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Investigation Interoperability Problems in Pharmacy Automation: A Case Study in Saudi Arabia

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Abstract

The aim of this case study is to investigate the nature of interoperability problems in hospital systems automation. One of the advanced healthcare providers in Saudi Arabia is the host of the study. The interaction between the pharmacy system and automated medication dispensing cabinets is the focus of the case system. The research method is a detailed case study where multiple data collection methods are used. The modelling of the processes of inpatient pharmacy systems is presented using Business Process Model Notation. The data collected is analysed to study the different interoperability problems. This paper presents a framework that classifies health informatics interoperability implementation problems into technical, semantic, organisational levels. The detailed study of the interoperability problems in this case illustrates the challenges to the adoption of health information system automation which could help other healthcare organisations in their system automation projects.

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Keywords: Electronic Health Record; Hospital information systems; interoperability problems; Information Modelling; Automation.

1. Introduction

Healthcare organisations typically have multiple, disparate Information Systems (IS). These systems have been deployed to support the specific needs of healthcare functions. Information sharing among these heterogeneous

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systems has always been a challenge to the healthcare management professionals. The non-integrated IT infrastructure is an unnecessary but frequent cause of medical errors, which may lead to fatalities[1,2]. Various integration approaches have emerged and been adopted to make information available to healthcare professionals in the way they need it and when they need it. However, there are still many remaining issues, such as patients' data security and process integration. The varieties of integration approaches have resulted in marketplace confusion, especially in sectors such as healthcare that do not necessarily have all the IT technical expertise.

Healthcare institutions do not conform to a single standard. The titles and codes of case reports, drugs, diseases, and examinations vary in different hospitals. The definition, description and practice operation in the healthcare domain are also not unified. Thus, for systems in this domain to be totally interoperable, there must be unified and authoritative hospital standardisation. The importance of conforming to a standard in the healthcare domain is to improve patient care by allowing interoperability among disparate systems[3].

In Saudi, tertiary hospitals focus on investing in networks, platforms, and other advanced clinical systems rather than focusing on health data standards[4]. Healthcare providers manage a variety of different formats of information infrastructure that are difficult to manage and integrate. Each healthcare provider has its own policy and procedures that usually depend on the qualification and experience of the hospital's staff. The Saudi Ministry of Defense runs more than 30 hospitals and it was planning to mandate an EHR system in all the hospitals aiming to achieve a central medical records database, thus reducing both effort and cost. However, this project is still immature and little progress has been made.

The authors attempt to contribute to the progress by investigating interoperability problems between the pharmacy system and automated medication dispensing cabinets (ADCs) system after the implementation of the Health Level 7 (HL7) standards in Prince Sultan Military Medical City (PSMMC)[5].

This paper is organised as follows: section 2 presents literature review, then background about PSSMC hospital and ADC system is presented in section 3. Section 4 discusses the research methodology, which includes research design and data collection. In Section 5 the data and nature of problems in PSMMC are analysed. Section 6 presents the discussion. Finally Section 7 presents conclusion and the possible future research topics.

2. Literature

A review of scholarly papers published between 2006 and 2015 about Saudi health informatics technology (HIT) implementation[4,6–20] was done to search for potential barriers associated with the adoption and use of HIT. Table 1 shows the results of top barriers from the 17 papers. The barriers are categorised into organisational, semantic, technical levels to help understand the root cause and possible remedial actions.

Of the 17 papers, some use single method and others uses a combination of methods. Altogether, there are 8 questionnaires, 3 interviews, 6 literature reviews, and 4 documentation analysis.

