Transforming to a Smart Hospital System: Proposed Application in the Medina Maternity and Children's Hospital

Dr.Nawaf Alharbe [1] and Prof.Anthony S. Atkins[2]
[1]*College of Community, Taibah University, Badr, Kingdom of Saudi Arabia*
[2]*Faculty of Computing, Engineering and Sciences, Staffordshire University, Beaconside, Stafford, United Kingdom, ST18 0AD*
nrharbe@taibahu.edu.sa and a.s.atkins@staffs.ac.uk

Abstract:-

Purpose Expert knowledge is an important organisational resource and organisations need to retain the knowledge learned by experience, which can be shared as part of inter professional learning. In a healthcare context, Radio Frequency IDentification (RFID) and ZigBee technologies can be used together, to provide real-time information for decision support and to create a secure and reliable Smart Hospital Management Information System (SHMIS) that allows the dynamic control of objects and transforms operational processes, while minimising any potential risks to patients and staff. The current use of RFID technology in Saudi Arabia is solely for the monitoring of new-born infants and has been subject to difficulties in the different stages of tagging and monitoring. The current system in Medina Maternity and Children's Hospital (MMCH) uses battery-powered active RFID tags, which are expensive and require routine maintenance.

Design /methodology/ approach -The extraordinary growth of Radio Frequency IDentification (RFID) and ZigBee technologies has made it possible to identify, locate and track objects in various environments in real-time. RFID technology is a non-contact identification technology that is cheap and reliable but has limited range in the case of passive tags. ZigBee has greater range and lower power consumption, giving more precise location of the object's movements (0.6 m). Passive RFID and/or combined with ZigBee technology could be used to improve healthcare organisations through continuous data collection, supporting real-time decision-making by applying expert knowledge of domain experts to data produced by communication from electronic and sensor technologies.

Findings A prototype object tracking system using RFID and ZigBee was developed to support the Knowledge Transformation for Knowledge Reasoning for Decision Support (KRDS) and the outcome from this research were validated with domain experts in hospitals in Saudi Arabia. Two feasibility case studies were conducted at MMCH in Saudi Arabia, in order to evaluate the proposed system. A survey was also administered to address the requirements at MMCH and the researcher adopted a range of strategy techniques, including interviews and meetings with staff, and the setting up of Communities of Practise (CoPs) in the target hospital.

Originality/value - To propose a prototype application of a Smart Hospital Management Information System (SHMIS) that allows the dynamic control of objects and transforms operational processes, while minimising any potential risks to patients and staff.

Keywords RFID, ZigBee, IoT, Real-time, Sensor technology, Cloud Computing, SHMIS, MMCH and KRDS

Paper type Research paper

1. Introduction

This paper discusses the way in which the Medina Maternity and Children's Hospital (MMCH) in Medina, Saudi Arabia could be transformed to a Smart Hospital Management Information System (SHMIS). We discuss the processes that would be required and present two proofs of concept studies that illustrate the scope for transformation. Currently there is no system in operation in Saudi Arabia that allows the monitoring and the tracking of patients within a hospital environment, or the tracking of patients and staff through the different hospital processes and the physical areas associated with them (Alharbe & Atkins 2015). At the moment, most healthcare providers in Saudi Arabia use a manual method to record patient entry and exit to wards/units in hospitals. In the proposed transformation to a SHMIS at MMCH, RFID and ZigBee technology, supported by the Knowledge Reasoning for Decision Support System described in Section 3, will be used to identify, record, and ensure an efficient, effective and smooth transition at all stages of patient care. We present proposals for a

transformation of the patient and staff tracking, and maternity security (babies) to improve capacity management and ultimately the overall care service in hospitals.

2. The proposed Smart Hospital Management Information System (SHMIS)

In order to improve hospital efficiency, both the Communities of Practise (CoPs) and the system developer will need to identify areas where RFID and / or ZigBee technologies could be beneficial. Figure 1 shows the regular meeting within Communities of Practise (CoPs) and the system developer. The areas identified in the discussions included real-time patients and healthcare staff tracking, operation theatre management, bed allocation, monitoring of medical equipment and the handling of prescription medications that need an authorisation before being given to a patient.

Figure 1 Communities of Practise (CoPs) and the System Developer Meetings

The primary technology identified for the proposed project is RFID. Passive RFID tags require low maintenance and are flexible, i.e. they can be adjusted to an object that is being tracked. An example could be a wristband embedded with a passive tag that could be worn by a healthcare staff. In addition, when a large number of tags are needed, passive tags (<5p) are low in cost in comparison to active tags (£100). Furthermore, passive tags are disposable, as they do not have a battery embedded. RFID technology can automatically measure a tag within a short read range, less than 11 meters from the deployed 'gate'. Transformation will also be supported by ZigBee as this offers a larger coverage to monitor and to confirm the location of the object throughout the hospital, with a lower Radio Frequency output. This technology is particularly important in applications with high security and accuracy requirements, and it would also be possible to merge location data with a Closed-circuit television (CCTV) system. ZigBee can also obtain data within a long read range, approximately 75 meters (from tag to reader). The RFID and ZigBee technologies do not require staff to scan the tags, as they are automatically inspected with no line of sight requirements. Different applications will use different technologies depending on the requirements. ZigBee provides unlimited network scale and significantly lower RF output. ZigBee tags also cost considerably more (approx. £100) than the RFID tags (<5p), so their use must be prioritised for financial reasons. For example, infant security is one such area where ZigBee would be chosen over RFID because the combination of both technologies will provide faster scanning speeds for large volumes of tags and ZigBee supports more accurate identification of location. Sensor technology will be used with the KRDS to support the transformation to a Smart Hospital Management Information System.

2.1 Problem Analysis

The requirements for a Smart Hospital Management Information System were confirmed after several meetings with the IT Director, managerial and operational staff of the Medina hospital in Saudi Arabia. The main requirements of the proposed Smart Hospital Management Information System are as follows:

- ***Real-Time display of the current location of the object:*** Object (patients, staff and assets) movement monitoring is required for recording purposes and for security measures. The hospital requires a system with the ability to display in real-time the location of objects, such as patients, hospital staff and mobile medical equipment
- ***Maternity Security:*** Extra security is required to prevent children being taken from the hospital, or being mismatched. Therefore, their exact location is needed. It is important that the proposed applications have backup functions.

2.1.2 Design and Implementation of the proposed Smart Hospital Management Information System in a real scenario

The interviews results suggested that MMCH required a SHMIS that would resolve some high-impact issues that the hospital has encountered in patient and assets monitoring. KRDS would enable the provision of decision making support to staff. Effective knowledge harvesting through interaction with information would lead to better decision making and therefore improve healthcare practice (Ko 2014).

2.1.3 Overview of the Proposed Smart Hospital Management Information System

The proposed system is an automatic real-time data collection system that will continuously monitor patient, staff, and assets movement, using sensor technologies to provide optimal real-time information for knowledge management decisions. The components of the proposed system are outlined as follows:

- ***RFID technology*** - this includes readers, antennas and passive tags to collect real-time data from the object (patient, medical assets and pharmaceuticals) and to obtain information for each 'gate' to locate objects in the coverage area.

