RFID-POWERED REAL TIME LOCATION SYSTEMS (RTLS) SHOWCASING CELEBRATION HEALTH/FLORIDA HOSPITAL

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ABSTRACT

This qualitative case study features the understanding and interpretation of the deployment of a real-time location system (RTLS) powered by radio frequency identification (RFID) by the Celebration Health/Florida Hospital (CH) in Orlando, Florida, U.S., using the structurational model of technology as a reference theoretical framework. Content analysis was used as the data analysis method. Primary data was obtained from transcriptions of the signature talks given by key Celebration Health executives in two major national conferences involving information technology used in the healthcare industry in 2015 and 2016. It is concluded that the structurational model of technology is a useful tool in reconstructing and comprehending the role of the human agents and structures of the organizational context within which technological transitions are made. Information technology alone cannot instigate major change. The human agents involved perform key roles in enacting major business process changes for both incremental and radical improvements.

Keywords: real-time location systems (RTLS); radio frequency identification (RFID); healthcare information systems; change management

INTRODUCTION

Hospitals in North America, specifically the U.S., have unique challenges to deal with as the provision of universal healthcare in itself has become an explosive political issue. The cost of providing healthcare has become an economic, financial, and political time bomb igniting opposing views about how it should be provided and financed. Regardless of this baggage, one thing that hospitals face, for sure, is the pressure to cut costs while providing increasingly responsive and innovative medical services to diverse patient populations.

The use of RFID-enabled real time location systems is not new in the healthcare industry and the literature has featured selected case studies of the use of RTLS systems for patient, personnel, and asset monitoring [1]. The simpler deployments involve tracking physical hospital assets: Dallas' Texas Presbyterian Hospital, for instance, uses an RFID-powered RTLS to monitor assets like hospital beds, wheel chairs, intravenous liquid poles, etc., throughout the hospital estate [2]. This has led to 15 percent savings in time spent by the medical staff locating these assets and US$30,000 monthly savings in equipment rental fees. In a slightly more complex deployment, the German state of Thuringia's University Hospital of Jena uses an RFID-enabled RTLS system supported by the SAP NetWeaver platform to match and track prescribed medications administered by the hospital's pharmacy with the patients [3]. A significant outcome was the drop in the incidence of undesirable medication side effects among patients, thus, raising the quality of medical treatment and patient recovery.

The next level up in system intricacy is the use of RTLS systems to track patients, medical personnel, and assets. The Royal Wolverhampton Hospitals National Health Service Trust in England uses an RFID/RTLS system to track patients, medical staff, selected physical assets, and enforce hand-hygiene compliance [4]. The Toronto University Health Network is also using an RTLS system to prevent the spread of certain infections by tracking patients, medical staff, and medical equipment [5].

This case study features the deployment experience of Celebration Health/Florida Hospital in introducing an RFID-enabled RTLS system to track patients and medical personnel/nurses in order to drive a data analytics-based culture that supports streamlined and smoothly flowing and coordinated business processes.

LITERATURE REVIEW

RFID and RTLS in Healthcare

Real-time location systems (RTLS) are an information technology solution designed to track people, objects, equipment, etc., in real time within defined confined spaces [6]. RFID tags were used in the earliest implementations of RTLS systems in the late 1990s, which are typically attached to objects or people intended to be tracked and the tags broadcast wireless signals to fixed reference points like WIFI nodes, RFID readers, etc. Location information for people and/or objects is, then, reported and shown in a computer screen or monitor. The flexibility in designing RTLS systems stems from the fact that both RFID tags and the fixed reference points can both transmit and receive signals. The healthcare industry accounts for a sizeable portion of the current demand for RTLS systems; thus, the RTLS market is expected to grow at an annual compound rate of 38 percent according to Technavio in its report, "Global Real Time Location Systems Market, 2014-2020" [6].

Celebration Health/Florida Hospital

This case study focuses on Celebration Health/Florida Hospital which is part of the Adventist Health System in Florida, which has about 24 campuses in Florida, U.S. [7]. As of 2016, the specific area targeted for the RTLS system was about a 204-bed campus, where new physical units were started to be built and where the hospital top management wanted to introduce information technology to boost its innovativeness and competitiveness in the Florida healthcare market.

