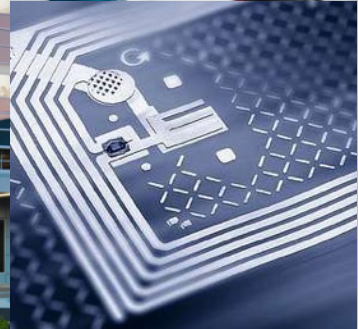




# Hospital 4.0 Consulting Report

*For University of Pittsburgh Medical Center*  
eBConsultants LLP©

**Team Fifteen Minutes**

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## **Table of Content**

|                                      |           |
|--------------------------------------|-----------|
| <b>Executive Summary</b>             | <b>1</b>  |
| <b>Introduction</b>                  | <b>2</b>  |
| <b>Surgery</b>                       | <b>3</b>  |
| <b>Food Services</b>                 | <b>8</b>  |
| <b>Cost Accounting</b>               | <b>11</b> |
| <b>Human Resources</b>               | <b>15</b> |
| <b>Appendix I - Cost Estimation:</b> | <b>20</b> |

## EXECUTIVE SUMMARY

ebConsultants is a technology-consulting firm located in Pittsburgh, PA. Our mission is to provide critical support to clients in helping form, design, and employ technologies to solve complex business problems. This report contains our expert recommendations to the University of Pittsburgh Medical Center in utilizing technology to improve its Surgical, Food Services, Cost accounting, and Human Resources divisions. Using principles rooted in Industry 4.0 and technologies associated with Internet of Things, we recommend the following things:

| System          | Technologies Used                                                                           | Recommendation                             |
|-----------------|---------------------------------------------------------------------------------------------|--------------------------------------------|
| Surgery         | Ceramic RFID Tags, RFID Readers, Medical-grade Terminal Devices, Cloud Servers and Database | Operating Room Management System (ORMS4.0) |
| Food Services   | RFID tags and readers, Temperature Sensors and Actuators, Auto-Heating System               | Meal Express                               |
| Cost accounting | RFID tags and readers, Database software, Touch Screen Tablets                              | Cost Optimum                               |
| Human Resources | IR sensors and readers, RFID tags and readers, Digital vital sign patches, Smart Watches    | Nurse Everywhere                           |

These recommendations are impactful in that they can alter the way UPMC operates. The implementation and deployment of Meal Express, our solution to Food Services problems, will cost UPMC approximately \$6 million. This investment, and all other investments made with these recommendations, will transform the quality and efficiency of healthcare UPMC has to offer to its customers.

# INTRODUCTION

## Overview of UPMC

The University of Pittsburgh Medical Center (UPMC) is a leading institution in medical care. With revenues exceeding \$11 billion and assets valuing at over \$10.5 billion, UPMC has established itself as a successful leader and a model for other hospitals. It brings together the expertise in world-class health with management success in its markets throughout the world (including China, Japan and India) to foster a globally interconnected delivery of healthcare<sup>1</sup>. The recommendations by ebConsultants will maintain this success by introducing a revolutionary application of Industry 4.0 principles to a hospital flow.

## System at a glance

- Our solutions collect and analyze necessary data, using appropriate sensor and computing systems, and delivers the output with valuable findings to related hospital processes instantly.
- This source data is easy to access, track and interpret.
- Our solutions flexibly adapt to changing requirements that UPMC would encounter.
- Our solutions enable machines to make intelligent decisions on their own when tasks are specifically delegated to the system's decision-making trees.

## Overview of Industry 4.0

The recommendations brought forth in this report are rooted in processes of the fourth industrial revolution, Industry 4.0. Industry 4.0 is “triggered by digital technologies” and can “transform the design, manufacture, and service of products and production systems”<sup>2</sup>. It can strongly affect the way companies innovate and sustain a competitive edge in their markets. The merits of Industry 4.0 are indisputable. Research conducted by The Boston Consulting Group has shown “in Germany, [Industry 4.0] alone will contribute about 1 percent per year to GDP over ten years, create as many as 390,000 jobs, and add \$250 billion to manufacturing investment”<sup>3</sup>.

## Report Organizations

We, at ebConsultants, want to bring the success associated with Industry 4.0 to UPMC. Our solutions will transform the efficiency and quality of healthcare delivery and position UPMC among the leading institutions in medical care. In this report, we will address problems in UPMC's Surgical, Food Services, Human Resources, and Cost Accounting divisions by highlighting innovative solutions using principles applied from Industry 4.0 and technologies grounded in Internet of Things.

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<sup>1</sup> “Industry 4.0 – The Capgemini Consulting View”, p 04.

<sup>2</sup> “Industry 4.0 – The Future of Productivity and Growth in Manufacturing Industries”, p 2.

<sup>3</sup> “Industry 4.0 – The Future of Productivity and Growth in Manufacturing Industries”, p 2.

## SURGERY

### Reshaping the Surgery Prep Work with IoT Technology

#### Overview

##### Objective

Reducing risks, while increasing efficiency, in the pre-operation phase of surgeries for UPMC

##### Solution

We are recommending the implementation of our Operating Room Management System 4.0 (ORMS4.0). It is designed to manage the distribution of individuals, instruments, and materials in an operation theatre accurately and in real-time.

#### Problem Statement

Surgery safety is a crucial issue to a hospital. However, a recent study by The National Practitioner Data Bank estimated that “the rate of [surgical errors] in the United States is approximately 1 in every 12,000 procedures<sup>4</sup>”, with human error as a leading cause<sup>5</sup>. Specifically, research indicates that 628 human factors contributed to surgical errors in the past year<sup>6</sup>. These factors included errors such as leaving instruments in patients and cross infections by utilizing unsterilized instruments. To mitigate these errors, we propose an implementation of an autonomous operating room management system that aims to elevate safety, reduce risks, and increase the efficiency of pre-operation procedures.