- ***ZigBee technology*** – this includes ZigBee coordinator, reader and tags to continually check the status of the target object and send this information to the proposed system.
- ***Databases*** - to store the data available for Knowledge Reasoning for Decision Support (KRDS) in order to propose the best solutions.
- ***Network infrastructure*** – to provide the best way of exchanging the data locally and to the Cloud services, if needed.
- ***Visualisation of data*** - display equipment, which includes screens, tablets, and projectors.
- ***Reasoning Technologies*** – to infer and interpret the information in real-time, using Knowledge Reasoning for Decision Support (KRDS), which covers most of the Knowledge harvesting model to provide healthcare intelligence by taking into account 'what-if' scenarios and real-time decision-making support.

2.1.4 Proposed System Function Analysis

The system features discussed in this paper were identified by the Communities of Practice (CoPs) (doctors, nurses, senior administrators, medical engineers, IT staff, supervisory team and the proposed system's developer) at Medina hospital. Some of those features were based on hardware components that require the ability to communicate with RFID and ZigBee equipment, and on the configuration of hardware parameters of both technologies:

1. ***Hardware communication and control***: - The proposed system must be able to communicate with both RFID and/or ZigBee hardware. This will enable it to receive data from both tags in real-time. Its features should also allow control of the hardware parameters, for example the proposed system should identify the areas that need to be monitored and which readers should be active.
2. ***Database design, communication, and control***: - The proposed system must be able to record the data received from the RFID and /or ZigBee system and store them in the database. This should include object RFID ID and /or ZigBee records. Also, the system's user should be able to extract the relevant data from the database. Based on the user requirement, in some application two wristbands or combination wristband (RFID and ZigBee) are required to provide better readability and increased security. The database must be designed to synchronise data from the different tag locations.
3. ***Identification bands for staff and patients***: - For the security of patients, RFID tags will be removed and disposed of, for disease control, after discharge. If a new identification band is required, the system

should be able to assign a new tag ID to any object. As ZigBee tags are currently relatively expensive they could be removed, reused and/or disposed of, as required. If new tags are used or tags are reused, then the system should be able assign a new tag ID to any object.

4. ***Knowledge Reasoning for decision support function: -*** The proposed system uses sensor data and knowledge harvested from the Communities of Practise and other sources, to provide decision support for healthcare professionals. This will improve operational and staff performance in the hospital environment by providing responses in real-time and display them in a clear and understandable format.
5. ***Visualisation: -*** The proposed system is able to show the current object's location. This will allow the system to analyse data from the tags and to display the information in real-time in a hospital environment. This will help hospital staff to respond very quickly to any enquiries.

2.1.5 Database Design

To support the studies discussed in this paper, which illustrate how transformation to a Smart Hospital Management Information System could be achieved, the data was stored in a relational database system, using the MySQL database. In a hospital wide implementation, data volumes might require a different data management solution. The design for the MySQL database is shown in Figure 2. In the prototype system discussed here, a unique object ID, associated with RFID_ID and /or ZigBee_ID, is used to identify the object. A data table, called 'RFID record', contains information about RFID ID, time, and gate information. The 'ZigBee record' table contains ZigBee ID, timestamp, coordinates and node ID. The stored information is used to identify the object's location and in certain applications this could be the location of staff or patients. The results of the object's identification and location are stored in the main object's entity associated with several tables, to answer queries from the user regarding the object. The answers that the proposed system could provide include where and what the object is, and when it enters and leaves the wards and or departments. With RFID, the data stored will be based on the location of the nearest gate. With ZigBee there is a possibility that an object will be at equal distance between two nodes, but for the proof of concept ZigBee objects are identified by the closest nodes. The system will use algorithms such as Distance Estimators, developed by Nebusens , to estimate the distance existing among the different modes (Nebusens 2010) .

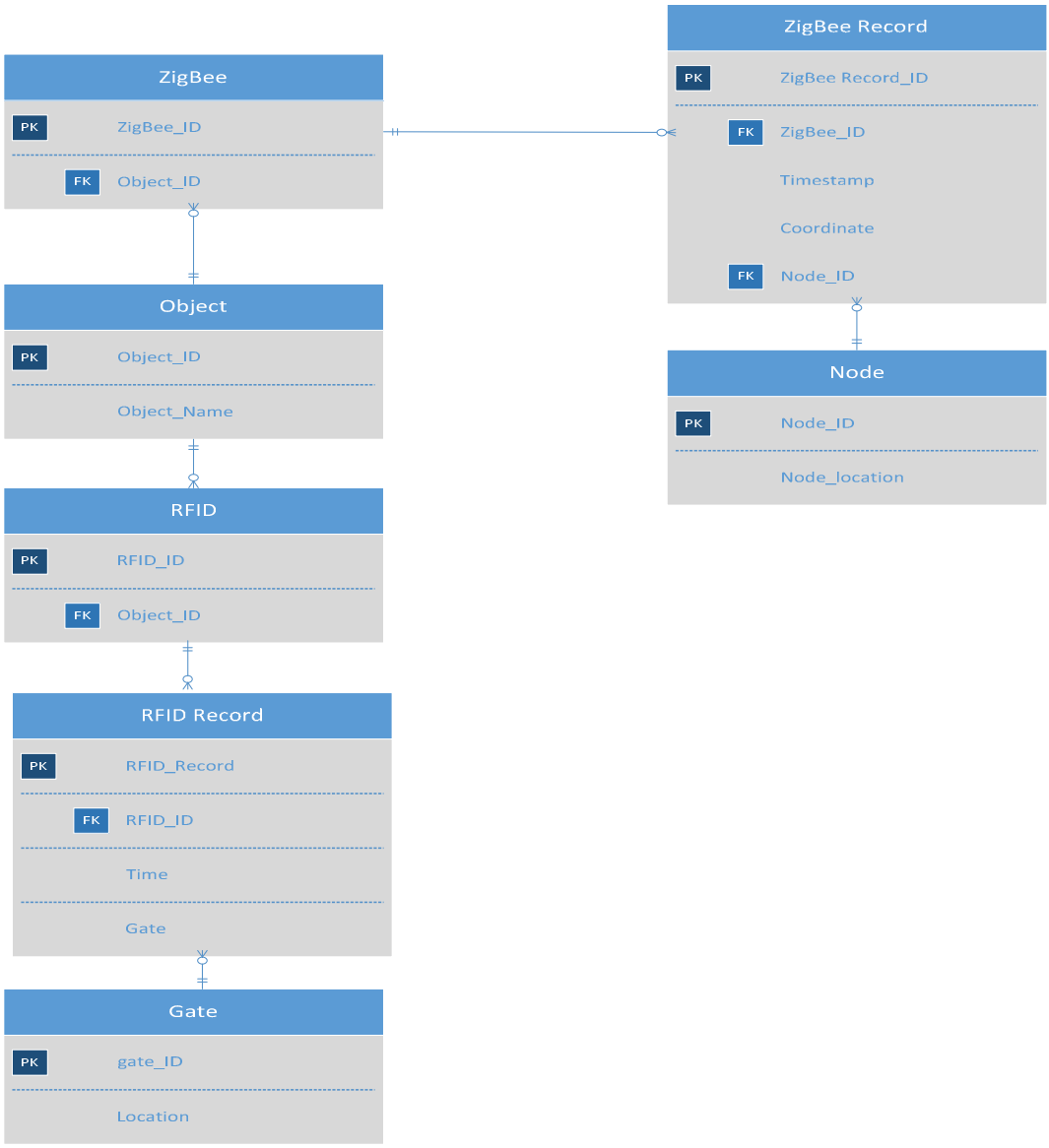

Figure 2 Data Relationship Diagram for the proposed Smart Hospital Management Information System