Structurational Model of Technology

This study applies Orlikowski's "Structurational Model of Technology," [8] [9] to understand how information technology(IT) interacts with organizations. The structurational model of technology discusses four critical issues [9]. First, IT is the product of human action, which is responsible for the creation, use, and maintenance of different forms of IT. It is only through the human appropriation of IT that it is able to influence human activity. Second, technology is the medium of human action. Since different forms of IT are used by organizational workers, they mediate organizational work either by facilitating it and in some ways, also constraining it. Third, organizational contexts shape human action within organizations. Human agents are influenced by the institutional properties of their setting which provide the resources, norms, and knowledge they need to work. Furthermore, IT is created and used within certain social and historical circumstances which influence the form and features of this technology. Fourth, human agents either reinforce or transform the institutional properties of an organization when using IT. Weick [10] characterized technology as "enacted environment" whose construction is determined by an organization's structures of signification, domination, and legitimation. Any change in these three structures indicate the "appropriation" and use of technology.

"Structure of signification" refers to the way the concepts and procedures intrinsic to the knowledge embedded in IT directs the manner in which problems are interpreted and work is conducted in the organization [8]. "Structure of domination" refers to IT's ability to control the work of organizational members once it is deployed. "Structure of legitimation" refers to the ability of IT to sanction a particular mode of conducting the work and thus, propagate a set of norms about what is considered legitimate business practice. Orlikowski also incorporates the three modalities of structuration --- interpretive schemes, resources, and norms --- in her application of the structures of signification, domination, and legitimation in the deployment of IT in an organization.

Orlikowski [8] incorporates the following components in her framework: first, the human agents, consisting of technology designers, end users, and decision makers; second, the material artifacts that constitute IT itself, and third, the institutional properties of organizations --- structural arrangements, business strategies, ideology, culture, control mechanisms, standard operating procedures, division of labor, expertise, communication patterns, and environmental pressures [8] [9].

RESEARCH METHOD

This study uses the case study approach in aligning the concepts prescribed by Orlikowski's framework [8] [9] to the RTLS system of CH. The case study is an appropriate methodology in testing the application of a conceptual framework to a real firm. Primary data based on the transcription of the conference presentations of two Celebration Health top IT executives: Ashley Simmons, Director of Innovative Development and Chuck Morris, Senior Innovation Specialist in two key conferences: the RFID Journal Live! 2016 Conference, Orlando, Florida, and the Healthcare Information and Management Systems Society (HIMSS) 2015 and 2016 Conference in New Orleans, Lousiana. In addition, secondary data sources from academic and trade articles were content analyzed using key concepts in the model.

The following are accepted definitions of the content analysis method:

> "Content analysis is any research technique for making inferences by systematically and objectively identifying specified characteristics within text." [11, p. 5].
>
> "Content analysis is a research technique for making replicable and valid inferences from data to their context." [12, p. 21].
>
> "Content analysis is a research method that uses a set of procedures to make valid inferences from text." [13, p. 9].

In this study, the concepts used for content analysis were derived from the structurational model of technology used as both the "context" of content analysis and "prior theory." "Analytical constructs operationalize what the content analyst knows about the context, specifically the network of correlations that are assumed to explain how available text are connected to the possible answers to the analyst's questions and the conditions under which these correlations could change….analytical constructs ensure that an analysis of given texts models the texts' context of use…" [14]. The following key conceptual elements of the content analysis method as stipulated by Krippendorf [14] were used in this study: (1) body of text selected for the analysis; (2) research question that needed to be addressed; (3) a context of analysis within which interpretations will be made; (4) analytical constructs that operationalize what the

analyst knows about the context; and (5) inferences that will be arrived at to address the research question.

FINDINGS

Structure of Domination

CH is facing unique challenges as a hospital in the healthcare industry, specifically, as it operates within the state of Florida in the U.S. CH is part of the U.S. MEDICARE market and as such, Florida residents are allowed to go to any hospital in the state and MEDICARE will pay for services from any hospital [15]. This creates a highly competitive situation in the hospital subsector of the healthcare industry that CH has to constantly face up to. In its effort to remain in the forefront of the healthcare industry in Florida, CH is using innovative technologies that will position it at the cutting edge of innovative healthcare service delivery.

CH's top management decided to incrementally pursue continuous improvement in hospital business processes through the use of the AeroScout software suite. The RTLS initiative for tracking nurses and patients is just an extension of an earlier tracking initiative wherein CH tracked hospital assets like wheelchairs and pumps, etc. [16]. CH had earlier invested in the AeroScout software suite which was acquired a number of years before the RTLS for personnel/patient tracking was started. Top management focused on a number of key points: staff workflow; patient experience; capacity and throughput of hospital units/facilities; safety (i.e., falls prevention; operating room suite and sterile supply; temperature and humidity monitoring; and hand hygiene); and the production of actionable information from the RTLS data [16].