An operating room management system based on IoT technology would easily trace the real-time information and organize instruments allocation and personnel scheduling efficiently and effectively.

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<sup>4</sup>“How Does Human Behavior Lead to Surgical Errors? Mayo Clinic Researchers Count the Ways” -- Mayo Clinic News Network

<sup>5</sup> Claire Swedberg. “Shimane University Hospital Tags Surgical Tools, Cuts Costs.” RFID Journal. Nov 18, 2014.

<sup>6</sup> Thiels CA, et al. “Surgical never events and contributing human factors.” Surgery. 2015 Aug;158(2):515-21.

## Business Benefits

- Error reduction
- Efficiency improvement
- Increase in surgeries due to reduction of surgery time
- The technology improves the efficiency of emergency surgery preparation, since employees can very quickly locate the necessary tools.

*“it took two to three workers (about) five to six hours to prepare a patients scheduled surgery on any given day. (But with the use of RFIDs) this amount (can) be reduced by 75 percent and the total work reduction for the surgical department can result in a saving equal to or greater than \$300,000 per year.”*

—Tsutomu Sawa, Vice President of Development at KRD Corp, Japanese provider of RFID system.

## Solution

### Overview

In solving this problem, we are recommending the implementation of our Operating Room Management System 4.0 (ORMS4.0). At its core, ORMS4.0 is designed to manage the distribution of individuals, instruments, and materials in an operation theatre accurately and in real-time in order to minimize errors in the pre-op phase.

### Utilized Technology

ORMS4.0 implements solutions simultaneously using RFID technology, medical-grade terminal, cloud service and databases to trace and manage surgical instruments and personals, which includes:

**Ceramic RFID Tags:** a mini, durable, heat-resistant passive RFID tag made from integrated circuits, antenna and memory, which could store unique identification information and communicate passively or actively with a RFID scanner

**RFID Scanners:** physically mounted structures on the gateway of each operating room to communicate with RFID tags actively

**Medical-grade terminal devices:** tablets or other portable devices with touchscreen, Bluetooth communication modules, and voice control function that have access to the hospital wireless network anytime and can interact with computational centers

**Cloud Servers and Database:** existing servers and database of hospital powered by Oracle Exadata Database Machine.

## System Design

The ORMS4.0 is composed by four separate units, which are listed below:

- **User Terminal Unit:** is the user interface of the system. Third-party authorized devices, working alongside with pre-installed ORMS4.0 software, make it possible for hospital staffs to monitor, request, and manage instruments and materials during all phases of the surgical process. Moreover, it allows for alerts to be received by appropriate hospital personnel.
- **Analysis Unit:** is the data storage and analysis center. Based on the existing Oracle Exadata Database Machine of UPMC and surgery related objects' information gathering from the identification unit, the Central Management Unit calculates the optimized instruments and personnel allocation scheme dynamically. Moreover, with the request from user terminal unit and the checking results from the sensor unit, analysis units checks the occurrence of all objects in the operating room and a mismatch would trigger an alert to the user terminal unit.
- **Sensor Unit:** is the data-collecting portal and is the input source of the ORMS4.0 software. It acts as the intermediary between the gateway and the Central Management Unit by reading and computing identification tags on personnel and medical instruments.
- **Identification Unit:** is the distributed identification tag. It is the unique key that allows sensor units to perform its functions by allowing each tagged individual or medical equipment to be registered as a unique entry in the database of the analysis units.

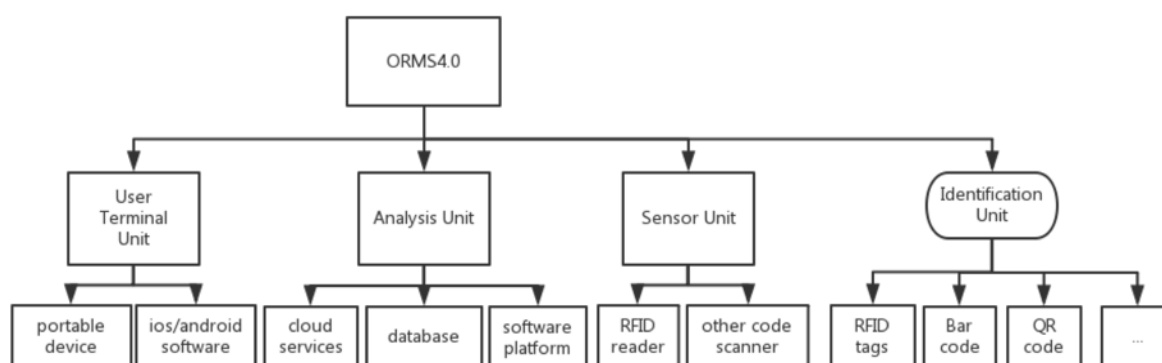


*Figure 1 ORMS4.0 System Diagram*

The working procedure and data flow between each modules of the ORMS4.0 is described below (see Figure 2 for reference):

During the pre-op phase, the user, the appropriate medical personnel such as surgeons, create a request. This request is done via any computer, tablet, or smart phone that has our unique ORMS4.0 software installed. This software allows the user to select two types of requests: packaged or dynamic. Since many surgeries performed are procedural in nature, we allow users to select pre-defined surgery packages. These package requests come with a preregistered “list” of personnel, medical instruments, and materials needed for the surgery. Likewise, the user also has the option to override the recommended packages and choose the dynamic request that provides complete freedom and autonomy over each of the aforementioned three components.

