisation, 2015).

The eHealth Strategy defines 10 strategic priorities as summarised in Figure 1.

Figure 1: Priority areas for the delivery on the eHealth Strategy (adapted from the South African National Department of Health (2012)

The focus of the eHealth Foundations strategic area highlighted in the Figure 1 is to build capability for eHealth and all future eHealth activities. The key areas of the eHealth Foundations strategic area as defined in the eHealth Strategy are (South African National Department of Health, 2012):

- Infrastructure;
- Connectivity;
- Registration of patients, facilities and providers; and a
- Basic national electronic health record.

The artifact outlined in this paper relates to the *registration of patients* as identified in the eHealth Foundations strategic priority area of the South African National Department of Health (2012). This paper reflects on a proposed design of an electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa.

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The paper is structured as follows: Section 2 describes the research methodology followed by a literature overview in Section 3 and description of the relevance of the work in Section 4. The proposed electronic Health Patient Registration System is described in Section 5. Section 6 concludes the paper.

Methodology

Design science research is an appropriate methodology as it facilitates the creation of artefacts usually for practical purposes. March and Smith (1995) differentiate among four different types of artefacts: concepts, models, methods and instantiations. Two important characteristics of design science artefacts are relevance and novelty (Hevner, March, Park, & Ram, 2004). An artefact must solve an important problem and, to differentiate design science research from routine design, Hevner et al. (2004) suggest that design science research should address either an unsolved problem in a unique and innovative way or a solved problem in a more effective or efficient way. The research articulated in this paper falls into what Gregor and Hevner (2013) describe as the exaptation quadrant. The result of which is to extend known solutions to new problems as a research opportunity and knowledge contribution.

Hevner et al. (2004) were the first authors to provide an Information Systems (IS) framework that was later further refined by Pirenen (2009) as well as Wang and Wang (2010). Both Hevner et al. (2004) and Pirenen (2009) stressed the relevance and rigor of design science research in IS that corresponds to the same need in conceptualisation of a proposed design of an Electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa.

The IS research framework suggested in Hevner et al. (2004) argues a focus on three inherent research cycles: relevance, rigor and design with creativity and how each of these contributes to the knowledge base of foundations and methodologies. In the framework people, organization and technology are three components of the environment of design research. Business needs are the driving force for design research so that design research can be relevant. Hevner et al. (2004) further proposed seven guidelines for design research. These are design as an artefact, problem relevance, design evaluation, research contributions, research rigor, design as a search process and communication of research.

Design science research can therefore be viewed as being inherently a problem solving process which involves the representation and presentation of a design related problem or issue and the subsequent generation and evaluation of a design-based solution that is aligned with the proposed research (Hevner, 2007). Each of the cycles outlined by Hevner et al. (2004) and Pirenen (2009) are related to the conceptualisation of a proposed design of an electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa as described below.

1. *Rigor cycle:* The research rigor is grounded in relevant research literature. The literature study aimed to, through the investigation of relevant literature; develop an understanding to ground the exploration of a proposed design of

an Electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa. The relevant literature reviews that pertain to this paper are outlined in the literature overview in Section 3.

2. *Relevance cycle:* The application domain initiates the Design Research through research requirements and criteria for the conceptualisation of the proposed design of an Electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa. The relevance of this study is described in Section 4.
3. *Design cycle:* The design cycle will be facilitated through the design, construction and refinement of the proposed Electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa as artefact through peer reviewed domain applications and implementation in 50 purposefully chosen locations. This paper however does not extend to the results from pilot implementation iterations but documents the conceptual design based on the relevance and rigor cycle.

Considerations and challenges for a patient registration system implementation

Implementing an electronic system for the registration of patients at healthcare facilities across South Africa will not be completed without challenges and obstacles. Most South African healthcare facilities do not have adequate infrastructure and Internet-connectivity. Adequate infrastructure and Internet connectivity is considered an important objective in delivering on the eHealth strategy. These lie within the mandate of the *Infrastructure and Connectivity* key initiatives of the eHealth Foundations strategic area. This mandate extends to include the procurement and installation of adequate infrastructure at health facilities (e.g. computers, printers, uninterrupted power supplies as well network infrastructure equipment) and the implementation of Internet respectively (South African National Department of Health, 2012).