2.1.6 Proposed hardware Deployment and installation

This section discusses how the technology could be deployed in a hospital environment. In the hospital environment, RFID and ZigBee readers will be placed on ceilings and walls to detect the tagged 'object'. RFID antennas will be used to communicate and to receive the data transmitted from the RFID tag, which is then transferred to the RFID reader. RFID and ZigBee readers act as exciters, transmitting continuously a radio frequency signal that is collected from the RFID and ZigBee tags, which in turn respond to the readers by sending their identification numbers. Each reader covers a certain zone known as the reading field. When a target object passes through the reading field of the reader, then the target object is in that zone. RFID would provide access information for each 'gate' and the ZigBee system would continually check the status of the target object.

For a target object that makes use of both RFID and ZigBee, once the target object passes the RFID covered area, the movement record could be checked against the ZigBee system. If the ZigBee system does not confirm the movement, or the object's ZigBee tag is missing, a warning message will be sent to operational staff, requiring them to check the object's status and, if necessary, to activate electronically the closure of the main entrance/exit doors. The proposed system integration of RFID and ZigBee can be viewed from two aspects. Firstly, the RFID system has limited communication range but could provide specific location information from deployed 'gates', to provide access control and location position. Secondly, ZigBee, which has a low power

output with larger coverage, is used for continuous monitoring, giving confirmation of approximate location information of the object, with an average accuracy of 0.63 meters over the entire hospital environment. Due to cost implications, ZigBee would only be used initially in high vulnerability environments such as the maternity unit and /or high value equipment assets.

2.1.7 The proposed interface design

The main aim of the interface is to display localisation data that include real-time movement records, object's name and type. The movement of the object's position will be recorded through the smart system that finds and checks this targeted object when it accesses the coverage area of RFID and/or ZigBee. In the laboratory environment, which simulated the Medina hospital environment, a prototype interface was developed to synchronise both RFID and/or ZigBee information, in order to identify and locate the object. The prototype system used in in the laboratory environment was developed using C#. The system connects to a ZigBee coordinator and RFID reader, to control the reader and coordinator through the RFID and ZigBee Application Interface (API). To implement the proposed transformation to a SHMIS in MMCH, the prototype interface would need expanding, based on their environment. For example, technical requirements will vary depending on staff numbers, RFID and ZigBee equipment used and the total number of objects that need to be tracked

Depending on the application, the user interface will need to be modified. Figure 3 illustrates the proposed system design, based on the prototype developed in the laboratory environment. In the event of system failure, the backup solution could be activated. In the prototype, SkyDrive was used to provide Cloud storage.

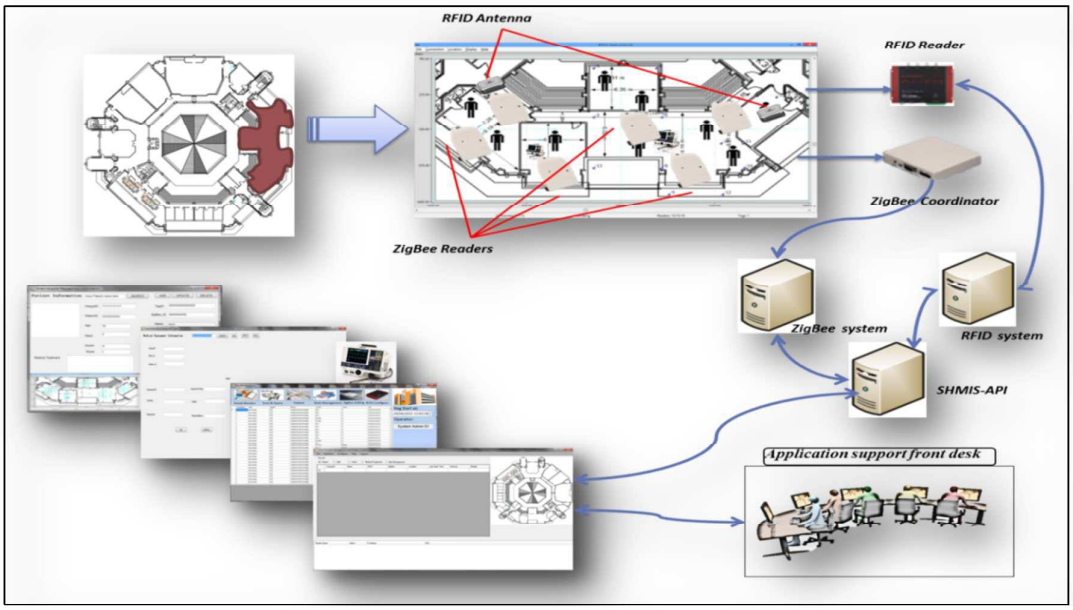

Figure 3 Proposed Software Design Smart Hospital Management Information System

2.2 Knowledge Reasoning for decision support function

Making tacit knowledge explicit can be difficult, as hospital staff often 'know what they know', and so helping hospital staff to talk about what they know, and then capturing that effectively, is a key skill. For this reason, knowledge harvesting is a key part of the KRDS. In a hospital environment, knowledge can be acquired from the data set and from expert knowledge, to assist in managing objects such as patients, medical equipment, nurses and doctors, so as to design a rule based set that will allow quick decisions for making the hospital environment smart. Rule-based sets could be used in the hospital environment to store and control knowledge and to interpret information. For example, it could be determined how long a nurse was beside a patient by comparing the patient's tag and the nurse's tag in a designated space and this could then be compared to government norms. Data Set can comprise information such as patient records, admission process, nursing scheduling and other patient-related information not classed as expert opinion or diagnosis. The function design of Knowledge Reasoning for decision support is shown in Figure 4.

It can be difficult to identify ''who'' is doing ''what'' within a busy hospital ward environment. It is even more difficult to tell the number of contacts that each patient receives by nursing staff. In hospital wards human error

and displacement of patients can happen, and delays can be expected for some jobs. The proposed system will provide data to track the use of resources and support more effective decision making. Effective decision making in hospital environment requires teamwork, which can improve effectiveness and efficiency and support better care for patients as well as providing planning information for the Ministry of Health (MoH). Figure 4 provides an illustration of the way in which the KRDS could be integrated with sensor technology and communities of practise.