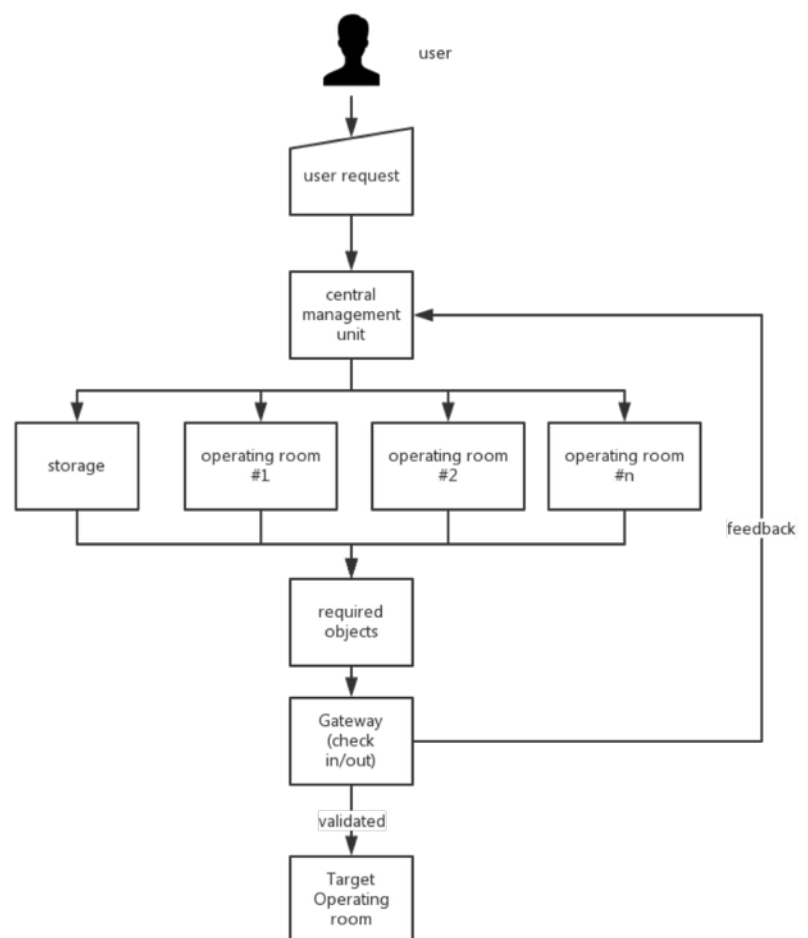


**Figure 2 ORMS4.0 Dataflow Diagram**

Additionally, the user can use both the packaged and dynamic requests simultaneously. Meaning, the user can choose a packaged request but can manually update the required personnel or medical instrument fields as needed. Once the user request is generated, it is sent to the Central Management Unit. When any RFID tagged object is transported through the gateway, the reader on the gateway recognizes the tag, connects the tag data back to the Central Management Unit and registers the tag as either an entry or a departure. An object is registered as “entered” when the system recognizes only one instance of the unique tag and an object is registered as “exited” when the system reads two instances of the same unique tag. This feedback is continuous and the ORMS4.0 software will only notify the user of the authority to use the targeted operating room when the user-generated request corresponds to the data registered from the gateway. In this process, the core function of the Central Management Unit is to crosscheck the user request with the information provided from the gateway that has been preinstalled in every surgery room to determine if the required components of a surgery are in the right place.

Moreover, our design accommodates for the dynamic nature of surgeries. We understand complications occur and the user may need to request additional personnel, equipment, or materials. Therefore, we have incorporated the use of speech-recognition technology while in the operating room theatre. If an unexpected complication occurs, the user can simply request the necessary item by speaking aloud and a speech recognition device will recognize the request, send it back to the Central Management Unit and a new user request will be generated. This time, the Central Management Unit scans its database from other operating room theaters and storage facilities and will notify the appropriate personnel in the operating room as to where the requested item can be found. When this item is brought into the operating room being used, the gateway and the Central Management Unit once again communicate to ensure the correct item is being entered.

## Advantages

ORMS4.0 not only reduces error in the pre-operation phase but also increases the efficiency of the surgery process by reducing the time it takes to set up a surgery. Before this revolutionary IoT based systems, “it took two to three workers [about] five to six hours to prepare a patients scheduled surgery on any given day. [But with the use of RFIDs] this amount [is] reduced by 75 percent and the total work reduction for the surgical department can result in a saving equal to or greater than \$300,000 per year<sup>7</sup>”. The technology is innovative, the results are impactful, and ebConsultants urge UPMC to consider this solution for their Surgical Division.

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<sup>7</sup> <http://www.rfidjournal.com/articles/view?12436>

## FOOD SERVICES

### Food Matters! Using IoT to Serve Patients Hot Meals.

#### Business Benefit

- Improved the patients' satisfaction with UPMC
- Improved the image of UPMC
- Reduced errors occur in the food delivery process
- Heating from chemical reaction costs less money and is less power-consuming.
- Safe precess of food heating

#### Problem Statement

Most hospitalized patients are dependent on hospital food for their nutritional requirements. A review of the Pennsylvania Patient Safety Reporting System (PA-PSRS) found<sup>8</sup> several events involving patients who received wrong diets that resulted in "harm"<sup>9</sup>. This sort of error is quite common across hospitals and many inpatients receive the wrong food. However, hospitalized patients are dependent on hospital food for their nutritional requirements. In trying to improve the food quality services, our research team found that patients felt the temperature, appearance and aroma of the food served to them were particularly important in forming their perception of hospital food<sup>10</sup>. Therefore, our solution will attempt to improve the quality of hospital food by improving the temperature of the food as well as ensuring the correct and accurate delivery of the food.