In many cases health facilities are located in rural areas far from cities and when facilities do require the expertise of technicians to fix Internet related problems onsite, it could take days to resolve issues as rural facilities are located far from cities and in sometimes difficult to reach mountainous areas. In addition, depending on the contract agreement with the service provider, data bundle limitations (e.g. 1GB per facility per month) could also cause problems for any electronic system dependent and requiring access to a central server via the Internet.

Cresswell and Sheikh (2009) summarised the literature relating to factors that result in the successful implementation and adoption of electronic health record systems across the world.

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Figure 2. Factors important for the successful implementation of an electronic health record system. Adapted from Cresswell and Sheikh (2009).

They identified the following factors for the successful implementation of an electronic health record system (Figure 2) as having four dimensions. These dimensions are technical, social or human, organisational and a wider macro environmental dimension. These dimensions can further be deconstructed as outlined below.

- Technical dimension
    - Usability,
    - Performance and integration
    - Adaptability and flexibility
- Social/Human dimension
    - Attitudes,
    - Motivations,
    - Resistance and expectations,
    - Engagement and user input in design,
    - Training and support,
    - Champions,
    - Integration with existing work processes,
- Organisation dimension
    - Getting the organization ready for change,
    - Planning,

    - Leadership and management,
    - Teamwork and communication,
    - Learning and evaluation,
    - Realistic expectations.
- Wider macro-environmental dimension.

Milenković, Jovanović-Milenković, Vujin, Aleksić, and Radojičić (2012) reflecting on an electronic healthcare system implementation in Serbia identified the following dimensions that essentially align with the factors from Creswell and Sheikh (2009).

- Technical issues (uncertain quality, functionality, usage, lack of integration with other applications);
- Financial issues (initial costs of hardware and software, maintenance, upgrades, replacement, investment reimbursement);
- Resource issues;
- Training and retraining;
- Resistance from potential users due to the changes in working practice; and
- Certification, security, ethics, privacy, and confidentiality.

Milenković et al. (2012) furthermore highlight additional technical, ethical and integration issues but does not introduce a new dimension. The specific minutia, however, are worth the consideration.

Within the South African context, the design and implementation of any patient registration system ought to also consider the following policies and regulations affecting eHealth as outlined in the eHealth Strategy (2012) as well as relevant industry standards. The relevant policies, regulations and industry standards implications and detail discussion is beyond the scope of this paper but are listed below for further reference (South African National Department of Health, 2012).

- State Information Technology Agency Act 88 of 1998,
- The Minimum Information Interoperability Standards (MIOS),
- Promotion of Access to Information Act, Act 2 of 2000,
- The Minimum Information Security Standard (MISS),
- The National Archives and Record Service of South Africa Act, Act 43 of 1996,
- The Policy of Free and Open Source Software Use for South African Government,
- The National Health Normative Standards Framework for Interoperability in eHealth in South Africa.

Relevance

Hevner et al. (2004, p. 89) infers that the relevance cycle affords “an application context that not only provides requirements for the research but also defines acceptance criteria for the ultimate evaluation of the research results.” The following section then aims to provide the requirements and criteria for the proposed Electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa.

The requirements and conceptualising of a proposed electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa was initiated in a joint application design sessions that formed the project team and included members of the CSIR, National Department of Health, StatsSA, and the National Department of Home Affairs. Daily operations and business processes at clinics were discussed and included into the requirements for a proposed health patient registration system. The resulting requirements were confirmed and refined through a site visit to two purposefully chosen clinics in Gauteng and the Eastern Cape respectively.

The refinement extended to include administrative processes as well as the information required from patients upon visiting facilities. The following noteworthy observations were made.