Structure of Signification

Celebration Health's RTLS system consists of the following IT infrastructural elements:

HARDWARE:

1) AeroScout T2 Tags (active RFID WIFI-based tags)
2) Exciters
3) Aruba WIFI network infrastructure
4) CH's Cisco WIFI network infrastructure

SOFTWARE:

1) AeroScout Location Engine
2) AeroScout MobileView
3) Celebration Health's business management software
4) Microsoft Excel; other CH business management software and analytics software like Tableau

On the hardware side, the first asset which is the AeroScout T2 active RFID tag, which is the most advanced WIFI-based active RFID tag that can be attached to people and various objects that need to be tracked and monitored. In CH's case, the battery-powered T2 tag is used for the patients' wristbands and for the nurses' badge clips. Messages coming from the T2 tags are processed by standard wireless access points or WIFI nodes [17]. CH's Cisco WIFI nodes installed throughout the hospital receive messages from T2 tags that transmit at 2.4 GHz [18]. T2 tags broadcast the unique identifiers of both itself and the exciter that triggered it, to nearby WIFI access points. T2 tags have choke-point detection capabilities, which means they can immediately be detected by exciters as the tags pass through choke points such as doorways or portals. Selected T2 functions of note are the following. T2 tags may be turned on and off and their transmission rates could be modified. T2 tags also have "call button

messaging" which enable the hospital staff to define events represented by the button pushed on the tag. Events like emergency alerts or reporting can be enabled by the push of a button and the staff can use the number of clicks to signify specific events (i.e., one click for sending message one and two clicks for sending message two). The T2 tags are also programmable --- up to 10 messages of 10 bytes each can be embedded in them. Thus, pre-programmed messages from the tag manager software or exciter may be executed when the tag is within range.

The "exciter" is a device that uses low-frequency signals (at about 125 kHz) to trigger the T2 active RFID tags as they get within the exciter's range [19]. Upon being triggered by exciters, T2 tags sends messages which are received by WIFI access points to provide instant notifications on the presence of persons or assets in a defined area. At CH, exciters are installed in patient rooms, some hospital gathering areas, common nursing areas, and entrances [18].

On the software side, the AeroScout "location engine" uses complex algorithms to transform data from the T2 tags and WIFI networking devices into accurate location and status data sought by end users [20]. This software also processes and analyzes signal strength, time-of-arrival, and presence data that AeroScout location receivers and WIFI access points beam to it. This software also easily integrates with major enterprise wireless local area network systems and also works with AeroScout's MobileView software in supporting enterprise-wide visibility and tracking applications.

AeroScout's MobileView software receives data from the T2 tags, WIFI clients, etc., and processes the data to produce dashboard visualization, reports, alerts, and visibility data to third party applications [21]. MobileView applies a consistent set of business rules to all hospital data gathered and presented to it. MobileView is supported by the MobileView platform which lends specific applications unique functionalities/features [22]. The MobileView platform enables end users to track persons or objects of interest and their status at specific locations; manage the assets and T2 tags used to track persons and objects; and set up event monitors that send alerts when certain conditions are met or when certain business rules are fired.

The new tower of CH has 31 patient rooms that are covered by the Stanley Healthcare RTLS system which sits on the hospital's existing CISCO WIFI network infrastructure [18]. T2 tags embedded in patients' wristbands and nurses' badge IDs generate data received by the WIFI network nodes, which, then, forwards it to the AeroScout MobileView software for processing.

Business Processes Supported by the AeroScout RTLS System

The following is a recreation of a typical business process involving nurses and patients. When a patient comes in early in the morning for surgery, he/she registers at the hospital waiting room. Hospital staff in the waiting room take the patient information and immediately identify the pre-operation procedures that need to be undertaken and where the patient needs to go [16]. The patient is given a wristband that has an embedded active T2 RFID tag; upon wearing the wristband, the patient's name immediately appears on a computer monitor and it also indicates that the patient is waiting to go to surgery. There is another monitor in the waiting room where the patient's family members are waiting. The location and status of this particular patient also shows in that computer monitor in a format that is appropriate for the end users (i.e., family members and friends) in that waiting room. The monitor informs them of where in the process their loved one is; for example, it tells them if the patient is already in the operating room, how long the surgery will take, and the other steps that need to take place after surgery and where the patient will be after the operation.

In the meantime, the hospital staff in the pre-operating unit (pre-OP) is also informed that the patient is in the waiting area already and they are alerted to set up the pre-OP area before the patient's arrival. This takes about an hour. Someone will fetch the patient from the waiting room and take him/her to the pre-OP room when it is time to do so and prepare the patient for surgery. Once prepared, the patient is wheeled to the operating room (i.e., OR) for the surgical procedure.