Table 1: The top barriers associated with the adoption of Saudi HIT

Levels of IOP	Barriers	No. Study out 17
Organisational	Resistance to Change	9
	Lack of Training	9
	Lack of financial support	7
	Lack of knowledge of using HIS	7
	Shortage of professionals	6
Semantic	Mapping issues	3
	Workflow needs redesign to match with HIT	1
	HIS modules are not fully integrated	1
	Interoperability and information exchange	1
Technical	Inadequate IT support and maintenance	8
	Complexity of the system	7

	Security and confidentiality	7
	Lack of standards	6
	Poor quality of ICT infrastructure	6

3. Case Background

The Prince Sultan Military Medical City (PSMMC), established by the Medical Services Department (MSD) of the Ministry of Defence, is one of the premier tertiary hospitals in Saudi Arabia. The PSMMC Health Information Systems (HIS) consists of a mainframe computer that runs the outpatient pharmacy and inpatient pharmacy, a patient registration systems (Admission, Discharge and Transfer ADT), plus many standalone systems such as laboratory and radiology etc.

In 2010, the Inpatient Pharmacy Department started the Profiled Pyxis project. The Pyxis MedStation system is an Automated medication Dispensing Cabinet (ADC)[21] which can help to manage medications by automating the process throughout the hospital. Pyxis cabinet is used to store patients' medications in each of the 58 wards in PSMMC. In the wards, nurses log into Pyxis with the correct credentials and patient information to obtain the medications for the right patient at the right time. The dispensing information is set up and reviewed by the pharmacists to ensure the correct prescription is set up for the patient, following the doctors' instructions and matching the supplies in the pharmacy. The system connects with the HIS to obtain and update patient records and admission history. The system streamlines medication distribution, improves nursing and pharmacy collaboration. Therefore, it was introduced to prevent dispensing and administrating errors.

In 2012, the hospital started the automation project to integrate all the hospital departments, starting with the Inpatient Pharmacy. The sharing of information should result in a higher quality of care and reduced medication costs. The hospital adopted HL7 health data standard using the Orion Health Rhapsody Integration Engine, a recognised global health informatics solution. After the adoption, the Inpatient Pharmacy began to suffer situations of losing inpatient information. In some occasions, the pharmacist profiled the patient medications into HIS, however, the information did not reach the ADC machine and the nurses could not obtain the patient medications. When this problem happened, the nurses had to spend extra time and effort to manually double check the patient's paper medication prescription with the ADC machine. Sometimes the nurses have to obtain the patient's medication from pharmacy or manual override the ADC which increased the chance of medication errors. These types of medication errors increase the risk faced by the patient in the cases when the medication is not received or not received on time. The hospital attempted different investigations to solve this problem in addition to working with the vendors who provided the system, but solutions were not reached.

4. Methodology

4.1. Research Design

The aim of this research is to investigate the nature of the pharmacy systems interoperability problem. The field research is designed to use multi-methods in this PSMMC detail case study to ensure that the research matches the hospital reality. Multiple methods of data collection to obtain different views and corroborate evidence enhance the researchers' findings[22]. The methods included interviews, documentation, business process modelling and information modelling. The data collection ran from June to October 2014. The inclusion of business process modelling and information modelling creates a novel, holistic approach to gain rich insight to the practical problems in HIT integration.

4.2. Data Collection

Interviews: Interviews were used to gain a full picture of the hospital as well as understanding the major barriers within the hospital. In particular, the researcher was interested to investigate the types, the level of integration and the barriers of implementation for inpatient systems. Semi-structured interviews were conducted using a script. The

interview focused on general background, business information and technical information. The interviews were conducted in three levels: exploration, in-depth and verification. Ten participants represented a mix of healthcare professionals (Pharmacist Manager, Senior Pharmacist and Pharmacy informatics coordinator) (Physicians and Nurses) and hospital staff (receptionist and IT team). The vendor (senior of hospital automation) responsible for maintenance and after implementation care also participated.

Documentation: Documentation was collected from the available sources around the project such as agenda; e-mail correspondence; future plans and other personal documents. Email correspondence between project team members was used to analyse causes of failures in the inpatient pharmacy system.