- During the visits to the clinics it became evident that at one, staff members were more inclined to request patients to provide proof of identification when visiting the facility, whereas at the other, patients were normally not required to produce proof of identification. Staff members at the latter explained that the clinic is community based and as they do not get many patients from outside, proof of identification is not strictly enacted as patients are known to them. The project team recognised that in order to have reliable verified patient identification information in the patient registration system database, business processes need to include requesting proof of identification for patients.
- Clerks are responsible for recording a patient’s personal details (name, surname, and date of birth/age) every time a patient visits a facility. In most clinics visited by the project team, patient details are written on pieces of paper and/or tick registers with one exception where Clerks were using MS Excel. These methods of capturing a patient’s details are time consuming and inefficient as a patient’s information is requested and recaptured every time the patient visits a facility, thus, increasing the time patients must wait.
- The number of patients visiting a facility are counted daily by Clerks and forwarded to Data Capturers who is responsible for communicating weekly/monthly totals to the relevant sub-district office. Sub-district offices in turn are responsible for aggregating totals for all clinics within its sub-district and reporting aggregated totals to the relevant district office. District offices in turn are responsible for verifying and aggregating totals received from their

respective sub-districts and informing provincial management of the total number of patients that visited their respective districts. District totals are verified by provincial staff prior to making it available to provincial management to facilitate decision making. Thus, delays in the information aggregation chain could negatively affect decision making and delay mechanisms introduce mechanisms to immediately respond to issues affecting clinics. The process of aggregating information from clinic to making information available to provincial management could take up 45 days without any major interruptions in the chain.

From the field visits it became clear that the system would have to be designed in such a way as not to negatively affect the waiting time if the Internet line at a clinic is slow, unavailable or should the central server be unavailable. Thus, in as far as possible, the system should run locally at a facility and when information is required to be retrieved or uploaded to the central patient register make use of the Internet. The advantage of such a design could also minimise the amount of data that must be download via an Internet line, thus minimising Internet data usage.

Functional requirements

Several joint application design sessions resulted in an extensive list of requirements for a proposed patient registration system. The project team prioritized the list of requirements that should be built in the short term and requirements to be delayed future iterations. The prioritisation process included the validation and verification (East, Kirby, & Liu, 2008) of requirements before requirements was accepted and signed by the National Department of Health. The high level functional requirements are summarised in Figure 3.

Users of the health patient registration system could be assigned any of the roles defined in the system. The roles are:

System administrator – system administrators are responsible for creating Facility Managers at a provincial level.

Facility manager – facility managers could have one or more clinics assigned within a certain district or sub-district. Generally, provincial Facility Managers manage district facility managers, who in turn are responsible for managing facility managers within their respective sub-districts. Sub-district Facility Managers in turn are responsible for managing facility managers responsible for individual clinics. The main function of a Facility Manager is to manage users for a clinic. That is, the person Clerks at clinics refer to for issues relating to the patient registration system.

Facility administrative clerk – the administrative clerk at the facility is central to the patient registration system as he/she is responsible for capturing patient information and recording patient visits in the electronic patient registration system.

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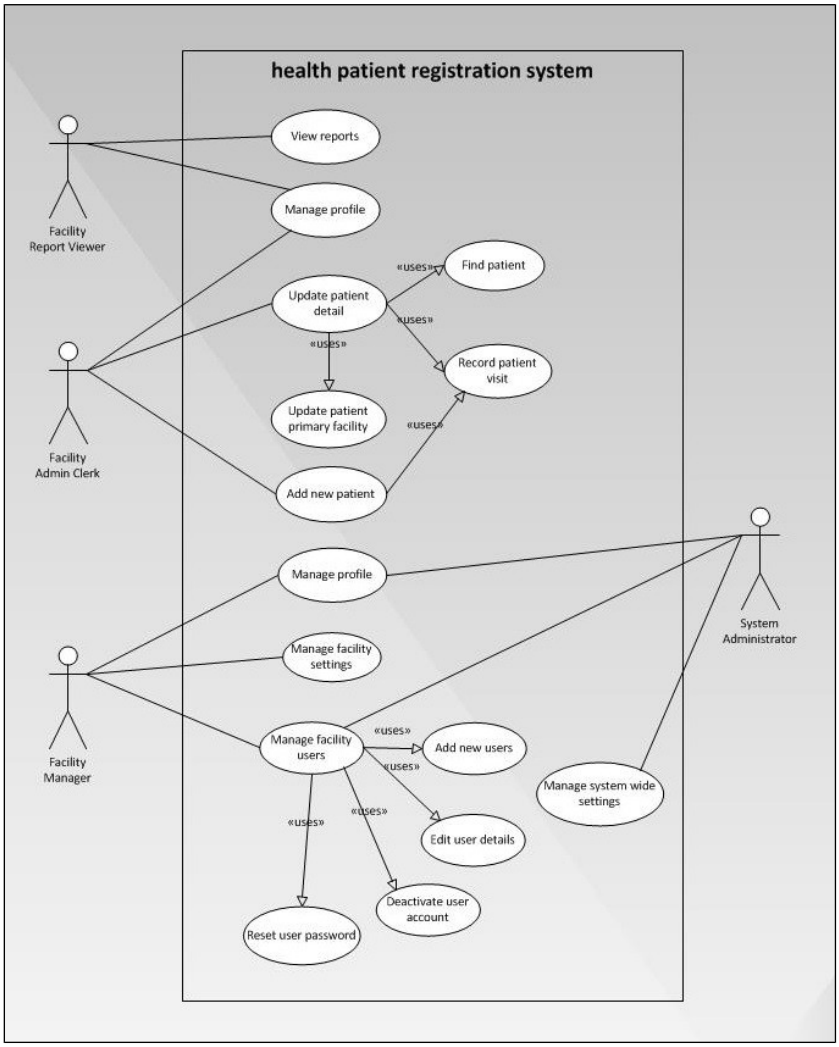