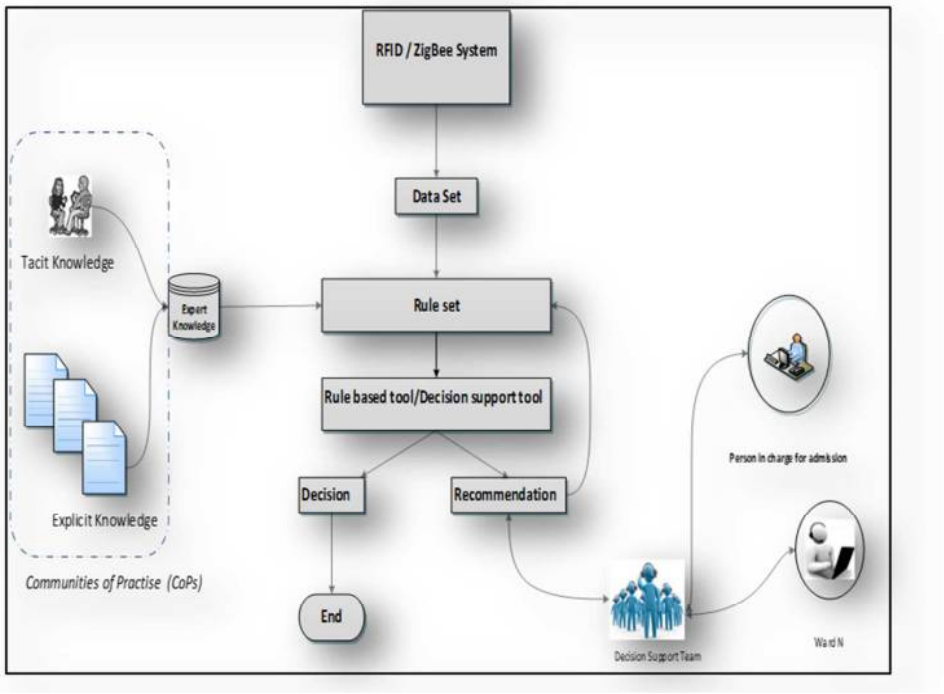

Figure 4 Knowledge Reasoning for Decision Support Function

On ethical and practicability grounds, it was considered that the feasibility of the proposed system should be investigated in a test environment approach before moving to implementation in a live hospital environment. A technical proof of concept prototype was developed in a laboratory environment and the results from the proof of concept were combined with data harvested from the CoPs to develop two studies which examined whether and how transformation could be applied to the manual systems currently in use in the Medina hospital. The following sections discuss the results of these studies.

3. Overview of the studies

The following two studies focus on using a KRDS process combined with sensor data to improve location of patients and staff and maternity security. Based on the results from these studies, the information received from the RFID tags will be used to propose a new Smart staff and patient location system. RFID tags will be used in the short term with the possibility of introducing ZigBee technology in the near future, to monitor staff and patient location, subject to the financial constraints discussed in Section 2. ZigBee tags combined with passive RFID tags will be applied to replace the present 'Hugs and Kisses' security system at MMCH, with possible future nationwide applications. The proposed a Knowledge Reasoning for Decision Support (KRDS) model, as shown in Figure 5, in order to transform expert knowledge within a hospital environment by incorporating sensor data to improve future operational and staff performance. The KRDS process was used in two studies – patient and staff tracking and maternity security and would be required to support the transformation to a Smart Hospital Management Information System.

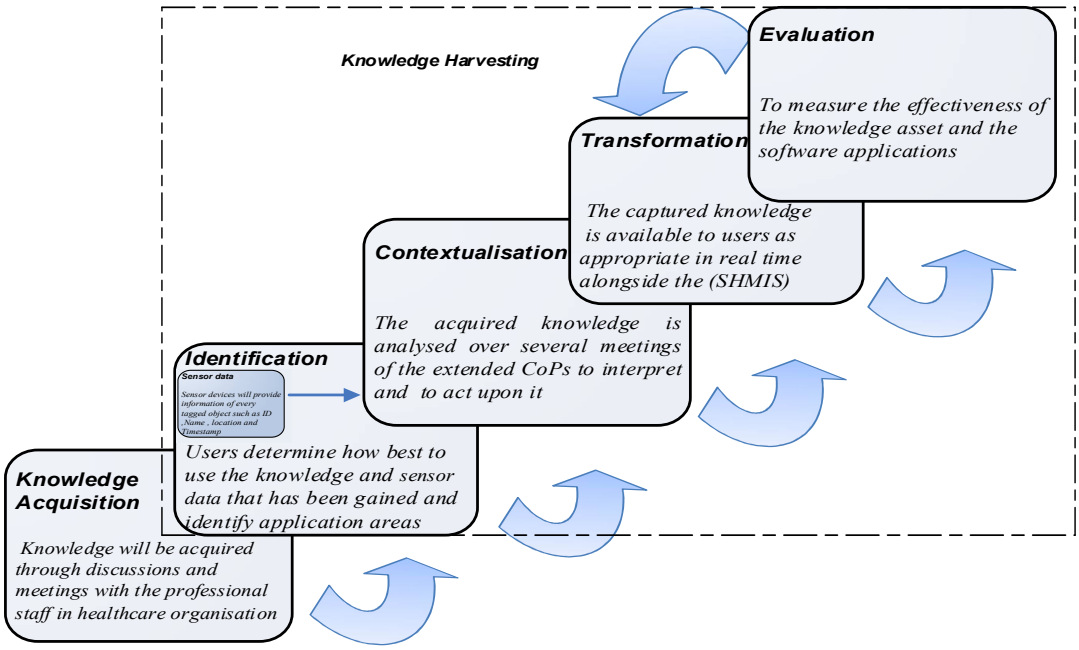

Figure 5 A Conceptual Views of KRDS

3.1 Study 1- Human Tracking Interactions Via Location Based Services

As in the rest of Saudi Arabia, the MMCH currently does not have the technical capability to monitor and track staff and patients in order to provide a safer environment as well as improving standard of care and quality of work. At present, there is no automatic real-time system providing the location and tracking history of hospital staff and patients. The MoH will benefit from accessing hospital data regarding location of staff and patients, in order to improve the security and performance. Also it will show where staff are in relation to the patients, and then use this information for selecting working patterns and future recruitment or even patient positioning. This study investigated whether the proposed transformation to a Smart hospital system could include using location to track human interactions.

3.1.1 Knowledge Acquisition

The first stage of the proposed new human tracking system is knowledge acquisition from the expert professionals (doctors, nurses, IT staff, system developer and managerial staff) who are familiar with staffing requirements and numbers, and with the related cost in each department. Several meetings were held with the expert professionals to discuss the present process of monitoring people and how the present system could be improved. Meetings were held at MMCH and questions were asked in order to gauge staff feelings regarding the new proposed monitoring system. One key issue, raised during the first meeting, was the role of cleaning and of ancillary staff, as they are able to visit each department every day and at any time to help patients, clean rooms or collect waste without being scheduled. As wards may be visited by large numbers of staff each day, and many of these visits are not scheduled or tracked, there is a need to implement a monitoring system for security purposes such as pharmaceutical shrinkage.

3.1.2 Identification

The second stage of the new human tracking system involved meetings with managerial staff and the system developer, to discuss their needs and requirements. RFID has been selected to track the hospital staff through ‘gates’, to provide real-time data regarding their current location, and also it can be integrated with Smart decision-making. The system developer suggested initially using ZigBee to provide the exact location of

patients and staff, as this could be integrated with the proposed system in the future, if needed. CoPs suggested that the data that could be provided by a RFID system on its own is sufficient at this stage. Also, during the meeting, staff indicated that privacy could be a concern, if staff are required to wear a tag. The proposed system is to support their daily tasks, not to monitor them, and assurances would be given that the system would not be used to impinge on privacy. In addition, a RFID tag is small in size and can be attached to a wristband, and RFID readers can easily be installed close to the entrance/exit gate in hospital wards/departments. RFID will provide information on every tagged human, such as his/her location.