Business Process Modelling: This method was used to build a business processes model about the inpatient pharmacy and to capture problems from the researcher's own observations. The business process model was built using the Business Process Model and Notation (BPMN). Analysing the workflow enabled precise identification of the integration problems. First, three formal meetings (the pharmacy automation team, the IT department team and the vendor meeting) were held to describe the business workflows from the time when the patient arrived at reception until medication is received. Second, each step of the process description was followed, from the hospital reception to admission and ward stay, to study the physical movement and the actual use of the technology, including the ADC machine (hardware). Third, general observation was carried out in the inpatient pharmacy and other departments.

Information modelling: The aim of information modelling is to understand the interoperability problem by studying and analysing the IT systems. Data schema from the mainframe databases, ADT system, ADC and from HL7 project records (Rhapsody) were extracted to understand the data definition and analyse using ontology model.

5. Results

The results from the data analysis revealed the nature of the problems experienced in the PSMMC.

5.1. Business Process Model

The modelling of inpatient pharmacy systems is an essential first step toward a more consistent and comprehensive understanding of interoperability problems, where management and improvements are more easily implemented by health professionals[23]. The processes are modelled using BPMN. The BPMN model scenario comprises of five participants and one system:

- Patient
- Receptionist
- Nurse
- Physician
- Pharmacist
- Pharmacy system

Model Information

- 5 actors
- 2 data objects
- Multiple events, connecting objects and activities

In the model (Fig. 1), the process starts by the ward receptionist admitting the patient in the ADT system. Then, the nurse looks up the patient's medical record, conduct an assessment (enter the patient height and weight, etc), then refer the patient to the physician. The physician reviews the patient's record, history and other relevant information, then meets with the patient. The physician then writes the inpatient pharmacy form (IPPF) informing the pharmacists of the prescribed medication. The nurse sends the IPPF to the pharmacy through email. The IPPF is verified by the pharmacist and profiled in the medication profile screen in the HIS. The HIS sends the IPPF information to the ADC

Console (server) through Rhapsody (HL7). The medications loaded in the ADC will appear in bold font while those unavailable will appear in dim font for the nurse's information. Finally, the nurse obtains the patient medication from ADC, and non-ADC medications are obtained from pharmacy.