Figure 3. Use Case for the health patient registration system functional requirements.

Facility report viewer – users with rights to view reports can view reports for clinics they have been assigned. For example, users at the National Department of Health, with rights to all facilities across South Africa can request reports for any clinic(s). Provincial users can only request reports for clinics within their respective provinces, likewise a facility manager at a clinic can only request reports for their clinic.

The requirements for the patient registration system include user authentication by unique username and password. Successful user authentication creates a session between the user and the central (or local facility application) server and time out after 20 minutes of inactivity. More detail into the high level requirements as summarised in Figure 3 are provided below:

- *Manage profile*: users are provided the functionality to edit their email address, contact telephone numbers as well as update their passwords.
- *View reports*: the patient registration system provides users with permission to

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view reports only for clinics they are assigned. Reports indicate over a selected period of time the number of patients visiting facilities, the patients that visited which clinics, the percentage of patients visiting clinics in and outside their catchment areas as well reports indicating the number of registered patients at clinics.

- *Find patient*: a search may be commenced by providing a patient's partial surname and first name. The search could include only patients that have prior visited the clinic or that is within the facility catchment area. Alternatively, the clerk could also request the system to perform a national search for the patient. The national patient search retrieve matching patient criteria from the national patient register, that is all patient across South Africa matching the search criteria.
- *Update patient detail*: once a patient's detail was successfully retrieved from the patient register and the patient's identity is confirmed may the clerk update the patient's details.
- *Update patient primary facility*: the primary facility of a patient whose identity is confirmed may be updated only to the facility the patient is visiting. That is, clerk are not permitted to update the primary facility to a facility other than the current facility
- *Record patient visit*: patients are requested clerks as to the reason for their visit to the clinic. The patient's reason for visit is selected from a predefined list of "reasons". Users also have the ability to indicate when the patient's visit occurred.
- *Manage facility settings*: facility managers have the functionality to define computers as patient registration system resources.
- *Manage facility users*: authenticated users may add, edit, or deactivate user accounts as well as reset the passwords of users for clinics they are assigned.
- *Manage system wide settings*: system administrators have the functionality to manage information lists (e.g. the list of reasons patients could visit a facility) as it appears in the patient registration system.

Design

The design of the patient registration system architecture considered 6 main technological and business areas that would result in an effective solution:

- Possible intermittent and/or slow Internet responses at clinics;
- Promptly available aggregated patient information to provincial and national management;
- Minimal cost to maintain system version at clinics,

- Implementation of Open Source technologies as far as possible to minimise licensing cost,
- The patient registration system must be able to respond instantaneously to requests from approximately 10,000 users from over 4,000 clinics across South Africa.
- Security and privacy requirements.