3.1.3 Contextualisation

In this stage, the acquired knowledge concerning monitoring patients and staff location was analysed and interpreted over several meetings (some via Skype conferencing) of the extended CoPs (Doctors, Nurses, Senior Administrators, IT staff and the SHMIS developer). Using RFID technology, as part of the transformation to SHMIS, will allow locating accurately any patients and staff, producing their location history reports and informing about any forthcoming appointment schedules. The overall RFID passive tag is relatively low cost compared to other radio frequency tagging technologies.

3.1.4 Transformation to smart strategy for human tracking interactions though location

This stage of the proposed new human tracking system will require all new patients and staff to have identification bands containing three passive RFID tags. The proposed system would be able to record the time at which patients arrive and leave a ward, monitor their activity within an operating theatre, and identify their exact location in real-time. Patient welfare should be the core responsibility of every hospital. As an example, if a hospital receives negative media attention, due to an accusation of negligence, leading to an internal investigation, as happened locally with Stafford Hospital, then it would be helpful to have a history of the location of staff and patients.

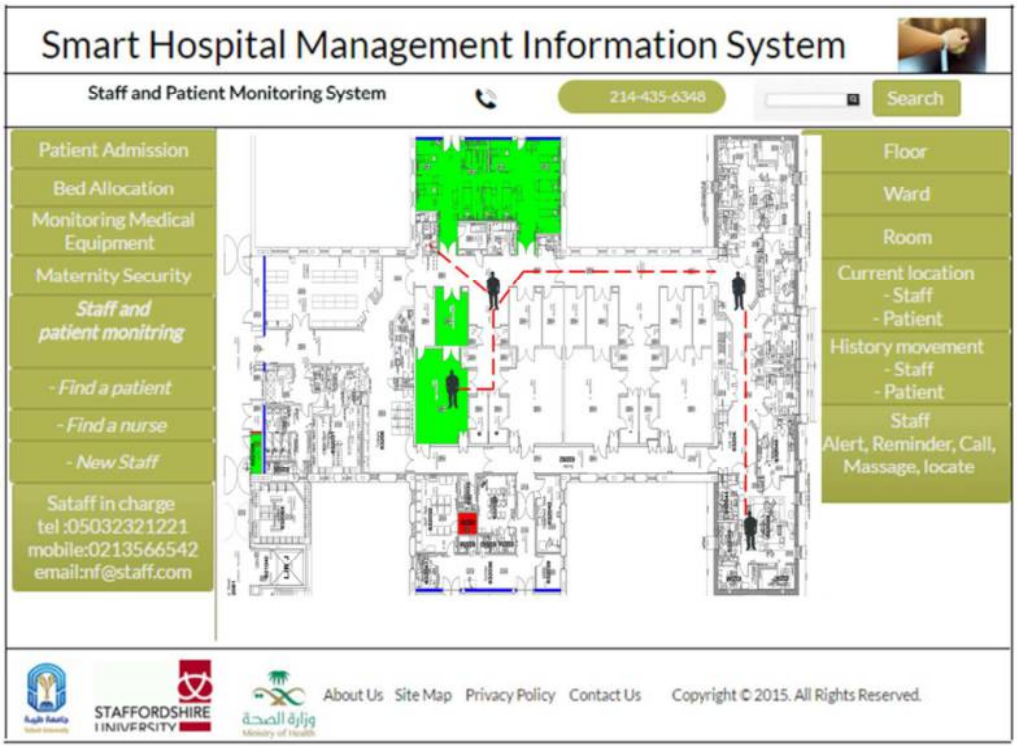

Figure 6 Proposed Human Tracking System

Figure 6 shows the visualisation of data that could be used by hospital staff. The integrated KRDS module for decision support will help indicate the location of the medical staff nearest to the patient and will find the best solution or recommendation. In the event of unexpected or unexplained movement of patients or equipment, a warning message will be sent to the nearest available member of staff. The system can also be used to verify

staff locations in the event of accident or emergency. This visualisation data will be clearly presented on the hospital floor layout to allow quick identification and location, in order to make Smart decisions.

3.1.5 Discussion

As part of the evaluation of the human tracking system and of the evaluation process, the system developer tested the ability of the system by tagging several colleagues. The identification bands containing passive RFID tags were used. The RFID test equipment was installed in the research centre area. When a tagged person left or entered the laboratory, the passive RFID tags attached to a person wrist were detected by the RFID readers. This was then recorded by SHMIS database automatically in real-time. The test showed that all the people tagged were identified and that the data were recorded.

3.2 Study 2-Maternity Security

The key issue with maternity security is to prevent children being taken from hospitals and mismatching babies and mothers. Video cameras provide limited security, whereas smart tags are able to provide real-time tracking and location (Heraldsun 2015; Alyaum 2011). The Maternity and Children's Hospital in Medina has used the 'Hugs and Kisses' tagging system as shown in Figure 7, which uses RFID technology. However, this type of tagging does not provide a comprehensive security system as the battery is not rechargeable and the signal can be read from different floor. The problem with the current system is its use of an active RFID tag. Furthermore, the present Hugs and Kisses system in MMCH has no tracking capability. It is similar to an electronic tagging system used by police forces. Also, Hugs and Kisses do not provide a real-time update about exact location. For example, it can only indicate that a baby is taken from the hospital ward. This study investigated whether the proposed transformation to a Smart hospital system could include improved security for the maternity unit.

3.2.1 Knowledge Acquisition

The first stage of the new maternity security system is knowledge acquisition from the expert professionals (doctors, nurses, senior administrators, bed Manager, and IT staff), who are involved in the Maternity Security as well as the technology provider who has knowledge of optimising the system. Several meetings were held (some via Skype conferencing) with the expert professionals, to discuss the present process of Security and how the present system could be improved. Discussions took place at MMCH regarding the possible abduction, mismatching, swapping, or mixing up of babies, and about staff satisfaction with the present Maternity Security System, along with possible improvements and human error in maternity security.

3.2.2 Identification

The second stage of new maternity security involved meetings (some via Skype conferencing) with doctors, nurses, senior administrators, IT staff, security staff and the smart system developer, to discuss needs and requirements. The new requirement is to have an exact location of every baby in the hospital ward in real-time, and not just when a baby leaves the ward or re-enters it. A combination of two technologies, RFID and ZigBee, was chosen to meet this requirement. The size of RFID passive tag is comparatively small and it is flexible enough to allow it to fit to a new born baby. Also the ZigBee tag is small and can be fitted on to the legs or arms as a form of identification band. RFID has a fixed ID, which is automatically programmed and monitored by the IT department in the hospital. It can be re-used but cannot be changed. The proposed system will use sensor technology to track, locate, and prevent incidences of abduction, mismatching, swapping, or mixing up of babies in the hospital. Sensor devices will provide information on every tagged baby and staff member, such as their location and timestamp. This information will enable the hospital staff to make competent decisions regarding several issues, such as queries, alarms and related triggers, as well as to detect anomalies, recognise specific behaviours and operate between hospitals wards. Furthermore, it will enable the provision of information about ward staffing and patient requirements. .