The following data/information is provided by the RTLS system as a result of patients wearing T2 active RFID tags on their wristbands, and nurses and other medical personnel who also wear T2 active RFID tags on their identification badges: (1) room status information to indicate when the room is ready for the next patient; (2) operational summary of all surgical services in real time; (3) information on what is currently happening in the waiting area, pre-OP room, OR, PACU (i.e., recovery unit)/Phase 2; (4) identification of delays in the patient flow through a process, giving the medical staff the change to mitigate/manage the delays; and (5) information that allow the medical staff to compare actual performance versus key performance indicators [16].

Nurses are alerted when the patient is about to complete the surgical procedure. While in the OR, a nurse will push a button in the patient's wristband and hold it for three seconds to activate the message, "Ready for Unit" in the monitor. That message alerts the nurses in the next stop that the patient is ready to be transferred to that unit. In the meantime, the staff has already pre-assigned the patient to a post-OR unit or room and to a nurse based on the information provided by the RTLS system. In the meantime, if something unexpected happens in the OR --- like a patient's blood pressure dropping unexpectedly or the patient's pain increasing, the attending nurse can write a digital note explaining what is happening and announces that there will be a delay in the patient's arrival in the PACU unit, the main recovery unit. Nurses eventually attend to the patient in the PACU unit to stabilize him/her post surgery and prepare him/her for the next stage.

Structure of Legitimation

The RTLS initiative at CH has attained a "structure of legitimation" due to a number of developments recently in the healthcare industry. Having "structure of legitimation," RFID item-level tagging has been the technological means by which hospitals have sanctioned a specific way of developing information systems to address certain business operations needs and propagate a set of norms about what is and what is not "professional" social practice within the industry. By using RTLS systems to track and monitor people of interest (i.e., nurses, medical staffers, and patients), CH is showcasing a "model system" that could be emulated by other hospitals in North America and for that matter, in the entire world. CH RTLS system success legitimizes its innovative hospital-related business processes empowered by Stanley Healthcare's RTLS system.

The other pillar supporting the "structure of legitimation" are the initiatives of GS1, a non-profit international organization that develops and maintains standards for supply and demand chains across industries. GS1 has a healthcare working group that addresses the development of standards needed for supporting RFID and RTLS systems used in the healthcare industry. Standards are needed to oversee the functioning of the different elements that make up an IT system in order to provide visibility. So, therefore, for an object to be visible in a business process, there is need to first identify an event, capture information about that event, and then, share information about it to end users who need information about that event [23]. Standards developed to ensure interoperability among the hardware components of an IT system also help organizations support "best practices" in using and managing its physical assets and business processes. In the case of RTLS systems which use different wireless technologies, the hardware devices involved in such systems can use standardized Global Location Numbers (GLNs) to identify exact physical locations and use Global Individual Asset Identifiers (GIAIs) to uniquely identify specific equipment units. Such standards also enable hospitals to use a wide range of IT solutions rather than being constrained to proprietary systems with limited applicability. Software developers and IT administrators also benefit in that they can freely develop new business applications without having to use customized/proprietary serial numbering

systems [23].

Social Structure and Social Consequences of the RTLS System

The most significant change structurally for CH was the elimination of siloed hospital units which resulted in disjointed business processes and lack of continuous communication and information/data flow among hospital units and medical personnel [16]. The second major structural improvement was the emergence of collaborative efforts among RFID and RTLS vendors with Stanley Healthcare as captain, in their drive to develop innovative solutions to [16] address problematic issues at CH. It were as if CH brokered these third party collaborations to serve CH's needs [16]. The third major structural improvement was the enhancement of the hospital culture that transitioned into a more trustful and collaborative entity in order to successfully implement an RTLS system that was basically tracking physical movements of key medical personnel, without introducing an atmosphere of paranoia and negative "Big Brother" watchfulness that could have harmed personnel morale. CH management won medical personnel trust in a number of ways: (1) CH empowered medical staffers by having them participate actively in different stages of the systems development life cycle [24] ---end users designed their own graphical user interfaces (GUI) in the form of dashboard designs/formats for the computer monitors mounted throughout the hospital and they specified data they needed to see in dashboards; (2) CH waited for nurses to experience the benefits of having the RTLS --- specifically, drastically reduced phone calls and greater attention paid to patients --- which led to higher nurse morale; and (3) in terms of policy repercussions, reassuring them that visibility data will not lead to punitive actions/penalties to nurses and medical staff (no "Big Brother" effect).