#### Solution

##### Overview

In attempting to improve the food quality at UPMC, ebConsultants propose a system that ensures patients to receive the right food and the temperature of the food to be at standards, which satisfies each patient's particular needs and preferences. Our system introduces an efficient way to reduce the errors that occur in the day-to-day delivery of hospital food. The smart cart design we propose will sense the temperature of the food severed, then automatically heat

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<sup>8</sup> <http://kolsbygordon.com/attorney-blogs/and-you-thought-that-hospital-food-only-tasted-bad/>

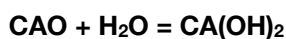
<sup>9</sup> Ibid

<sup>10</sup> Stanga, Roselli, Sterchi, Tanner, "Hospital food: a surgery of patients' perceptions"

up the food with chemical reaction and with the help of RFID technology ensure the right patients are given the right food.

### Utilized Technology

In our system, we introduce RFID technology to identify specific food and specific patients. The system consists of Central Management Unit, Database, Tagging Terminal, Auto-heating Unit and RFID Reader. As for our design of smart carts, we introduce temperature sensors and actuators. The heat in the auto-heating unit is basically from the chemical reaction:



### System Design

Our system data flow diagram is as following:

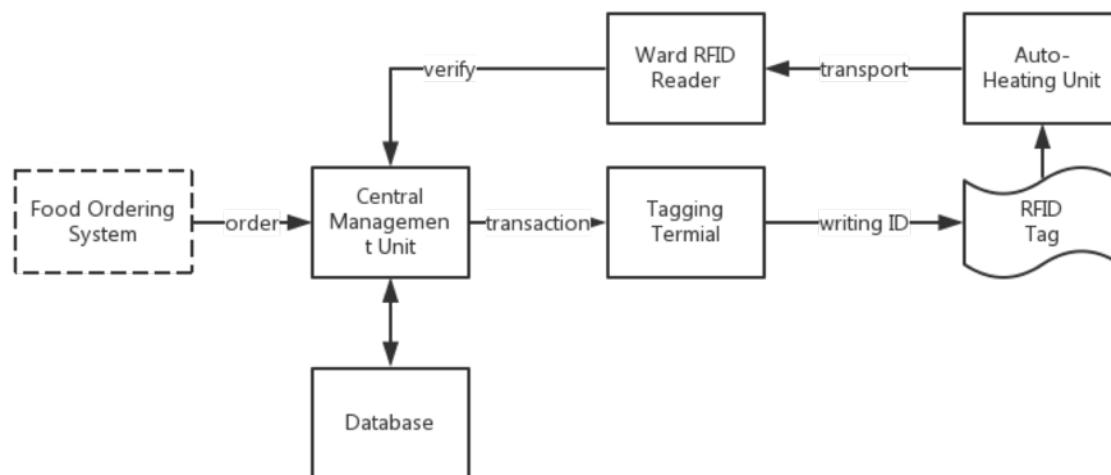


**Figure 3 Food Service Dataflow Diagram**

In UPMC, the food orders are performed by nurses who place the orders in accordance with a patient's medical records and dietary restrictions. Our Central Management Unit retrieves this ordering data from the food ordering system used by the nurses. The Central Management Unit utilizes an internal database that stores the specific food request with a unique RFID tag of a patient. The database will also set a unique RFID to the currently being packaged meal. Then, when the meal is ready to be transported, the RFID tags

are placed on the meal package (which contains information as to which patient the food is designated to go to).

The second part of our system ensures that the packaged meal is actually delivered to the correct patient. We recommend the installation of a ward RFID reader that can be placed by the patient's bedside. When the RFID tag of the packaged meal comes in very close proximity to the RFID reader by the patient bedside, the reader "reads" the tag and checks if the meal is being delivered to the right patient. This information will be uploaded to Central System Unit through UPMC's LAN network. This information will be verified with the data in the database and the delivery process will be allowed only when the unique food RFID matches the unique patient RFID and a green light will light up on the food service cart to indicate this match.

As to addressing heating the food to correct temperatures, ebConsultants recommend the implementation of a smart cart. Each unit within the service cart stores a pre-packaged meal and comes installed with a temperature sensor that works under a certain frequency and can detect the temperature of the food at any given time. The sensor relays this information to the decision making tree of our system. The system decides if the food requires heating; this is done in one of two ways. If the temperature is below 165°F, the required standard established by the U.S. Department of Agriculture, the sensor triggers the actuator which activates the auto heating system. The auto heating system can also be triggered if the temperature is not at the preferred level of the patient, whose input is recorded via a survey that is completed prior to being admitted in the hospital. In the event that the temperature of the food is above 165°F and is at the preferred temperature of the patient, the food is ready to be served.

Once the system decides to activate the auto heating system, the food goes through a complex chemical process. Temperature sensors are placed on the outside chamber, which is connected to the inside chamber with the help of an actuator. Once the sensors detect the temperature, the heating system will calculate the quantity of the water needed to proceed with the chemical reaction. Then, the water tank is pushed open with the help of an internal motor and the desired amount is filtered through. At the same time, the chemical chamber, which is stored with calcium oxide, releases an appropriate amount of calcium oxide that is proportional with the water previously calculated to catalyze the chemical process. As the chemical reaction takes place, the hot gas that is formed as a result is pushed through tiny holes on the top of the outer chamber. This hot gas is the driver behind the heating of the food. After the reaction is completed, the food is heated to the appropriate temperature, with the help of the hot gas, and the temperature sensors are activated. The decision tree is evoked again and in the case that the temperature does not meet standards, this process is repeated until the optimal temperature is achieved.