3.2.3 Contextualisation

In this stage, the acquired knowledge concerning monitoring patients and staff location was analysed and interpreted over several meetings (some via Skype conferencing) of the extended CoPs (doctors, nurses, senior administrative staff, IT staff and the system developer). Using both RFID and /or ZigBee technologies will allow to locate accurately any babies, identify staff who were responsible for treatment last time, produce history movement reports and inform about any forthcoming appointment to see a doctor, for X-ray, etc.,. The

overall cost of a ZigBee and RFID passive tags is outweighed by the potential loss or miss-match of a baby (Alyaum 2011).

3.2.4 Transformation to a Smart maternity security system

The proposed Smart maternity security system would be able to record the time at which a baby arrives and leaves a ward, monitor their activity, and if non-authorised persons are on the premises. In the proposed system, babies will be provided with both an RFID tag and a ZigBee tag in the form of two small bands, one applied to the baby's wrist and one to the ankle. The ZigBee tag will provide location data. Figure 7 shows the visualisation of data that could be used by hospital staff. In the proposed system, the combination of ZigBee and RFID is designed for two reasons, firstly to provide access control and location position, and secondly, to use low power output. ZigBee devices offer a larger coverage to monitor and to confirm the location of the babies and continually monitor their movement. The proposed system combines sensor technologies with the KRDS module for decision support, and will allow Smart solutions and recommendations based on CoPs knowledge.

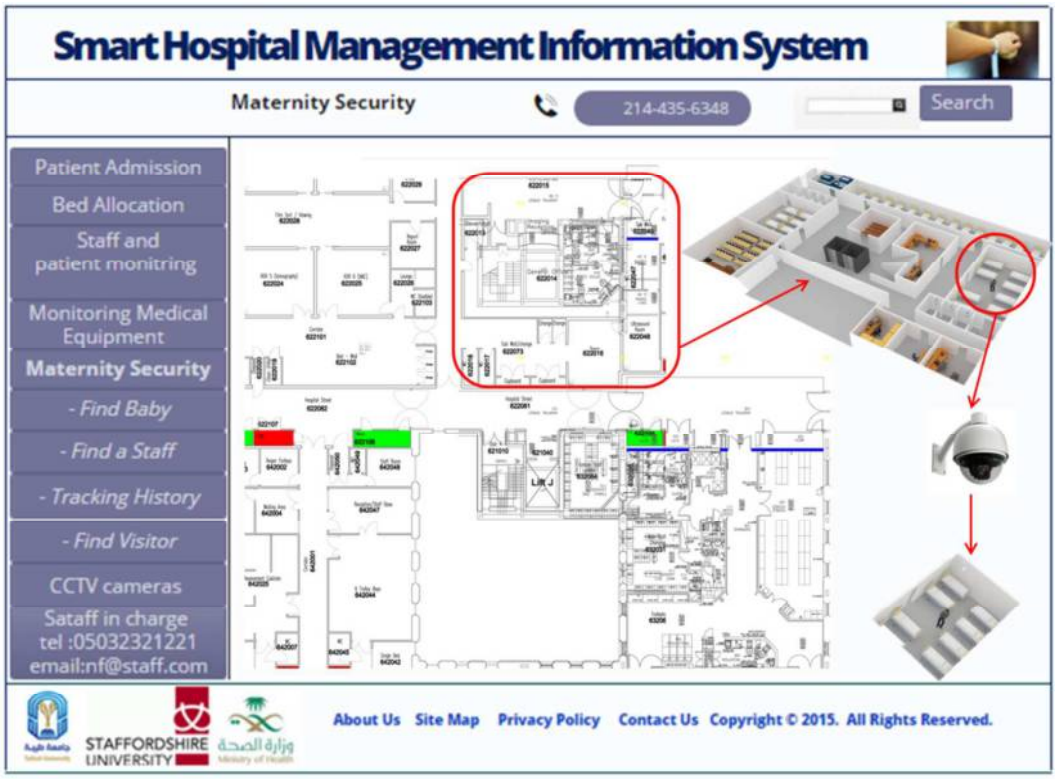

Figure 7 Proposed Maternity Security System

This visualisation data will be clearly presented in relation to the hospital floor layout and will allow quick identification and location, in order to make smart decisions. The system will be able to give an exact location of a baby and the nearest hospital staff. Visitors will also be tracked and monitored, to increase security issue in the Maternity ward.

3.2.5 Discussion

Under the Proposed Maternity Security System human tracking system, and as a part of the evaluation process, the system developer tested the system by tagging several colleagues with RFID tags and a separate ZigBee band. The RFID and ZigBee test equipment was installed in the research centre area, in order to test the efficiency of the proposed new system and to identify and prevent anomalies. When a person is leaving or entering the laboratory the location data RFID would activate the RFID 'gates' to be locked down and ZigBee would provide the exact location in real-time. This data will be stored on the database automatically in real-time.

3.3 How is the proposed system different from the traditional system?

Currently there is no automatic healthcare tracking and monitoring system for patients and asset tracking in Saudi Arabia, and many hospitals still rely on manual operation to collect the 'object' data (Alharbe & Atkins 2015). The healthcare systems in Saudi Arabia are not operating in real-time and this could result in the hospital staff having difficulties in obtaining up to date information. For example, equipment and patients real-time display location and bed allocation are not available in real-time. Also, exchanging this information between hospitals (sites) is time-consuming. According to the statistical data, a nurse spends up approximately 60 minutes per shift searching for medical assets (Dare 2009).

In the case of MMCH, with more than 950 nurses this could result in significant time lost and consequent cost. Also, there is a strong need for managing thousands of staff, patients and guests, which creates a complex environment. Furthermore, asset management, such as bed allocation and locating mobile medical equipment, is extremely time consuming and requires human involvement that is labour intensive. The integration of RFID and/or ZigBee technologies combined with CoPs experts' knowledge and a KRDS module for decision support can be a solution to the above issues.

Presently, some Saudi hospitals already use RFID technology, with the "hugs and kisses" system using active tags. However, it was reported that the main issues are related to the high cost of maintenance, as the battery cannot be charged and technical issues mean that there is no tracking and location capability. Staff require special training to use the Hug and Kisses system, which means it, is more complex to operate than the proposed system. RFID and/or ZigBee technologies can automatically scan and use non-contact and non-intervention for tracking objects. The users of the proposed system will be able to receive real-time information and visualisation of objects such as patients, staff and equipment location throughout the hospital, which will improve the management information systems and provide more effective decision support systems.

3.4 Main Benefits of the Proposed Transformation to a SHMIS

As a result of discussing the proposed system with CoPs a number of potential benefits, have been identified and presented in Figure 8. These benefits are also based on systems that used sensor technologies in other applications.