Action and Social Consequences of the RTLS System

The most important change all stakeholders valued after the RTLS implementation was the significant drop in the number and frequency of phone calls between and among medical personnel [24]. This is one aspect of the drastic business process improvements management and medical staff noticed was taking place in the hospital. Medical staff also significantly improved their relationships with patients and their families and friends who now have access to the patients' status information during their hospital stay. Interactions with the patients and their families are now more meaningful and supportive, rather than just responses to request for information.

Another important "action" change is the introduction of basic data analytics skills through the use of the RTLS data processed in MobileView software for simple visibility/tracking end user views in the monitors, and also for more advanced data analysis reporting using software like Tableau by hospital end users who are more skilled with data analytics and have more complex analytical tasks to perform [24].

CH expressed major learnings primarily for the IT support staff after this RTLS deployment experience [25]. First, CH found that it was far more difficult to make changes to the the visual maps of the different elements of the RTLS infrastructure once the exciters, cells, and zones have been added. Second, CH emphasizes the importance of reliable IT infrastructure support for the RTLS system requiring the collaboration between the teams supporting the network and the RTLS system. Third, when it comes to data management, the structure of the RTLS database must be understood very well in order to perform effective data analytics; consistent and frequent data backups are also critical. Fourth, RTLS systems are complex and they have many "moving parts"; implementing system enhancements, if not done carefully, could have many unanticipated repercussions when changes are made to one area/module of the RTLS environment.

Measures of Success

The following are the key measures of success of the RTLS system that CH recognizes: (1) "Improved communication with visibility boards in the surgical waiting room, gives family members peace of mind of knowing the real-time process and general location of their loved one"; (2) "6-16 minute decrease in

PACU hold times from when a patient meets release criteria to when transported to an acute care unit"; (3) "Total recovery times are significantly more predictable, on average 20% less variation"; and (4) "75% reduction in calls between departments to confirm basic information, which is now displayed through dashboards" [7].

CONCLUSIONS

To recap, the structurational model of technology has been a useful tool in understanding CH's RTLS system implementation experience. The crux of this theoretical framework emphasizes the importance of human agency in the deployment of any IT system. Technology, alone, will not bring desired changes in the organization. "Structure of domination" clearly demonstrated how motivating factors drove top management and key IT executives in CH to produce the momentum to lead major business process changes in CH to keep up with the competition in the healthcare industry market in Florida, which was under the purview of the U.S. MEDICARE system. Culture change as a continuous, evolving, and sustained experience was a reinforcing element for the "structure of domination" and is one of the key learnings of CH top management and staff. "Structure of signification" described the IT infrastructural elements of the RTLS system that used the knowledge and competencies embedded in the AeroScout suite of selected hardware and software products. The RTLS system directed the manner in which hospital-related business processes related to the entire journey of a patient, from admission to recovery/discharge as visibility was actualized by the RTLS system. "Structure of legitimation" featured the role of the standards body called GS1 in enforcing standards and protocols that would govern: (1) the functioning of hardware and software elements of the RTLS system based on an open platform that would embrace a wide range of original equipment manufacturers' products, and (2) the design of business processes in hospital-provided healthcare services that would encourage and maintain data/information exchange among internal and external entities in the healthcare industry that need "visibility" in order to serve patients' interests best and optimize the use of costly hospital resources. A final key lesson for CH was ensuring that the IT team maintained a robust and reliable IT infrastructure at the backend (networking, databases, etc.) due to the many distributed "moving parts" of the RTLS system.

A possible future direction to take with this research is to pursue a cross-case comparison matrix to detect patterns in the organizational experiences of a number of hospitals and healthcare settings, still using the structurational model of technology. The sources of the data will be similar --- from fairly high ranking administrative officers of these hospitals and content analysis will be employed as well. This is the "top down" view of the RTLS deployment.

Another very different approach in the future would be to take a "bottoms up" view of what's going on from the behavioral standpoint --- especially from the point of view of the medical staffers and patients who will be tracked by RFID tags. A separate branch of research on RTLS technologies using RFID focuses on the privacy concerns and issues surrounding modification of business processes involved with monitoring humans in the hospital setting. An "umbrella" theoretical framework broadly used in this research is the socio-technical theory of organizations. "…understanding the place of these new [information] technologies from a sociological perspective requires avoiding a purely technological interpretation and recognizing the embeddedness and the variable outcomes of these technologies for different social orders…" [26, p. 365].

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