## COST ACCOUNTING

### Overview

#### The need

*“54 percent of the hospitals have installed cost accounting systems such as Activity Based Costing; these existing systems are relatively unsophisticated, therefore accurate cost improvement is highly data intensive, labor intensive, and change intensive...yet quite necessary.”*

—HFMA in conjunction with Deloitte Haskins & Sells Survey

#### The solution

Technology is implemented to automate the data capture process in order to eliminate the current human element in cost accounting in UPMC and this improves the accuracy of the data capture process and manages the costs burdened by patients.

## Introducing Automated Cost Accounting

### Problem Statement

As it stands currently, UPMC lacks a deep understanding of how to financially audit the accurate delivery of its healthcare services. This obstacle results in incorrect billings and impedes the quality of healthcare provided to its customers<sup>11</sup>.

Since every medical procedure, test, examination and drug has a price, the recording of these services is vital. Currently, nurses manually perform this task. It is very time consuming, error-prone and it distracts nurses from performing actual nursing services. ebConsultants recommends solutions that will improve the efficiency of this data capture process, enhance patient satisfaction and contain costs.

The healthcare industry is in the process of great transformation from manual paperwork to automated online processes. There has been an increased investment on Internet of things in healthcare that has affected all aspects of healthcare services, ranging from costs to patient safety to security and privacy of patient records.

There is significant data showing that medical errors and unnecessary tests boost health care costs substantially. Studies show that one-third of health care dollars are wasted on too much care, too little care or inappropriate care<sup>12</sup>.

<sup>11</sup> <https://hbr.org/2011/09/how-to-solve-the-cost-crisis-in-health-care>

<sup>12</sup> <http://www.aficio.org/Features/Innovators/Bending-the-Health-Care-Cost-Curve>

## Business Benefits

- Implementation of Automatic Data Capture of the Medical Service Process
- Avoiding human elements and errors in cost accounting
- Setting the nurses free of unwanted workload

## Solution Component

### Software

The new algorithm dictates that when multiple RFID are scanned at a time, it analyses the patient's RFID tag to use the information in their prescription database, then compares it with RFID tag of the medicine which was scanned and verifies that this is the correct medicine and dose for this patient and also records that it was given by a particular nurse.

### Sensors

- RFID tag
- Active RFID scanner

Therefore, the problem we are addressing is that nurses are unable to devote their full attention to the treatment of the patients and this lack of attention reduces the quality of healthcare provided by UPMC and also wastes a lot of its resources.

## Solution

### Utilized Technology

We have chosen to use the RFID technology to implement the automation of the data capture process. To execute the RFID technology we replaced all barcodes, which is currently being used by UPMC, from medicine, drugs and other small instruments and replaced them with RFID (NFC) tags.

UPMC does not also have an accurate costing system in place for standard medical procedures, such as blood tests, X-rays, and MRIs. Therefore, we are introducing RFID tags for standardized medical procedures and tests. We also include smart device touch screens, such as tablets, that will be used by nurses to verify the correct drug and dose information at the moment of delivery.

### System Design

The implementation of our system requires RFID tags on: medicine packaging, the nurse and the patient. Specifically, the nurse who will personally administer the medicine to the patient.

Our system uses the current software, by providing an internal software update, to integrate the database of the patient, doctor and medicines to create an automated system for billing.

To realize our system, we are using high-frequency RFID<sup>13</sup> located adjacent to the patient bed and within the range of a RFID reader. Additionally, we are using touchscreen systems that are made available to the nurses for the verification process of the delivery of the medicine.

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<sup>13</sup> Passive High-Frequency RFID at 3 to 60 MHz and at a range of 1 to 1.5 meters