- Real-time access to data, by providing an up-to-date database covering every tagged objects information, which can be accessed by hospital staff at any time. Availability of these data includes current and previous records.
- Improved quality of care, by providing better management of both medical staff and equipment. Also, a quick location of objects such as patients, staff and medical equipment, providing a better coordination to response in various situations.
- Improved risk management, by allowing frequent and fast device auditing across all hospital wards, reducing the risk of utilizing potentially faulty and un-maintained equipment. The system can inform medical engineers or admin staff about the service status of medical equipment.
- Record of experts' knowledge, in order to improve and continuously monitor the status and quality of medical staff and patients.
- The production of real-time and historical reports will provide data to enable routine tasks to be scheduled and implemented more efficiently Cost reduction, by saving a large portion of time by automatically managing data with less time consuming manual tasks.
- Increased security, to prevent the loss of mobile medical equipment and unauthorized access to hospital wards.
- It could allow monitoring of healthcare services.

Future work could include expanding this approach to the entire Saudi National Health Service.

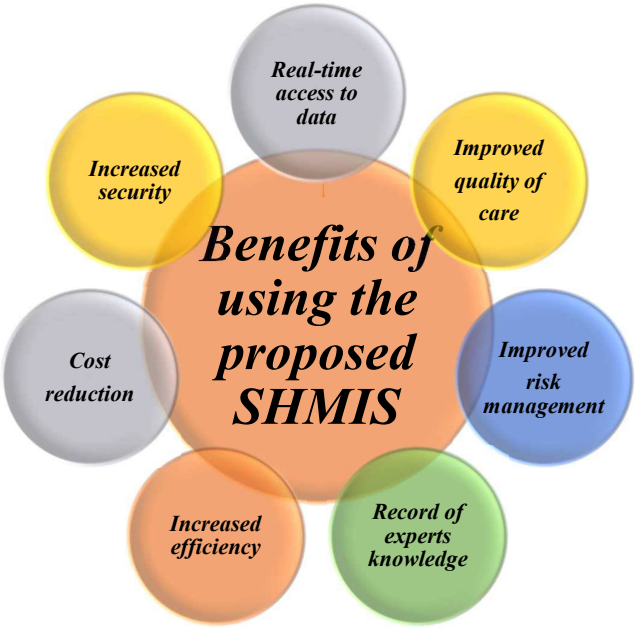

Figure 8 Main Benefits of Using the Proposed SHMIS

4. Evaluation

Knowledge Reasoning for Decision Support System, combined with data from sensor technologies for a hospital system could help determine how best to improve and transform expert knowledge for improving future operational and staff performance. It would greatly enhance maternity security, by reducing the risk of accidental events and by reducing the chance of cross infection between babies, which is mainly caused by health professionals and unmonitored patients and visitors.

In the proposed system, the ZigBee tag has a lower RF output (compared to RFID technology), thus it will be used in the maternity department to periodically monitor infant location. If an infant is moved by an unauthorised person (which could be someone from outside the hospital or a member of staff with no authority in that area), the location data from ZigBee will activate the RFID 'gates' to be locked down. The proposed system was evaluated to check if the data from both RFID and/or ZigBee, with the help of a KRDS module, were able to activate a 'lock down' of the door entry system to prevent the unauthorised movement of infants. The system gives also real-time location of human and medical equipment and bed management. This could be integrated with CCTV images for evidential purposes to both static TV monitors and Smart phones. The integration of RFID and/or ZigBee technologies and its feasibility were evaluated from Senior hospital management staff. The evaluation of the proposed SHMIS requires the use of quantitative and qualitative approaches, such as testing the ability of the system and the feedback. The feedback investigation was conducted by collecting feedback from the senior managerial staff at the hospital, rather than from users of the proposed SHMIS.

The interviews were conducted in English and were arranged with the senior administration staff, including the Hospital Director, IT Director, Hospital IT Manager and the Head Nurse. Following this, the system was explained in detail, to allow the hospital staff to ask questions. Then, the structured interviews were conducted with both quantitative and qualitative feedback. The answers have been scored using Likert scale 5-1 where 5 represents the most positive response, 3 is neutral and 1 is the most negative.

Table 1 Overview of Feedback Investigation

Questions	***Participants***				Conclusion
	P1	P2	P3	P4	
	Hospital Director /10years experiences	Hospital IT Director /8years experiences	Hospital IT Manager /8years experiences	Head Nurse 5years experiences	
Q1-Do you think the proposed system for providing information about the monitoring and tracking of patients would provide more informative results than the current system?	5	4	5	5	Strong support
Q2- Do you think the proposed system for providing information about the monitoring and tracking of assets (e.g. defibrillators) would provide more informative results than the current system?	4	5	5	5	Strong support
Q3-Do you think that staff would find the proposed system intuitive and easy to use?	4	3	4	4	Staff seen as the most problematic
Q4-Do you think staff will accept the proposed new system?	4	4	5	5	Strong support
Q5-Do you think the proposed new system will be beneficial to patients?	5	4	5	5	Strong support
Q6- Do you think the proposed new system will be beneficial for the hospital?	5	5	4	5	Strong support

4.1 Feedback

Overall, the feedback investigation indicates that the higher level of administration in MMCH is in agreement that the proposed system would provide for the requirements and would benefit both patient and staff. Table 1 shows the individual responses and the average score. The majority of the participants strongly supported the

conclusion that the proposed system will provide more informative results than the current system, in terms of monitoring and tracking of patients and assets. Intuitive and easy use of the proposed system were seen by the staff as the most problematic elements. The feedback indicated that work would need to be done with the staff to ensure their acceptance of the system, and that the prototype interface would need to be further developed to increase ease of use; for example, the current interface is in English and would need to be in Arabic. Compared to other questions, the participants gave lower scores in this section of feedback. However, most of them were positive and only one was neutral. The reservations may come from lack of understanding of technology. Therefore, appropriate induction and training for staff could help to resolve this issue. Also, the participants agreed and strongly supported that the staff of MMCH will accept the proposed new system. Furthermore, the majority of the participants strongly supported the conclusion that the proposed system will be beneficial to patients, as well as beneficial for the MMCH in general. The proposed system can provide benefits to the MMCH, and can be implemented in a hospital environment as the maternity department, who are already familiar with sensor technology.

The overall feedback received from this investigation is very positive: all participants supported the idea of implementing the proposed system in the hospital environment as it will result in a number of benefits.

- **Hospital Director comments:**
  The implementation of the proposed system would result in improvement of hospital security and reduction of waiting time, which would lead to higher performance and patients' satisfaction. This was a positive comment that matched the predicted benefits. However, there was a suggestion to tag all visitors, to achieve full security in the hospital environment. This suggestion can be considered from two points of view. First, from the technology point of view, this is not an issue, since the RFID and/ or ZigBee tags can be unique identifiers. The second point of view is from a management team, and it is that this will increase the running cost. Although visitor ZigBee tags could be re-used, this will require additional training for the staff and, potentially, it would increase slightly the time needed to register all visitors. However, security should not be compromised, as the benefits of tagging all visitors are very important, especially in the maternity unit.