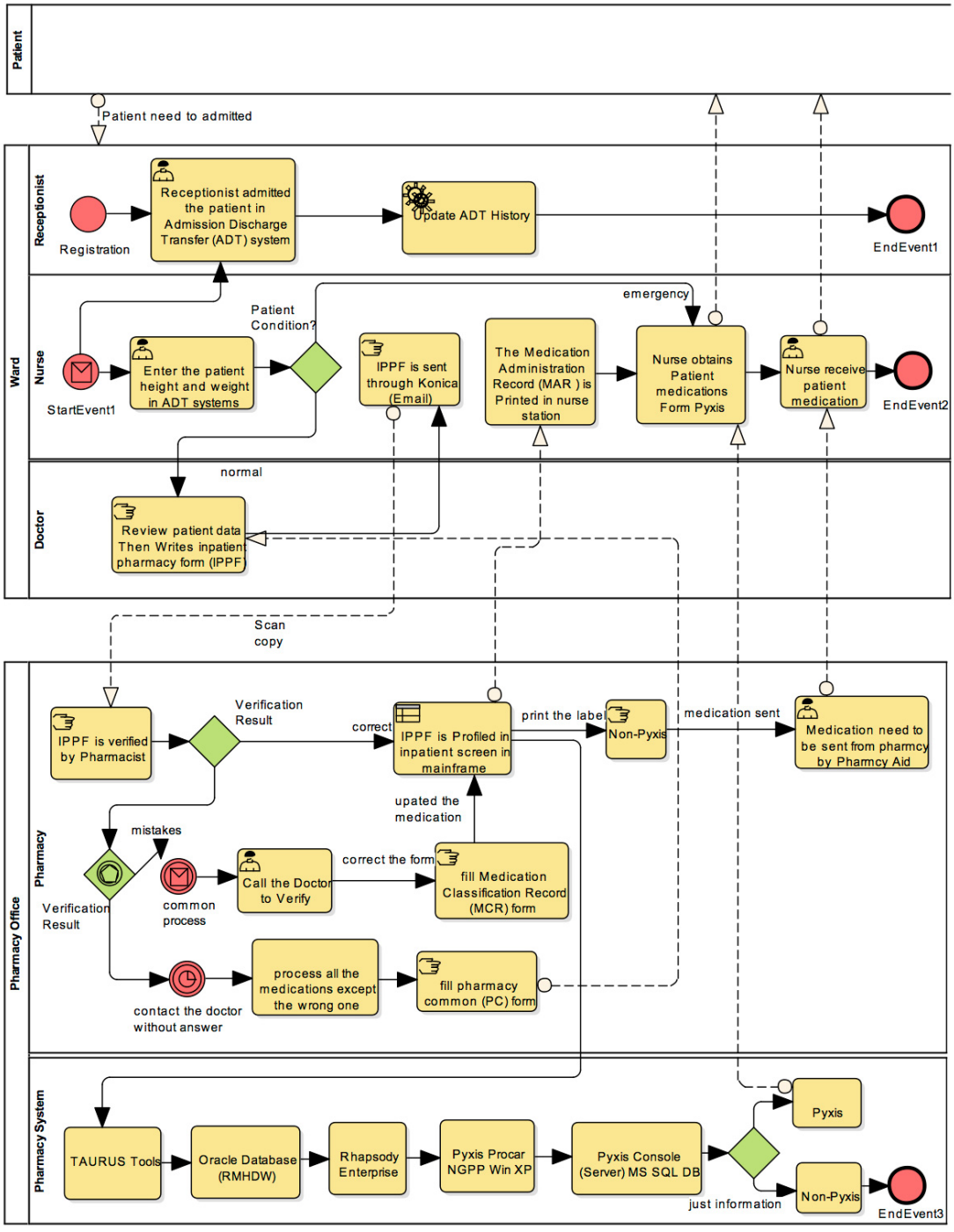


Fig. 1. A simplified BPMN inpatient pharmacy process modelled in Enterprise Architect editor

The benefit from using business processes model is to identify any problems in the detail operations workflow. The problems identified have different types related to different causes. There are two types of mapping problems between the HIS and ADC systems. First, the process problem in which some work processes are not designed in HIS system and are completed manually, and the semantic problem in which some steps in the workflow have integration issues.

- The communication between nursing and pharmacy relies mainly on telephone calls. Communication through phone calls has many advantages such as it is personal, immediate, effective, interactive, confidential, and safe. On the other hand it has many disadvantages such as it is hardly documented and it can be a source of interruptions within the pharmacy operations. The frequent interruptions can have a significant bad effect on memory; interruptions may result in loss of concentration, leading to medication errors and increase TurnAround Time (TAT). The reason behind this high number of phone calls is the difficulty in recognising the prescription priority by pharmacist after the prescription is sent. There is no medication tracking system that displays real-time status, priority and delivery time. Andersen[24] examined important differences in barriers to implementing a medication tracking system as experienced by nurses and physicians.
- In addition, the maximum capacity of patient drug profile is 100 medication transactions for each patient in the HIS while many patients exceed this number of transaction that cause losing track of medications record for patients. Because of this problem, the new medications will not be available in the patient profile therefore; the chance of medication errors will be increased.
- Currently, pharmacists document and monitor their clinical interventions using medication clarification record (MCR) which is paper based and therefore this process consumes time and needs a lot of efforts. Also, it is very difficult to analysis the intervention data. The intervention documentation is quality process in order to improve the patient safety and identifying the areas of interventions to improve the patient outcomes. Fox et al[25] suggested that the providing clinical intervention documentation system to pharmacy that could improve patient outcomes and reduce costs for their organisations.
- Difficulty in recognising the prescription priority by pharmacist after the prescription is sent by nurse using imaging system.
- In order to meet the urgent needs of patients in a dynamic healthcare sector, pharmacy must have an accurate, efficient and real time medication inventory management system. The benefits of inventory system include but not limited to minimise medications wastage, utilize the pharmacy space and improve the patient outcomes through increasing pharmacist contact time with patients and increase the availability of medications. The inventory system (Oasis) and the HIS are not integrated that lead to lose the medications inventory tracking.
- The cancel of discharge code in ADT system enables the clerks to cancel the patient discharge. Nevertheless, this code is not defined in the ADC consequently, the patient will be considered as discharge patient in ACD while the patient still is admitted in the ADT system that cause disappearing of patient medication from ADC. To overcome this problem the pharmacist has to profile all patient medications again.
- A part of the admission procedure for children, in PSMMC, is calculating the doses of Cardiopulmonary resuscitation (CPR) medications. The doses will be calculated based on the children weight. The CPR medications chart consists of 14 medications, a procedure and the length of Tracheal Tubes. The CPR medications chart is calculated manually therefore, it is highly prone for errors. Vardi et al[26] studied the impact of CPOE and CDSS on the frequency of errors in ordering CPR medications.