The patient registration system architecture consists of multi-tiered client-server architecture – (i) client tier, (ii) presentation tier, (iii) business tier, and a (iv) data tier (Johan van Zyl, 2015). Figure 4 outlines the physical implementation model for the patient registration system solution.

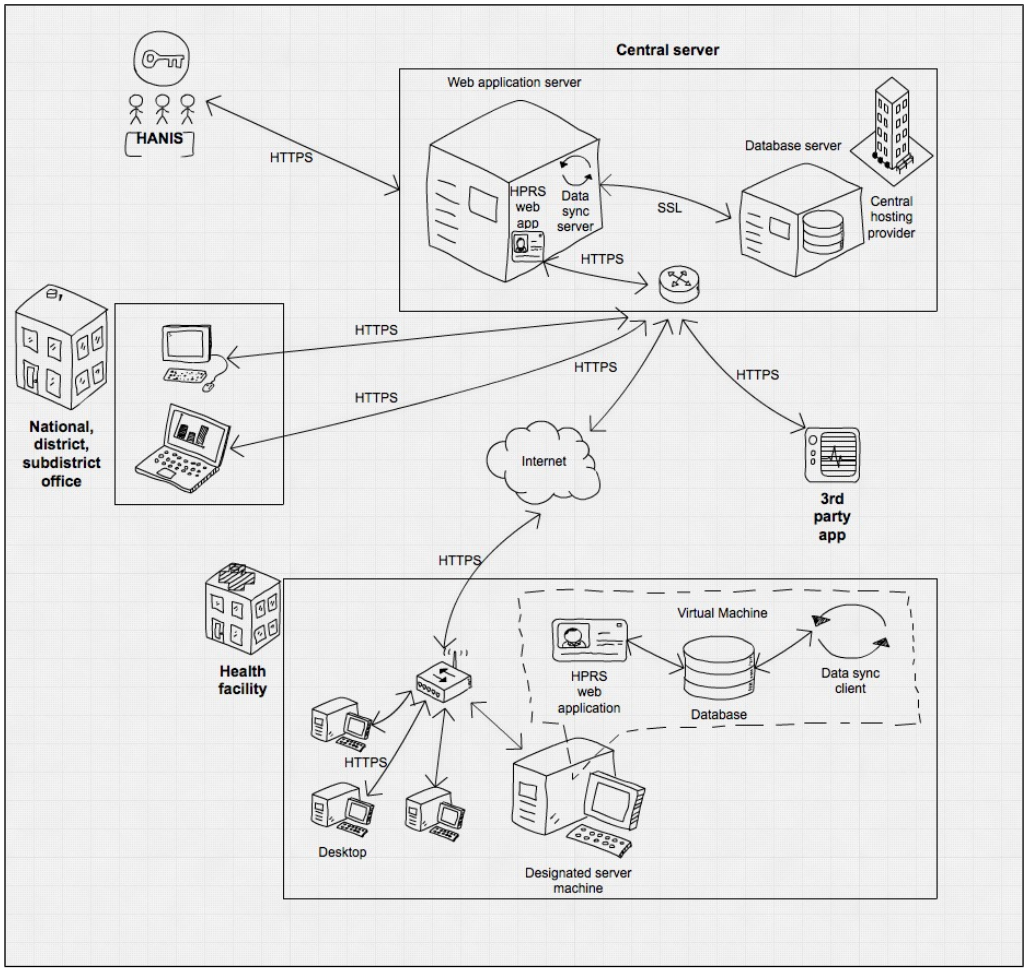

Figure 4. The physical model for the health patient registration system. Adapted from "Architecture Blueprint for the Health Patient Registration System" by (Van Zyl, 2014)

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The patient registration system consists of the following main implementation environments:

- Central server;
- Health facility implementation;
- National, district, and sub-district management offices;
- Home Affairs National Identification System (HANIS); and
- Third-party application.

Central server environment

The central server environment is the core component of the patient registration system and consists of the web application server and the database server respectively.

The web application server contains the web application and the data synchronisation server. The web application is responsible for responding to HTTPS requests from external sources, for example a request from a Clerk at a clinic to search for a patient's demographic information. The synchronisation server listens for incoming requests from synchronisation clients residing at health facilities. Synchronisation requests are requests from health facilities to synchronise data with the central server. These requests are communicated to the central database server.