- **Hospital IT Director comments**: The IT Director can see clearly the benefits of implementing the proposed system, which include reduction of cost, as the passive tags are relatively cheap and can be disposed of. However, the IT Director was concerned on how to link the proposed system with the current system. The proposed system should replace the existing manual system with minimal effects on patients and hospital operations. The IT Director option is to run both systems simultaneously (for a few months) to allow staff to familiarise with the proposed systems, and add any other functionality as made possible by budget constraints.
- **Hospital IT Manager comment:** The Hospital system programmer pointed out a number of benefits of the proposed system, such as: detection of abnormal events and prompt notification to relevant staff, effective communications, reducing the wasted time, raising the quality of care by providing accurate and reliable data, providing performance measurements, better utilisation of hospital resources, improving patients' care. Some suggestions were made as to how the data could be visualised in a more efficient and clearer format and in the Arabic language.
- **Head Nurse comments:** The Head Nurse stated clearly that the new system will allow the nurses to quickly locate mobile medical equipment, which is currently an issue. The suggestion was to link the sensor tracking data from medical devices with the hospital CCTV system. This can also provide additional evidence in case any equipment is missing.

Based on the above comments, the proposed system developer will consider issues related to staff and patient acceptability. Some staff could be anxious about recording and tracking their location and some patients may also have concerns. These issues will need to be addressed before deployment and during training sessions.

5. Discussion

Group commitment is important for obtaining the knowledge from the experts. However, this depends on culture, management style and communications between staff and management. The SECI model of knowledge creation could be decomposed into three levels, as suggested by (Andreeva & Ikhilchik 2011). This was applied in the application of the SECI model in the Russian cultural context. The results suggested that more fine-grained analysis could be obtained (Andreeva & Ikhilchik 2011). The majority of the technological components required in building a Smart hospital environment are becoming readily available on the market. Currently, in academia (Fuhrer & Guinard 2006; Chernbumroong et al. 2010; Ruan et al. 2011; Tsay et al. 2012; Aminian & Naji 2013) and industry (Tapia et al. 2012) many systems are under development and there are some commercial systems (Orlov 2009) that are now capable of providing monitoring services. It is essential,

however, that any transformation includes knowledge sharing of experience in healthcare organisations, in order to build smart and deployable systems that allow the users a dynamic control of objects and transform operational processes, while minimising any potential risks to the "objects", such as patients and staff.

The KRDS module will be integrated into the hospital to effectively support healthcare tracking and monitoring system goals. By integrating specific hospital information, with functionalities that accept information in formats that are relevant for the hospital, and by providing incentives, users are encouraged to participate in the process and the hospital increases usable information (Pierson 2012). The KRDS was designed to improve operational and staff performance in the hospital environment by providing automatic responses or recommendations in real-time. The effective KRDS module process will take into account the means to harvest knowledge in formats that are relevant for the hospital, including audio, image, video clips or text, in order to increase the reusability of the information. Comments suggested that hospital management staff were unsure of some of the terminology used in the KRDS module. Integrating the KRDS module of decision making into the Smart SHIMS may help hospital staff to see the part their own knowledge plays in the continuous efforts to improve hospital care, and potentially it could lessen their reluctance to share knowledge.

6. Conclusion

This paper starts with a list of key requirements for the proposed Smart Hospital Management Information System that have been discussed in details in Section 2.1. Next, the components of the proposed system are discussed. These include RFID technology, ZigBee technology, Databases, Network infrastructure, Visualisation of data and Reasoning Technologies. The majority of data used to support the proposed system are organised in a relational database system. Furthermore, the system features that were identified by the CoPs and the selected hardware specification are listed. Hardware and software specification and configuration have been discussed. Knowledge from healthcare organisations professional staff, covered by the KRDS module, combined with the data coming from sensor technologies, will help healthcare organisation to make improved decisions. This paper also described two feasibility studies, as possible applications under the proposed SHIMS in order to improve and transfer MMCH system to Smart environment. The KRDS process is used to apply expert knowledge to the different scenarios on, patients and staff monitoring and maternity security (babies). Potential applications were discussed with the senior managerial and operational levels staff at MMCH. The results have shown that the current challenge to the MMCH is the design of a comprehensive and reliable system that would be accessible in real-time for various applications, in order to improve the quality of healthcare services. Such a system would need to take into account all the circumstances and local factors, with emphasis on the human factors. In order to achieve this, hospitals need comprehensive effective management systems, to ensure time is used effectively and to provide prompt and efficient care for patients. Finally, the expected benefits of the proposed system are presented and potential issues and areas for further development are discussed.

7. References

Alharbe & Atkins, 2015. Private communication- Madina Maternity and Children Hospital.

Alyaum, 2011. Infant protection in Saudi hospitals. *newspaper*. Available at: http://www.alyaum.com/article/3004333 [Accessed June 23, 2015].

Aminian, M. & Naji, H., 2013. A hospital healthcare monitoring system using wireless sensor networks. *J Health Med Inform*, 04(02), pp.4–9.

Andreeva, T. & Ikhilchik, I., 2011. Applicability of the SECI model of knowledge creation in Russian cultural context: theoretical analysis. *Knowledge and Process Management*, 18(1), pp.56–66. Available at: http://onlinelibrary.wiley.com/doi/10.1002/kpm.351/full [Accessed June 19, 2015].

Chernbumroong, S., Atkins, A. & Yu, H., 2010. Document Management System using Wireless RFID Technology for Intelligent Healthcare Operations. *IADIS International Conference e-Health*, pp.69–76.

Dare, F., 2009. The High Cost of Nurses' Communication Challenges. *Cisco Internet Business Solutions Groups*, (September 2009). Available at: http://cisco.dnip.net/web/strategy/docs/healthcare/Nurses_Survey_Report.pdf [Accessed May 27, 2015].

Fuhrer, P. & Guinard, D., 2006. Building a Smart Hospital using RFID Technologies. *ECEH*. Available at: http://www.gmipsoft.com/unifr/docs/wp_smarthospital.pdf [Accessed March 25, 2015].

Heraldsun, 2015. Baby given to wrong mum in maternity ward. *newspaper*. Available at: http://www.heraldsun.com.au/news/victoria/baby-given-to-wrong-mum-in-maternity-ward-at-st-vincents-private-hospital/story-fni0fit3-1227276809904.

Ko, T., 2014. Closing the Knowledge Gap: Internet-based Diabetes Self-Management Support System led by Community Pharmacist. , 18(1), pp.7–15. Available at: http://pharmacy-today.co.nz/media/810042/p7_ko_final.pdf [Accessed June 17, 2015].

Nebusens, 2010. n-Core platform. Available at: http://www.nebusens.com/index.php/en/ [Accessed September 15, 2014].

Orlov, L., 2009. Living Independently Group. Available at: http://www.ageinplacetech.com/blog/ho-hum-ge-buys-living-independently-group-quietcare.

Pierson, M., 2012. Designing a knowledge harvesting tool: Lessons learned. *Performance Improvement*, 51(4), pp.21–28.

Ruan, Q., Xu, W. & Wang, G., 2011. RFID and ZigBee based manufacturing monitoring system. In *2011 International Conference on Electric Information and Control Engineering*. IEEE, pp. 1672–1675.

Tapia, D., García, Ó. & Alonso, R., 2012. Evaluating the n-core polaris real-time locating system in an indoor environment. *Trends in Practical ...*, pp.1–8. Available at: http://link.springer.com/chapter/10.1007/978-3-642-28795-4_4 [Accessed March 25, 2015].

Tsay, L.-S., Williamson, A. & Im, S., 2012. Framework to Build an Intelligent RFID System for Use in the Healthcare Industry. In *2012 Conference on Technologies and Applications of Artificial Intelligence*. IEEE, pp. 109–112.