5.2. Information Modelling

Data schema were extracted from HIS databases (Mainframe, Oracle, and Pyxis) and HL7 project records (Rhapsody). The “Development Methodology 101” ontology engineering approach proposed by Noy and McGuiness[27] was used to create the ontology model in Protégé[28]. Protégé does not allow having the same name in the class hierarchy and highlight the need either to create the classes so that terminology is used only once or to create different name for the attribute. Ontology modelling analyse the connection between names before creating a hierarchy and prevents the same name used twice or in different places in the system. This work uses the process to build the model to highlight interoperability problems. The final merged ontology of the inpatient pharmacy was

made by identifying the relevant classes, sub-classes, properties and instances. The created structure was visualised using the OWL Viz plug-in. By using the map, the user can observe the structure of attributes in functions and look for relations between them.

After analysing the information in current systems and examine the important redundancy, duplication and missing concepts between these systems, the following problems were discovered:

- **There is an inconsistent formatting (Syntactic) in systems**. For example, nationality could be spelled out as text in some system and represented as a code in others. Consistent formatting avoids having different terminology for the same word (different type of spelling). One way is to use display list for all predefined items.
- **Each domain has its own terminology (ontology) of the meaning**. For example, 'ID' is sued to refer to insurance policy number in some systems and as Saudi national ID in others.
- **The same terminology in one system sometimes is used more than once**. For example, the alternative ID was found to have two meanings, once for the formulary ID and once for the Patient's ID. Similarly, Saudi national ID refers to either "Nationality" or "alternative ID 2". In Pyxis, "Med ID" and "ID" Indicate to code of Medication.
- **PSMMC does not have in-depth knowledge of multiple applications and their attributes**. For instance, there was unclear system implementation plan between the IT team and the vendor. Knowledge of the system entries is important before starting to develop the HIS data structure. Without that, it is hard to understand how the legacy and target data are connected and how to make sure that they are going to be adequately linked in case of any differences. One way to do that is to work with a person responsible for the function that would explain the attributes or to have a documentation that would help to understand the connection.

5.3. Interviews and documentation

Further investigation into interoperability barriers were analysed by descriptive analysis of the interview results and documentation. E-mail correspondence was analysed by studying the email records that reported failures cases in systems within the project team or between project team and vendor. In this way, process-mapping problems in the pharmacy system were detected. For example, the medication due time was not appearing expected the ADC screen for at least 20 patients. This timing is crucial to alert the nurse and staff of what medication is due at certain time. When the Oracle system was checked, another problem was found related to the dosing interval which disappeared with some patients.