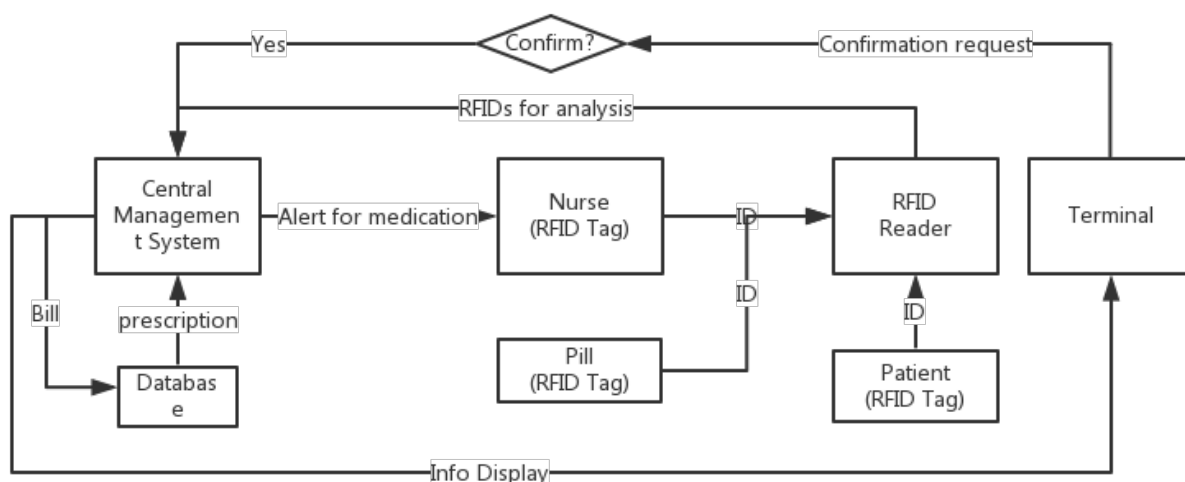


**Figure 4 Cost Accounting Dataflow Diagram**

1. When a patient is admitted they are given a unique RFID tag that contains the reference to their preexisting medical information in the database. The doctor then examines the patient. The doctor's prescription is loaded into the database for the particular patient using the unique RFID tag and ensuring the right drugs are being prescribed to the right patient. The doctor can also easily insert, update or delete the information electronically.
2. Sequence of events:
  - When the nurse brings the medicine to the patient, the RFID reader near the patient automatically reads the RFID tags of the medicine, the patient and the nurse.
  - The nurse administers the medicine to the patient.
  - The software which has already analyzed the database, recognizes from the prescription database and medicine RFID tag which drug and what dosage is being administered to the patient at this time.
  - The information about the drug and the dosage is immediately displayed to the touchscreen in front of the nurse, he/she then verifies by a single touch that they have administered the correct drug and dosage to the patient at the correct time. To ensure this happens, our software update reads and analyses the patients' database so that we can enable an alarm system to trigger when nurses miss the appointed time for the drug administration. Moreover, the system sends reminders to the nurse a periodically before the scheduled administration.
  - This process automatically adds the price of the drug to the patient's bill.
3. For a patient undergoing a medical test or procedure:

When the patient is taken to particular procedure room, the RFID reader on the gateway, which are pre-installed, scan the patient's RFID tag. The software now pulls the data from the prescription database of the patient to compare it with what particular medical procedure RFID gateway the patient was scanned

from and registers that this patient has undergone that specific standard medical procedure. This verification is also done by the nurse confirming the procedure via a touch screen tablet installed near the medical equipments. Instantly after this verification, the cost of the standard medical procedure is added to the patient's bill immediately.

This is how we have implemented the automation of data capture of the process, thus removing the human element (and errors) and introducing smart communication between machines themselves.

## Advantages

Currently UPMC uses barcodes to identify patients and the drugs. The barcode requires a handheld scanner, which the nurse uses to manually scan the medicine and then the patient. This procedure of scanning the drug first and then the patient adds he specified drug into the patients billing account.

But for a barcode to be read, the scanner must be placed directly in front of each label, and both need to oriented in a very specific position to work properly and sometimes even the barcode digits have to be entered manually if the reader can't scan the barcode. Whereas in an RFID tag it just need to come into range of the RFID reader to read automatically (i.e. multiple scans can be performed at time which reduced time wastage on clerical work by nurses) which would substantially reduce errors and workload on nurses so that they give attention to care of patients.

The addition and usage of standardized medical procedures is very limited in many hospitals, it would greatly benefit UPMC if they used these standard procedure costs for billing the specific patient according to their medical conditions.

Our solution also supports patient safety, as the software will prompt the nurse if the wrong drug is being given to the patient. The speed and quality of healthcare delivery can be increased with use of our solution.

In sum, our technology uses the existing UPMC's database but improves the wireless sensors that are being used and also improves the functioning of the software.

# HUMAN RESOURCES

## Overview

### The need

America is seeing vast increases in the number of people over 65. This age group has many medical and health needs, and will put a strain on our health system. Recent reforms in healthcare will give millions of people access to the healthcare system. With shortage of nurses, better way to leveraging current human resources of nurses and health professionals is needed in response. (<http://www.utimes.pitt.edu/?p=2431>)

### The solution

- Real time tracking system of the nurses and the patients
- Computational system to match the need of the patients and the medical support around available
- Feedback system for coordination

## Connecting Nurses and Patients with IoT System

### Problem Statement

UPMC has over 60,000 employees, including 3,500 doctors and 11,000 registered nurses<sup>14</sup>, who provide essential health care. However, a significant obstacle facing UPMC in Human Resources is the expected shortage of registered nurses (RNs). "Over the next 20 years, the average age of the RN will increase and the size of the workforce will plateau as large numbers of RNs retire. Because demand for RNs is expected to increase during this time, a large and prolonged shortage of nurses is expected to hit the US in the latter half of the next decade."<sup>15</sup> The shortage of nurses coupled with the ever-increasing number of patients<sup>16</sup> creates a workload burden on the RNs and make it difficult for them to provide quality healthcare.

Nurses are feeling short of hands to take care of the entire patients throughout the building. From time to time, they can not arrive in a timely manner to provide care for patients with an urgent need as they have little idea about where needs them most and where the other nurses are. Their work must be more clearly directed based on the current state of patients and what services they require. UPMC wants to improve the way it manages employee hence the efficiency of the human resources, especially nurses to leverage its nursing recourses.

<sup>14</sup> <http://www.upmc.com/ABOUT/FACTS/NUMBERS/Pages/default.aspx>

<sup>15</sup> <http://www.aacn.nche.edu/media-relations/fact-sheets/nursing-shortage>

<sup>16</sup> <http://www.cdc.gov/nchs/fastats/hospital.htm>

## Business Benefits

- Replacing human intervention of telling the staff where to go to provide help
- Avoiding the delay and mistake of human verdicts
- Connecting the need of patients and the available human resources around to provide efficient and timely support for quality medical careEasier allocation of work among nursing unit staff

## How does the system work?

It breaks hospital into sections of unit that several nurses can take care of by utilizing multiple sensors that track and analyze the movement of nurses and patients.

With this source of information, the system can figure out how many nurses and patients are in every monitored section and whether there is enough human resources for that particular section.

It can push messages to send to available closest nurse for assistance if certain sections require support due to lack of existing human recourse or patients calling for urgent care.