The database server consist of a relational database using open source PostgreSQL version 9.3 and is responsible for centrally storing patient demographic information for health facilities across South Africa. It is also responsible for handling requests from the web application server via secure protocols.

Health facility implementation

The health facility implementation environment includes the (i) desktop computers, (ii) facility LAN router, and the (iii) designated server machine at health facilities.

Desktop computers are any windows compatible computer at the health facility that is connected to the local network via the facility router. The patient registration system is mainly accessed from desktop computers located in the reception areas of health facilities. In addition, desktop computers in the reception areas of pilot health facilities have a barcode or driver's license scanner as well as a finger print reader connected. The barcode scanners assist Clerks to scan the barcode on a patient's identification documentation. Alternatively, if patients provide their South African driver's license card, the Clerk use the driver's license scanner to scan the PDF417 code containing the patient's identification number. The fingerprint reader is used to scan the patient's fingerprint is displayed on the patient registration system upon a successful scan. The patient's fingerprint image and South African identification number will be sent to the South African Home Affairs National Information System (HANIS) for identity verification. The HANIS environment is discussed in more detail

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in the section covering the HANIS component.

The *facility router* is the gateway to designated server machines and the Internet for health facility computers. Thus, if the facility router is unavailable or faulty, computers in the facility would be unable to access the patient registration system on the designated server machine.

The *facility designated server machine* acts as the “local” server hosting a virtual machine consisting of the patient registration system web application, database, and a data sync client. Desktop computers in health facilities are setup to access the patient registration system on the virtual machine residing on the designated server machine. The main advantage of accessing the patient registration system “locally” via the virtual machine is that this architecture approach limits the dependency on slow and intermittent Internet access. Thus, patients would spend less time waiting for *Clerks* to retrieve their patient information from the patient registration system. The data sync client are responsible for checking if a *good* Internet connection is available and initiating a data synchronisation request with the central server. Alternatively, data synchronisation requests are also automatically initiated by the central server at predefined periods during the day.

Department of Health offices

Authorised users at national, district and sub-district health offices are permitted to access the patient registration system reports as well as to view in real-time the number of patients visiting clinics across South Africa. Users only have access to facilities they are assigned. Thus, districts are not permitted to view reports for another district or view real-time patient visiting totals.

Using supported browsers (e.g. Chrome and Internet Explorer), users at Department of Health offices may access the patient registration system on the central server after a successfully authenticated. Access for users at national, district, and sub-district health offices are permitted directly via the Internet without the use of a router as is required by health facilities.

HANIS

The South African Home Affairs National Identification System is requested by the patient registration system to verify the identity of patients visiting health facilities. The identity of patients is verified using the patient’s identification number and an image of the patient’s fingerprint as minimum criteria. Therefore, if a patient does not provide proof of identification (e.g. RSA identity document, driver’s license card) the identity may not be verified via the HANIS system. Visits by patients where the identity could not be verified, are marked as “unverified” patient visits, alternatively, where the identity can be verified the visits are marked as “verified” patient visits by the patient registration system.

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Third party application

The third party application environment refers to any external system requiring access to the national patient register. For example, health facilities that have existing healthcare information systems to manage patient demographic information and record patient visits would access the national patient register directly via application programming interface (API) hosted on the central server.

Summary

In its endeavours to improve the landscape of the health information system, the South African health department developed an eHealth strategy. The eHealth strategy will guide the health sector from the current situation to an improved future health information system. The eHealth Foundations strategic priority area is one of 10 strategic priority areas outlined in the eHealth strategy and requires for the registration of patients. The *registration of patients* key area is achieved by the design and implementation of the national health patient registration system (HPRS).

This paper outlines the considerations and challenges that should be considered for the successful implementation of a patient registration system. Requirements for the patient registration system were confirmed during visits to various health facilities. The design considered 6 main technological and business areas and resulted in a proposed electronic Health Patient Registration System (HPRS) towards a national HPRS for South Africa.
Future work will include iterations of implementation, evaluation, design and development towards enabling a long and healthy life for all South Africans (South African National Department of Health, 2012).

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