6. Discussion

In recent years, interoperability scholars have started to focus on non-technical issues in addition to the technical issues. The field study confirmed that barriers identified are mixed between pure technical issues (networks, databases, and software applications), or technology issues (strategy, vision and action plans). Thirteen barriers (Table 2) were identified that affect the efficiency of the PSMMC hospital integration and classified into three levels (organisational, semantic, technical). This is the result of a five-step analysis. First, the researcher combined all the issues identified in interviews, documents, process modelling and information modelling. Second, the documented data were refined to remove duplication and unnecessary information, resulting in 13 barriers. Third, the researcher started to sort and categorise the barriers into one of the interoperability levels: technical, semantic and organisational. Fourth, the categorised barriers were presented to the members of the PSMMC project group for validation. Finally, the barriers were rated in importance by the PSMMC project group, representative PSMMC staff and the IT team.

Relevant literature that touched on the barriers is also added.

The organisational context is a necessity for any IT innovation adoption, including e-health. The analysis of the data confirmed the strong relationship between the adoption of health standards and the identified organisational barriers. For instance, resistance to change has been addressed by all interviewees as a major obstacle slowing the systems' implementation. This barrier is also one of the most common barriers in the region among employees, senior officers and managers[4,16,29,30,15]. Several studies[31,32] examining the organisational barriers associated with the

adoption of health standards have identified similar factors as in Table 2. Pardo Del Val and Martinez[6] identified twenty-four different sources of resistance to change in the strategy formulation and in the implementation stage.

Table 2 The barriers associated with the adoption of HL7 standard and their importance (●: important; ✪: neutral; and ○: less important). The relevant studies are also highlighted.

Levels of IOP	Barriers	Importance	Reference
Organisational	Resistance to Change	●	4,31–35
	Lack of Training	✪	33,35,36
	Lack of Adequate Policies and Procedures	●	4,33,37–40
	Loss of Productivity	○	31,35,36
	Lack of Process	●	31,35–37,40
	National Healthcare Systems	✪	4,40
	Cost	○	4,34,35,37,38,40,41
Semantic	Lack of Mapping	●	3,4,30,31,37
	Compatibility (Lack of standards)	●	4,15,31,34,36,37,39
	Market Uncertainty	✪	4,15,37,41
Technical	Old Infrastructure	●	4,15,31,33,34,42
	Shortage of Professionals	●	4,40,43
	Complexity	✪	4,15,31,34,37

The result of the field study is compared with those reported in literature. Most of the major barriers identified in literature were also found important in the field study. For example, resistance to change and lack of training were the top identified organisational barriers (mentioned in 9 studies) and they are also identified from the case study. Cost was also mentioned in both the case study and the literature as many papers (7 papers) stressed on the lack of financial support or the high initial cost of implementation.

The analysis revealed that organisational factors are the most common mentioned barriers to the HIT standards' adoption in both literature and case study. This reflects the importance of considering the organisational factors to ensure successful implementation and in particular resistance to change and lack of training which are found to be the most identified barrier across all levels. As a result, it can be seen that there is a gap between user acceptance and the process of successful HIT adoption. This is supported by[44] who argued that there is a lack of research in considering both IT innovation adoption and user acceptance in organisations. This is because most of the studies only consider factors affecting the adoption of IT until the acquisition of innovation without judgment on whether this innovation will develop to be a part of the user's regular practice. Additionally, studies on user acceptance focus on the behaviour and attitudes of individuals towards the acceptance of an innovation.

Regarding the semantic barriers, mapping issues were not discussed commonly in literature (only three papers). However, Some papers discussed the interoperability problem and the importance of developing a standardised system and reach an integration/medical exchange on national level.

7. Conclusion and Recommendations

This case study aimed to investigate interoperability problems between the pharmacy system and the automated medication dispensing cabinets (ADCs) system after HL7 standards was implemented. The multi-methods approach allows the researchers to gain insight on the interaction between the organisation and technical issues. The findings of this study provide decision makers in PSMMC and other healthcare organisations with a better understanding of the adoption challenges of health data standard.

The researchers continue to work with the hospital to prepare implementation of other HIT projects to improve the adoption success and continue to learn from the new experience and refine theoretical development.

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