## Solution

### Overview

ebConsultants want to mitigate the adverse affects of the shortage by leveraging the current nursing resources at UPMC and directing care towards addressing real-time state of patients and services they require. Moreover, we want to be able to track nurses and assure that the closest qualified nurses are taking care of patients in need. Simply put, we propose a system that can track, gather and analyze real time information of the UPMC nurses and patients for improved quality of healthcare. We believe this will ensure proper care of the patients while also increasing the efficiency of the distribution of UPMC human resources.

### Utilized Technology

#### Geographical Sensing

The sensor technologies used in the HR system contain active and passive infrared (IR) sensors.<sup>17</sup>

- Passive IR sensors work by detecting heat within their range and when a warm object (such as person) moves within range of a passive IR sensor, the sensor is tripped.
- Active IR sensors consist of two units, an emitter and a detector. The emitter gives out a beam of infrared light onto the detector, which sends a signal when the beam is interrupted.

Each room is divided into a grid with a passive IR sensor, while active IR sensors are placed at each door to detect movement in the hallways (which generally has more foot traffic). Since nurses are more active in moving around a hospital than a patient, we employ active IR sensors to track their movement because active IR sensors are more readily able to monitor multiple and frequent occurrences of

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<sup>17</sup> [https://www.wpi.edu/Pubs/E-project/Available/E-project-042513-081838/unrestricted/Real\\_Time\\_Person\\_Tracking\\_and\\_Identification\\_using\\_the\\_Kinect\\_sensor.pdf](https://www.wpi.edu/Pubs/E-project/Available/E-project-042513-081838/unrestricted/Real_Time_Person_Tracking_and_Identification_using_the_Kinect_sensor.pdf)

movement. The patients are “monitored” in respect to their location using passive IR sensors because they tend to be less mobile in their day-to-day activities in the hospital and an passive IR sensor is better suited for such surveillance. Therefore, with the use of passive and active IR sensors, the HR system is able to accurately track patients and nurses.

### **Patient Vital Sign Sensing**

Digital vital signs patch is used for patient vital sign sensing in our HR system. It is a disposable, ultra-thin plaster which continuously monitors the patient’s heart rate, respiratory rate and temperature while hospitalized. Patient vital sign sensing, unlike traditional, bulky, wired monitoring products, allow patients to be fully mobile while being monitored. The device continuously monitors patients’ vital signs (heart-rate, respiration rate & temperature) and wirelessly communicates this data to doctors and nurses via the hospital’s IT system.<sup>18</sup>

### **Coordination Mechanism:**

Nurses are equipped with smart watches, which replaces the current use of pagers, that can receive the coordination instruction from computational system to achieve computational system based coordinating.

## **System Design**

This design consists of three major components that work together: sensing, computing and feedback. The sensing part of our system works by gathering two important sources of data: the location of the patients and nurses and the vital body signs of the patients. The location of patient and nurses are made possible through the use of tracking sensors and detectors. Specifically, we are adopting technologies based on infrared (IR) sensors and RFIDs.

The location tracking system works by providing IR-RFID badges to nurses and patients, which are worn high on the body near the lapel. These badges emit safe, low-powered Infrared (IR) and RFID signals. IR signal is an invisible light whose strength is similar to that of signals transmitted “by ordinary remote controls<sup>19</sup>”. An independent study was conducted in August 2000 by the United States Department of Health and Human Services regarding the safety of Infrared light and study concluded that the Infrared signals “show no hazards<sup>20</sup>”. Moreover, IR provides accuracy necessary to precisely locate people. We also employ the use low-

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<sup>18</sup> <http://www.toumaz.com/major-hospital-pilot-deployment-toumaz's-wireless-patch-monitor-vital-signs-underway#.VfYoAsa87dIR>

<sup>19</sup> <http://www.versustech.com/rtls-technology/faq/#faq-4>

<sup>20</sup> Ibid

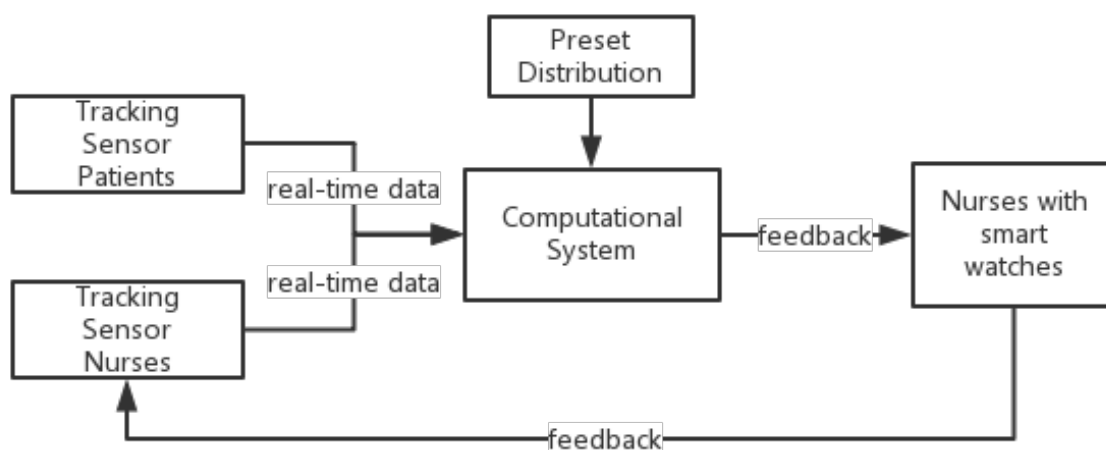


**Figure 5 Human Resources Dataflow Diagram**

power RFID signals because they can provide general locations and are tagged with a unique ID that can easily allow the system to identify the specific nurse or patient. When we couple the accuracy of the IR signals to the readings from the RFID signals, we are able to get a more complete picture of the real time location of patients and nurses. Next, we use wireless IR detectors and RFID readers to capture these signals. These detectors and readers are discreetly mounted in the ceilings or at the bedside of the patients and can receive both signals. The IR detectors directly correspond to a predefined location and can be tightly focused to create multiple locations readings, as desired by hospital management. When an IR detector identifies a signal, the signals is cross checked with the RFID reader, which reads RFID signals that are unique to each patient and nurse, to tell the computational system the identity and location of the source signal. In order to monitor vital body signs of patients, we will be employing the use of digital sign patches, as discussed in the previous page.

The second component of our system, the computational system, receives data from both the location tracking sensors and the vital sign monitoring system. The core duty of the computational system is to evaluate the real time data by cross checking the location of nurses with the location of patients, while

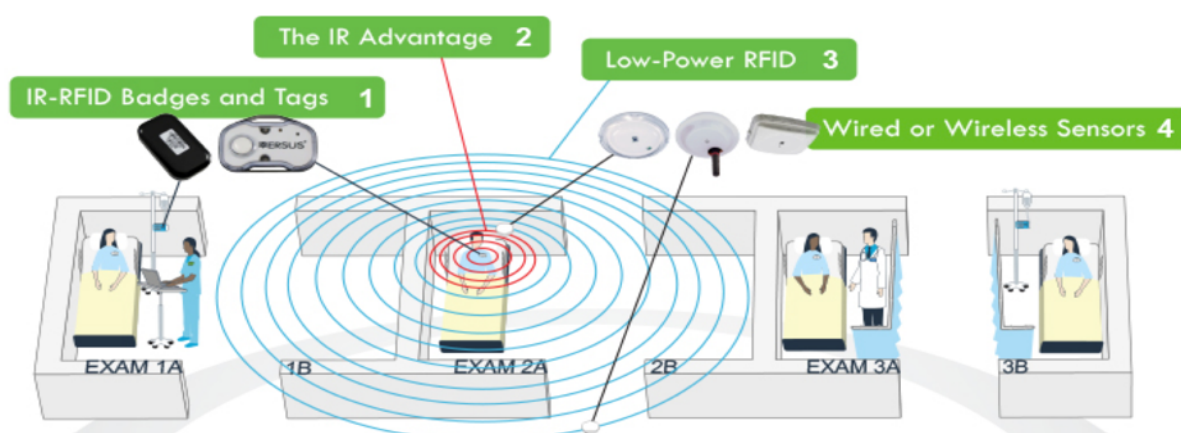


**Figure 6 Illustration for Location Tracking System**

Source of image: <http://www.versustech.com/rtls-technology/>

prioritizing the needs of urgent care patients. Using a user inputted ratio of patients to nurses, generally from that of the head nurse, the computational system figures out if this ratio is being met at all targeted places and sends this information to the feedback component of our system.

If nurses are required to move from one location to another, the feedback messaging feature pushes the coordination instructions to smart watches worn by the nurses (provided ahead of time). Once the nurse enters the designated location, she confirms her arrival through her smart watch and the tracking sensors are once again activated to confirm the location of the nurse. The data logs are updated and the system loops back to the sensing and the process continues.

## Appendix I - Cost Estimation:

UPMC current licensed bed number: 5,100 beds<sup>21</sup>

We put one RFID Reader to every room, and have 5% machines for back-up.

The number of RFID Reader we need is  $5,100 * (1 + 5\%) = 5,355$

Assume the cost of one RFID Reader is \$1,000,

So the total cost of RFID Reader is  $5,355 * \$1,000 = \$5,355,000$

Assume average occupancy rate: 60% <sup>22</sup>

So, the number of inpatients will be around  $5,100 * 60\% = 3,060$

Assume on average 80% of them will order food at UPMC, so

The food packages needed per meal will be  $3,060 * 80\% = 2,500$

Assume one Tagging Terminal will tag 40 packages per meal and UPMC need around 20 more machines for back-up.

The total number of Tagging Terminal will be  $2,500/40 + 20 = 70$

Assume the cost of one Tagging Terminal is \$1,200

The total cost of Tagging Terminal is  $70 * \$1,200 = \$84,000$

Assume the cost of Central Management Unit plus Database is \$800,000

As for food carts, the cost of one pair of Sensor and Actuator: \$30<sup>23</sup>

We assume that one cart with 10 pairs of Sensor and Actuator serves 50 packages per meal and the cost of one cart is \$80.<sup>24</sup>

So the total cost of smart carts is  $(\$30 * 10 + \$80) * (3,060/50) = \$23,256$

The total cost of Food Serves System is

$\$5,355,000 + \$84,000 + \$800,000 + \$23,256 = \$6,262,256$

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<sup>21</sup> <http://www.upmc.com/about/facts/numbers/Pages/default.aspx>

<sup>22</sup> <http://jocelynmonahan.com/omeka-1.5/upmcsitesabout>

<sup>23</sup> <http://www.robotshop.com/en/temperature-sensors.html>

<sup>24</sup> [http://www.amazon.com/Trinity-THL-UCAP3-3-Tier-Utility-Cart/dp/B00166LB8M/ref=sr\\_1\\_1?ie=UTF8&qid=1442369797&sr=8-1&keywords=food+cart](http://www.amazon.com/Trinity-THL-UCAP3-3-Tier-Utility-Cart/dp/B00166LB8M/ref=sr_1_1?ie=UTF8&qid=1442369797&sr=8-1&keywords=food+cart)